SEL-400G

Advanced Generator Protection System

Instruction Manual

20250214

SCHWEITZER ENGINEERING LABORATORIES

Part Number: PM400G-01

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Preface

This manual provides information and instructions for installing and operating the relay. The manual is for use by power engineers and others experienced in protective relaying applications. Included are detailed technical descriptions of the relay and application examples. While this manual gives reasonable examples and illustrations of relay uses, you must exercise sound judgment at all times when applying the relay in a power system.

Manual Overview

The SEL-400G Instruction Manual consists of two volumes:

- SEL-400G Instruction Manual
- SEL-400 Series Relays Instruction Manual

SEL-400G Instruction Manual

Preface. Describes manual organization and conventions used to present information, as well as safety information.

Section 1: Introduction and Specifications. Introduces the relay features. Summarizes relay functions and applications. Lists relay specifications, type tests, and ratings.

Section 2: Installation. Discusses the ordering configurations and interface features (control inputs, control outputs, and analog inputs, for example). Provides information about how to design a new physical installation and secure the relay in a panel or rack. Details how to set relay board jumpers and make proper rear-panel connections (including wiring to CTs, PTs, and a GPS receiver). Explains basic connections for the relay communications ports.

Section 3: Testing. Describes techniques for testing the relay.

Section 4: Front-Panel Operations. Describes the LCD messages and menu screens that are unique to the SEL-400G.

Section 5: Protection Functions. Describes the function of various relay protection elements. Describes how the relay processes these elements. Gives detailed specifics on protection scheme logic for the differential elements. Provides trip logic diagrams, and current and voltage source selection details.

Section 6: Protection Application Examples. Provides an example of configuring the SEL-400G for a common application.

Section 7: Metering, Monitoring, and Reporting. Describes SEL-400G specific metering, monitoring, and reporting features.

Section 8: Settings. Provides a list of all relay settings and defaults. The settings list is organized in the same order as in the relay and in the SEL Grid Configurator Software.

Section 9: ASCII Command Reference. Provides an alphabetical listing of all ASCII commands with examples for each ASCII command option.

Section 10: Communications Interfaces. Describes the SEL-400G specific communications characteristics.

Section 11: Relay Word Bits. Contains a summary of Relay Word bits.

Section 12: Analog Quantities. Contains a summary of analog quantities.

Appendix A: Firmware, ICD File, and Manual Versions. Lists the current firmware and manual versions and details differences between the current and previous versions.

SEL-400 Series Relays Instruction Manual

Preface. Describes manual organization and conventions used to present information, as well as safety information.

Section 1: Introduction. Introduces SEL-400 series relay common features.

Section 2: PC Software. Explains how to use SEL Grid Configurator and ACSELERATOR QuickSet SEL-5030 Software.

Section 3: Basic Relay Operations. Describes how to perform fundamental operations such as applying power and communicating with the relay, setting and viewing passwords, checking relay status, viewing metering data, reading event reports and Sequential Events Recorder (SER) records, operating relay control outputs and control inputs, and using relay features to make relay commissioning easier.

Section 4: Front-Panel Operations. Describes the LCD messages and menu screens. Shows you how to use front-panel pushbuttons and read targets. Provides information about local substation control and how to make relay settings via the front panel.

Section 5: Control. Describes various control features of the relay, including circuit breaker operation, disconnect operation, remote bits, and one-line diagrams.

Section 6: Autoreclosing. Explains how to operate the two-circuit breaker multishot recloser. Describes how to set the relay for single-pole reclosing, three-pole reclosing, or both. Shows selection of the lead and follow circuit breakers.

Section 7: Metering. Provides information on viewing current, voltage, power, and energy quantities. Describes how to view other common internal operating quantities.

Section 8: Monitoring. Describes how to use the circuit breaker monitors and the substation dc battery monitors.

Section 9: Reporting. Explains how to obtain and interpret high-resolution raw data oscillograms, filtered event reports, event summaries, history reports, and SER reports. Discusses how to enter SER trigger settings.

Section 10: Testing, Troubleshooting, and Maintenance. Describes techniques for testing, troubleshooting, and maintaining the relay. Includes the list of status notification messages and a troubleshooting chart.

Section 11: Time and Date Management. Explains timekeeping principles, synchronized phasor measurements, and estimation of power system states using the high-accuracy time-stamping capability. Presents real-time load flow/power flow application ideas.

Section 12: Settings. Provides a list of all common SEL-400 series relay settings and defaults.

Section 13: SELOGIC Control Equation Programming. Describes multiple setting groups and SELOGIC control equations and how to apply these equations. Discusses expanded SELOGIC control equation features such as PLC-style commands, math functions, counters, and conditioning timers. Provides a tutorial for converting older format SELOGIC control equations to new freeform equations.

Section 14: ASCII Command Reference. Provides an alphabetical listing of all ASCII commands with examples for each ASCII command option.

Section 15: Communications Interfaces. Explains the physical connection of the relay to various communications network topologies. Describes the various software protocols and how to apply these protocols to substation integration and automation. Includes details about Ethernet IP protocols, SEL ASCII, SEL Compressed ASCII, SEL Fast Meter, SEL Fast Operate, SEL Fast SER, and enhanced MIRRORED BITS communications.

Section 16: DNP3 Communication. Describes the DNP3 communications protocol and how to apply this protocol to substation integration and automation. Provides a Job Done example for implementing DNP3 in a substation.

Section 17: IEC 61850 Communication. Describes the IEC 61850 protocol and how to apply this protocol to substation automation and integration. Includes IEC 61850 protocol compliance statements.

Section 18: Synchrophasors. Describes the Phasor Measurement Unit (PMU) functions of the relay. Provides details on synchrophasor measurement and real-time control. Describes the IEEE C37.118 Synchrophasor Protocol settings. Describes the SEL Fast Message Synchrophasor Protocol settings.

Section 19: Digital Secondary Systems. Describes the basic concepts of digital secondary systems (DSS). This includes both the Time-Domain Link (TiDL) system and UCA 61850-9-2LE Sampled Values.

Appendix A: Manual Versions. Lists the current manual version and details differences between the current and previous versions.

Appendix B: Firmware Upgrade Instructions. Describes the procedure to update the firmware stored in Flash memory.

Appendix C: Cybersecurity Features. Describes the various features of the relay that impact cybersecurity.

Glossary. Defines various technical terms used in the SEL-400 series instruction manuals.

Safety Information

Dangers, Warnings, and Cautions

This manual uses three kinds of hazard statements, defined as follows:

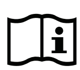
DANGER
Indicates an imminently hazardous situation that, if not avoided, **will** result in death or serious injury.

WARNING
Indicates a potentially hazardous situation that, if not avoided, **could** result in death or serious injury.

CAUTION
Indicates a potentially hazardous situation that, if not avoided, **may** result in minor or moderate injury or equipment damage.

Safety Symbols

The following symbols are often marked on SEL products.

	**CAUTION** Refer to accompanying documents.	**ATTENTION** Se reporter à la documentation.
	Earth (ground)	Terre
	Protective earth (ground)	Terre de protection
	Direct current	Courant continu
	Alternating current	Courant alternatif
	Both direct and alternating current	Courant continu et alternatif
	Instruction manual	Manuel d'instructions

Safety Marks

The following statements apply to this device.

General Safety Marks

⚠CAUTION There is danger of explosion if the battery is incorrectly replaced. Replace only with Rayovac no. BR2335 or equivalent recommended by manufacturer. See Owner's Manual for safety instructions. The battery used in this device may present a fire or chemical burn hazard if mistreated. Do not recharge, disassemble, heat above 100°C or incinerate. Dispose of used batteries according to the manufacturer's instructions. Keep battery out of reach of children.	⚠ATTENTION Une pile remplacée incorrectement pose des risques d'explosion. Remplacez seulement avec un Rayovac no BR2335 ou un produit équivalent recommandé par le fabricant. Voir le guide d'utilisateur pour les instructions de sécurité. La pile utilisée dans cet appareil peut présenter un risque d'incendie ou de brûlure chimique si vous en faites mauvais usage. Ne pas recharger, démonter, chauffer à plus de 100°C ou incinérer. Éliminez les vieilles piles suivant les instructions du fabricant. Gardez la pile hors de la portée des enfants.
⚠CAUTION To ensure proper safety and operation, the equipment ratings, installation instructions, and operating instructions must be checked before commissioning or maintenance of the equipment. The integrity of any protective conductor connection must be checked before carrying out any other actions. It is the responsibility of the user to ensure that the equipment is installed, operated, and used for its intended function in the manner specified in this manual. If misused, any safety protection provided by the equipment may be impaired.	⚠ATTENTION Pour assurer la sécurité et le bon fonctionnement, il faut vérifier les classements d'équipement ainsi que les instructions d'installation et d'opération avant la mise en service ou l'entretien de l'équipement. Il faut vérifier l'intégrité de toute connexion de conducteur de protection avant de réaliser d'autres actions. L'utilisateur est responsable d'assurer l'installation, l'opération et l'utilisation de l'équipement pour la fonction prévue et de la manière indiquée dans ce manuel. Une mauvaise utilisation pourrait diminuer toute protection de sécurité fournie par l'équipement.
For use in Pollution Degree 2 environment.	Pour l'utilisation dans un environnement de Degré de Pollution 2.

Other Safety Marks (Sheet 1 of 2)

⚠DANGER Disconnect or de-energize all external connections before opening this device. Contact with hazardous voltages and currents inside this device can cause electrical shock resulting in injury or death.	⚠DANGER Débrancher tous les raccordements externes avant d'ouvrir cet appareil. Tout contact avec des tensions ou courants internes à l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠DANGER Contact with instrument terminals can cause electrical shock that can result in injury or death.	⚠DANGER Tout contact avec les bornes de l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠WARNING Use of this equipment in a manner other than specified in this manual can impair operator safety safeguards provided by this equipment.	⚠AVERTISSEMENT L'utilisation de cet appareil suivant des procédures différentes de celles indiquées dans ce manuel peut désarmer les dispositifs de protection d'opérateur normalement actifs sur cet équipement.
⚠WARNING Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.	⚠AVERTISSEMENT Seules des personnes qualifiées peuvent travailler sur cet appareil. Si vous n'êtes pas qualifiés pour ce travail, vous pourriez vous blesser avec d'autres personnes ou endommager l'équipement.
⚠WARNING This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.	⚠AVERTISSEMENT Cet appareil est expédié avec des mots de passe par défaut. A l'installation, les mots de passe par défaut devront être changés pour des mots de passe confidentiels. Dans le cas contraire, un accés non-autorisé á l'équipement peut être possible. SEL décline toute responsabilité pour tout dommage résultant de cet accés non-autorisé.
⚠WARNING Do not look into the fiber ports/connectors.	⚠AVERTISSEMENT Ne pas regarder vers les ports ou connecteurs de fibres optiques.
⚠WARNING Do not look into the end of an optical cable connected to an optical output.	⚠AVERTISSEMENT Ne pas regarder vers l'extrémité d'un câble optique raccordé à une sortie optique.
⚠WARNING Do not perform any procedures or adjustments that this instruction manual does not describe.	⚠AVERTISSEMENT Ne pas appliquer une procédure ou un ajustement qui n'est pas décrit explicitement dans ce manuel d'instruction.
⚠WARNING Incorporated components, such as LEDs and transceivers are not user serviceable. Return units to SEL for repair or replacement.	⚠AVERTISSEMENT Les composants internes tels que les leds (diodes électroluminescentes) et émetteurs-récepteurs ne peuvent pas être entretenus par l'usager. Retourner les unités à SEL pour réparation ou remplacement.

Other Safety Marks (Sheet 2 of 2)

⚠CAUTION Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.	⚠ATTENTION Les composants de cet équipement sont sensibles aux décharges électrostatiques (DES). Des dommages permanents non-décelables peuvent résulter de l'absence de précautions contre les DES. Raccordez-vous correctement à la terre, ainsi que la surface de travail et l'appareil avant d'en retirer un panneau. Si vous n'êtes pas équipés pour travailler avec ce type de composants, contacter SEL afin de retourner l'appareil pour un service en usine.
⚠CAUTION Equipment damage can result from connecting ac circuits to Hybrid (high-current interrupting) control outputs. Do not connect ac circuits to Hybrid control outputs. Use only dc circuits with Hybrid control outputs.	⚠ATTENTION Des dommages à l'appareil pourraient survenir si un circuit CA était raccordé aux contacts de sortie à haut pouvoir de coupure de type "Hybrid." Ne pas raccorder de circuit CA aux contacts de sortie de type "Hybrid." Utiliser uniquement du CC avec les contacts de sortie de type "Hybrid."
⚠CAUTION Substation battery systems that have either a high resistance to ground (greater than 10 kΩ) or are ungrounded when used in conjunction with many direct-coupled inputs can reflect a dc voltage offset between battery rails. Similar conditions can exist for battery monitoring systems that have high-resistance balancing circuits or floating grounds. For these applications, SEL provides optional ground-isolated (optoisolated) contact inputs. In addition, SEL has published an application advisory on this issue. Contact the factory for more information.	⚠ATTENTION Les circuits de batterie de postes qui présentent une haute résistance à la terre (plus grande que 10 kΩ) ou sont isolés peuvent présenter un biais de tension CC entre les deux polarités de la batterie quand utilisés avec plusieurs entrées à couplage direct. Des conditions similaires peuvent exister pour des systèmes de surveillance de batterie qui utilisent des circuits d'équilibrage à haute résistance ou des masses flottantes. Pour ce type d'applications, SEL peut fournir en option des contacts d'entrée isolés (par couplage optoélectronique). De surcroît, SEL a publié des recommandations relativement à cette application. Contacter l'usine pour plus d'informations.
⚠CAUTION Do not install a jumper on positions A or D of the main board J18 header. Relay misoperation can result if you install jumpers on positions J18A and J18D.	⚠ATTENTION Ne pas installer de cavalier sur les positions A ou D sur le connecteur J18 de la carte principale. Une opération intempestive du relais pourrait résulter suite à l'installation d'un cavalier entre les positions J18A et J18D.
⚠CAUTION Insufficiently rated insulation can deteriorate under abnormal operating conditions and cause equipment damage. For external circuits, use wiring of sufficiently rated insulation that will not break down under abnormal operating conditions.	⚠ATTENTION Un niveau d'isolation insuffisant peut entraîner une détérioration sous des conditions anormales et causer des dommages à l'équipement. Pour les circuits externes, utiliser des conducteurs avec une isolation suffisante de façon à éviter les claquages durant les conditions anormales d'opération.
⚠CAUTION Relay misoperation can result from applying other than specified secondary voltages and currents. Before making any secondary circuit connections, check the nominal voltage and nominal current specified on the rear-panel nameplate.	⚠ATTENTION Une opération intempestive du relais peut résulter par le branchement de tensions et courants secondaires non conformes aux spécifications. Avant de brancher un circuit secondaire, vérifier la tension ou le courant nominal sur la plaque signalétique à l'arrière.
⚠CAUTION Severe power and ground problems can occur on the communications ports of this equipment as a result of using non-SEL cables. Never use standard null-modem cables with this equipment.	⚠ATTENTION Des problèmes graves d'alimentation et de terre peuvent survenir sur les ports de communication de cet appareil si des câbles d'origine autre que SEL sont utilisés. Ne jamais utiliser de câble de modem nul avec cet équipement.
⚠CAUTION Do not connect power to the relay until you have completed these procedures and receive instruction to apply power. Equipment damage can result otherwise.	⚠ATTENTION Ne pas mettre le relais sous tension avant d'avoir complété ces procédures et d'avoir reçu l'instruction de brancher l'alimentation. Des dommages à l'équipement pourraient survenir autrement.
⚠CAUTION Use of controls or adjustments, or performance of procedures other than those specified herein, may result in hazardous radiation exposure.	⚠ATTENTION L'utilisation de commandes ou de réglages, ou l'application de tests de fonctionnement différents de ceux décrits ci-après peuvent entraîner l'exposition à des radiations dangereuses.

General Information

The SEL-400G Instruction Manual uses certain conventions that identify particular terms and help you find information. To benefit fully from reading this manual, take a moment to familiarize yourself with these conventions.

Typographic Conventions

There are three ways to communicate with SEL-400 series relays:

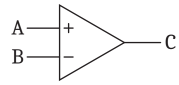
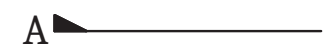
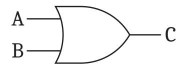
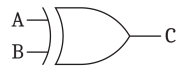
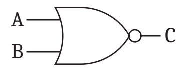
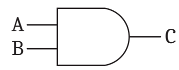
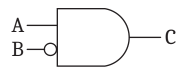
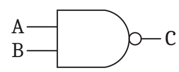
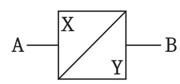
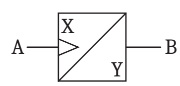
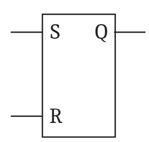
- ➤ Using a command line interface on a PC terminal emulation window, such as Microsoft HyperTerminal
- ➤ Using the front-panel menus and pushbuttons
- ➤ Using Grid Configurator Software or ACSELERATOR QuickSet SEL-5030 Software

The instructions in this manual indicate these options with specific font and formatting attributes. The following table lists these conventions:

Example	Description
STATUS	Commands, command options, and command variables typed at a command line interface on a PC.
n **SUM *n***	Variables determined based on an application (in bold if part of a command).
<Enter>	Single keystroke on a PC keyboard.
<Ctrl+D>	Multiple/combination keystroke on a PC keyboard.
Start > Settings	PC software dialog boxes and menu selections. The > character indicates submenus.
ENABLE	Relay front- or rear-panel labels and pushbuttons.
`MAIN > METER`	Relay front-panel LCD menus and relay responses visible on the PC screen. The > character indicates submenus.

Logic Diagrams

Logic diagrams in this manual follow the conventions and definitions shown below.

NAME	SYMBOL	FUNCTION
Comparator		Input A is compared to Input B. Output C asserts if Input A is greater than Input B.
Input Flag		Input A comes from other logic.
OR		If either Input A or Input B asserts, Output C asserts.
Exclusive OR		If either Input A or Input B asserts, Output C asserts. If Input A and Input B are of the same state, Output C deasserts.
NOR		If neither Input A nor Input B asserts, Output C asserts.
AND		If Input A and Input B assert, Output C asserts.
AND w/ Inverted Input		If Input A asserts and Input B deasserts, Output C asserts. Inverter "O" inverts any input or output on any gate.
NAND		If Input A and/or Input B deassert, Output C asserts.
Time-Delayed Pick Up and/or Time-Delayed Drop Out		X is a time-delay-pickup value; Y is a time-delay-dropout value. Output B asserts Time X after Input A asserts; Output B does not assert if Input A does not remain asserted for Time X. If Time X is zero, Output B asserts when Input A asserts. If Time Y is zero, Input B deasserts when Input A deasserts.
Edge Trigger Timer		Rising edge of Input A starts timers. Output B asserts Time X after the rising edge of Input A. Output B remains asserted for Time Y. If Time Y is zero, Output B asserts for a single processing interval. Input A is ignored while the timers are running.
Set-Reset/Flip-Flop		Input S asserts Output Q until Input R asserts. Output Q deasserts or resets when Input R asserts.
Falling Edge		Output B asserts at the falling edge of Input A.
Rising Edge		Output B asserts at the rising edge of Input A.

Trademarks

Trademarks appearing in this manual are shown in the following table.

ACSELERATOR Architect®	MIRRORED BITS®
ACSELERATOR QuickSet®	SELOGIC®
Connectorized®	SELBOOT®

Technical Support

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

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S E C T I O N 1

Introduction and Specifications

Overview

The SEL-400G Advanced Generator Protection System, shown in *Figure 1.1*, provides a suite of elements for the comprehensive protection and monitoring of generators of all types and sizes. In total, the relay consists of 24 analog channels, of which 18 channels are for 6 three-phase current inputs, and 6 channels are for 2 three-phase voltage inputs. One of the three-phase current inputs can be configured as three single-phase current inputs and one of the three-phase voltage inputs can be configured as three single-phase voltage inputs.

Figure 1.1 SEL-400G Advanced Generator Protection System

Protect Generator and Transformer. The SEL-400G includes two differential zones, one of which can include an in-zone transformer and can accept as many as six sets of CT inputs to protect both the generator and generator step-up (GSU) without the need for an additional transformer differential relay. Each current terminal can be included into either or both differential zones. Increasing the number of inputs to the differential zone removes the need to parallel CTs when including various circuits connecting to the zone. This, in turn, makes it much more practical to provide overcurrent, breaker failure, and inadvertent energization protection for multiple breakers.

Adaptive Slope Differential. A high-speed algorithm automatically increases the slope setting during periods when CT saturation is more likely. This provides greatly increased security for external faults and external transformer energization during black starting.

Pumped-Storage Logic. The SEL-400G internally corrects the phase transpositions introduced by the reversing switch. The logic ensures that the phasing of the differential element and the phase rotation are correct. This allows a pumped-storage hydro unit to be protected with a single SEL-400G without the need to externally switch the CT or PT secondary wiring.

SEL-400G, SEL-2664, SEL-2664S Complete Coverage, Online and Off. Combine the SEL-400G relay, SEL-2664 Field Ground Module, and SEL-2664S Stator Ground Module for complete generator protection under all operating conditions, including offline and during starting. Analog measurements from the SEL-2664 can be received on the EIA-232 port by using an SEL-2812M or an SEL-2814M for ST connectors; the SEL-2664 requires the PROTO setting be set to SEL protocol at a data rate of 9600 bps. Analog measurements from the SEL-2664S can also be received via Ethernet connection.

Comprehensive Temperature Monitoring. When the SEL-400G is used in conjunction with the SEL-2600 RTD Module and/or SEL-2411 Programmable Automation Controller, as many as 24 temperature measurements over serial and 24 over Ethernet are available. Each can be programmed for two levels of thermal protection per element.

Extended Range Frequency Tracking of 5–120 Hz. Generators may, at times, operate at frequencies significantly different than nominal. The SEL-400G wide-range frequency tracking algorithm ensures that all protection functions are secure and dependable regardless of the system frequency. The SEL-400G also independently tracks the generator and system frequencies.

Capability-Based Loss of Field. Use this function to more effectively coordinate with the minimum excitation limiter (MEL), generator capability curve (GCC), and steady-state stability limit (SSSL). The element can dynamically adapt with voltage to maintain coordination with the MEL.

Generator Unbalance. In the past, rotor thermal protection elements have responded only to the negative-sequence component of the fundamental frequency stator current. Generators also have a harmonic current capability limit. The SEL-400G accounts for heating because of the fundamental and harmonic components as high as the 15th. In accordance with IEEE C50.12 and IEEE C50.13, each component is scaled by a weighting factor based on its sequence (positive or negative) and its harmonic order. This weighting factor accounts for skin effect. Two elements are provided, each of which can respond either to the fundamental or the fundamental plus harmonics.

Thermal Overload Modeling. The SEL-400G provides thermal overload protection based on the thermal model described in IEC standard 60255-149. The model can be biased by ambient temperature if the RTD option is used.

Breaker Failure Protection. High-speed breaker failure is provided for as many as four breakers with breaker flashover logic and a slip frequency check for non- or low-current protection.

Out-of-Step Tripping. The SEL-400G provides dual zone, single- or double-blinder out-of-step tripping (OST) with independent pole slip counters for generator and system OST coordination.

Adaptive Split-Phase Compensation. Split-phase protection can detect a wide range of stator winding faults. This scheme can be negatively impacted by both steady-state and transient circulating currents. The SEL-400G provides the ability to detect and nullify the standing current offset. The element is also supervised by an external fault detector. This provides security without compromising on operating speed.

Disturbance Report. The SEL-400G triggers disturbance reports with record lengths of as long as 300 seconds (5 minutes). As many as four records can be stored. Each record can have 20 analog and 800 digital quantities at a sampling rate of 20 ms. The disturbance report can be configured to include filtered quantities (fundamental, rms, harmonics, etc.), frequency, power, protection operating signals, and transducer inputs. Digitals include protection Relay Word bits, contact inputs, and remote digitals received over a communications channel. Use the disturbance recorder to capture power swings, synchronizing events, and slowly evolving protection operations.

Synchrophasors. The SEL-400G provides synchrophasor measurement of all 18 current and 6 voltage channels available in the relay, including derived positive-sequence quantities. The relay complies with the IEEE C37.118.1 (2011) synchrophasors standard. Time-stamping of generating station data can be very useful for monitoring and validating various generator control system performances. This includes terminal voltages, terminal currents, speed, active power, field voltage, field current, temperature, etc. Synchrophasors provide a mechanism to time stamp the generator data and make them readily available for online and offline control system monitoring applications like generator model validation, automatic voltage regulator (AVR) or excitation control system performance, power system stabilizer (PSS) tuning and performance, and governor control tuning and performance. The SEL-400G creates synchrophasor data by using standard transducers and can transmit these data using the IEEE C37.118 format. In addition, the SEL-400G can be programmed to store a PMU record length of 120 seconds based on user-settable disturbance triggers. The SEL-400G supports real-time control applications through use of synchrophasors.

Digital Relay-to-Relay Communications. Use MIRRORED BITS communications to monitor internal element conditions among relays within a station, or among stations, by using SEL fiber-optic transceivers. Send digital, analog, and virtual terminal data over the same MIRRORED BITS channel. Receive synchrophasor data from as many as two other devices transmitting IEEE C37.118 format synchrophasors at rates as fast as 60 messages per second. The SEL-400G time correlates the data for use in SELOGIC control equations.

Automatic Generator Synchronization for as Many as Three Breakers. The SEL-400G-1 provides comprehensive automatic synchronization control of governor and voltage regulator. Several control modes are supported including proportional pulse width, proportional pulse frequency, and fixed pulse. The SEL-400G uses control pulses to interface with the generator controls.

Automation. Take advantage of enhanced automation features that include programmable elements for local control, remote control, protection latching, and automation latching.

Local metering on the large-format, front-panel LCD eliminates the need for separate panel meters.

Programmable display points on the front-panel LCD can be customized to provide meaningful operator information for a wide variety of operating and protection events.

Three EIA-232 serial ports and two station bus Ethernet ports efficiently transmit key information, including:

- Metering data
- Protection element and control I/O status
- IEEE C37.118 synchrophasors
- IEC 61850 GOOSE messages
- Sequential Events Recorder (SER) reports
- Breaker monitor reports
- Summary event reports
- Time-synchronization reports

Use expanded SELOGIC control equations with math and comparison functions in control applications.

Incorporate as many as 250 lines of protection logic along with 1000 lines of automation logic to accelerate and improve control actions.

High-isolation control input circuits allow reliable interface points for inputs from other systems.

Comprehensive Metering. Use the extensive metering values in the SEL-400G to allow operators to eliminate standalone meters. Use full metering capabilities of the SEL-400G that include rms, fundamental, maximum/minimum, demand/peak, energy, harmonics, differential, synchronism-check, synchrophasor, and thermal values.

Breaker and Battery Monitoring. Schedule breaker maintenance when accumulated breaker duty indicates possible excess contact wear. The SEL-400G records electrical and mechanical operating times for both the last operation and the average of operations since function reset. Breaker monitoring provides notification of substation battery voltage problems using voltage dip detection during trip or close operations.

Ethernet Access. Access all relay functions with the optional Ethernet card. Use IEC 61850, Modbus TCP, or DNP3 protocol directly to interconnect with automation systems. You can also connect to DNP3 or Modbus TCP networks through a communications processor. Use File Transfer Protocol (FTP) for high-speed data collection. Connect to substation or corporate LANs to transmit synchrophasors in the IEEE C37.118 format, using TCP or UDP internet protocols.

Parallel Redundancy Protocol (PRP). Provide seamless recovery from any single Ethernet network failure with this protocol, in accordance with IEC 62439-3. You can connect all PRP compatible devices in two independent networks and duplicate the traffic on both. The station bus and process bus Ethernet networks support PRP.[1]

High-Availability Seamless Redundancy (HSR) Protocol. Provide seamless recovery from any single Ethernet network failure with this protocol, in accordance with IEC 62439-3. You can connect all HSR compatible devices in a

[1] Only the five-port Ethernet card ordering option supports PRP on both the station bus and the process bus. HSR is only supported on the five-port Ethernet card.

ring, fully duplicate the traffic, and send the traffic in both clockwise and counterclockwise directions around the ring. The station bus and process bus Ethernet networks support HSR.[1]

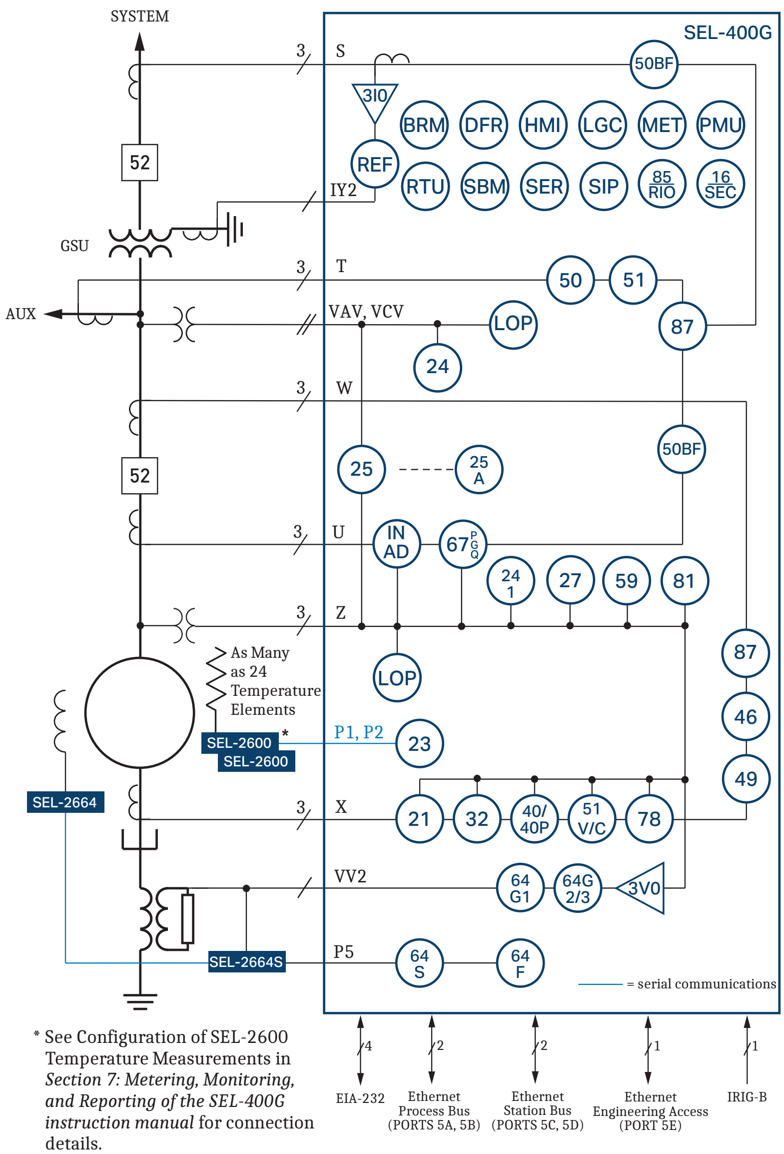
Oscillography. Record voltages, currents, and internal logic points at sampling rates as fast as 8 kHz and with time stamp based on absolute time. Phasor and harmonic analysis features allow investigation of relay and system performance.

SER. Record the last 1000 entries, including setting changes, relay startup, password access, and as many as 250 selectable logic elements.

Rules-Based Settings Editor. Use an ASCII terminal to communicate and set the relay, or use the PC-based SEL Grid Configurator Software to configure the SEL-400G, view a replica of the relay front- panel HMI, analyze fault records with relay element response, and view real-time phasors and harmonic levels.

Features

The SEL-400G contains many protection, automation, and control features. *Figure 1.2* presents a simplified functional overview of the relay.



ANSI NUMBERS/ACRONYMS AND FUNCTIONS	
21	Phase Distance
23	RTD Temperature—SEL-2600
24	Volts/Hertz
25	Synchronism Check
25A	Autosynchronizer
27	Undervoltage
32	Directional Power
40	Loss of Field
40P	Capability-Based Loss of Field
46	Current Unbalance
49	IEC 60255-Compliant Thermal Model
50BF	Breaker Failure Overcurrent
50N	Neutral Overcurrent
50 (P, G, Q)	Overcurrent (Phase, Ground, Neg. Seq.)
51C	Voltage-Controlled Inverse-Time Overcurrent
51N	Neutral Time-Overcurrent
51 (P, G, Q)	Time-Overcurrent (Phase, Ground, Neg. Seq.)
51V	Voltage-Restrained Inverse-Time Overcurrent
59	Overvoltage
64G1	Stator Ground (Fundamental Neutral Overvoltage)
64G2	Third-Harmonic Difference/Undervoltage
64G3	Third-Harmonic Ratio
64F	Rotor Ground—SEL 2664
64S	Stator Ground (Subharmonic Injection)—SEL 2664S
67 (P, G, Q)	Directional Overcurrent (Phase, Ground, Neg. Seq.)
78	Out-of-Step
81 (O, U)	Over- and Underfrequency
81A	Accumulated Frequency
81R (O, U)	Over- and Under-Rate-of-Change-of-Frequency
85 RIO	SEL Mirrored Bits Communications
87 (U, R, Q)	Universal Differential (Unrestrained, Restrained, Neg. Seq.)
DFR	Event and Disturbance Reports
HMI	Operator Interface
INAD	Inadvertent Energization
LGC	Expanded SELogic Control Equations
LOP	Loss of Potential
MET	High-Accuracy Metering
PMU	Synchrophasors
REF	Restricted Earth Fault
RTU	Remote Terminal Unit
SER	Sequential Events Recorder

ADDITIONAL FUNCTIONS	
16 SEC	Access Security (Serial, Ethernet)
BRM	Breaker Wear Monitor
LDP	Load Data Profiling
SBM	Station Battery Monitor
SIP	Software-Invertible Polarities

Five-port Ethernet card ordering option depicted.

Figure 1.2 Functional Overview

The SEL-400G includes the following features:

Distance Protection With Load Encroachment (21). The SEL-400G provides two phase impedance elements with load encroachment blinders. A reverse reach setting is also included. Transformer phase shift compensation is provided to ensure correct reach for power system faults.

RTD Temperature (23). When the SEL-400G is used in conjunction with the SEL-2600 and/or the SEL-2411, as many as 24 thermal elements in the relay can be programmed for two levels of thermal protection per element. Each

RTD input provides an alarm and trip temperature pickup setting in degrees C, provides open and shorted RTD detection, and is compatible with the following three-wire RTD types:

- PT100 (100-ohm platinum)
- Ni100 (100-ohm nickel)
- Ni120 (120-ohm nickel)
- Cu10 (10-ohm copper)

Additionally, you can configure and use the winding RTDs and the ambient temperature RTD to bias the generator thermal model and thermal protection.

Volts-Per-Hertz Elements (24). The SEL-400G provides two volts/hertz elements, each with inverse-time and definite-time characteristics. Each element has two levels, one of which can be used for alarming and the other for tripping. You can assign each to different potential, allowing both the generator and transformer to be protected using separate elements. You can enable a composite inverse-time characteristic with a two-step definite-time characteristic, a definite/inverse-time characteristic, or a simple inverse-time characteristic. The SEL-400G also provides a custom curve option.

Synchronism Check (25). The SEL-400G provides synchronization-check elements for as many as three breakers. The synchronism-check function is extremely accurate and provides supervision for acceptable voltage window and maximum percentage difference, maximum and minimum allowable slip frequency, target closing angle, and breaker closing delay. Use the disturbance report to capture complete information on the five latest paralleling operations, including generator and system voltages and frequencies, slip frequency, and phase angle when the close was initiated. The relay also keeps a running average of the breaker close time.

Autosynchronizer (25A). Selected SEL-400G-1 models have a built-in autosynchronizer function for as many as three breakers. The element monitors the voltage across the selected breaker and sends variable control pulses to the generator field voltage regulator and the prime mover speed control governor.

The 25A implements three types of pulse control:

PW	Proportional pulse width—the pulse width is proportional to the error signal (slip or voltage difference) and the pulse period is fixed.
PF	Proportional pulse frequency—the pulse width is fixed and the pulse frequency is proportional to the error signal.
FD	Both the pulse width and pulse frequency are fixed.

Once frequency, voltage, and phase are matched, the function sends a close command to the selected breaker. The close command is time-advanced by using the slip measurement and breaker close time such that the primary contacts close when the voltage angle across the breaker is zero. Use the integrated disturbance report to capture generator synchronizing events.

Over- and Undervoltage Protection (27, 59). Phase, phase-to-phase, and positive-sequence undervoltage (27), overvoltage (59), residual overvoltage (59G), and negative-sequence overvoltage (59Q) help you create protection and control schemes, such as undervoltage load shedding or standby generation start/stop schemes.

- Phase and phase-to-phase undervoltage elements based on configurable operating quantities operate with the minimum of the measured voltage magnitudes; these elements operate when any single measurement falls below the set thresholds.
- Phase and phase-to-phase overvoltage elements operate with the maximum of the measured voltage magnitudes.
- The positive-sequence undervoltage elements operate when the calculated positive-sequence voltage V1 drops below the set thresholds.
- The positive-sequence overvoltage elements operate when the calculated positive-sequence voltage V1 exceeds the set thresholds.
- The negative-sequence overvoltage elements operate when the calculated negative-sequence voltage V2 exceeds set thresholds.
- The residual-ground voltage element operates when the zero-sequence voltage 3V0 exceeds the set point. All voltage elements provide definite-time delay settings.

Six over- and six undervoltage elements are provided. Both definite-time and inverse-time characteristics are selectable.

Directional Power Detection (32). Sensitive directional power elements in the SEL-400G provide anti-motoring and/or low forward power tripping. As many as four elements for detecting real (W) or reactive (VARs) directional power flows, having independent time delays and sensitivities, are provided. Directly trip the generator under loss-of-prime mover conditions to prevent prime movers from motoring, or use low forward power indication as a tripping interlock when an orderly shutdown is required.

The SEL-400G includes a biased characteristic. This provides extra dependability for a motoring event where motoring power is very low and reactive power is high. Under these circumstances, small angle errors associated with the instrument transformers can have a more significant impact on the power calculation.

The directional power element can be assigned to a dedicated CT. It also incorporates an integrating timer.

Loss-of-Field Protection (40). Two offset positive-sequence mho elements detect loss-of-field conditions. Settable time delays help reject power swings that pass through the machine impedance characteristic. By using the included directional supervision, one of the mho elements can be set to coordinate with the generator MEL and its SSSL.

Capability-Based Loss of Field Protection (40P). Use this function to more effectively coordinate with the GCC, SSSL, and under-excitation limiter (UEL). The element can dynamically shift with voltage to maintain coordination with the UEL. This element provides an alarm for operation outside the GCC. It also provides a trip for an under-excitation event. It can alarm or trip for an SSSL event.

Current Unbalance (46). Negative-sequence current heats the rotor at a higher rate than positive-sequence current. The negative-sequence definite-time element provides alarm for early stages of an unbalanced condition. The inverse-time overcurrent element provides tripping for sustained unbalance conditions to prevent machine damage. The inverse-time negative-sequence element provides industry standard $I_2^2 \bullet t$ protection curves. The element accounts for heating due to the harmonic components as high as the 15th. In accordance with IEEE C50.12 and IEEE C50.13, each component is scaled by a weighting factor based on its sequence (positive or negative) and its harmonic order.

Thermal Model (49). The SEL-400G thermal element provides thermal overload protection based on the thermal model described in IEC standard 60255-149. The model can be biased by ambient temperature if the RTD option is used. The relay operates a thermal model with a trip value defined by the relay settings and a present heat estimate that varies with time and changing generator current.

Overcurrent Protection (50/67). The SEL-400G provides complete overcurrent protection with as many as four sets of three-phase CTs. One set of three-phase CTs can be configured as single-phase current inputs for applications requiring neutral CT inputs. Phase overcurrent protection is provided for all three-phase inputs. The following overcurrent elements are provided.

Instantaneous Overcurrent Elements (50). All instantaneous overcurrent elements provide torque control and definite-time delay settings.

- ➤ As many as four instantaneous phase overcurrent elements (50P).
- ➤ As many as four instantaneous negative-sequence overcurrent (50Q) elements.
- ➤ As many as four residual-ground instantaneous overcurrent (50G) elements. These elements use calculated residual (3I0) current levels.

Split Phase Overcurrent Protection (60). The high-set element is implemented as a conventional split phase function, i.e., a definite-time overcurrent element with unique pickup settings for the A-, B-, and C-Phases.

The adaptive low-set element is intended for use where there is a steady-state offset in the split phase current. The adaptive offset logic provides more sensitivity by tracking the value of the offset and subtracting this value from the operating signal.

The element is supervised by the external fault detector (differential element) for increased security for external events.

Time-Overcurrent Elements (51). The SEL-400G provides as many as 12 configurable time-overcurrent elements. These time-overcurrent elements support the IEC and US (IEEE) time-overcurrent characteristics. Electromechanical disk reset capabilities are provided for all time-overcurrent elements.

Directional Instantaneous Overcurrent Elements (67). The following directional overcurrent elements are available in the SEL-400G with directional control.

- ➤ As many as four directional phase overcurrent elements (67P).
- ➤ As many as four directional negative-sequence overcurrent elements (67Q).
- ➤ As many as four directional ground overcurrent elements (67Q).

Inadvertent Energization Detection (INAD). The breaker for an out-of-service generator may be closed inadvertently. The SEL-400G detects this condition by using voltage, current, and other supervisory conditions you select through a SELogic control equation. The INAD logic is available for as many as four breakers.

Breaker Failure Protection (50BF). The SEL-400G offers high-speed breaker failure protection for as many as four three-pole breakers. Use the breaker failure detection to issue retrip commands to the failed breaker, or to trip adjacent breakers by using the relay contact output logic or communications-based tripping schemes.

Loss-of-Potential Logic (60). Relay functions that use phase voltages or symmetrical component voltages rely on valid inputs to make the correct decisions. The LOP logic detects open voltage transformer fuses or other conditions that cause a loss of relay secondary voltage input. The SEL-400G with voltage inputs includes loss-of-potential logic that detects one, two, or three potentially blown fuses. When two three-phase voltages are available, the SEL-400G can implement a traditional voltage-balance LOP scheme.

100 Percent Stator Ground Detection (64G). The SEL-400G detects stator ground faults on high-impedance grounded generators using a conventional neutral overvoltage element and either a third-harmonic voltage detection scheme or the SEL-2664S Stator Ground Protection Relay. Together these functions provide 100 percent stator winding coverage.

The neutral overvoltage element (64G1) detects winding ground faults in approximately 90 percent of the winding.

Two third-harmonic schemes are provided:

- The 64G2 requires a grounded-wye terminal PT. It operates on the difference between the third harmonic at the neutral and terminals. It offers sensitive resistive fault coverage but requires a third-harmonic survey for determination of optimal settings. This scheme incorporates built-in logic to adapt to changes in terminal capacitance when a low-side generator breaker is present.
- The 64G3 operates on the ratio of the third harmonic at the neutral and to the total third harmonic. It is less sensitive than the 64G2 but does not require a third-harmonic survey. If a grounded-wye terminal PT is available, the total third harmonic is measured as the vector sum of the neutral and terminal third harmonic voltages. If a grounded-wye terminal PT is not available, a patented algorithm estimates the total third harmonic using terminal voltages and currents.

The 64G output logic incorporates an acceleration path and an integrating timers to ensure correct operation for intermittent ground faults.

Field Ground Protection (64F). The SEL-400G, with the SEL-2664 Field Ground Module, detects field ground faults by measuring field insulation-to-ground resistance by using the switched dc voltage injection method. Two-level protection for alarm and trip functions is provided.

Stator Ground Protection Using Subharmonic Injection (64S). Combine the SEL-400G and the SEL-2664S Stator Ground Protection Relay to provide rapid and reliable detection of stator ground faults under all operating conditions (including offline) by using patented Multi-Sine injection from the SEL-2664S and 100 percent stator ground protection (64G) in the SEL-400G. The SEL-2664S remains operational at standstill and during starting.

Out-of-Step Protection (78). SEL-400G relays use a single- or a double-blinder scheme, depending on user selection, to detect an out-of-step condition. In addition to the blinders, the scheme uses a mho circle that restricts the coverage of the out-of-step function to the desired extent. Furthermore, both schemes contain current supervision and torque control to supervise the operation of the out-of-step element. The out-of-step protection also employs a reactance line to divide the characteristic into a generator and system zone, each with independent pole slip counters.

Frequency Elements (81). Six independent levels of over- or underfrequency elements detect abnormal frequency operating conditions. Use the independently time-delayed output of these elements to trip or alarm.

Phase undervoltage supervision prevents undesired frequency element operation during start up, shutdown, and faults, and while the field is de-energized. A frequency element can act as an offline overspeed function. The relay can measure frequency at a minimum of 5 volts secondary, allowing it to respond to the residual core flux prior to field application. Unsupervised Relay Word bits are provided for use in custom generator overspeed schemes.

Rate-of-Change-of-Frequency Elements (81R). Six independent rate-of-change-of-frequency (ROCOF) elements are provided with individual time delays for use when frequency changes occur, for example, when there is a sudden unbalance between generation and load. They speed up control action or switching action such as network decoupling or load shedding. Each element includes logic to detect either increasing or decreasing frequency and above or below nominal frequency. Any of the six levels of ROCOF elements can operate as either an under-ROCOF element or as an over-ROCOF element.

Off-Frequency Accumulators (81AC). The SEL-400G tracks the total time-of-operation in as many as eight off-nominal frequency bands. If the off-nominal time of operation exceeds one of the independent time set points, each band can be configured to accumulate-only, trip, or alarm. The relay also supports continuous bands.

Universal Differential Protection (87-1, -2). When specified, the SEL-400G detects faults in the generator zone and in the overall zone using a secure, sensitive current differential function. This function has a sensitive percentage-restrained differential element and an unrestrained element. The differential function provides the unique capability of power transformer and CT connection compensation. This allows you to conveniently include the unit step-up transformer in the generator differential zone using wye-connected CTs for both input sets. The relay allows you to choose harmonic blocking, harmonic restraint, or both, providing a reliable differential protection during transformer inrush conditions. Even-numbered harmonics (second and fourth) provide security during energization, while fifth-harmonic blocking provides security for overexcitation conditions. Set second-, fourth-, and fifth-harmonic thresholds independently. The dual-slope percentage restraint characteristic improves element security for through-fault conditions.

REF. Apply the restricted earth fault (REF) protection feature for the sensitive detection of internal ground faults on grounded wye-connected windings. The neutral current CT provides the operating current. Polarizing current is derived from the residual current calculated for the protected winding. A sensitive directional element determines whether the fault is internal or external. Zero-sequence current thresholds and selectable CT saturation logic supervise tripping. The REF scheme is applicable to single-phase banks with one CT on each neutral.

Pumped-Storage Logic. Switching from generator to pump mode impacts elements that use sequence components. This can be addressed by dynamically changing the phase rotation setting. A second impact occurs if the differential zone includes the reversing switch. In the past, this was addressed by the switching of the CT secondary wiring. The SEL-400G solution addresses both problems using an intuitive approach. The user identifies any CTs and PTs that are downstream from the reversing switch. The relay then rolls the phasing internally to correct the phase change introduced in the primary circuit.

Models and Options

Depending on the number of interface boards, the SEL-400G is available in 6U (one interface board), 7U (as many as two interface boards), or 8U size (as many as three interface boards) (U is one rack unit in height—44.45 mm or 1.75 in). Select I/O boards from a choice of five interface boards, each board designed to provide a wide range of input and output combinations to tailor the relay for your specific application. If your application requires more I/O, add contact I/O with the SEL-2505/SEL-2506 Remote I/O Module.

Firmware Options

The SEL-400G comes in two different ordering options: Advanced Generator Protection System (SEL-400G-0) and Advanced Generator Protection System and Autosynchronizer (SEL-400G-1). The SEL-400G-1 has the same relay functionality and adds the autosynchronizer function.

Current Channel Options

Select the CT secondary current for Terminals S, T, and U as either 1 A or 5 A (all three phases of all three terminals as 1 A or 5 A). For Terminals W and X, select the CT secondary current as 1 A or 5 A. For the three inputs of Terminal Y, various combinations can be selected for each of the inputs.

NOTE: For Options 1, 2, and 3, the Y terminal can be configured in software as three-phase or single-phase. For Options 4–8, the Y terminal can only be configured as single phase. A three-phase Y input can be included in a differential zone. A single-phase Y input can be used as the operate signal for the REF, ground overcurrent, and ground directional elements.

Table 1.1 Supported 1 A/5 A Terminal Combinations

Terminals S, T, U	Terminals W, X, IY1, IY2, IY3
Terminal S = 5 A Terminal T = 5 A Terminal U = 5 A	Terminal W = 5 A Terminal X = 5 A Terminal IY1, IY2, IY3 = 5 A, 5 A, 5 A
Terminal S = 1 A Terminal T = 1 A Terminal U = 1 A	Terminal W = 5 A Terminal X = 5 A Terminal IY1, IY2, IY3 = 1 A, 1 A, 1 A
	Terminal W = 1 A Terminal X = 1 A Terminal IY1, IY2, IY3 = 1 A, 1 A, 1 A
	Terminal W = 5 A Terminal X = 5 A Terminal IY1, IY2, IY3 = 5 A, 1 A, 1 A
	Terminal W = 5 A Terminal X = 5 A Terminal IY1, IY2, IY3 = 0.2 A, 0.2 A, 0.2 A
	Terminal W = 1 A Terminal X = 1 A Terminal IY1, IY2, IY3 = 0.2 A, 0.2 A, 0.2 A
	Terminal W = 5 A Terminal X = 5 A Terminal IY1, IY2, IY3 = 5 A, 5 A, 0.2 A
	Terminal W = 5 A Terminal X = 5 A Terminal IY1, IY2, IY3 = 1 A, 1 A, 0.2 A

Voltage Channel Options

300 V phase-to-neutral wye configuration PT inputs

Connector Type

- ➤ Screw-terminal block inputs
- ➤ Connectorized

Conformal Coat

Conformal coating provides an additional barrier to harsh environments, such as high humidity and airborne contaminants. See selinc.com/conformalcoating/ for more information.

Interface Board (I/O) Options

Select from five interface boards to provide flexibility with the diverse I/O requirements when installing the SEL-400G at power plants, transmission, and distribution networks. You can install the interface boards in any combination in the relay. *Table 1.2* provides I/O information about the five interface boards.

Table 1.2 Interface Board Information

Board Name	Inputs	Description	Outputs	Description
INT2	8	Optoisolated, independent, level-sensitive	13	Standard Form A
			2	Standard Form C
INT4	18	Two sets of 9 common optoisolated, level-sensitive	6	High-speed, high-current interrupting, Form A
	6	Optoisolated, independent, level-sensitive	2	Standard Form A
INT7	8	Optoisolated, independent, level-sensitive	13	High-current interrupting, Form A
			2	Standard Form C
INT8	8	Optoisolated, independent, level-sensitive	8	High-speed, high-current interrupting, Form A
INTD	24	Optoisolated, common, level-sensitive	8	Standard Form A

Voltage ranges for the inputs on the main board as well as for the inputs on the four interface boards are as follows:

- ➤ 24 Vdc
- ➤ 48 Vdc
- ➤ 110 Vdc
- ➤ 125 Vdc
- ➤ 220 Vdc
- ➤ 250 Vdc

Power Supply Options

- ➤ 24–48 Vdc
- ➤ 48–125 Vdc or 110–120 Vac
- ➤ 125–250 Vdc or 110–240 Vac

Ethernet Connection Options

Four-port Ethernet card with port combinations of:

- Four copper (10BASE-T/100BASE-TX)
- Four fiber (100BASE-FX)
- Two copper (10BASE-T/100BASE-TX) and two fiber (100BASE-FX)

Five-port Ethernet card with small form-factor pluggable (SFP) ports (100BASE-FX and 1000BASE-X)[2]

Ethernet Communications Protocols

- FTP
- Telnet
- DNP3
- PRP
- HSR
- IEC 61850 Edition 2.1
- Modbus TCP

Ordering Assistance

Contact the SEL factory or your local Technical Service Center for ordering information (see *Technical Support on page 3.51*). You can also view the latest ordering information on the SEL website at selinc.com.

Applications

Steam Turbine

Figure 1.3 shows the SEL-400G applied to a large steam turbine. One differential element is fed from CTs at the generator neutral and generator terminals. A second differential is fed from CTs at the generator neutral, AUX transformer, and GSU HV breakers. REF protection is implemented on the GSU HV winding. Synchronism-check and autosynchronizing are implemented on each breaker. High-speed breaker failure and inadvertent energization is provided for each breaker.

Field ground protection is provided by the SEL-2664. One-hundred percent stator ground is provided by the SEL-2664S. RTD temperature sensing is provided by the SEL-2600. The SEL-400G can interface with two SEL-2600 Modules for a total of 24 RTDs.

Overcurrent protection is provided for the HV side of the AUX transformer.

[2] All ports support 100 Mbps speeds. **PORT 5A** and **PORT 5B** also support 1 Gbps speeds.

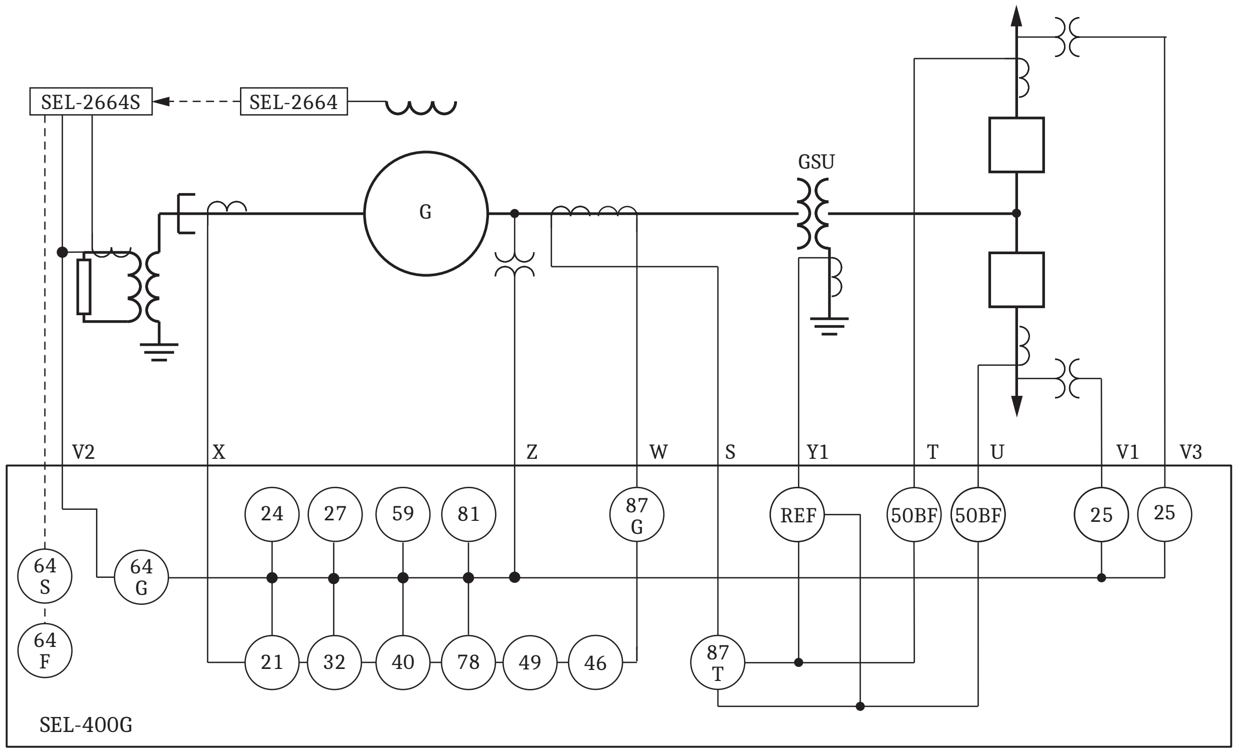


Figure 1.3 Steam Turbine Generator

Hydro Generator

Figure 1.4 shows the SEL-400G applied to a large hydro generator. The SEL-400G can track frequency as high as 120 Hz, ensuring the accuracy of all protection functions.

In this application, one differential element provides transverse differential protection by using the branch CTs at the generator neutral. These currents are summated to provide the generator neutral-side current. The second differential element provides overall differential protection using the neutral branch currents, the braking and exciter transformer CTs and the GSU HV breaker CT.

When three-phase voltages are available on both sides of the sync-breaker, the SEL-400G provides additional security against VT wiring errors, equivalent to a three-phase synchronism-check.

The frequency element can act as an offline overspeed function. It measures at a minimum of 5 volts secondary, allowing it to respond to the residual core flux prior to field application.

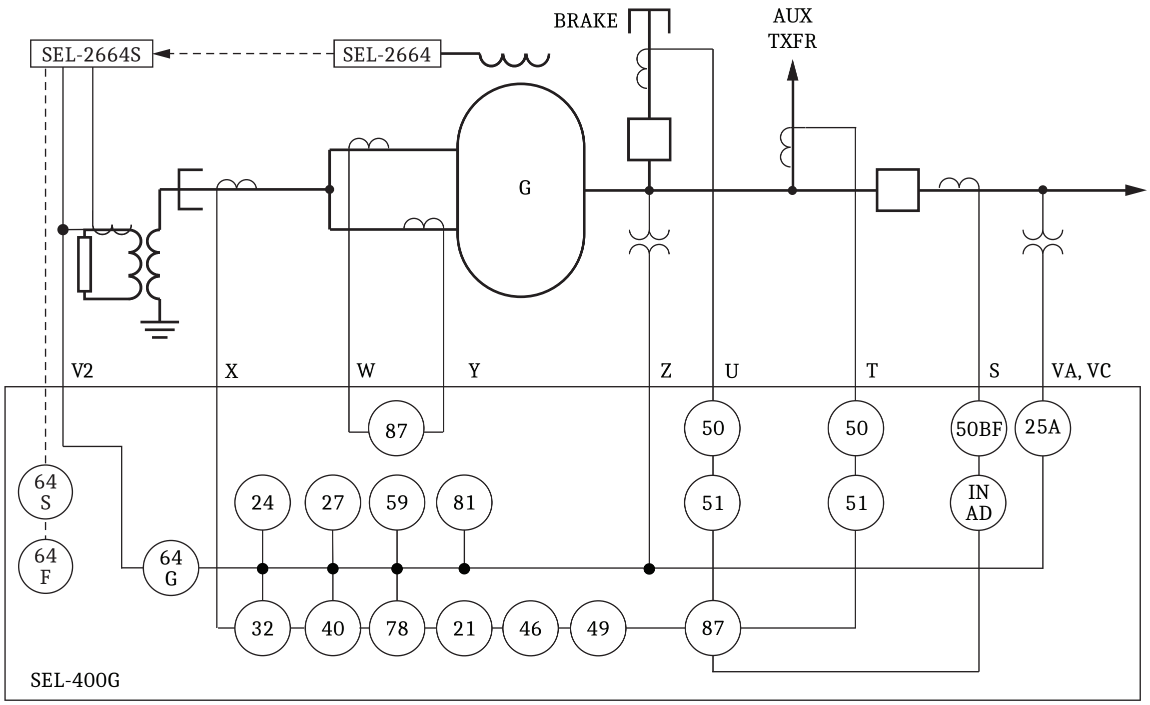


Figure 1.4 Hydro Generator

Combustion Gas Turbine

Figure 1.5 shows the SEL-400G applied to a combustion gas turbine. A load commutated inverter (LCI) is typically used for starting these generators.

Using an open-corner delta connection, you can configure the V2 input to provide ground fault protection for the isophase bus duct. The SEL-2664S provides ground fault protection throughout the start process.

To provide effective protection during startup, inputs S, T, and Y1 are frequency-tracked using the system frequency, which is derived from V1 and V3 voltage inputs. The same approach can be employed for other generators that start at off-nominal frequency, such as pumped-storage hydro or cross-compound units. See *Frequency Tracking on page 5.12* for more details. One differential element protects the generator and the second protects the GSU.

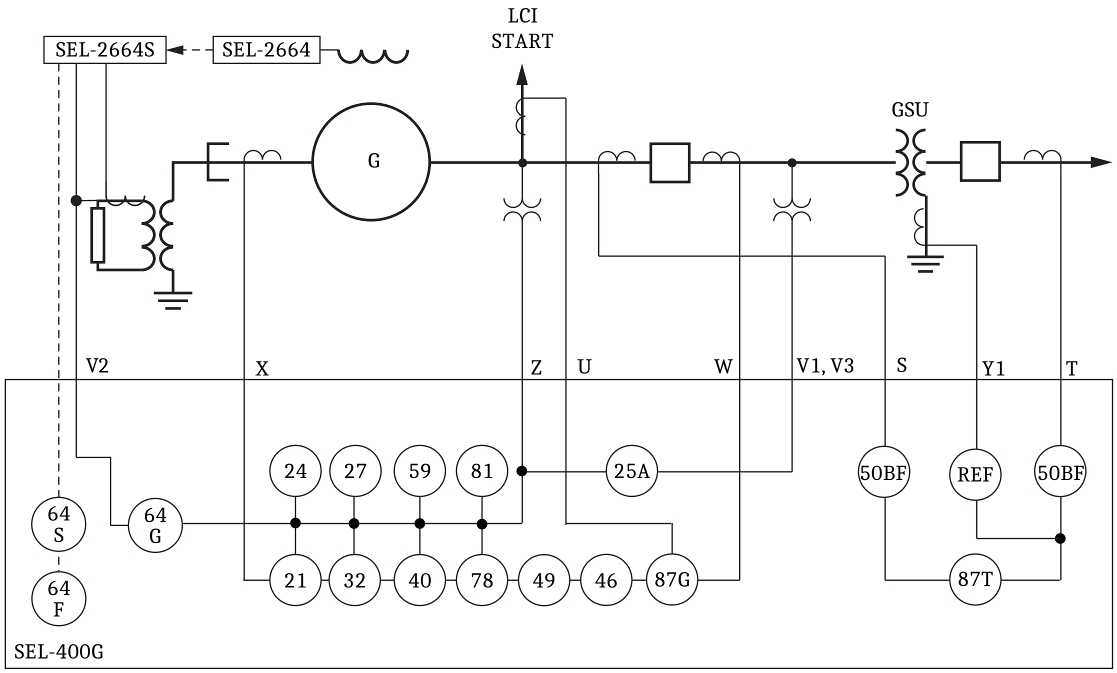


Figure 1.5 Combustion Gas Turbine

Product Characteristics

Each SEL-400-series relay shares common features, but has unique characteristics. *Table 1.3* summarizes the unique characteristics for the SEL-400G.

Table 1.3 SEL-400G Characteristics (Sheet 1 of 2)

Characteristic	Value
Standard Processing Rate	2.5 ms
Battery Monitor	One
Autorecloser	None
SELOGIC	
Protection Freeform	250 lines
Automation Freeform	10 blocks of 100 lines each
SELOGIC Variables	64 protection 256 automation
SELOGIC Math Variables	64 protection 256 automation
Conditioning Timers	32 protection 32 automation
Sequencing Timers	32 protection 32 automation
Counters	32 protection 32 automation
Latch Bits	32 protection 32 automation

Table 1.3 SEL-400G Characteristics (Sheet 2 of 2)

Characteristic	Value
Control	
Remote Bits	64
Breakers	Four: S, T, U, Y Three-pole only
Disconnects	10
Bay Control	Supported
Metering	
Maximum/Minimum Metering	Supported
Energy Metering	Supported
Synchronism Check Metering	Supported
Demand Metering	Supported
Instantaneous Metering	Supported
Harmonics Metering	Supported
RMS Metering	Supported
Thermal Metering	Supported
Synchrophasor Metering	Supported

Specifications

Compliance

Designed and manufactured under an ISO 9001 certified quality management system

FCC Compliance Statement

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference in which case the user will be required to correct the interference at his own expense.

UL Listed to U.S. and Canadian safety standards (File E212775; NRGU, NRGU7)

CE Mark

General

AC Analog Inputs

Sampling Rate:	8 kHz

AC Current Inputs (Secondary Circuits)

Note: Current transformers are Measurement Category II.

Input Current

5 A Nominal:	S, T, U, W, X, and Y terminals
1 A Nominal:	S. T, U, W, X, and Y terminals
0.2 A/1 A/5 A Nominal:	Y terminal only (REF)

Current Rating (With DC Offset at X/R = 10, 1.5 cycles)

5 A Nominal:	91.0 A
1 A Nominal:	18.2 A
0.2 A Nominal:	3.64 A

Continuous Thermal Rating

5 A Nominal:	15 A 20 A (+55°C)
1 A Nominal:	3 A 4 A (+55°C)
0.2 A Nominal:	0.6 A 0.8 A (+55°C)

Saturation Current (Linear) Rating

5 A Nominal:	100 A
1 A Nominal:	20 A
0.2 A Nominal:	4 A

One-Second Thermal Rating

5 A Nominal:	500 A
1 A Nominal:	100 A
0.2 A Nominal:	20 A

One-Cycle Thermal Rating

5 A Nominal:	1250 A-peak
1 A Nominal:	250 A-peak
0.2 A Nominal:	50 A-peak

Burden Rating

5 A Nominal:	≤0.5 VA at 5 A
1 A Nominal:	≤0.1 VA at 1 A
0.2 A Nominal:	≤0.02 VA at 0.2 A

A/D Current Limit

Note: Signal clipping may occur beyond this limit.

5 A Nominal:	247.5 A
1 A Nominal:	49.5 A
0.2 A Nominal:	9.9 A

AC Voltage Inputs

Three-phase, four-wire (wye), and two PT delta and single-phase (only V terminal) connections are supported.

Rated Voltage Range:	55–250 V_{LN} (V and Z terminals)
Operational Voltage Range:	0–300 V_{LN}
Ten-Second Thermal Rating:	600 Vac
Burden:	≤0.1 VA @ 125 V

Frequency and Rotation

Rotation:	ABC ACB
Nominal Frequency Rating:	50 60
Frequency Tracking (Requires PTs):	Tracks between 5.0–120.0 Hz Below 5.0 Hz = 5.0 Hz Above 120.0 Hz = 120.0 Hz
Maximum Slew Rate:	30 Hz/s

Power Supply

24–48 Vdc

Rated Voltage:	24–48 Vdc
Operational Voltage Range:	18–60 Vdc
Vdc Input Ripple:	15% per IEC 60255-26:2013
Interruption:	20 ms at 24 Vdc, 100 ms at 48 Vdc per IEC 60255-26:2013
Burden:	<40 W

48–125 Vdc or 110–120 Vac

Rated Voltage:	48–125 Vdc, 110–120 Vac
Operational Voltage Range:	38–140 Vdc 85–140 Vac
Rated Frequency:	50/60 Hz
Operational Frequency Range:	30–120 Hz
Vdc Input Ripple:	15% per IEC 60255-26:2013
Interruption:	14 ms @ 48 Vdc, 160 ms @ 125 Vdc per IEC 60255-26:2013
Burden:	<40 W, <90 VA

125–250 Vdc or 110–240 Vac

Rated Voltage:	125–250 Vdc, 110–240 Vac
Operational Voltage Range:	85–300 Vdc 85–264 Vac
Rated Frequency:	50/60 Hz
Operational Frequency Range:	30–120 Hz
Vdc Input Ripple:	15% per IEC 60255-26:2013
Interruption:	46 ms @ 125 Vdc, 250 ms @ 250 Vdc per IEC 60255-26:2013
Burden:	<40 W, <90 VA

Control Outputs

Note: IEEE C37.90-2005 and IEC 60255-27:2013

Update Rate: 2.5 ms

Make (Short Duration Contact Current): 30 Adc
1,000 operations at 250 Vdc
2,000 operations at 125 Vdc

Limiting Making Capacity: 1000 W at 250 Vdc (L/R = 40 ms)

Mechanical Endurance: 10,000 operations

Standard

Rated Voltage: 24–250 Vdc
110–240 Vrms

Operational Voltage Range: 0–300 Vdc
0–264 Vrms

Operating Time: Pickup ≤6 ms (resistive load)
Dropout ≤6 ms (resistive load)

Short-Time Thermal Withstand: 50 A for 1 s

Continuous Contact Current: 6 A at 70°C
4 A at 85°C

Contact Protection: MOV protection across open contacts
264 Vrms continuous voltage
300 Vdc continuous voltage

Limiting Breaking Capacity/Electrical Endurance: 10,000 operations
10 operations in 4 seconds, followed by 2 minutes idle

Rated Voltage	Resistive Break	Inductive Break L/R = 40 ms (DC) PF = 0.4 (AC)
24 Vdc	0.75 Adc	0.75 Adc
48 Vdc	0.63 Adc	0.63 Adc
125 Vdc	0.30 Adc	0.30 Adc
250 Vdc	0.20 Adc	0.20 Adc
110 Vrms	0.30 Arms	0.30 Arms
240 Vrms	0.20 Arms	0.20 Arms

Hybrid (High-Current Interrupting)

Rated Voltage: 24–250 Vdc

Operational Voltage Range: 0–300 Vdc

Operating Time: Pickup ≤6 ms (resistive load)
Dropout ≤6 ms (resistive load)

Short-Time Thermal Withstand: 50 Adc for 1 s

Continuous Contact Current: 6 Adc at 70°C
4 Adc at 85°C

Contact Protection: MOV protection across open contacts
300 Vdc continuous voltage

Limiting Breaking Capacity/Electrical Endurance: 10,000 operations
4 operations in 1 second, followed by 2 minutes idle

Rated Voltage	Resistive Break	Inductive Break
24 Vdc	10 Adc	10 Adc (L/R = 40 ms)
48 Vdc	10 Adc	10 Adc (L/R = 40 ms)
125 Vdc	10 Adc	10 Adc (L/R = 40 ms)
250 Vdc	10 Adc	10 Adc (L/R = 20 ms)

Note: Do not use hybrid control outputs to switch ac control signals.

Fast Hybrid (High-Speed High-Current Interrupting)

Rated Voltage: 24–250 Vdc

Operational Voltage Range: 0–300 Vdc

Operating Time: Pickup ≤10 µs (resistive load)
Dropout ≤8 ms (resistive load)

Short-Time Thermal Withstand: 50 Adc for 1 s

Continuous Contact Current: 6 Adc at 70°C
4 Adc at 85°C

Contact Protection: MOV protection across open contacts
300 Vdc continuous voltage

Limiting Breaking Capacity/Electrical Endurance: 10,000 operations
4 operations in 1 second, followed by 2 minutes idle

Rated Voltage	Resistive Break	Inductive Break
24 Vdc	10 Adc	10 Adc (L/R = 40 ms)
48 Vdc	10 Adc	10 Adc (L/R = 40 ms)
125 Vdc	10 Adc	10 Adc (L/R = 40 ms)
250 Vdc	10 Adc	10 Adc (L/R = 20 ms)

Note: Do not use hybrid control outputs to switch ac control signals.

Control Inputs

Optoisolated (Use With AC or DC Signals)

INT2, INT7, and INT8 Interface Boards: 8 inputs with no shared terminals

INT4 and INTD Interface Boards: 6 inputs with no shared terminals
18 inputs with shared terminals (2 groups of 9 inputs with each group sharing one terminal)

Voltage Options: 24, 48, 110, 125, 220, 250 V

Current Drawn: <5 mA at nominal voltage
<8 mA for 110 V option

DC Thresholds (Dropout Thresholds Indicate Level-Sensitive Option)

24 Vdc: Pickup 19.2–30.0 Vdc
Dropout: <14.4 Vdc

48 Vdc: Pickup 38.4–60.0 Vdc;
Dropout <28.8 Vdc

110 Vdc: Pickup 88.0–132.0 Vdc;
Dropout <66.0 Vdc

125 Vdc: Pickup 105–150 Vdc;
Dropout <75 Vdc

220 Vdc: Pickup 176–264 Vdc;
Dropout <132 Vdc

250 Vdc: Pickup 200–300 Vdc;
Dropout <150 Vdc

AC Thresholds (Ratings Met Only When Recommended Control Input Settings Are Used—see *Table 2.1*.)

24 Vac: Pickup 16.4–30.0 Vac rms
Dropout: <10.1 Vac rms

48 Vac: Pickup 32.8–60.0 Vac rms;
Dropout <20.3 Vac rms

110 Vac: Pickup 75.1–132.0 Vac rms;
Dropout <46.6 Vac rms

125 Vac: Pickup 89.6–150.0 Vac rms;
Dropout <53.0 Vac rms

220 Vac: Pickup 150.3–264 Vac rms;
Dropout <93.2 Vac rms

250 Vac: Pickup 170.6–300 Vac rms;
Dropout <106 Vac rms

Sampling Rate: 2 kHz

Communications Ports

EIA-232: 1 front and 3 rear

Serial Data Speed: 300–57600 bps

Ethernet Card Slot for the Optional Four-Port Ethernet Card

Ordering Option: 10/100BASE-T

Connector Type: RJ45

Ordering Option: 100BASE-FX Fiber-Optic

Connector Type: LC

Fiber Type: Multimode

Wavelength: 1300 nm

Source: LED

Min. TX Power: –19 dBm

Max. TX Power: –14 dBm

RX Sensitivity: –32 dBm

Sys. Gain: 13 dB

Ethernet Card Slot for the Optional Five-Port Ethernet Card

Ordering Option: 100BASE-FX fiber-optic Ethernet SFP transceiver

Part Number: 8103-01 or 8109-01

Mode: Multi

Wavelength (nm): 1310

Source: LED

Connector Type: LC

Min. TX Pwr. (dBm): –24

Max. TX Pwr. (dBm): –14

Min. RX Sens. (dBm): –31

Max. RX Sens. (dBm): –12

Approximate Range: 2 km

Transceiver Internal Temperature Accuracy: ±3.0°C

Transmitter Average Optical Power Accuracy: ±3.0 dB

Received Average Optical Input Power Accuracy: ±3.0 dB

Ordering Option: 1000BASE-LX fiber-optic Ethernet SFP transceiver

Part Number: 8130-01, 8130-02, 8130-03, or 8130-04

Mode: Single

Wavelength (nm): 1310

Source: LED

Connector Type: LC

	Part Number			
	8130-01	8130-02	8130-03	8130-04
Min. TX Pwr. (dBm)	–9.5	–6	–5	–2
Max. TX Pwr. (dBm)	–3	–1	0	3
Min. RX Sens. (dBm)	–21	–22	–24	–24
Max. RX Sens. (dBm)	–3	–3	–3	–3
Approximate Range (km)	10	20	30	40

Transceiver Internal Temperature Accuracy: ±3.0°C

Transmitter Average Optical Power Accuracy: ±3.0 dB

Received Average Optical Input Power Accuracy: ±3.0 dB

Ordering Option: 1000BASE-XD fiber-optic Ethernet SFP transceiver

Part Number: 8130-05

Mode: Single

Wavelength (nm): 1550

Source: LED

Connector Type: LC

Min. TX Pwr. (dBm): –5

Max. TX Pwr. (dBm): 0

Min. RX Sens. (dBm): –24

Max. RX Sens. (dBm): –3

Approximate Range: 50 km

Transceiver Internal Temperature Accuracy: ±3.0°C

Transmitter Average Optical Power Accuracy: ±3.0 dB

Received Average Optical Input Power Accuracy: ±3.0 dB

Ordering Option: 1000BASE-ZX fiber-optic Ethernet SFP transceiver

Part Number: 8130-06, 8130-08, or 8130-10

Mode: Single

Wavelength (nm): 1550

Source: LED

Connector Type: LC

	Part Number		
	8130-06	8130-08	8130-10
Min. TX Pwr. (dBm)	0	1	5
Max. TX Pwr. (dBm)	5	5	8
Min. RX Sens. (dBm)	–24	–36	–36
Max. RX Sens. (dBm)	–3	–10	–10
Approximate Range (km)	80	160	200

Transceiver Internal Temperature Accuracy: ±3.0°C

Transmitter Average Optical Power Accuracy: ±3.0 dB

Received Average Optical Input Power Accuracy: ±3.0 dB

Ordering Option: 1000BASE-SX fiber-optic Ethernet SFP transceiver

Part Number: 8131-01

Mode: Multi

Wavelength (nm): 850

Source: LED

Connector Type: LC

Min. TX Pwr. (dBm): –9

Max. TX Pwr. (dBm): –2.5

Min. RX Sens. (dBm): –18

Max. RX Sens. (dBm): 0

Approximate Range: 300 m for 62.5/125 µm; 550 m for 50/125 µm

Transceiver Internal Temperature Accuracy: ±3.0°C

Transmitter Average Optical Power Accuracy: ±3.0 dB

Received Average Optical Input Power Accuracy: ±3.0 dB

Time Inputs

IRIG Time Input—Serial PORT 1

Input:	Demodulated IRIG-B
Rated I/O Voltage:	5 Vdc
Operational Voltage Range:	0–8 Vdc
Logic High Threshold:	≥2.8 Vdc
Logic Low Threshold:	≤0.8 Vdc
Input Impedance:	2.5 kΩ

IRIG-B Input—BNC Connector

Input:	Demodulated IRIG-B
Rated I/O Voltage:	5 Vdc
Operational Voltage Range:	0–8 Vdc
Logic High Threshold:	≥2.2 Vdc
Logic Low Threshold:	≤0.8 Vdc
Input Impedance:	>1 kΩ
Dielectric Test Voltage:	0.5 kVac

PTP

Input:	IEEE 1588 PTPv2
Profiles:	Default, C37.238-2011 (Power Profile), IEC/IEEE 61850-9-3-2016 (Power Utility Automation Profile)
Synchronization Accuracy:	±100 ns @ 1-second synchronization intervals when communicating directly with master clock

Operating Temperature

–40° to +85°C (–40° to +185°F)

Note: LCD contrast impaired for temperatures below –20° and above +70°C. Stated temperature ranges not applicable to UL applications.

Humidity

5% to 95% without condensation

Weight (Maximum)

6U Rack Unit:	15.9 kg (35 lb)
7U Rack Unit:	17.6 kg (39 lb)
8U Rack Unit:	20.4 kg (45 lb)

Terminal Connections

Rear Screw-Terminal Tightening Torque, #8 Ring Lug

Minimum:	1.0 Nm (9 in-lb)
Maximum:	2.0 Nm (18 in-lb)

User terminals and stranded copper wire should have a minimum temperature rating of 105°C. Ring terminals are recommended.

Wire Sizes and Insulation

Wire sizes for grounding (earthing), current, voltage, and contact connections are dictated by the terminal blocks and expected load currents. You can use the following table as a guide in selecting wire sizes. The grounding conductor should be as short as possible and sized equal to or greater than any other conductor connected to the device, unless otherwise required by local or national wiring regulations.

Connection Type	Min. Wire Size	Max. Wire Size
Grounding (Earthing) Connection	14 AWG (2.5 mm^2)	N/A
Current Connection	16 AWG (1.5 mm^2)	10 AWG (5.3 mm^2)
Potential (Voltage) Connection	18 AWG (0.8 mm^2)	14 AWG (2.5 mm^2)
Contact I/O	18 AWG (0.8 mm^2)	10 AWG (5.3 mm^2)
Other Connection	18 AWG (0.8 mm^2)	10 AWG (5.3 mm^2)

Type Tests

Installation Requirements

Overvoltage Category:	2
Pollution Degree:	2

Safety

Product Standards: IEC 60255-27:2013
IEEE C37.90-2005
21 CFR 1040.10

Dielectric Strength: IEC 60255-27:2013, Section 10.6.4.3
2.5 kVac, 50/60 Hz for 1 min: Analog Inputs, Contact Outputs, Digital Inputs
3.6 kVdc for 1 min: Power Supply, Battery Monitors
2.2 kVdc for 1 min: IRIG-B
1.1 kVdc for 1 min: Ethernet

Impulse Withstand: IEC 60255-27:2013, Section 10.6.4.2
IEEE C37.90-2005
Common Mode:
±1.0 kV: Ethernet
±2.5 kV: IRIG-B
±5.0 kV: All other ports
Differential Mode:
0 kV: Analog Inputs, Ethernet, IRIG-B, Digital Inputs
±5.0 kV: Standard Contact Outputs, Power Supply Battery Monitors
+5.0 kV: Hybrid Contact Outputs

Insulation Resistance: IEC 60255-27:2013, Section 10.6.4.4
>100 MΩ @ 500 Vdc

Protective Bonding: IEC 60255-27:2013, Section 10.6.4.5.2
<0.1 Ω @ 12 Vdc, 30 A for 1 min

Ingress Protection: IEC 60529:2001 + CRGD:2003
IEC 60255-27:2013
IP30 for front and rear panel
IP10 for rear terminals with installation of ring lug
IP40 for front panel with installation of serial port cover
IP52 for front panel with installation of dust protection accessory

Max Temperature of Parts and Materials: IEC 60255-27:2013, Section 7.3

Flammability of Insulating Materials: IEC 60255-27:2013, Section 7.6
Compliant

Electromagnetic (EMC) Immunity

Product Standards:	IEC 60255-26:2013 IEC 60255-27:2013 IEEE C37.90-2005
Surge Withstand Capability (SWC):	IEC 61000-4-18:2006 + A:2010 IEEE C37.90.1-2012 Slow Damped Oscillatory, Common and Differential Mode: ±1.0 kV ±2.5 kV Fast Transient, Common and Differential Mode: ±4.0 kV
Electrostatic Discharge (ESD):	IEC 61000-4-2:2008 IEEE C37.90.3-2001 Contact: ±8 kV Air Discharge: ±15 kV
Radiated RF Immunity:	IEEE C37.90.2-2004 IEC 61000-4-3:2006 + A1:2007 + A2:2010 20 V/m (>35 V/m, 80% AM, 1 kHz) Sweep: 80 MHz to 1 GHz Spot: 80, 160, 450, 900 MHz 10 V/m (>15 V/m, 80% AM, 1 kHz) Sweep: 80 MHz to 1 GHz Sweep: 1.4 GHz to 2.7 GHz Spot: 80, 160, 380, 450, 900, 1850, 2150 MHz
Electrical Fast Transient Burst (EFTB):	IEC 61000-4-4:2012 Zone A: ±2 kV: Communication ports ±4 kV: All other ports
Surge Immunity:	IEC 61000-4-5:2005 Zone A: ±2 kV_{L-L} ±4 kV_{L-E} ±4 kV: Communication ports **Note:** Cables connected to IRIG-B ports shall be less than 10 m in length for Zone A compliance. Zone B: ±2 kV: Communication ports
Conducted Immunity:	IEC 61000-4-6:2013 20 V/m; (>35 V/m, 80% AM, 1 kHz) Sweep: 150 kHz–80 MHz Spot: 27, 68 MHz
Power Frequency Immunity (DC Inputs):	IEC 61000-4-16:2015 Zone A: Differential: 150 V_{RMS} Common Mode: 300 V_{RMS}
Power Frequency Magnetic Field:	IEC 61000-4-8:2009 Level 5: 100 A/m; ≥60 Seconds; 50/60 Hz 1000 A/m 1 to 3 Seconds; 50/60 Hz **Note:** 50G1P ≥0.05 (ESS = N, 1, 2) 50G1P ≥0.1 (ESS = 3, 4)
Power Supply Immunity:	IEC 61000-4-11:2004 IEC 61000-4-17:1999/A1:2001/A2:2008 IEC 61000-4-29:2000 AC Dips & Interruptions Ripple on DC Power Input DC Dips & Interruptions Gradual Shutdown/Startup (DC only) Discharge of Capacitors Slow Ramp Down/Up Reverse Polarity (DC only)
Damped Oscillatory Magnetic Field:	IEC 61000-4-10:2016 Level 5: 100 A/m

EMC Compatibility

Product Standards:	IEC 60255-26:2013
Emissions:	IEC 60255-26:2013, Section 7.1 Class A 47 CFR Part 15B Class A Canada ICES-001 (A) / NMB-001 (A)

Environmental

Product Standards:	IEC 60255-27:2013
Cold, Operational:	IEC 60068-2-1:2007 Test Ad: 16 hours at –40°C
Cold, Storage:	IEC 60068-2-1:2007 Test Ad: 16 hours at –40°C
Dry Heat, Operational:	IEC 60068-2-2:2007 Test Bd: 16 hours at +85°C
Dry Heat, Storage:	IEC 60068-2-2:2007 Test Bd: 16 hours at +85°C
Damp Heat, Cyclic:	IEC 60068-2-30:2005 Test Db: +25°C to +55°C, 6 cycles (12 + 12-hour cycle), 95% RH
Damp Heat, Steady State:	IEC 60068-2-78:2013 Severity: 93% RH, +40°C, 10 days
Cyclic Temperature:	IEC 60068-2-14:2009 Test Nb: –40°C to +80°C, 5 cycles
Vibration Resistance:	IEC 60255-21-1:1988 Class 2 Endurance, Class 2 Response
Shock Resistance:	IEC 60255-21-2:1988 Class 1 Shock Withstand, Class 1 Bump Withstand, Class 2 Shock Response
Seismic:	IEC 60255-21-3:1993 Class 2 Quake Response

Reporting Functions

High-Resolution Data

Rate:	8000 samples/second 4000 samples/second 2000 samples/second 1000 samples/second
Output Format:	Binary COMTRADE

Note: Per IEEE C37.111-2013, *Common Format for Transient Data Exchange (COMTRADE) for Power Systems*.

Event Reports

Length:	0.25–24 seconds (based on LER and SRATE settings)
Volatile Memory:	3 s of back-to-back event reports sampled at 8 kHz
Nonvolatile Memory:	At least 4 event reports of a 3 s duration sampled at 8 kHz
Resolution:	2.5 ms

Disturbance Recorder

Length: 60–300 seconds (based on DRLER setting)

Volatile Memory: At least 1 DR event of 300 s duration sampled at 50 Hz

Nonvolatile Memory: At least 4 DR events of 300 s duration sampled at 50 Hz

Resolution: 20 ms for all elements

Event Summary

Storage: 100 summaries

Breaker History

Storage: 128 histories

Sequential Events Recorder

Storage: 1000 entries

Trigger Elements: 250 relay elements

Resolution: 0.5 ms for contact inputs

Resolution: 2.5 ms for all elements

Processing Specifications

AC Voltage and Current Inputs

8000 samples per second, 3 dB low-pass analog filter cut-off frequency at 3.1 kHz, ±5%
Digital filtering
Full-cycle cosine after low-pass analog filtering

Analog Update Rate (Arate)

Frequency (Hz)	Update Rate (ms)
20 < F ≤ 120	2.5
10 < F ≤ 20	5
5 < F ≤ 10	7.5

Protection and Control Processing

2.5 ms (minimum)

Control Points

64 remote bits
64 local control bits
32 latch bits in protection logic
32 latch bits in automation logic

Relay Element Pickup Ranges and Accuracies

Differential Elements (General)

Number of Zones: 2 (A, B, and C elements)

Number of Terminals: 6

TAP Pickup: (0.1–32.0) • I_{NOM} A secondary

TAP Range: $TAP_{MAX}/TAP_{MIN} \leq 35$

Time-Delay Accuracy: ±0.1% plus ±2.5 ms

Differential Elements (Restraint)

Pickup Range: 0.1–4.0 per unit

Pickup Accuracy: 1 A nominal: ±5%
5 A nominal: ±5% ±0.10 A

Pickup Time (If E87UNB = N): 1.25 cyc minimum
1.25 cyc + 2.5 ms typical
1.25 cyc + 5.0 ms max

Pickup Time (If E87UNB = Y): 0.5 cyc minimum
0.5 cyc + 2.5 ms typical
1.5 cyc max

Slope Setting Range: 5%–90%

Differential Elements (Unrestraint)

Pickup Range: (1.0–20.0) • TAP

Pickup Accuracy: ±5% of user setting, ±0.02 • I_{NOM} A

Pickup Time (Filtered Unrestraint): 0.7 cyc minimum
0.85 cyc typical
1.2 cyc maximum

Pickup Time (Raw Unrestraint): 0.25 cyc minimum
0.5 cyc typical
1.0 cyc maximum

Note: The raw unrestraint pickup is set to U87P • $\sqrt{2}$ • 2

Harmonic Elements (2nd, 4th, 5th)

Setting Range: OFF, 5–100% of fundamental

Pickup Accuracy: 1 A nominal ±5% ±0.02 A
5 A nominal ±5% ±0.10 A

Time-Delay Accuracy: 0.1% + 1 processing interval

Negative-Sequence Differential Element

Pickup Range: 0.05–1 per unit

Slope Range: 5–100%

Pickup Accuracy: ±5% of user setting, ±0.02 • I_{NOM} A

Maximum Pickup/Dropout Time: 2 cycles

Winding Coverage: 2%

Incremental Restraint and Operating Threshold Current Supervision

Setting Range: 0.1–10.0 per unit

Accuracy: ±5% ±0.02 • I_{NOM}

Open-Phase Detection Logic

3 elements per terminal (S, T, U, Y)

Pickup Range

1 A Nominal: 0.04–1.00 A

5 A Nominal: 0.2–5.00 A

Maximum Pickup/Dropout Time: 1/2 cyc + 0.0025 ms

Restricted Earth Fault (REF)

Three Elements: 1 per IY1, IY2, IY3

Setting Range: 0.05–3 per unit

Pickup Accuracy

1 A Nominal: 0.01 A

5 A Nominal: 0.05 A

Maximum Pickup/Dropout Time: 1.25 cyc + Arate + 0.0025 s

Instantaneous/Definite-Time Overcurrent Elements (50)

Phase- and Negative-Sequence, Ground-Residual Elements

Setting Range

5 A Nominal: 0.25–100.00 A secondary, 0.01-A steps

1 A Nominal: 0.05–20.00 A secondary, 0.01-A steps

Accuracy (Steady State)

5 A Nominal: ±0.05 A plus ±3% of setting

1 A Nominal: ±0.01 A plus ±3% of setting

Transient Overreach (Phase and Ground Residual)

5 A Nominal: ±5% of setting, ±0.10 A

1 A Nominal: ±5% of setting, ±0.02 A

Transient Overreach (Negative Sequence)

5 A Nominal: ±6% of setting, ±0.10 A

1 A Nominal: ±6% of setting, ±0.02 A

Time-Delay Range: 0.00–400 s

Timer Accuracy:	±0.005 s plus ±0.1% of setting
Maximum Pickup/Dropout Time:	1.25 cyc + Arate + 0.005 s

Adaptive Time-Overcurrent Elements (51S and 51CV)

Setting Range (Adaptive Within the Range)	
5 A Nominal:	0.25–16.00 A secondary, 0.01 A steps
1 A Nominal:	0.05–3.20 A secondary, 0.01 A steps
Accuracy (Steady State)	
5 A Nominal:	±0.05 A plus ±3% of setting
1 A Nominal:	±0.01 A plus ±3% of setting
Transient Overreach	
5 A Nominal:	±5% of setting, ±0.10 A
1 A Nominal:	±5% of setting, ±0.20 A
Time Dial Range	
U.S.:	0.50–15.00, 0.01 steps
IEC:	0.05–1.00, 0.01 steps
Timing Accuracy:	±1.25 cyc ± 5 ms ±4% of curve time (for current between 2 and 30 multiples of pickup)

Curves operate on definite time for current greater than 30 multiples of pickup.

Reset:	20 ms or electromechanical reset emulation time

Voltage-Controlled Overcurrent Element

Setting Range:	0.25–16.00 A, sec
Curve:	U1–U5, C1–C5
Time Dial:	0.05–15.0
EM Reset:	Y, N
Pickup Accuracy:	±1.25 cyc + Arate + 0.005s
Time-Delay Accuracy:	±0.1% of setting ±0.005 s

Voltage-Restrained Overcurrent Element

Setting Range:	2.00–16.00 A, sec
Curve:	U1–U5, C1–C5
Time Dial:	0.50–15.00
EM Reset:	Y, N
Pickup Accuracy:	±1.25 cyc + Arate + 0.005 s
Time-Delay Accuracy:	±0.1% of setting ±0.005 s

Phase Directional Elements (67)

Number:	4 (1 each for S, T, U, Y)
Outputs:	Forward and reverse
Accuracy:	±0.05 Ω secondary
Transient Overreach:	+5% of set reach
Maximum Delay:	1.25 cycles + Arate + 5 ms

Ground Directional Elements

Number:	4 (1 each for S, T, U, Y)
Outputs:	Forward and reverse
Polarization Quantity:	Zero-sequence voltage
Operate Quantity:	Zero-sequence current ($3I_0$) (where $3I_0$ = IA + IB + IC)
Sensitivity:	0.05 • I_{NOM} A of secondary $3I_0$
Accuracy:	±0.05 Ω secondary
Transient Overreach:	+5% of set reach
Maximum Delay:	1.25 cycles + Arate + 5 ms

Negative-Sequence Directional Element

Number:	4 (1 each for S, T, U, Y)
Outputs:	Forward and reverse
Polarization Quantity:	Negative-sequence voltage
Operate Quantity:	Negative-sequence current ($3I_2$)
Sensitivity:	0.05 • I_{NOM} A of secondary $3I_2$
Accuracy:	±0.05 Ω secondary
Transient Overreach:	+5% of setting
Maximum Delay:	1.25 cycles + Arate + 5 ms

Undervoltage and Overvoltage Elements (27/59)

Setting Ranges	
Phase Elements:	2–300 V_{LN} in 0.01-V steps
Phase-to-Phase Elements:	4–520 V_{LL} in 0.01-V steps
Sequence Elements:	2–300 V_{LN} in 0.01-V steps
Pickup Accuracy (Steady State)	
Phase Elements:	±3% of setting, ±0.5 V
Phase-to-Phase Elements Wye):	±3% of setting, ±0.5 V
Phase-to-Phase Elements (Delta):	±3% of setting, ±1 V
Sequence Elements:	±5% of setting, ±1 V
Pickup Accuracy (Transient Overreach)	
Phase Elements:	±5%
Phase-to-Phase Elements Wye):	±5%
Phase-to-Phase Elements (Delta):	±5%
Sequence Elements:	±5%
Maximum Pickup/Dropout Time	
Phase Elements:	1.25 cycles ± Arate + 5.0 ms
Phase-to-Phase Elements Wye):	1.25 cycles ± Arate + 5.0 ms
Sequence Elements:	1.25 cycles ± Arate + 5.0 ms
Time Delay Accuracy:	±0.1% of user setting ±5 ms
Inverse Time Delay Accuracy:	±1% of user setting ±5 ms

Underfrequency and Overfrequency Elements (81)

Setting Range:	5.01–119.99 Hz, 0.01-Hz steps
Accuracy, Steady State Plus Transient:	±0.005 Hz for frequencies between 40.00 and 70.00 Hz
Maximum Pickup/Dropout Time:	3.0 cycles
Setting Range, Undervoltage Blocking:	20.00–200.00 V_{LN} (Wye) or V_{LL} (Open-Delta)
Pickup Accuracy, Undervoltage Blocking:	±2% ±0.5 V
Time-Delay Range:	0.05–400.00 s, 0.01-s increment
Time-Delay Accuracy:	±0.1% of setting ±0.005 seconds

Accumulated Frequency Elements (81A)

Setting Range:	5.01–119.99 Hz, 0.01-Hz steps
Accuracy, Steady State Plus Transient:	±0.005 Hz for frequencies between 40.00 and 70.00 Hz
Maximum Pickup/Dropout Time:	0–400 s for 81AD and 0.5–6000 for band times
Time-Delay Range:	0.050–80.000 s, 0.005-s increment
Time-Delay Accuracy:	±0.1% of setting ±0.005 seconds

Rate-of-Change-of-Frequency Elements (81R)

Setting Range:	–29.95 to 29.95 Hz/s, 0.05-Hz/s steps
Setting Range, Undervoltage Blocking:	20.00–200.00 V_{LN} (wye) or V_{LL} (open-delta)
Accuracy:	±0.005 Hz/s frequencies between 20.00 and 80.00 Hz
Pickup Accuracy, Undervoltage Blocking:	±2% ±0.5 V
Time-Delay Range:	0.050–80.000 s, 0.005 s increment
Time-Delay Accuracy:	±0.1% of setting ±5 ms seconds

Mho Phase Distance Elements

Number of Zones:	2
Pickup Range	
5 A Nominal:	OFF, 0.05 to 100 ohms, sec
1 A Nominal:	OFF, 0.25 to 500 ohms, sec
Offset Range	
5 A Nominal:	0.00–10 ohms, sec
1 A Nominal:	0.00–50 ohms, sec
Pickup Accuracy:	±5% of user setting ±0.1 Inom
Maximum Operating Time:	1.00 cycle + Arate + 10 ms
Time Delay Accuracy:	±0.1% of user setting ± 5 ms

Breaker Inadvertent Energization Protection Logic

Setting Range, Overcurrent	
5 A Nominal:	0.25–5.00 A secondary, 0.01 A steps
1 A Nominal:	0.05–1.00 A secondary, 0.01 A steps
Accuracy (Steady State)	
5 A Nominal:	±0.05 A plus ±3% of setting
1 A Nominal:	±0.01 A plus ±3% of setting
Transient Overreach	
5 A Nominal:	±5% of setting, ±0.10 A
1 A Nominal:	±5% of setting, ±0.20 A
Setting Range, Undervoltage:	1.00–300 V, sec in 0.01-V steps
Accuracy, Undervoltage:	±2% ±0.5 V
Time-Delay Range (Arm/Disarm):	0.0000–100 s
Time-Delay Range:	0.0000–10 s
Time-Delay Accuracy:	±0.1% of setting ±0.005 s

Volts/Hertz Elements (24)

Definite-Time Element

Setting Range:	100–200% steady state
Pickup Accuracy, Steady-State:	±1% of set point
Maximum Pickup/Dropout Time:	1.5 cycles + delay time setting
Time-Delay Range:	0.040–6000 s
Time-Delay Range, Reset:	0.040–6000 s
Time-Delay Accuracy:	±0.1% of setting ±5 ms

User-Definable Curve Element

Setting Range:	100–200%
Pickup Accuracy:	±1% of set point
Reset Time-Delay Range:	0.040–6000 s
Timing Accuracy:	±0.1% ±0.1% of curve time ±5 ms

Synchronism-Check Elements (25)

Slip Frequency PU Range:	0.005-0.500 Hz, 0.001 Hz steps
Slip Frequency PU Accuracy:	±0.0025 Hz plus ±2% of setting
Close Angle Range:	0.1-80 degrees, 0.1-degree steps
Close Angle Accuracy:	±0.1 degrees

Autosynchronism Elements (25A)

Frequency Matching	
Raise/Lower:	Digital Output
Setting Range, Control Pulse Mode:	OFF, Proportional Width, Fixed Duration, Proportional Frequency
Setting Range, Control Slope:	0.01–100 Hz/s
Setting Range, Control Pulse Period:	0.000–60 s
Setting Range, Control Pulse Duration:	0.000–60 s
Timing Accuracy:	±1% ±5.0 ms
Voltage Matching	
Raise/Lower:	Digital Output
Setting Range, Control Pulse Mode:	OFF, Proportional Width, Fixed Duration, Proportional Frequency
Setting Range, Control Slope:	0.01–100 V/s
Setting Range, Control Pulse Period:	0.000–60 s
Setting Range, Control Pulse Duration:	0.000–60 s
Timing Accuracy:	±0.1% ±5.0 ms
Time-Delay Range, Control Expiration:	0.000–400 s
Time-Delay Accuracy, Control Expiration:	±0.1% of setting ±5 ms

Breaker Failure Instantaneous Overcurrent

Setting Range	
5 A Nominal:	0.50–50 A secondary, 0.01-A steps
1 A Nominal:	0.10–10.0 A, 0.01-A steps
Accuracy	
5 A Nominal:	±0.05 A, ±3% of setting
1 A Nominal:	±0.01 A, ±3% of setting
Transient Overreach	
5 A Nominal:	±5%, ±0.10 A
1 A Nominal:	±5%, ±0.02 A
Maximum Pickup Time:	1.25 cyc + Arate + 5 ms
Maximum Dropout Time:	1.25 cyc + Arate + 5 ms
Maximum Reset Time:	1.25 cyc + Arate + 5 ms
Time-Delay Range:	0.0000–20 s, 0.0025 s steps
Time-Delay Accuracy:	±0.1% of setting ±5 ms

Breaker Flashover Elements

Setting Range:	0.50–50 A secondary, 0.01 A steps
Accuracy, Steady State Plus Transient:	±5% of setting, ±0.10 A
Maximum Pickup/Dropout Time:	1.25 cyc + Arate + 2.5 ms
Time-Delay Range:	0.00–100.00 s, 0.01-s steps
Time-Delay Accuracy:	±0.1% of setting ±5 ms

Directional Overpower/Underpower Element (32)

Operating Quantities:	OFF, 3P*m*F, 3Q*m*F,3P*qp*F, 3Q*qp*F (*m* = S, T, U, Y, G *qp* = ST, TU, UW, WX)
Setting Range	
5 A:	–2000.00 to 2000.00 VA, 0.02 VA, sec steps
1 A:	–400.00 to 400.00 VA, 0.02 VA, sec steps
Pickup Accuracy:	±3% of setting and ±5 VA, power factor >±0.5 at nominal frequency
Time-Delay Range:	0.000–400 s
Time-Delay Accuracy:	±0.1% of setting ±5 ms

Impedance-Based Loss of Field Element (40Z)

Zone 1

Setting Range, Mho Diameter	
5 A Nominal:	OFF, 0.1–100 ohms, sec
1 A Nominal:	OFF, 0.5–500 ohms, sec
Setting Range, Offset Reactance	
5 A Nominal:	–50.0 to 0 ohms, sec
1 A Nominal:	–250.0 to 0 ohms, sec
Pickup Accuracy:	±3% at an impedance angle of –90 degrees

Zone 2

Setting Range, Mho Diameter	
5 A Nominal:	OFF, 0.1–100 ohms, sec
1 A Nominal:	OFF, 0.5–500 ohms, sec
Setting Range, Offset Reactance	
5 A Nominal:	–50.0 to 50 ohms, sec
1 A Nominal:	–250.0 to 250 ohms, sec
Setting Range, Supervision Angle:	–20.0 to 0 deg in 0.1 deg steps
Pickup Accuracy:	±3% at an impedance angle of –90 degrees
Time-Delay Range:	0.000–400 s
Time-Delay Accuracy:	±0.1% of setting ±0.005 s

PQ-Based Loss of Field Element (40P)

Setting Range, Zones 1, 2, 4	
5 A Nominal:	–2000.00 to –1.00 VA sec, 0.01 VA sec step
1 A Nominal:	–400.00 to –0.20 VA, sec, 0.01 VA sec step
Setting Range, Zones 2 and 4 (Ranges Depend on GCC Point Specifying)	
5 A Nominal:	–2000.00 to 2000.00 VA sec, 0.01 VA sec steps
1 A Nominal:	–400.00 to 400.00 VA sec, 0.01 VA sec steps
Pickup Accuracy:	±3% of setting and ±5 VA, power factor > ±0.5 at nominal frequency
Time-Delay Range:	0.000–400 s
Time-Delay Accuracy:	±0.1% of setting ±0.005 s

Current Unbalance Element (46)

Operate Quantity:	I2GP, I2GPEQ
Setting Range %:	OFF, 2.0–100
Level 1 Delay:	0.000–1000.000 s
Level 2 Time Dial:	1–100 s
Pickup Accuracy:	Harmonic filtering is run every 5 s
Time-Delay Accuracy:	±0.1% of setting ±0.005 seconds
Harmonic Filtering Accuracy Range:	20–80 Hz of tracked frequency

Split-Phase Element (60P/N)

Setting Range	
5 A Nominal:	0.1–100 A, sec, 0.01 A sec step
1 A Nominal:	0.02–20 A, sec, 0.01 A sec steps
0.2 A Nominal:	0.01–4 A, sec, 0.01 A sec steps
Time-Delay Range:	0.000–400 s
Time-Constant Range:	1–2400 s
Pickup Accuracy:	±1% of setting
Time-Delay Accuracy:	±0.1% of setting ±5.0 ms

100% Stator Ground Element (64G)

Setting Range, Voltage:	0.1-150.0 volts sec
Pickup Accuracy:	±3% of setting, ±0.1 V
Setting Range, Power Supervision	
5 A Nominal:	OFF, 1.00–2000 VA sec, 0.01 VA steps
1 A Nominal:	OFF, 0.20–400 VA sec, 0.01 VA steps
Time-Delay Range:	0.000–400 s
Time-Delay Accuracy:	±0.1% of setting ±5.0 ms

Field Ground Element (64F)

Setting Range:	OFF, 0.5–200 kilohms
Pickup Accuracy:	Defined by the SEL-2664
Time-Delay Range:	0.000–400 seconds
Time-Delay Accuracy:	±0.1% of setting ±5.0 ms

Injection-Based Stator Ground Element (64S)

Setting Range:	OFF, 0.1–10 kilohms
Pickup Accuracy:	Defined by the SEL-2664S
Time-Delay Range:	0.000–400 seconds
Time-Delay Accuracy:	±0.1% of setting ±5.0 ms

Out-of-Step Element (78)

Setting Range, Mho and Blinder Reach	
5 A Nominal:	0.05 to 100 ohms, sec
1 A Nominal:	0.25 to 500 ohms, sec
Setting Range, Current Supervision	
5 A Nominal:	1.00–100 A, sec
1 A Nominal:	0.20–20 A, sec
Time-Delay Range, OOS:	0.000–1 s
Time-Delay Range, Trip:	0.000–1 s
Time-Delay Range, Trip Duration:	0.000–5 s
Setting Range, Generator Slip Counter:	1–5
Setting Range, System Slip Counter:	OFF, 1–10
Setting Range, Total Slip Counter:	OFF, 1–10
Time-Delay Range, Slip Counter Reset:	0.000–1 s

Accuracy (Steady State)

5 A Nominal:	±5% of setting plus ±0.01 A for SIR (source to line impedance ratio) < 30 ±10% of setting plus ±0.01 A for 30 ≤ SIR ≤ 60
1 A Nominal:	±5% of setting plus ±0.05 A for SIR (source to line impedance ratio) < 30 ±10% of setting plus ±0.05 A for 30 ≤ SIR ≤ 60
Transient Overreach:	<5% of setting plus steady-state accuracy
Time-Delay Accuracy:	±0.1% of setting ±5.0 ms

Load Encroachment Element

Setting Range, Impedance Reach

5 A Nominal:	0.05 to 64 ohms, sec
1 A Nominal:	0.25 to 320 ohms, sec
Setting Range, Forward Load Angle:	–90.0 to 90 deg
Setting Range, Reverse Load Angle:	90.0 to 270 deg
Impedance Accuracy:	±3%
Time-Delay Accuracy:	±0.1% of setting ±5.0 ms

Bay Control

Breakers:	4 maximum
Disconnects (Isolators):	10 maximum
Time-Delay Range:	0.020–2000 s, 5 ms step
Time-Delay Accuracy:	±0.1% of setting ±5.0 ms

Station DC Battery System Monitor

Rated Voltage:	15–300 Vdc
Operational Voltage Range:	0–350 Vdc
Input Sampling Rate:	2 kHz
Processing Rate:	5 ms
Operating Time:	≤1.5 seconds (element dc ripple) ≤30 ms (all elements but dc ripple)

Setting Range

DC Settings:	1 Vdc Steps (OFF, 15–300 Vdc)
AC Ripple Setting:	1 Vac Steps (1–300 Vac)
Pickup Accuracy:	±10% ±2 Vdc (dc ripple) ±3% ±2 Vdc (all elements but dc ripple)

Metering Accuracy

All metering accuracies are based on an ambient temperature of 20°C and nominal frequency.

Currents

Phase Current Magnitude

5 A Model:	±0.2% plus ±4 mA (0.05–3.0) • I_{NOM}
1 A Model:	±0.2% plus ±0.8 mA (0.05–3.0) • I_{NOM}
0.2 A Model:	±0.2% plus ±0.8 mA (0.05–0.5) • I_{NOM} ±0.2% plus ±0.4 mA (0.5–3.0) • I_{NOM}

Phase Current Angle

5 A Model:	±0.6° in the current range (0.05–0.5) • I_{NOM} ±0.2° in the current range (0.5–3.0) • I_{NOM}
1 A Model:	±0.6° in the current range (0.05–0.5) • I_{NOM} ±0.2° in the current range (0.5–3.0) • I_{NOM}
0.2 A Model:	±1.5° in the current range (0.05–0.5) • I_{NOM} ±0.3° in the current range (0.5–3.0) • I_{NOM}

Sequence Current Magnitude

5 A Model:	±0.3% plus ±4 mA (0.5–100 A s)
1 A Model:	±0.3% plus ±0.8 mA (0.1–20 A s)

Sequence Current Angle

All Models:	±0.3°

Voltages

300 V Maximum Inputs

Phase and Phase-to-Phase Voltage Magnitude:	±2.5% ±1 V (5–33.5 V) ±0.1% (33.5–300 V)
Phase and Phase-to-Phase Angle:	±1.0° (5–33.5 V) ±0.5° (33.5–300 V)
Sequence Voltage Magnitude (V1, V2, 3V0):	±2.5%, ±1 V (5–33.5 V) ±0.1% (33.5–300 V)
Sequence Voltage Angle (V1, V2, 3V0):	±1.0° (5–33.5 V) ±0.5° (33.5–300 V)

Power

MW (P), Per Phase (Wye), 3ϕ (Wye or Delta) Per Terminal

±1% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1ϕ)
±0.7% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (3ϕ)

MVAr (Q), Per Phase (Wye), 3ϕ (Wye or Delta) Per Terminal

±1% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 0, 0.5 lead, lag (1ϕ)
±0.7% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 0, 0.5 lead, lag (3ϕ)

MVA (S), Per Phase (Wye), 3ϕ (Wye or Delta) Per Terminal

±1% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1ϕ)
±0.7% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (3ϕ)

PF, Per Phase (Wye), 3ϕ (Wye or Delta) Per Terminal

±1% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1ϕ)
±0.7% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (3ϕ)

Energy

MWh (P), Per Phase (Wye), 3ϕ (Wye or Delta)

±1% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1ϕ)
±0.7% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (3ϕ)

MVARh (Q), Per Phase (Wye), 3ϕ (Wye or Delta)

±1% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 0, 0.5 lead, lag (1ϕ)
±0.7% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 0, 0.5 lead, lag (3ϕ)

Demand/Peak Demand Metering

Time Constants:	5, 10, 15, ..., 250, 255, 300 minutes
IA, IB, and IC per Terminal:	±0.2% ±0.0008 • I_{NOM}, (0.1–1.2) • I_{NOM}
3I2 per Terminal 3I0 (IG) per Terminal (Wye-Connected Only):	±0.3% ±0.0008 • I_{NOM}, (0.1–20) • I_{NOM}

Optional RTD Elements (Models Compatible With SEL-2600 Series RTD Module)

24 RTD inputs via SEL-2600 Series RTD Module and SEL-2800 Fiber-Optic Transceiver

Monitor Ambient or Other Temperatures

PT 100, NI 100, NI 120, and CU 10 RTD-Types Supported, Field Selectable

As long as 500 m Fiber-Optic Cable to SEL-2600 Series RTD Module

Synchrophasor

Synchrophasor Measurement:	IEC/IEEE 60255-118-1:2018 (IEEE C37.118.1:2011, 2014a)
Synchrophasor Data Transfer:	IEEE C37.118.2:2011
Number of Synchrophasor Data Streams:	5

Number of Synchrophasors for Each Stream:
24 Phase Synchrophasors (6 Voltage and 18 Currents)
8 Positive-Sequence Synchrophasors (2 Voltage and 6 currents)

Number of User Analogs for Each Stream:	16

Number of User Digitals for Each Stream:	64
Synchrophasor Data Rate:	As many as 60 messages per second (60 Hz) As many as 50 messages per second (50 Hz)
Synchrophasor Accuracy:	Class P
Synchrophasor Data Recording:	Records as much as 120 s IEEE C37.232-2011, File Naming Convention

Breaker Monitoring

Running Total of Interrupted Current (kA) per Pole:	±5% ±0.02 • I_{NOM}
Percent kA Interrupted for Trip Operations:	±5%
Percent Breaker Wear per Pole:	±5%
Compressor/Motor Start and Run Time:	±1 s
Time Since Last Operation:	±1 day

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SECTION 2

Installation

The first steps in applying the SEL-400G Advanced Generator Protection System are installing and connecting the relay. This section describes installation requirements for the physical configurations of the SEL-400G.

To install and connect the relay safely and effectively, you must be familiar with relay configuration features and options and relay jumper configuration. You should carefully plan relay placement, cable connections, and relay communication. This section also contains drawings of typical ac and dc connections to the SEL-400G (see *AC/DC Connection Diagrams on page 2.42*). Use these drawings as a starting point for planning your particular relay application. Consider the following when installing the SEL-400G.

It is also very important to limit access to the SEL-400G settings and control functions by using passwords. For information on relay access levels and passwords, see *Changing the Default Passwords in the Terminal on page 3.11 in the SEL-400 Series Relays Instruction Manual*.

For more introductory information on using the relay, see *Section 2: PC Software* and *Section 3: Basic Relay Operations in the SEL-400 Series Relays Instruction Manual*.

Shared Configuration Attributes

There are common or shared attributes among the many possible configurations of the SEL-400G. This section discusses the main shared features of the relay.

Relay Sizes

The relay is available in 6U, 7U, and 8U sizes. Relay sizes correspond to height in rack units, U, where U is approximately 44.45 mm (1.75 in). All relay sizes are available in a horizontal configuration as a rack-mount or panel-mount relay. The 6U size is available with one I/O board. The 7U version can support as many as two I/O boards, and the 8U version can support as many as three I/O boards.

Front-Panel Templates

Front-panel templates are the same for all sizes of the relay. *Figure 2.1* illustrates an example front-panel templates. The front panel has three pockets for slide-in labels: one pocket for the target LED labels, and two pockets for the operator control labels. *Figure 2.1* shows the front-panel pocket areas and openings for typical relay orientations; dashed lines denote the pocket areas. Refer to the instructions included in the Configurable Label kit for information on reconfiguring front-panel LED and pushbutton labels.

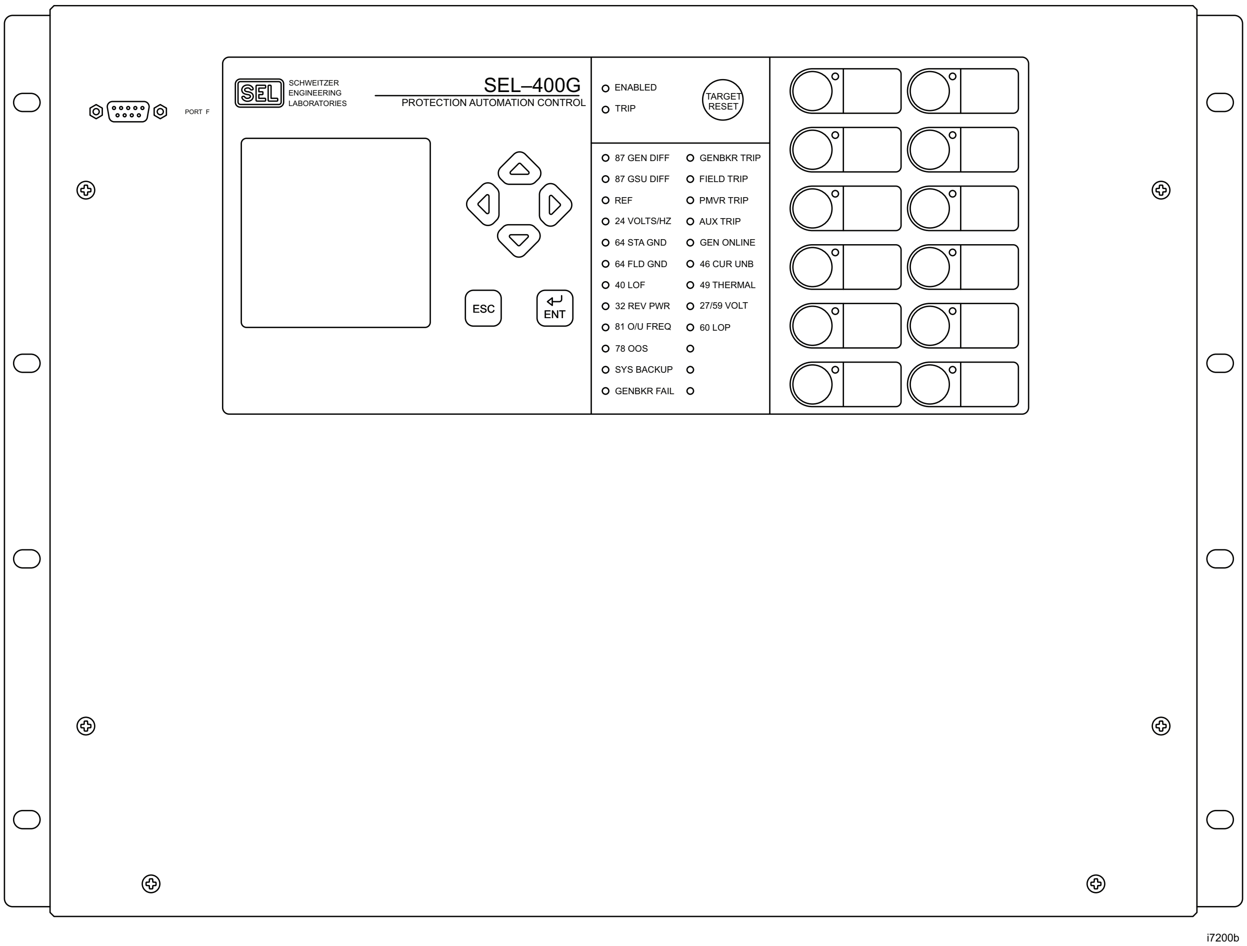


Figure 2.1 SEL-400G 8U Front Panel

Rear Panels

Figure 2.2, *Figure 2.3*, and *Figure 2.4* show the 8U, 7U, and 6U rear panels, respectively. Fixed terminal blocks are shown in *Figure 2.2* and Connectorized terminal blocks are shown in *Figure 2.3* and *Figure 2.4*.

Connector Types

Screw-Terminal Connectors—I/O and Battery Monitor/Power

Connection to the relay I/O and Monitor/Power terminals on the rear panel is through screw-terminal connectors. You can remove the entire screw-terminal connector from the back of the relay to disconnect relay I/O, dc battery monitor, and power without removing each wire connection. The screw-terminal connectors are each uniquely keyed (see *Figure 2.32*) and will only fit into one slot on the rear panel. In addition, the receptacle key prevents you from inverting the screw-terminal connector. This feature makes relay removal and replacement easier.

Secondary Circuit Connectors

Fixed Terminal Blocks

Connect CT and PT inputs to the fixed terminal blocks in the bottom two rows of the relay rear panel. You cannot remove these terminal blocks from the relay rear panel. These terminals offer a secure high-reliability connection for CT and PT secondaries.

Connectorized

The Connectorized SEL-400G features receptacles that accept plug-in/plug-out connectors for terminating CT and PT inputs. This requires ordering a Connectorized wiring harness kit (SEL-WA0487E) with mating plugs and wire leads. *Figure 2.3* shows the relay with Connectorized CT and PT analog inputs (see *Connectorized on page 2.36* for more information).

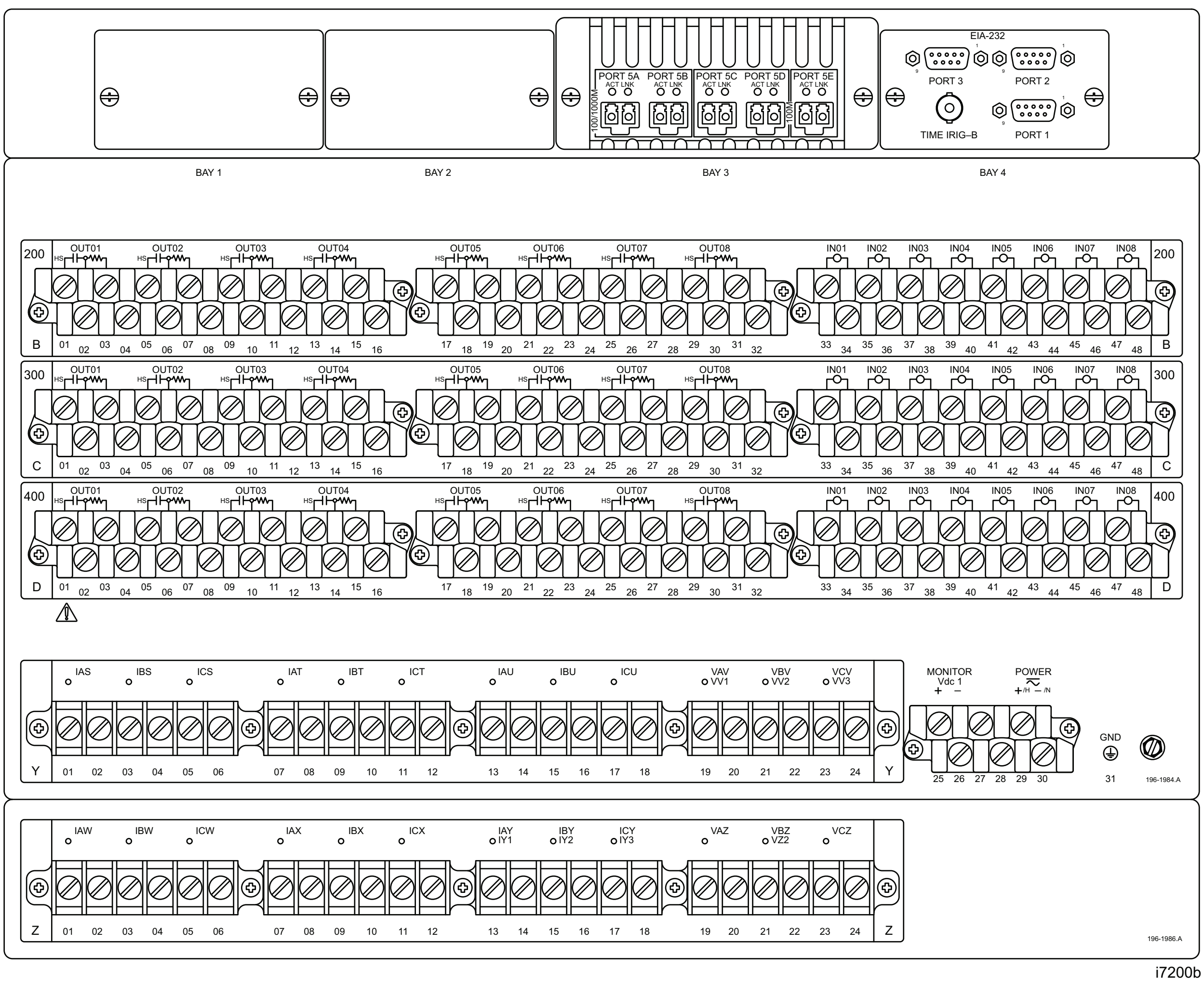


Figure 2.2 Rear Panel With Fixed Terminal Blocks (8U) and INT8 I/O Boards

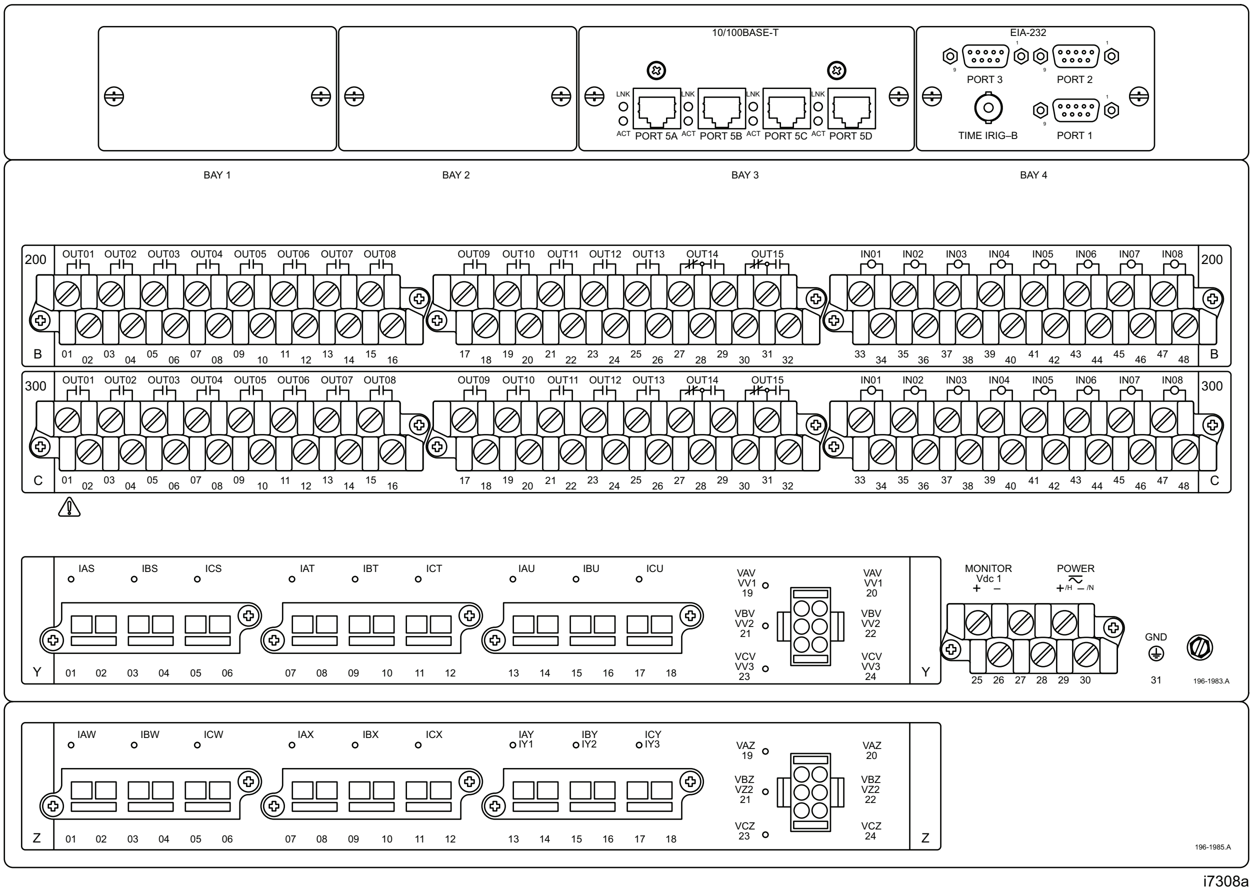


Figure 2.3 Rear Panel Connectorized (7U) With INT2 I/O Boards

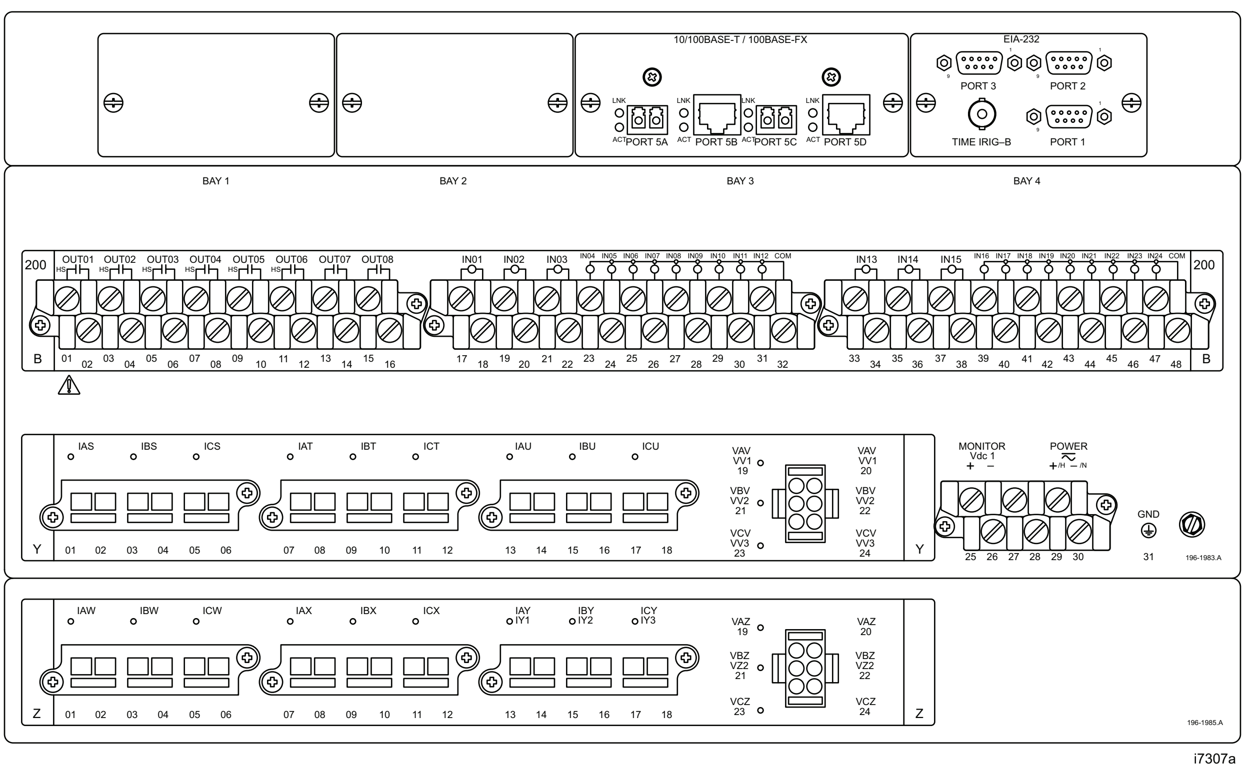


Figure 2.4 Rear Panel Connectorized (6U) With INT4 I/O Board

Secondary Circuits

The SEL-400G presents a low burden load on the CT secondaries and PT secondaries. The relay accepts the following five sets of three-phase CT inputs:

- IAS, IBS, and ICS
- IAT, IBT, and ICT
- IAU, IBU, and ICU
- IAW, IBW, and ICW
- IAX, IBX, and ICX

If the Y terminals is configured as Y, a sixth three-phase CT input is available as follows:

IAY, IBY, and ICY

⚠WARNING
Before working on a CT circuit, first apply a short to the secondary winding of the CT.

If the Y terminals is configured as 1PH, then the relay also accepts the following three single-phase CT inputs, primarily for restricted earth fault protection: IY1, IY2, and IY3.

For 5 A terminals, the rated nominal input current, I_{NOM}, is 5 A. For 1 A terminals, the rated nominal input current, I_{NOM}, is 1 A. For 0.2 A terminals, the

rated nominal input current, I_{NOM}, is 0.2 A. Continuous input current for both relay types is 3 • I_{NOM} (or 4 • I_{NOM} as high as 55°C). See *AC Current Inputs (Secondary Circuits) on page 1.19* for complete CT input specifications.

The relay also accepts the following two sets of three-phase potentials from power system PT or CCVT (capacitor-coupled voltage transformer) secondaries.

- VAV, VBV, and VCV
- VAZ, VBZ, and VCZ

The SEL-400G supports several variations of VT configurations and connections. See *Configuration of Voltage Inputs on page 5.3* for more information.

The nominal line-to-neutral input voltage for the PT inputs is 67 volts with a range of 0–300 volts, and a burden of less than 0.1 VA at 125 volts, L-N. PT connections can be four-wire (wye) or open-delta connections.

Control Inputs

The SEL-400G inputs on the I/O interface boards (INT2, INT4, INT7, INT8, or INTD I/O boards) are fixed pickup threshold, optoisolated, control inputs. Specify the pickup voltage level for each board when you order the relay. Use these inputs for monitoring change-of-state conditions of power system equipment.

Inputs can be independent or common. Independent inputs have two separate ground-isolated connections, with no internal connections among inputs. Common inputs share one input leg in common; all input legs of common inputs are ground-isolated. Each group of common inputs is isolated from all other groups.

Nominal current drawn by these inputs is 8 mA or less with six voltage options covering a wide range of voltages, as listed in *Interface Board (I/O) Options on page 1.13*. You can debounce the control input pickup delay and dropout delay separately for each input, or you can use a single debounce setting that applies to all the contact input pickup and dropout times (see *Global Settings on page 8.2*).

AC Control Signals

Optoisolated control inputs can be used with ac control signals, within the ratings shown in *Interface Board (I/O) Options on page 1.13*. *Table 2.1* shows the specific pickup and dropout time-delay settings necessary when applying ac to the inputs.

Table 2.1 Required Settings for Use With AC Control Signals[a]

Global Settings	Description	Entry[b]	Relay Recognition Time for AC Control Signal State Change
IN*nmm*PU[c]	Pickup Delay	2.5 ms	10 ms
IN*nmm*DO[c]	Dropout Delay	17.5 ms	20 ms

[a] First set Global setting EICIS := Y to gain access to the individual input pickup and dropout timer settings.
[b] These are the only setting values that SEL recommends for detecting ac control signals. Other values may result in inconsistent operation.
[c] Where n is 1 for Interface Board 1, 2 for Interface Board 2, and 3 for Interface Board 3; mm is the number of available contact inputs depending on the type of board.

Control Outputs

I/O control outputs from the relay include standard outputs, hybrid (high-current interrupting) outputs, and high-speed high-current interrupting outputs. Form A (normally open) output contacts are individually isolated, and Form C outputs share a common connection between the NC (normally closed) and NO (normally open) contacts.

The relay updates control outputs every 2.5 ms. Updating of relay control outputs does not occur when the relay is disabled. When the relay is reenabled, the control outputs assume the state that reflects the protection processing at that instant.

Standard Control Outputs

NOTE: You can use ac or dc circuits with standard control outputs.

The standard control outputs are dry Form A (NO) contacts rated for tripping duty. Ratings for Standard outputs are 30 A make, 6 A continuous, and 0.75 A or less break (depending on circuit voltage). Standard contact outputs have a maximum voltage rating of 250 Vac/330 Vdc. Maximum break time is 6 ms with a resistive load. The maximum pickup time for the standard control outputs is 6 ms. *Figure 2.5* shows a representative connection for a Form A standard control output on the main board I/O terminals.

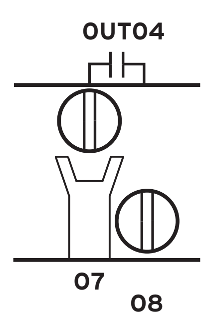


Figure 2.5 Standard Control Output Connection

See *Control Outputs on page 2.6* for complete standard control output specifications.

Hybrid (High-Current Interrupting) Control Outputs

⚠CAUTION
Equipment damage can result from connecting ac circuits to hybrid (high-current interrupting) control outputs. Do not connect ac circuits to hybrid control outputs. Use only dc circuits with hybrid control outputs.

The hybrid (high-current interrupting) control outputs are polarity-dependent and are capable of interrupting high-current, inductive loads. Hybrid control outputs use an insulated gate bipolar junction transistor (IGBT) in parallel with a mechanical contact to interrupt (break) highly inductive dc currents. The contacts can carry continuous current while eliminating the need for heat sinking and providing security against voltage transients.

With any hybrid output, break time varies according to the L/R (circuit inductive/resistive) ratio. As the L/R ratio increases, the time needed to interrupt the circuit fully increases also. The reason for this increased interruption delay is that circuit current continues to flow through the output MOV after the output deasserts until all of the inductive energy dissipates. Maximum dropout (break) time is 6 ms with a resistive load, the same as for the standard control outputs. The other ratings of these control outputs are similar to the standard control outputs, except that the hybrid outputs can break current as great as 10 A. Hybrid contact outputs have a maximum voltage rating of 330 Vdc.

The maximum contact closing time for the hybrid control outputs is 6 ms. *Figure 2.6* shows a representative connection for a Form A hybrid control output on the main board I/O terminals.

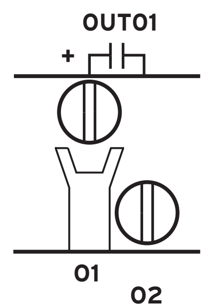


Figure 2.6 Hybrid Control Output Connection

See *Control Outputs on page 2.6* for complete hybrid control output specifications.

High-Speed, High-Current Interrupting Control Outputs

NOTE: You can use only dc circuits with high-speed, high-current interrupting outputs.

In addition to the standard control outputs and the hybrid control outputs, the INT4 and INT8 I/O interface boards offer high-speed high-current interrupting control outputs. An MOV protects against excess voltage transients for each contact. These control outputs have a resistive load contact closing time of 10 µs, which is much faster than the 6 ms contact closing time of the standard and hybrid control outputs. The high-speed contact outputs open at a maximum time of 8 ms. The maximum voltage rating is 330 Vdc. See *Control Outputs on page 2.6* for more information.

Figure 2.7 shows a representative connection for a Form A high-speed contact output on the INT4 I/O interface terminals. The HS marks are included to indicate that this is a high-speed control output.

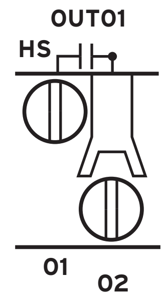


Figure 2.7 INT4 High-Speed Control Output Connection

Figure 2.8 shows a representative connection for a Form A fast hybrid control output on the INT8 I/O interface terminals.

The INT8 high-speed contact output uses three terminal positions, while the INT4 high-speed contact output uses two. The third terminal of each INT8 high-speed control output is connected to precharge resistors that can be used to mitigate transient inrush current conditions, as explained below. A similar technique can be used with INT4 board high-speed control outputs using external resistors. Short transient inrush current can flow at the closing of an external switch in series with open high-speed contacts. This transient will not energize the circuits in typical relay-coil control applications (trip coils and close coils), and standard auxiliary relays will not pick up. However, an extremely sensitive digital input or light-duty, high-speed auxiliary relay can pick up for this condition. This false pickup transient occurs when the capacitance of the high-speed output circuitry charges (creating a momentary short circuit that a fast, sensitive device sees as a contact closure). A third terminal (03 in *Figure 2.8*) provides an internal path for precharging the high-speed output circuit capacitance when the circuit is open.

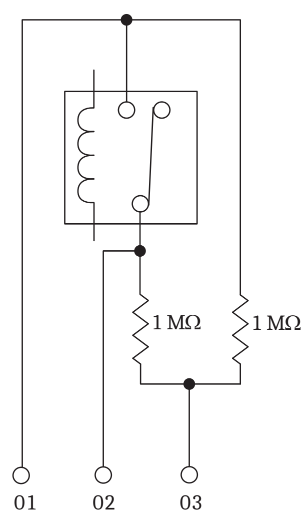


Figure 2.8 High-Speed Control Output Typical Terminals, INT8

Figure 2.9 shows some possible connections for this third terminal that will eliminate the false pickup transients when closing an external switch. In general, you must connect the third terminal to the dc rail (positive or negative) that is on the same side as the open external switch condition. If an open switch exists on either side of the output contact, then you can accommodate only one condition because two open switches (one on each side of the contact) defeat the precharge circuit.

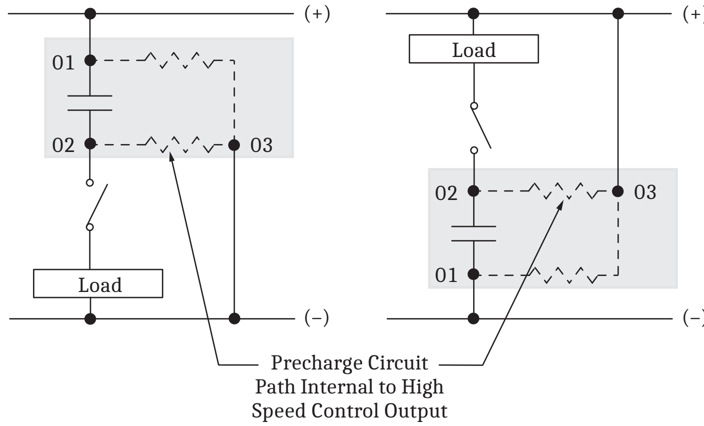


Figure 2.9 Precharging Internal Capacitance of High-Speed Output Contacts, INT8

For wiring convenience, on the INT8 I/O Interface Board, the precharge resistors shown in *Figure 2.9* are built into the I/O board, and connected to a third terminal. On the INT4 I/O Interface Board, there are no built-in precharge resistors, and each high-speed control output has only two terminal connections.

IRIG-B Inputs

The SEL-400G has a regular IRIG-B timekeeping mode, and a high-accuracy IRIG-B timekeeping mode. The IRIG-B serial data format consists of a 1-second frame containing 100 pulses divided into fields, from which the relay decodes the second, minute, hour, and day fields and sets the internal time clock upon detecting valid time data in the IRIG time mode. There is one IRIG-B input on the SEL-400G rear panel, capable of supporting the HIRIG mode.

IRIG-B Pins of Serial PORT 1

This IRIG-B input is capable of regular IRIG mode timekeeping only. Timing accuracy for the IRIG time mode is 500 µs.

IRIG-B BNC Connector

This IRIG-B input is capable of both modes of timekeeping. If the connected timekeeping source is qualified as high-accuracy, the relay enters the HIRIG mode, which has a timing accuracy of 1 µs. If both inputs are connected, the SEL-400G will use the IRIG-B BNC connector signal if a signal is detected.

Battery-Backed Clock

If relay input power is lost or removed, a lithium battery powers the relay clock, providing date and time backup. The battery is a 3 V lithium coin cell, Rayovac no. BR2335 or equivalent. If power is lost or disconnected, the battery discharges to power the clock. At room temperature (25°C), the battery will operate for approximately 10 years at rated load.

When the SEL-400G is operating with power from an external source, the self-discharge rate of the battery is very small. Thus, battery life can extend well beyond the nominal 10-year period because the battery rarely discharges after the relay is installed. The battery cannot be recharged.

If the relay does not maintain the date and time after power loss, replace the battery (see *Replacing the Lithium Battery on page 10.27 in the SEL-400 Series Relays Instruction Manual*).

Communications Interfaces

The SEL-400G has several communications interfaces you can use to communicate with other intelligent electronic devices (IEDs) via EIA-232 ports: **PORT 1**, **PORT 2**, **PORT 3**, and **PORT F**. See *Section 10: Communications Interfaces* for more information and options for connecting your relay to the communications interfaces.

An optional Ethernet card provides Ethernet capability for the SEL-400G. An Ethernet card gives the relay access to popular Ethernet networking standards including TCP/IP, FTP, Telnet, DNP3, IEEE C37.118 Synchrophasors, and IEC 61850 over local area and wide area networks (the Ethernet card with IEC 61850 support is available at purchase as a factory-installed option). For information on DNP3 applications, see *Section 16: DNP3 Communication in the SEL-400 Series Relays Instruction Manual*. For information on Modbus TCP applications, see *Modbus TCP Communication on page 10.63*. For more information on IEC 61850 applications, see *Section 17: IEC 61850 Communication in the SEL-400 Series Relays Instruction Manual*.

Plug-In Boards

The SEL-400G is available in 6U (select as many as one interface board), 7U (select as many as two interface boards), and 8U (select as many as three interface boards).

An optional Ethernet plug-in communications card allows you to use TCP/IP, FTP, Telnet, DNP3, LAN/WAN, and IEC 61850 applications on an Ethernet network. This card is available at the time of purchase of a new SEL-400G as a factory-installed option or as a conversion to an existing relay.

I/O Interface Boards

You can choose among five input/output interface boards (INT2, INT4, INT7, INT8, and INTD) for I/O. *Figure 2.10–Figure 2.13* show the rear screw-terminal connectors of these interface boards.

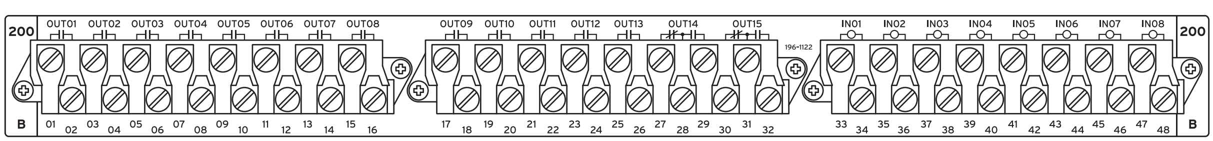


Figure 2.10 I/O Interface Board INT2

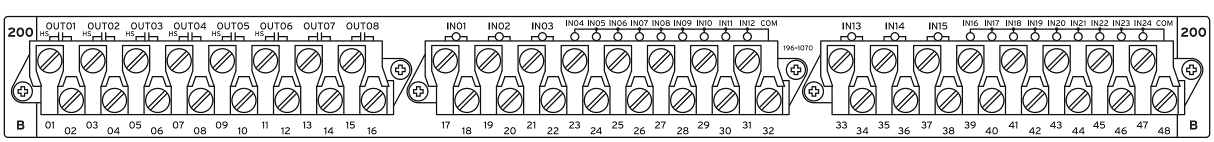


Figure 2.11 I/O Interface Board INT4

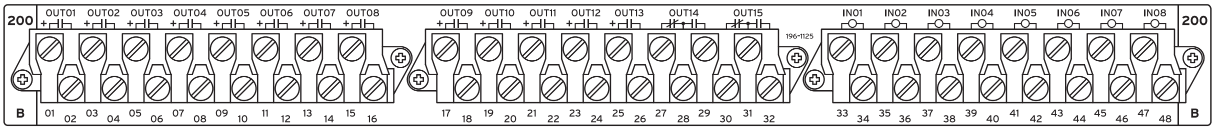


Figure 2.12 I/O Interface Board INT7

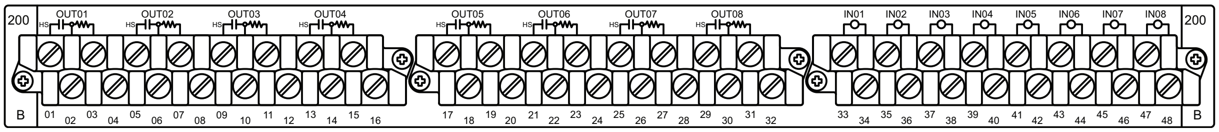


Figure 2.13 I/O Interface Board INT8

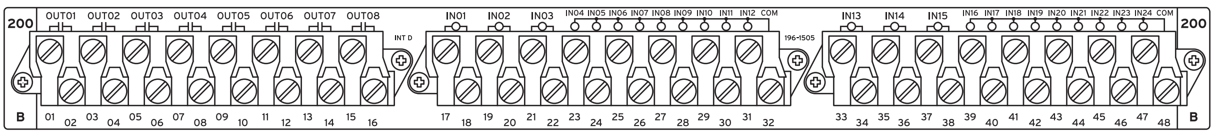


Figure 2.14 I/O Interface Board INTD

I/O of the interface boards vary by the type and amount of output capabilities. *Table 2.2* lists the inputs of the I/O interface boards, and *Table 2.3* lists the outputs of the I/O interface boards.

Table 2.2 Control Inputs

Board	Independent Contact Pairs	Common Contacts
INT2, INT7, and INT8	8	
INT4, INTD	6	Two sets of 9

Table 2.3 Control Outputs

Board	Standard		Fast Hybrid[a]	Hybrid[b]
	Form A	Form C	Form A	Form A
INT2	13	2		
INT4	2		6	
INT7		2		13
INT8			8	
INTD	8			

[a] High-speed/high-current interrupting.
[b] High-current interrupting.

Ethernet Card Option

You can add Ethernet communications protocols to the SEL-400G by purchasing one of the Ethernet card options. Factory-installed in the rear relay **PORT 5**, the Ethernet card provides Ethernet ports for industrial applications that process data traffic between the SEL-400G and a LAN.

Jumpers

The SEL-400G contains jumpers that configure the relay for specific operating modes. These jumpers are located on the main board (the top board) and the I/O interface boards (one or two boards located immediately below the main board).

Main Board Jumpers

The jumpers on the main board of the relay perform these functions:

- ➤ Temporary/emergency password disable
- ➤ Circuit breaker and disconnect control enable
- ➤ Rear serial port +5 Vdc source enable

Figure 2.16 shows the positions of the main board jumpers. The main board jumpers are in two locations. The password disable jumper and circuit breaker control jumper are at the front of the main board. The serial port jumpers are on the EIA-232 card.

Password and Circuit Breaker Jumpers

You can access the password disable jumper and circuit breaker control jumper without removing the main board from the relay cabinet. Remove the SEL-400G front cover to view these jumpers (use appropriate ESD precautions). The password and circuit breaker jumpers (position number J18) are located on the front of the main board, immediately left of the power connector (see *Figure 2.15*).

⚠**CAUTION**
Do not install a jumper on Positions A or D of the main board J18 header. Relay misoperation can result if you install jumpers on positions J18A or J18D.

There are four jumpers denoted **D**, **BREAKER**, **PASSWORD**, and **A** from left to right (position **D** is on the left). Position **PASSWORD** is the password disable jumper; position **BREAKER** is the circuit breaker control enable jumper. Positions **D** and **A** are for SEL use. *Figure 2.15* shows the jumper header with the circuit breaker/control jumper in the **ON** position and the password jumper in the **OFF** position; these are the normal jumper positions for an in-service relay. *Table 2.4* lists the jumper positions and functions.

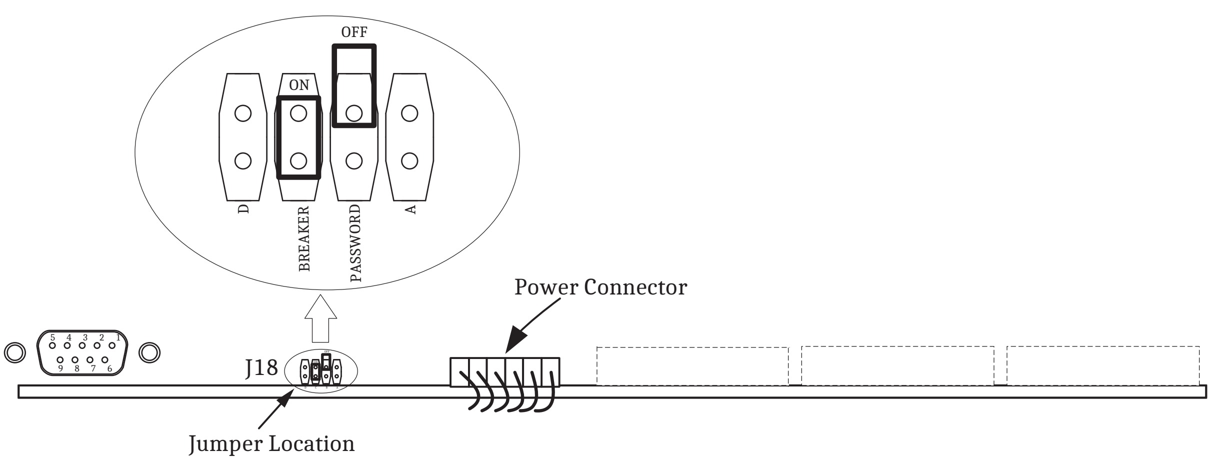


Figure 2.15 Jumper Location on the Main Board

Table 2.4 Main Board Jumpers[a]

Jumper	Jumper Location	Jumper Position	Function
A	Front	OFF	For SEL use only
PASSWORD	Front	OFF	Enable password protection (normal and shipped position)
		ON	Disable password protection (temporary or emergency only)
BREAKER	Front	OFF	Disable circuit breaker commands (**OPEN** and **CLOSE**) and output **PULSE** commands[b] (shipped position)
		ON	Enable circuit breaker command (**OPEN** and **CLOSE**) and output **PULSE** commands[b]
D	Front	OFF	For SEL use only

[a] ON is the jumper shorting both pins of the jumper location. Place the jumper over one pin only for OFF.

[b] Also affects the availability of the Fast Operate Breaker Control Messages and the front-panel LOCAL CONTROL > BREAKER CONTROL and LOCAL CONTROL > OUTPUT TESTING screens.

The password disable jumper, PASSWORD, is for temporary or emergency suspension of the relay password protection mechanisms. Under no circumstance should you install the PASSWORD jumper on a long-term basis. The SEL-400G ships with the PASSWORD jumper in the OFF position (passwords enabled).

The circuit breaker control enable jumper, BREAKER, supervises the **CLOSE *n*** command, the **OPEN *n*** command, the **PULSE OUT*nnn*** command, and front-panel local bit control. To use these functions, you must install the BREAKER jumper. The relay checks the status of the BREAKER jumper when you issue **CLOSE *n***, **OPEN *n***, **PULSE OUT*nnn***, and when you use the front panel to close or open circuit breakers, control a local bit, or pulse an output. The SEL-400G ships with the PASSWORD jumper in the OFF position. For commissioning and testing of the SEL-400G contact outputs, it may be convenient to set the BREAKER jumper to ON, so that the **PULSE OUT*nnn*** commands can be used to check output wiring. The BREAKER jumper must also be set to ON if SCADA control of the circuit breaker via Fast Operate is required, or if the LOCAL CONTROL > BREAKER CONTROL screens are going to be used.

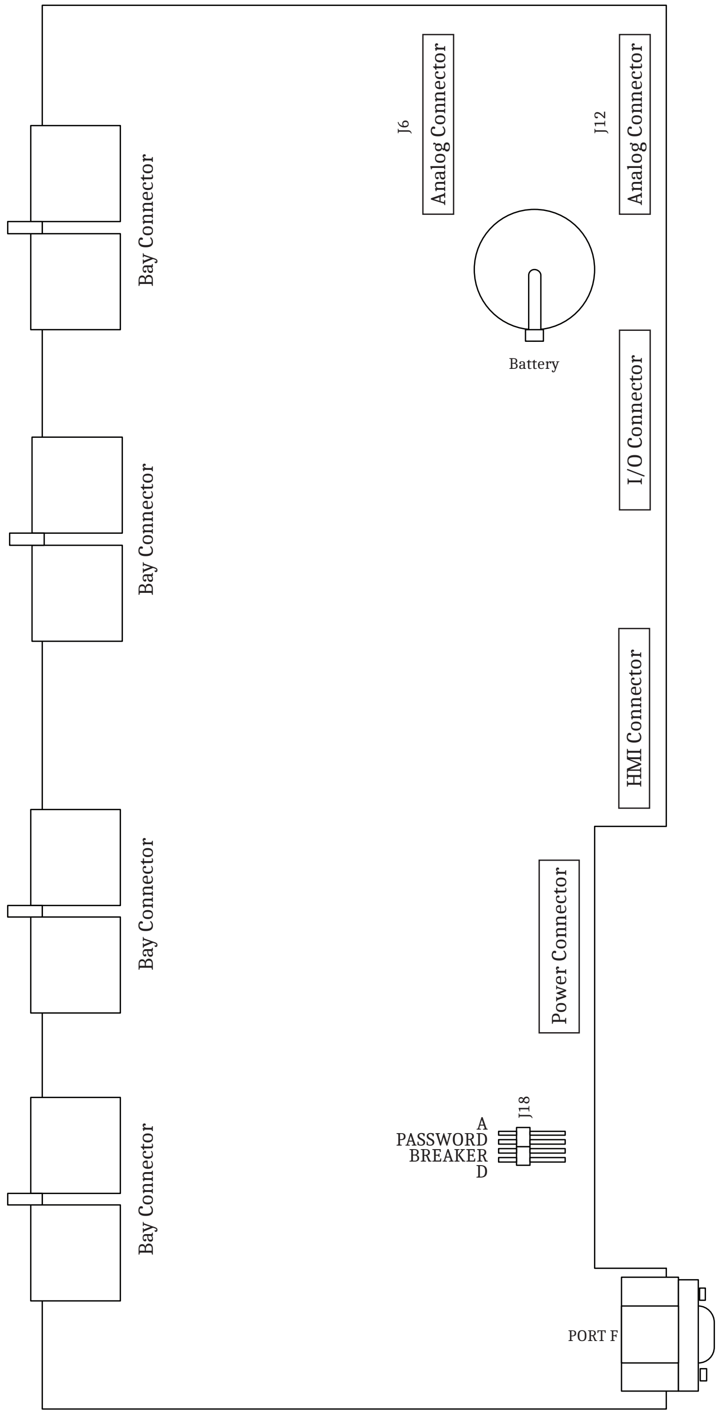


Figure 2.16 Major Component Locations on the SEL-400G Main Board

Serial Port Jumpers

Place jumpers on the EIA-232 board to connect +5 Vdc to Pin 1 of each of the three rear-panel EIA-232 serial ports. The maximum current available from this Pin 1 source is 0.5 A. The Pin 1 source is useful for powering an external modem. *Table 2.5* describes the JMP1 and JMP2 positions. Refer to *Figure 2.16* for the locations of these jumpers. The relay ships with JMP1A, JMP2A, and JMP2B jumpers in the OFF position (no +5 Vdc on Pin 1).

Table 2.5 Serial Port Jumpers

Jumper Label	Jumper A or Jumper B	Jumper Position[a]	Function
JMP1	A	OFF	Serial PORT 1, Pin 1 = not connected
		ON	Serial PORT 1, Pin 1 = +5 Vdc
	B	—	Not used
JMP2	A	OFF	Serial PORT 2, Pin 1 = not connected
		ON	Serial PORT 2, Pin 1 = +5 Vdc
	B	OFF	Serial PORT 3, Pin 1 = not connected
		ON	Serial PORT 3, Pin 1 = +5 Vdc

[a] ON is the jumper shorting both pins of the jumper. Place the jumper over one pin only for OFF.

Changing Serial Port Jumpers

⚠DANGER
Contact with instrument terminals can cause electrical shock that can result in injury or death.

⚠WARNING
Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.

⚠CAUTION
Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.

You must remove the main board to access the serial port jumpers. Perform the following steps to change the **JMP2**, **JMP3**, and **JMP4** jumpers in an SEL-400G.

Step 1. Follow your company standard to remove the relay from service.

Step 2. Disconnect power from the SEL-400G.

Step 3. Retain the **GND** connection, if possible, and ground the equipment to an ESD mat.

Step 4. Remove the communications cable connected to the front-panel serial port, if applicable.

Step 5. Remove the rear-panel **EIA-232 PORTS** mating connectors.

Unscrew the keeper screws and disconnect any serial cables connected to the **PORT 1**, **PORT 2**, and **PORT 3** rear-panel receptacles, as well as the BNC and Ethernet connectors.

Step 6. Remove all Ethernet and IRIG-B connections.

Step 7. Loosen the four front-panel screws (they remain attached to the front panel), and remove the relay front panel.

Step 8. Remove the 34-pin ribbon cable from the front panel by pushing the extraction ears away from the connector.

Step 9. Disconnect the power, interface board, and analog input board cables from the main board.

Step 10. Carefully pull out the drawout assembly containing the main board.

Step 11. Locate the jumper you want to change.

Jumpers **JMP2**, **JMP3**, and **JMP4** are located at the rear of the main board, directly in front of **PORT 3**, **PORT 2**, and **PORT 1**, respectively (see *Figure 2.16*).

Step 12. Install or remove the jumper as needed (see *Table 2.5* for jumper position descriptions).

Step 13. Reinstall the SEL-400G main board and reconnect the power, interface board, and analog input board cables.

Step 14. Reconnect the cable removed in *Step 7* and reinstall the relay front-panel cover.

Step 15. Reattach the rear-panel connections.

Step 16. Reconnect any serial, BNC, or Ethernet cables that you removed from the relay in the disassembly process.

Step 17. Follow your company standard procedure to return the relay to service.

I/O Interface Board Jumpers

Jumpers on the I/O interface boards identify the particular I/O board configuration and I/O board control address. Five I/O interface boards are available: INT2, INT4, INT7, INT8, and INTD. The jumpers on these I/O interface boards are at the front of each board, as shown in *Figure 2.17*.

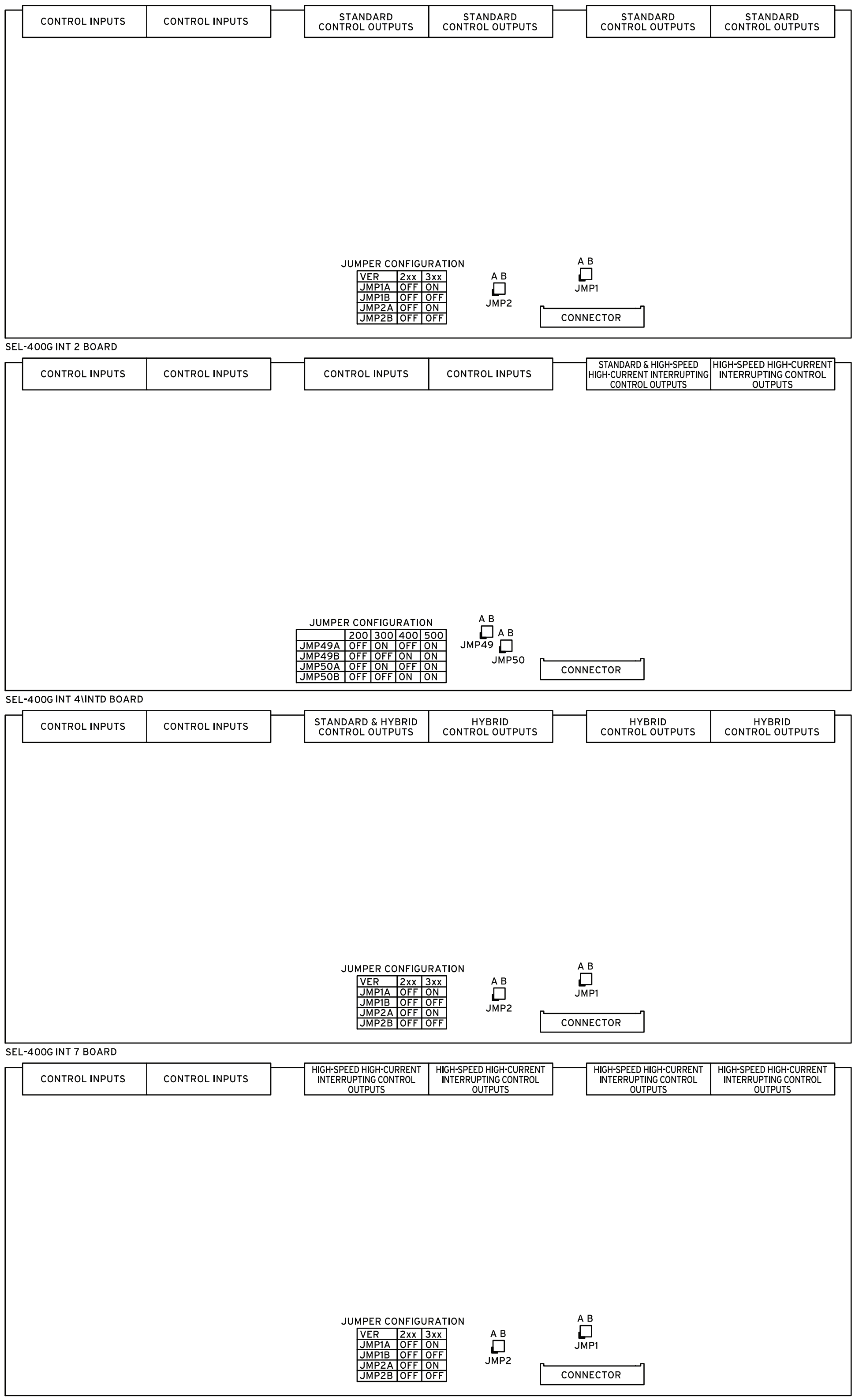


Figure 2.17 Top to Bottom: INT2, INT4, INT7, INT8, and INTD With Jumper Locations Indicated

To confirm the positions of your I/O board jumpers, remove the front panel and visually inspect the jumper placements. *Table 2.6* lists the four jumper positions for I/O interface boards. Refer to *Figure 2.17* for the locations of these jumpers.

The I/O board control address has a hundreds-series prefix attached to the control inputs and control outputs for that particular I/O board chassis slot. A 6U chassis has a 200-addresses slot for inputs IN201, IN202, etc., and outputs OUT201, OUT202, etc. A 7U chassis has a 200-addresses slot and a 300-addresses slot. An 8U chassis has 200-addresses, 300-addresses, and 400-addresses slots. The drawout tray on which each I/O board is mounted is keyed. See *Installing Optional I/O Interface Boards on page 10.30 in the SEL-400 Series Relays Instruction Manual* for information on the key positions for the 200-addresses slot trays and the 300-addresses slot trays.

Table 2.6 I/O Board Jumpers

I/O Board Control Address	JMP1A/ JMP49A[a]	JMP1B/ JMP49B[a]	JMP2A/ JMP50A[a]	JMP2B/ JMP50B[a]
2XX	OFF	OFF	OFF	OFF
3XX	ON	OFF	ON	OFF
4XX	OFF	ON	OFF	ON

[a] INT4 I/O interface board jumper numbering.

Relay Placement

Proper placement of the SEL-400G helps make certain that you receive years of trouble-free power system protection. Use the following guidelines for proper physical installation of the SEL-400G.

Physical Location

You can mount the SEL-400G in a sheltered indoor environment (a building or an enclosed cabinet) that does not exceed the temperature and humidity ratings for the relay.

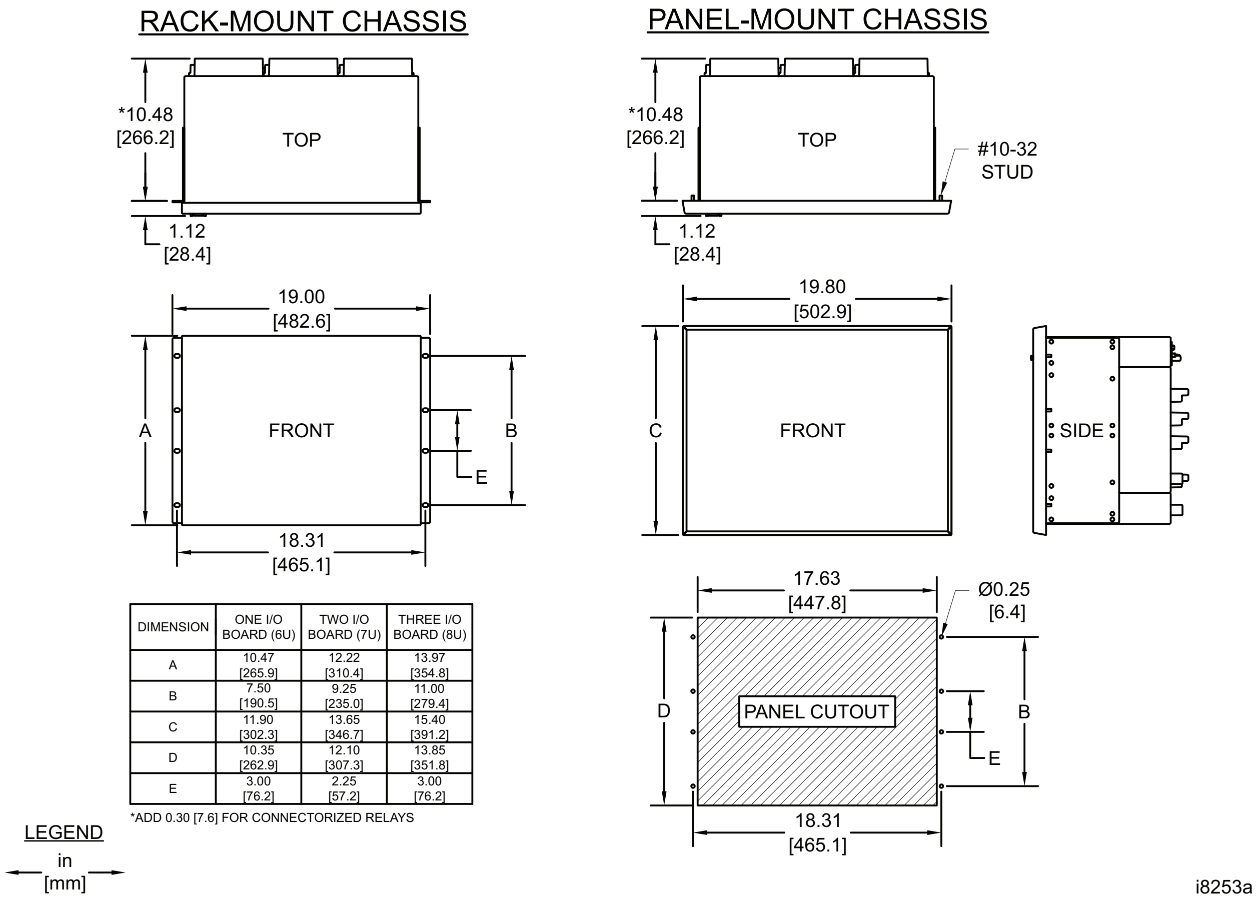
The relay is rated at Installation/Overvoltage Category II and Pollution Degree 2. This rating allows mounting the relay indoors or in an outdoor (extended) enclosure where the relay is protected against exposure to direct sunlight, precipitation, and full wind pressure, but neither temperature nor humidity are controlled.

You can place the relay in extreme temperature and humidity locations. The temperature range over which the relay operates is –40° to +185°F (–40° to +85°C, see *Operating Temperature on page 1.22*). The relay operates in a humidity range from 5 percent to 95 percent, no condensation, and is rated for installation at a maximum altitude of 2000 m (6560 ft) above mean sea level.

Rack Mounting

The semiflush mount results in a small panel protrusion from the relay rack rails of approximately 27.9 mm (1.1 in).

See *Figure 2.18* for exact mounting dimensions. Use four screws of the appropriate size for your rack.



DIMENSION	ONE I/O BOARD (6U)	TWO I/O BOARD (7U)	THREE I/O BOARD (8U)
A	10.47 [265.9]	12.22 [310.4]	13.97 [354.8]
B	7.50 [190.5]	9.25 [235.0]	11.00 [279.4]
C	11.90 [302.3]	13.65 [346.7]	15.40 [391.2]
D	10.35 [262.9]	12.10 [307.3]	13.85 [351.8]
E	3.00 [76.2]	2.25 [57.2]	3.00 [76.2]

*ADD 0.30 [7.6] FOR CONNECTORIZED RELAYS

Figure 2.18 SEL-400G Chassis Dimensions

Panel Mounting

Place the panel-mount versions of the SEL-400G in a switchboard panel. See the drawings in *Figure 2.18* for panel cut and drill dimensions (these dimensions apply to both the horizontal and vertical panel-mount relay versions). Use the supplied mounting hardware to attach the relay.

SEL-2664 and SEL-2664S Application

The SEL-400G is equipped with protecting the generator stator winding from ground fault for 100 percent of the stator windings. The 64G1 element in the SEL-400G uses the fundamental frequency generator neutral voltage to protect as much as 95 percent of the stator winding, while the 64G2 and 64G3 elements protect the remaining stator winding by using the third-harmonic component of the machine.

In addition to the stator winding ground fault that is based on 64G elements, the SEL-400G uses 64S logics to protect the generator from a ground fault at stator winding. It also uses the 64F logic to protect the field winding.

The 64S and 64F elements operate based on subscribed insulation resistor values from the SEL-2664S Stator Ground Protection Relay and the SEL-2664 Field Ground Module. The SEL-2664S is connected to the generator neutral and injects a multi-sine current (I_SRC). Injecting a subharmonic signal onto the stator requires the SEL-2664S to be connected to the stator winding either through the neutral grounding transformer (NGT) when the neutral grounding resistor (NGR) is located on the NGT secondary (*Figure 2.19*) or through a voltage transformer of sufficient thermal rating if the NGR is connected between ground and the generator neutral point (*Figure 2.20*). For complete guidance on SEL-2664S application design and settings considerations, see the *SEL-2664S Stator Ground Protection Relay Instruction Manual*.

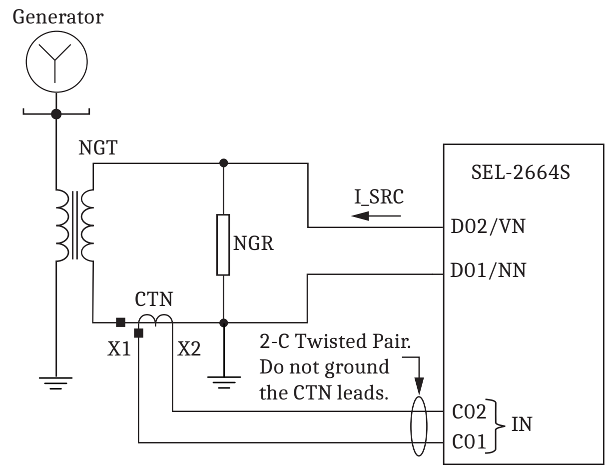


Figure 2.19 AC Connections With NGR on the Secondary Side of the Neutral Grounding Transformer

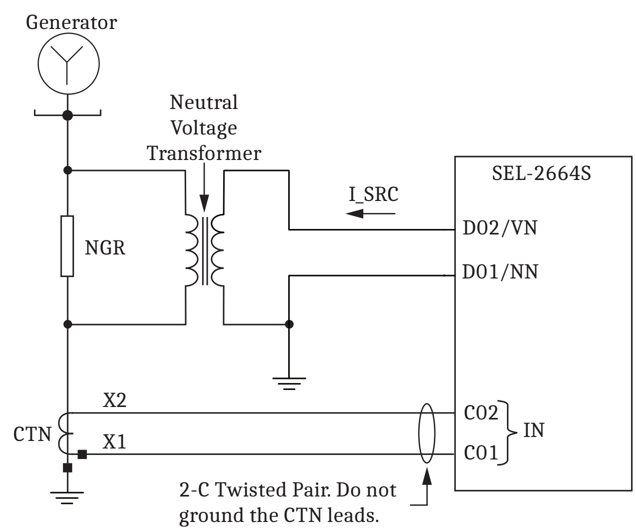
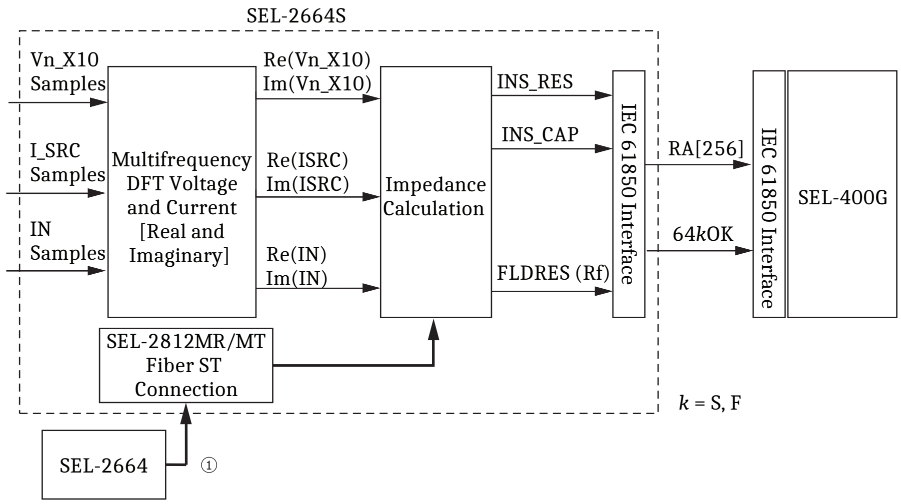


Figure 2.20 AC Connections With NGR Between the Generator Neutral Point and Ground

From the injected I_SRC, the SEL-2664S calculates the insulation resistance and capacitances and make them available to the SEL-400G through GOOSE messages. The SEL-2664 Field Ground Module directly measures the field insulation resistance and sends it to the SEL-2664S, where the SEL-2664S makes it available as a GOOSE message for the SEL-400G. Note in *Figure 2.21*, the SEL-2664 is connected to the SEL-2664S.



① The SEL-2664 can either connect directly to **PORT 2** of the SEL-2664S (see Figure 2.22) or through an SEL-2814 directly to an EIA-232 port on the SEL-400G.

Figure 2.21 Insulation Resistance and Capacitance Received From SEL-2664S

The SEL-400G subscribes to SEL-2664S as a remote measurement device to directly collect three analog values and one digital quality bit as GOOSE messages via IEC-61850 protocol. The two SEL-2664S calculated analog values are the stator insulation resistance INS_RES and capacitance INS_CAP. The other analog is the SEL-2664 measured field resistor FLDRES value that was directly sent to the SEL-2664S from the SEL-2664. All three analogs are mapped to remote analog RA[256] to be available in the SEL-400G for logic operation and metering purposes. In addition to the three analogs, a digital quality bit that is programed in the SEL-2664S to indicate the quality of the analogs made available.

SEL-2664/SEL-2664S/SEL-400G Communication Configuration

The SEL-400G can receive stator insulation resistance and capacitance (as well as other signals) from an SEL-2664S over an Ethernet communications channel. In addition, the SEL-400G can receive field insulation resistance directly from an SEL-2664 or via the SEL-2664S. These signals can then be mapped to the injection-based stator ground fault function (64S) and the field ground fault function (64F). These signals can also be assigned to the analog signal profiling function and to event reporting.

SEL-2664/SEL-400G SEL Fast Message Protocol Configuration

The SEL-400G supports a serial connection to the SEL-2664 via fiber-optic cable (SEL-C807) and the SEL-2814. To initiate communication, ensure the following SEL-400G settings are used:

- Port 1 settings
  - PROTO := SEL
  - SPEED := 9600
- Group settings
  - E64F := Y
  - 64FIRM :=PORT1

This example uses Port 1; however, Serial Ports 2 and 3 also support this functionality.

Issuing a **MET G** command displays the measured field insulation resistance as they are received by the SEL-400G.

```
Insulation Meter:
            Resistance                   Capacitance      Quality
Field  (kOhms)   431.00                                     OK
```

If there is a communications error, the Relay Word bit 64FFLT asserts. This is indicated by the Quality display that reads FAIL.

SEL-2664/SEL-2664S/SEL-400G IEC 61850 Configuration

The physical communications connections for this configuration are shown in *Figure 2.22*. The Ethernet PORT 5 of the SEL-400G is connected to PORT 1 of the SEL-2664S. A duplex, multimode fiber-optic cable (SEL-C808) can be used for this connection. The serial port (TX) on the SEL-2664 is connected to the RX of PORT 2 of the SEL-2664S. A simplex, multimode fiber-optic cable (SEL-C807) is used for this connection.

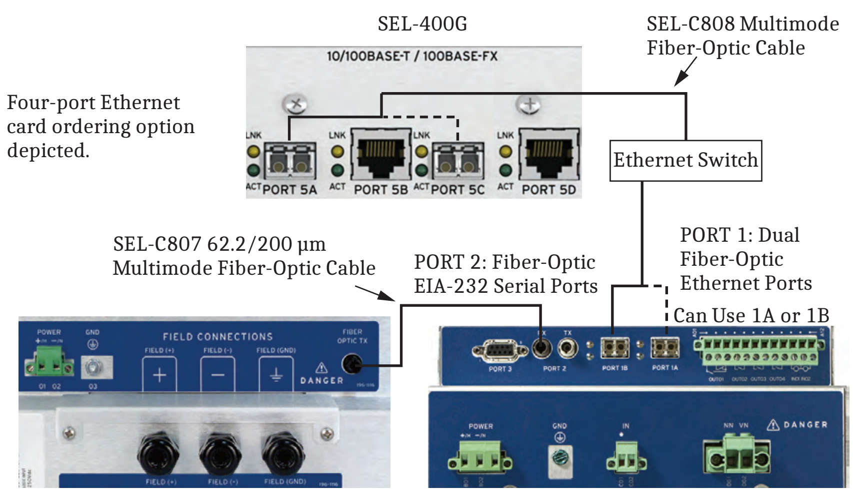


Figure 2.22 Communication Connection Between the SEL-400G, SEL-2664S, and SEL-2664

The IEC 61850 protocol is used for communications between the SEL-400G and the SEL-2664S. After establishing communications between the two relays, use ACSELERATOR Architect SEL-5032 Software to map the logical nodes in the SEL-400G IED capability description (ICD) file for GOOSE receive and SEL-2664S data set for transmit.

The SEL-400G IEC 61850 compatibility library provides the logical nodes for the stator insulation resistance and capacitance streamed directly from the SEL-2664S and for the field insulation resistance indirectly sent from the SEL-2664 via the SEL-2664S. The SEL-2664 transmits the measured field insulation resistance to the SEL-2664S, and the subscribing unit, the SEL-400G, receives this measurement from the SEL-2664S along with the stator insulation resistance and capacitance measured values.

As *Table 2.7* indicates, the SEL-400G IEC 61850 library describes the functional constraint, the logical nodes, and their attributes. The three analog signals available to the SEL-400G as GOOSE messages are mapped using Architect to be received and mapped to remote analogs. There is also an SEL-2664 message quality bit mapped through a protection SELogic variable and a GOOSE message quality identifier mapped to provide an indication to the SEL-400G on the health of the analog data.

Table 2.7 SEL-2664S Logical Device: ANN (Annunciation)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = MX			
RESGGIO16	AnIn01.instMag.f	INS_RES	Stator Insulation Resistance
RESGGIO16	AnIn02.instMag.f	INS_CAP	Stator Insulation Capacitance
RESGGIO16	AnIn04.instMag.f	FLDRES	Field Insulation Resistance
Functional Constraint = ST			
SVGGIO3	Ind01.stVal–Ind02.stVal	SV01–SV02	SELogic Variables (SV01, SV02)

The following steps summarize the process of configuring each relay for transmission and reception of the items listed in *Table 2.7* by using Architect.

Step 1. In the Architect project editor (*Figure 2.23*), add the two devices (SEL-400G and SEL-2664S) and enter the communications details for each device.

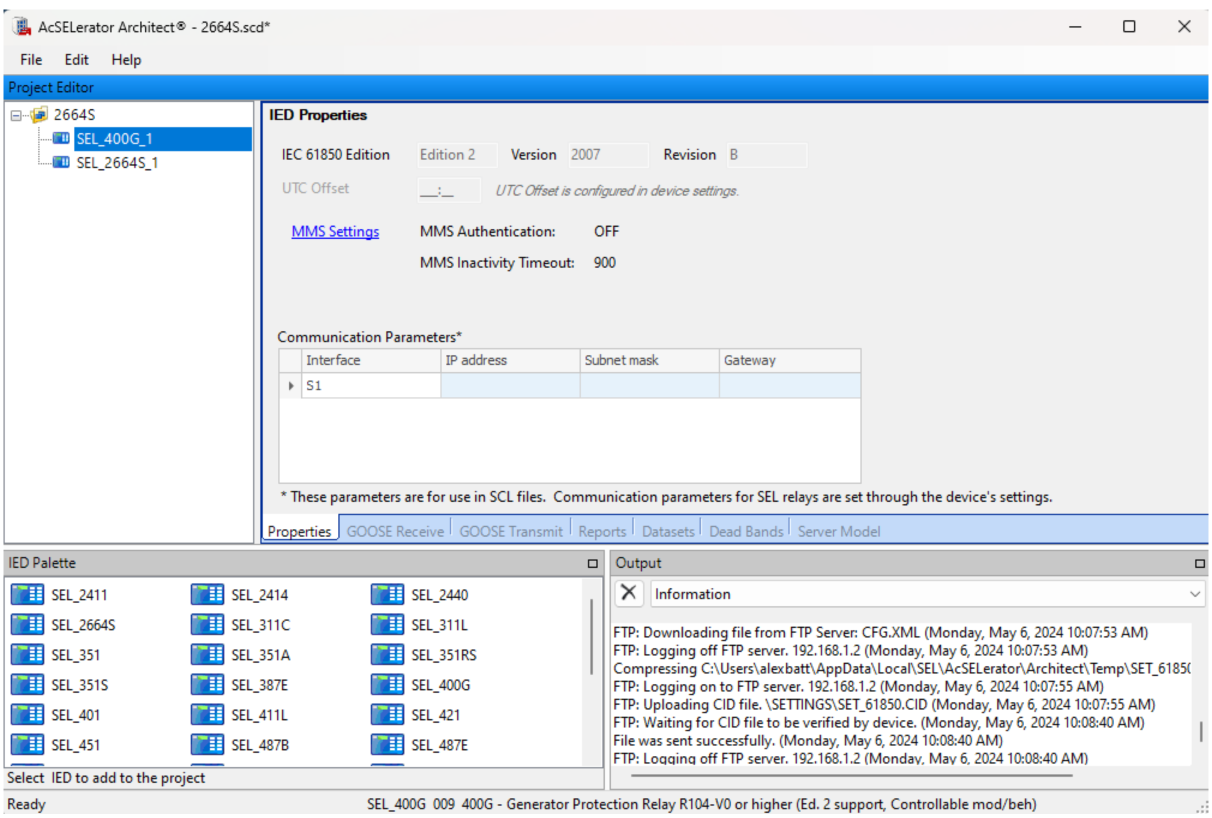


Figure 2.23 Project Editor

Step 2. From the project editor, select the Datasets tab (*Figure 2.24*) and select **New**.

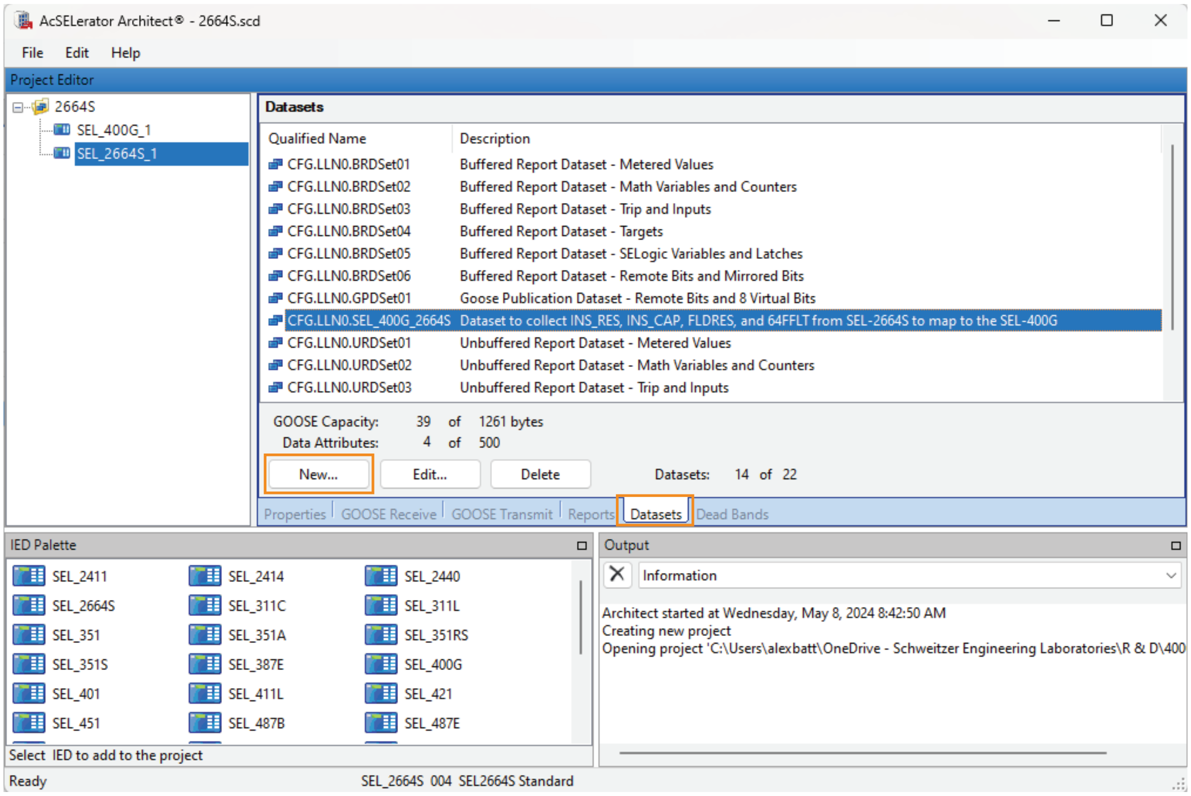


Figure 2.24 Project Editor Dataset Selection

Step 3. Referring to *Table 2.7*, select the appropriate functional constraint (*Figure 2.25*) and drag and drop the four data attributes to the window on the right. Make a note of the name and description fields. Use an identifiable name and description for your project.

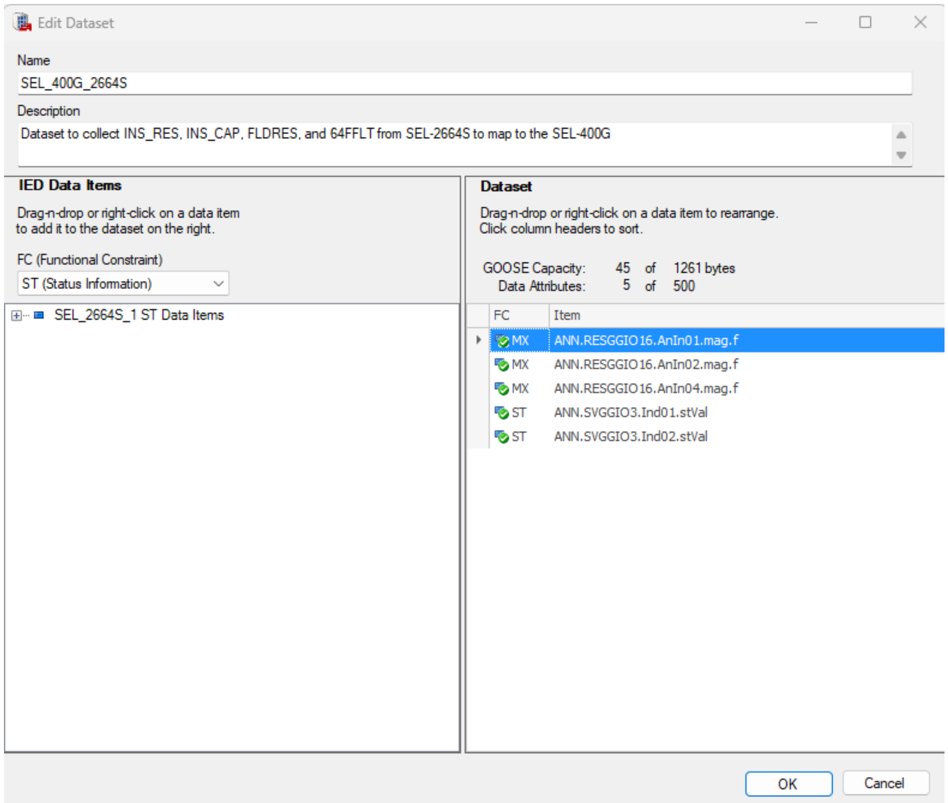


Figure 2.25 Dataset Editor

Step 4. Select the GOOSE Transmit tab and select **New**.

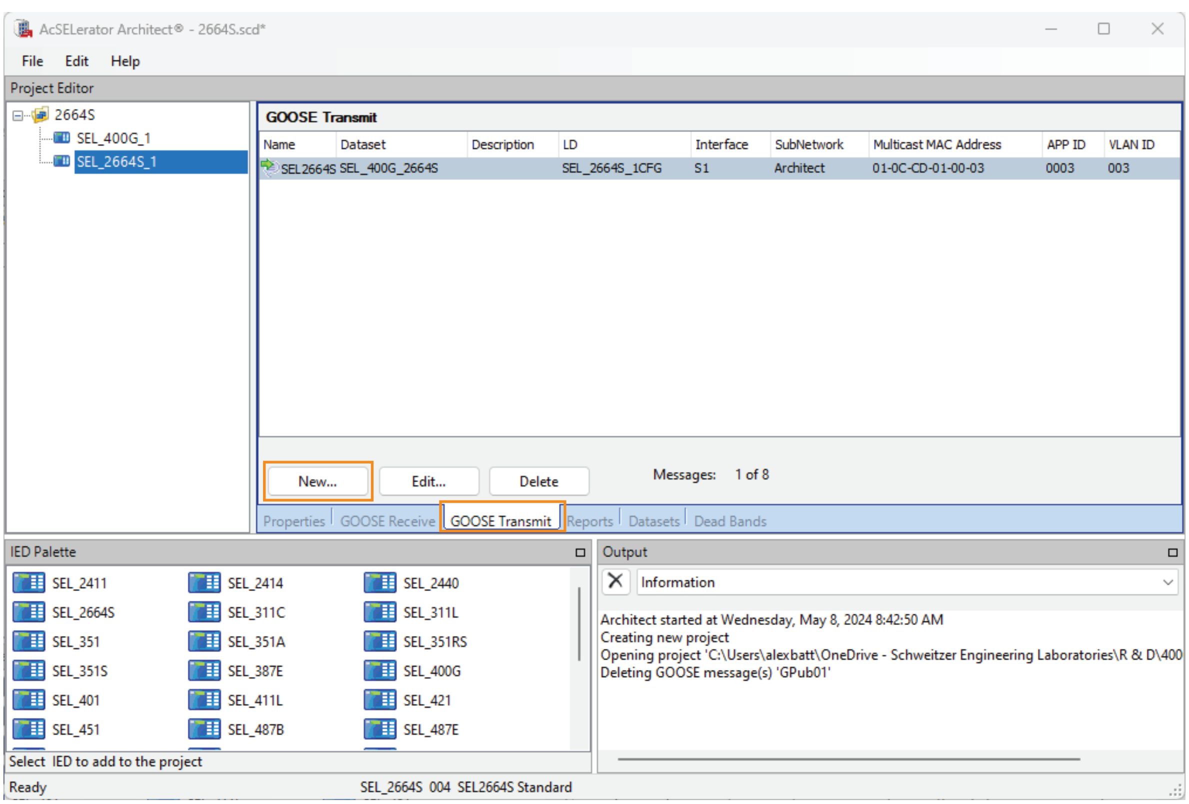


Figure 2.26 GOOSE Transmit Editor

Step 5. From GOOSE transmit window (*Figure 2.27*), open the Datasets tab at the bottom of the window and select the data set name as it was set on the data set editor at *Figure 2.25*. Fill out the message name and GOOSE ID and configure the address data.

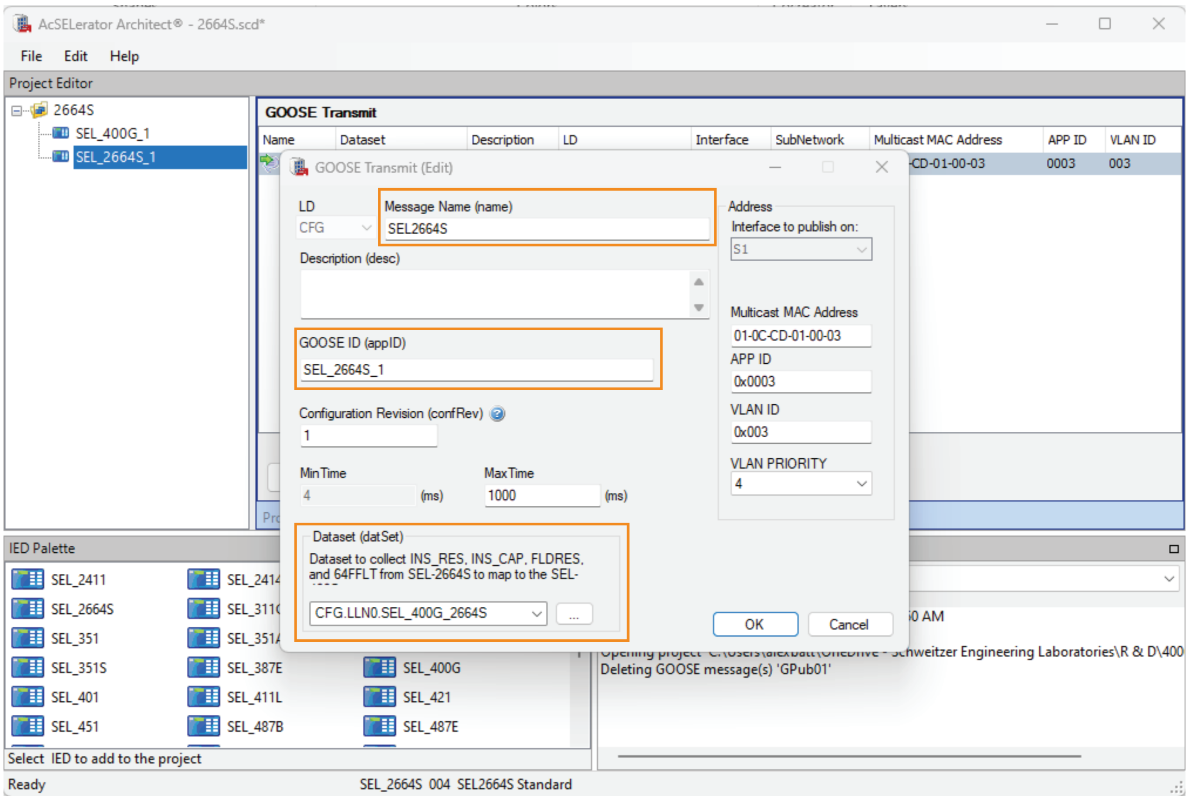


Figure 2.27 GOOSE Transmit Editor for Dataset

Step 6. Highlight the SEL-400G device from the left window and select **GOOSE Receive** (*Figure 2.28*). Collapse the SEL-2664S tab from the middle window and drag all three analog GOOSE attributes to the right side of the window under RA for remote analogs.

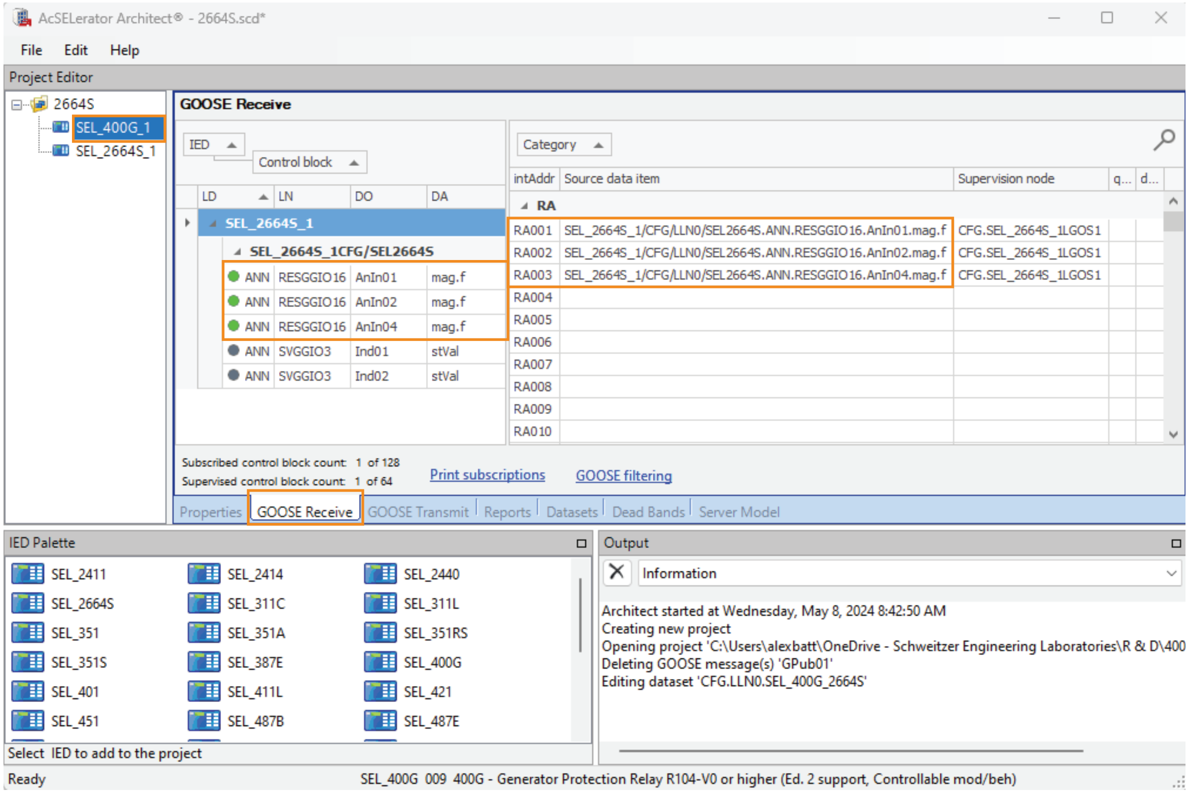


Figure 2.28 GOOSE Receive Editor for Remote Analogs

Step 7. Right-click the entry box for VB001 and select **Message Quality**. This maps the GOOSE message quality to VB001 in the SEL-400G. Repeat *Step 6 on page 2.26* for the remaining items in the list (digital quantity) under VB for virtual bit (*Figure 2.29*).

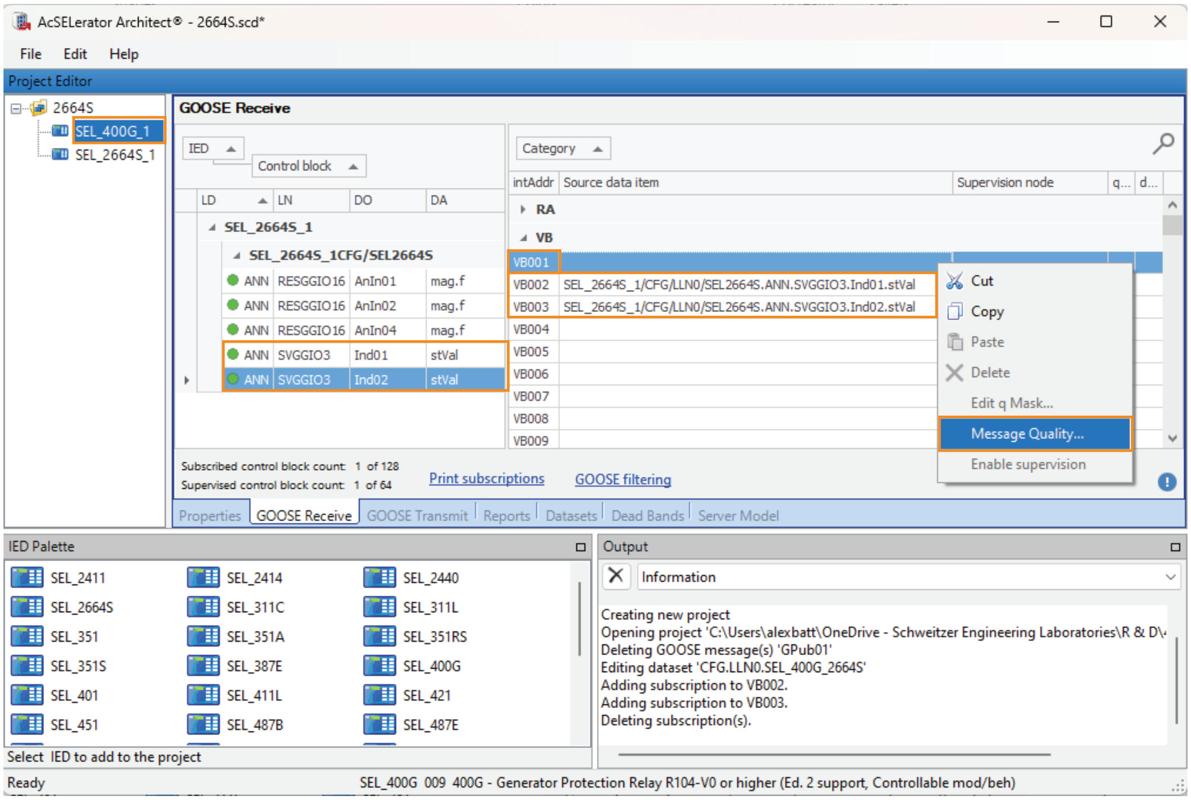


Figure 2.29 GOOSE Receive Editor for Virtual Bits

Step 8. Select **OK** on (*Figure 2.27*) and right-click **SEL-2664S** under the project name (*Figure 2.28*) and select **Send CID**. Make sure the CID file is saved in the SEL-2664S by typing **GOOSE** on the terminal.

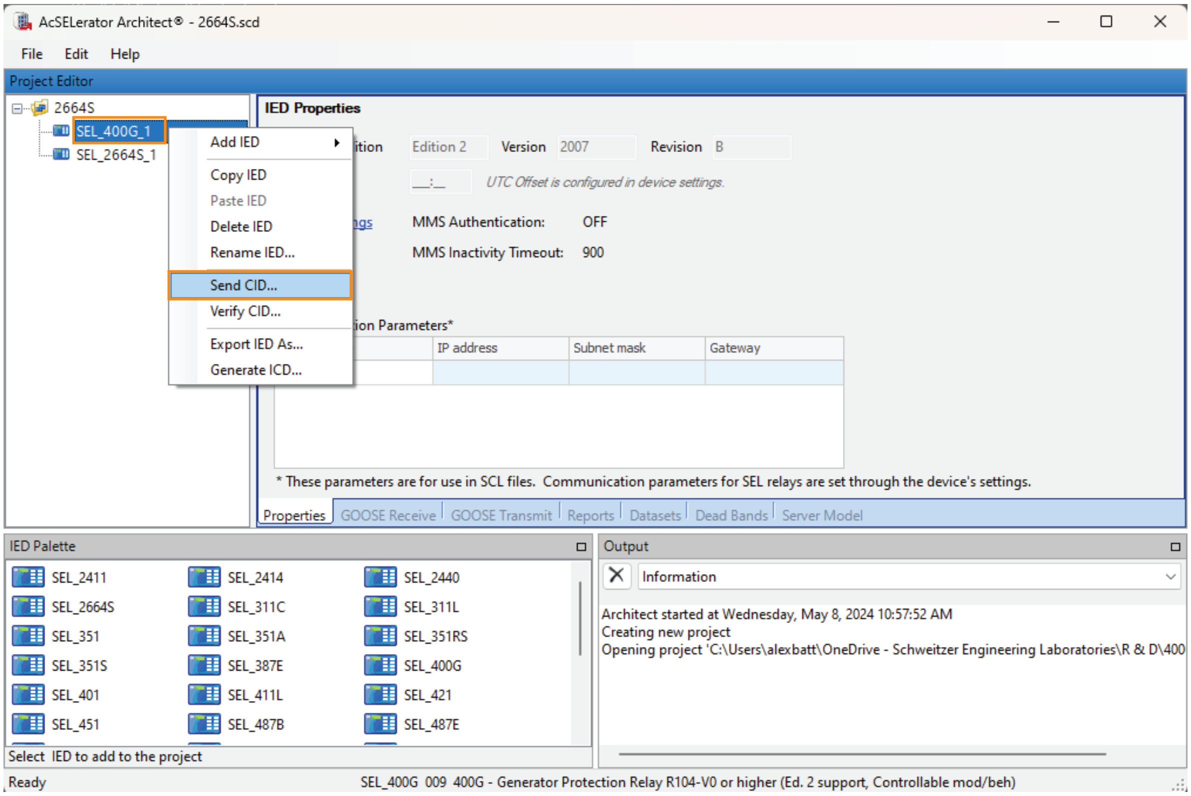


Figure 2.30 Sending CID to SEL-400G

Step 9. Right-click **SEL-400G** under the project name and select **SEND CID** (*Figure 2.30*). Make sure the CID file is saved in the SEL-400G by typing **GOOSE** on the terminal.

Step 10. In the SEL-2664S, set the following to map the NOT of the SEL-2664 failure bit (64FFLT) to SV01 and the SEL-2664S torque-control bit and 64S element enable bit (AMP_ON) to SV02.

Set Logic settings:

SV01 := NOT 64FFLT

SV02:= AMP_ON AND 64S1TC

Step 11. To verify the reception of insulation resistance and capacitance for metering or 64S and 64F logic operations, map the received remote analogs to the analog quantities of 64S and 64F and map the received digital virtual bit to 64S and 64F quality bit settings as shown.

Set Port 5 settings:

E61850 := Y

EGSE := Y

Set Group settings:

E64S := Y

E64F := Y

64FIRM := RA003

64FIQ := NOT (VB001) AND VB002

64SIRM := RA001

64SICM := RA002

64SIQ := NOT (VB001)

64S1TC := VB003

Map RA[256] to PMV*nn* and map VB*nn* to PSV*nn* to show the received analog and digital quantities through **MET PMV**.

The fundamental metering in the **MET G** command displays the resistance and capacitance values of the stator and field insulations as they are received by the SEL-400G. The total operating time to update changing values including the configurable time delay could be as long as 500 ms.

```
Insulation Meter:
             Resistance                  Capacitance       Quality
Stator (kOhms)   0.00       Stator (uF) 99.99               OK
Field  (kOhms)   431.00                                     OK
```

Connection

⚠CAUTION
Insufficiently rated insulation can deteriorate under abnormal operating conditions and cause equipment damage. For external circuits, use wiring of sufficiently rated insulation that will not break down under abnormal operating conditions.

The SEL-400G is available in many different configurations, depending on the number and type of control inputs, control outputs, and analog input termination you specified at ordering. This section presents a representative sample of relay rear-panel configurations and the connections to these rear panels.

When connecting the SEL-400G, refer to your company plan for wire routing and wire management. Be sure to use wire that is appropriate for your installation with an insulation rating of at least 90°C.

Rear-Panel Layout

Figure 2.2–Figure 2.3 show some of the available SEL-400G rear panels.

All relay versions have screw-terminal connectors for I/O, power, and battery monitor. You can order the relay with fixed terminal blocks for the CT and PT connections, or you can order SEL Connectorized rear-panel configurations that feature plug-in/plug-out PT connectors and shorting CT connectors for relay analog inputs.

The screw-terminal connections for the INT2 and the INT7 I/O interface boards are the same. The INT8 I/O interface board has control output terminals grouped in threes, with the fourth terminal as a blank additional separator (Terminals 4, 8, 12, 16, 20, 24, 28, and 32). The INT4 and INT8 I/O interface boards both contain fast hybrid control outputs, but use a different terminal layout—see *Control Outputs on page 2.6* for details.

For more information on the main board control inputs and control outputs, see *IRIG-B Inputs on page 2.9*. For more information on the I/O interface board control inputs and control outputs, see *I/O Interface Board Jumpers on page 2.16*.

Rear-Panel Symbols

There are important safety symbols on the rear of the SEL-400G (see *Figure 2.31*). Observe proper safety precautions when you connect the relay at terminals marked by these symbols. In particular, the danger symbol located on the rear panel corresponds to the following: *Contact with instrument terminals can cause electrical shock that can result in injury or death*. Be careful to limit access to these terminals.

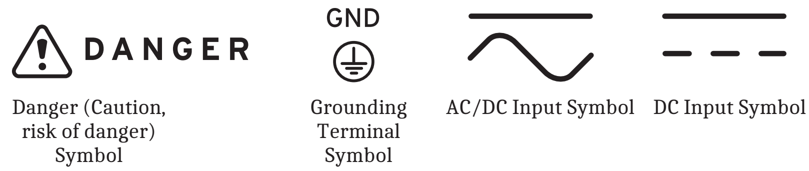


Figure 2.31 Rear-Panel Symbols

Screw-Terminal Connectors

Terminate connections to the SEL-400G screw-terminal connectors with ring-type crimp lugs. Use a #8 ring lug with a maximum width of 9.1 mm (0.360 in). The screws in the rear-panel screw-terminal connectors are #8-32 binding-head, slotted, nickel-plated brass screws. Tightening torque for the terminal connector screws is 1.0 Nm to 2.0 Nm (9 in-lb to 18 in-lb).

You can remove the screw-terminal connectors from the rear of the SEL-400G by unscrewing the screws at each end of the connector block. Perform the following steps to remove a screw-terminal connector.

Step 1. Remove the connector by pulling the connector block straight out. Note that the receptacle on the relay circuit board is keyed; you can insert each screw-terminal connector in only one location on the rear panel.

Step 2. To replace the screw-terminal connector, confirm that you have the correct connector and push the connector firmly onto the circuit board receptacle.

Step 3. Reattach the two screws at each end of the block.

Changing Screw-Terminal Connector Keying

You can rotate a screw-terminal connector so that the connector wire dress position is the reverse of the factory-installed position (for example, wires entering the relay panel from below instead of from above). In addition, you can move similar function screw-terminal connectors to other locations on the rear panel. To move these connectors to other locations, you must change the screw-terminal connector keying. Inserts in the circuit board receptacles key the receptacles for only one screw-terminal connector in one orientation. Each screw-terminal connector has a missing web into which the key fits (see *Figure 2.32*). If you want to move a screw-terminal connector to another circuit board receptacle or reverse the connector orientation, you must rearrange the receptacle keys to match the screw-terminal connector block. Use long-nosed pliers to move the keys. *Figure 2.33* shows the factory-default key positions.

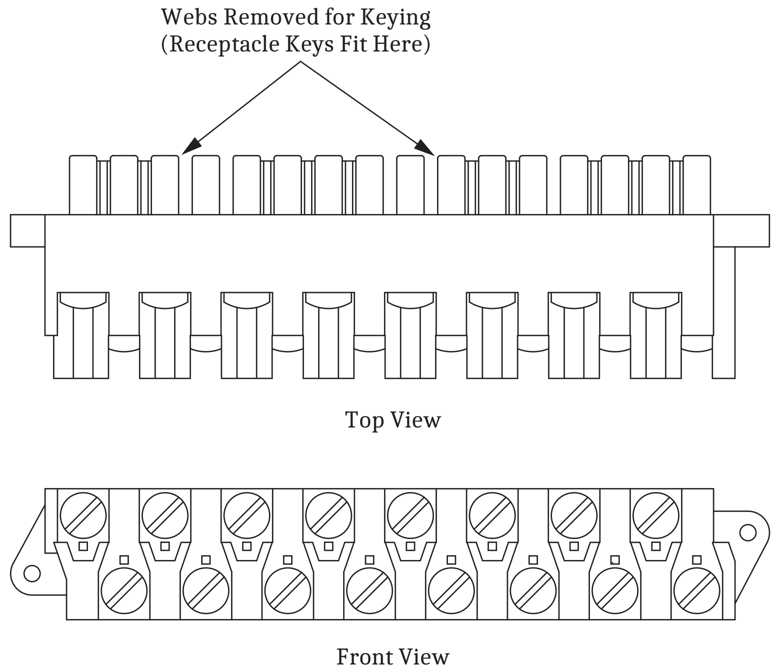


Figure 2.32 Screw-Terminal Connector Keying

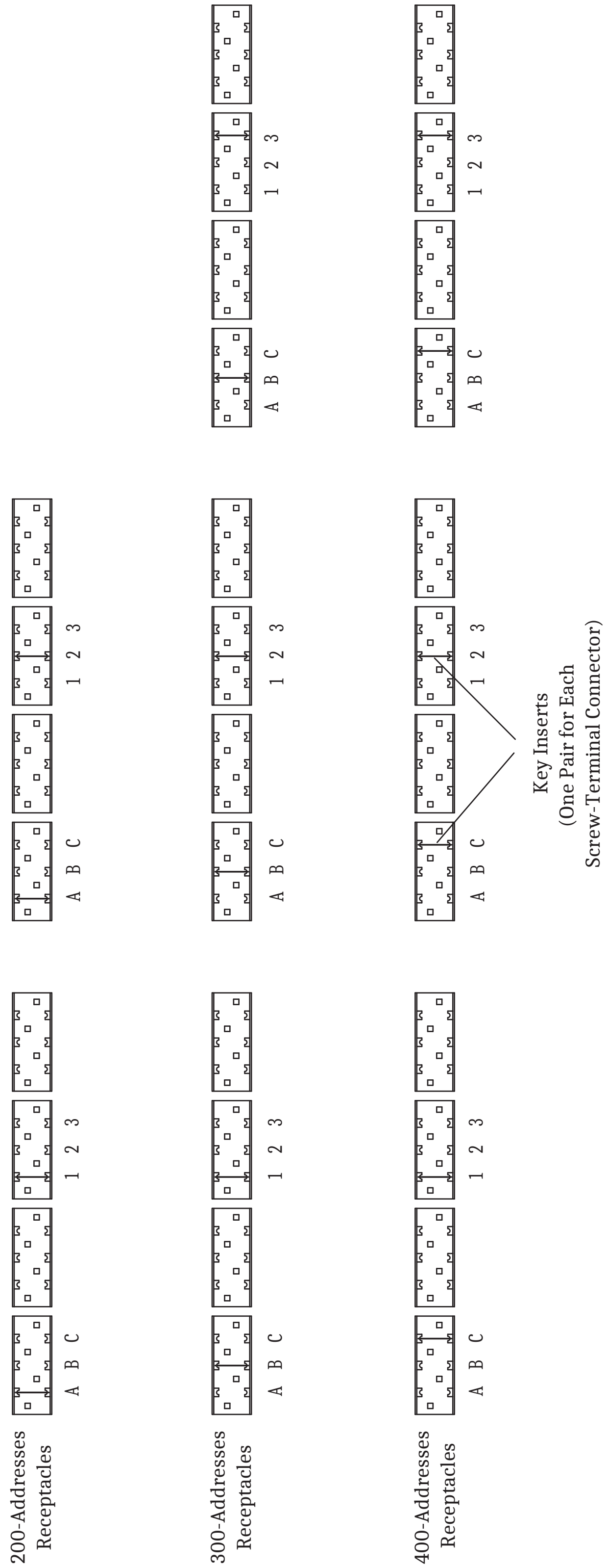


Figure 2.33 Rear-Panel Receptacle Keying

Grounding

Connect the grounding terminal (#**Y31**) labeled **GND** on the rear panel to a rack frame ground or main station ground for proper safety and performance. This protective earthing terminal is in the lower right side of the relay panel. The symbol that indicates the grounding terminal is shown in *Safety Symbols on page xxii in the Preface*. Use 2.5 mm^2 (14 AWG) or larger wire less than 2 m (6.6 ft) in length for this connection. This terminal connects directly to the internal chassis ground of the SEL-400G.

Power Connections

The terminals labeled **POWER** on the rear panel (#**Y29** and #**Y30**) must connect to a power source that matches the power supply characteristics that your SEL-400G specifies on the rear-panel serial number label (see *Power Supply on page 1.19*, for complete power input specifications). For the relay models that accept dc input, the serial number label specifies dc with the symbol shown in *Figure 2.31*.

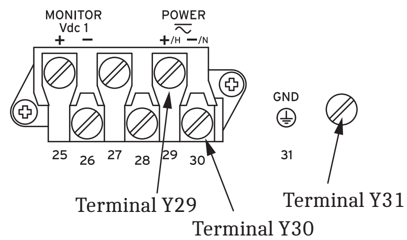


Figure 2.34 Power Connection Area of the Rear Panel

NOTE: The combined voltages applied to the **POWER** and **MONITOR** terminals must not exceed 600 V (rms or dc).

The **POWER** terminals are isolated from chassis ground. Use 0.8 mm^2 (18 AWG) or larger wire to connect to the **POWER** terminals. Connection to external power must comply with IEC 60947-1 and IEC 60947-3 and must be identified as the disconnect device for the equipment. Place an external disconnect device, switch/fuse combination, or circuit breaker in the **POWER** leads for the SEL-400G; this device must interrupt both the hot (**H/+**) and neutral (**N/–**) power leads. The current rating for the power disconnect circuit breaker or fuse must be 20 A maximum.

Operational power is internally fused by power supply Fuse F1. *Table 2.8* lists the SEL-400G power supply fuse requirements. Be sure to use fuses that comply with IEC 127-2.

You can order the SEL-400G with one of three operational power input ranges listed in *Table 2.8*. Each of the three supply voltage ranges represents a power supply ordering option. As noted in *Table 2.8*, model numbers for the relay with these power supplies begin 0487E3X*n* (or 487E4X*n*), where *n* is 2, 4, or 6, to indicate low, medium, and high voltage input power supplies, respectively. Note that each power supply range covers two widely used nominal input voltages. The SEL-400G power supply operates from 30 Hz to 120 Hz when ac power is used for the **POWER** input.

Table 2.8 Fuse Requirements for the Power Supply

Rated Voltage	Operational Voltage Range	Fuse F1	Fuse Description	Model Number
24–48 Vdc	18–60 Vdc	T5.0AH250V	5x20 mm, time-lag, 5.0 A, high break capacity, 250 V	0487E3X2 or 0487E4X2
48–125 Vdc or 110–120 Vac	38–140 Vdc or 85–140 Vac (30–120 Hz)	T3.15AH250V	5x20 mm, time-lag, 3.15 A, high break capacity, 250 V	0487E3X4 or 0487E4X4
125–250 Vdc or 110–240 Vac	85–300 Vdc or 85–264 Vac (30–120 Hz)	T3.15AH250V	5x20 mm, time-lag, 3.15 A, high break capacity, 250 V	0487E3X6 or 0487E4X6

The SEL-400G accepts dc power input for all power supply models. The 48–125 Vdc supply also accepts 110–120 Vac; the 125–250 Vdc supply also accepts 110–240 Vac. When connecting a dc power source, you must connect the source with the proper polarity, as indicated by the + (Terminal #Y29) and – (Terminal #Y30) symbols on the power terminals. When connecting to an ac power source, the + Terminal #Y29 is hot (H), and the – Terminal #Y30 is neutral (N). Each model of the SEL-400G internal power supply exhibits low power consumption and a wide input voltage tolerance. For more information on the power supplies, see *Power Supply on page 1.19*.

Monitor Connections (DC Battery)

The SEL-400G monitors one dc battery system. For information on the battery monitoring function, see *Station DC Battery System Monitor on page 7.18*. Connect the positive lead of the battery system to Terminal #Y25 and the negative lead to Terminal #Y26. (Usually the battery system is also connected to the rear-panel POWER input terminals.)

Secondary Circuit Connections

⚠CAUTION
Relay misoperation can result from applying anything other than specified secondary voltages and currents. Before making any secondary circuit connections, check the nominal voltage and nominal current specified on the rear-panel nameplate.

⚠DANGER
Contact with instrument terminals can cause electrical shock that can result in injury or death.

The SEL-400G has five sets of three-phase current inputs, three single-phase current inputs that can be reconfigured as a three-phase input, a three-phase voltage input, and three single-phase voltage inputs that can be reconfigured as a three-phase voltage input. *Shared Configuration Attributes on page 2.1* describes these inputs in detail. The alert symbol and the word DANGER on the rear panel indicate that you should use all safety precautions when connecting secondary circuits to these terminals.

To verify these connections, use SEL-400G metering (see *Metering on page 7.2*). You can also review metering data in an event report that results when you issue the **TRIGGER** command (see *Triggering Data Captures and Event Reports on page 9.7 in the SEL-400 Series Relays Instruction Manual*).

Fixed Terminal Blocks

Each V and Y input has two labels corresponding to whether it is configured as a three-phase (ABC) or a single-phase (123) input. Connect the secondary circuits to the Y and Z terminal blocks on the relay rear panel. Note the polarity dots above the odd-numbered terminals for CT inputs. Similar polarity dots are above the odd-numbered terminals for PT inputs.

Connectorized

For the Connectorized SEL-400G, order the wiring harness kit, SEL-WA0487E. The wiring harness contains eight prewired connectors for the relay current and voltage inputs.

You can order the wiring harness with various wire sizes and lengths. Contact your local Technical Service Center or the SEL factory for ordering information.

Perform the following steps to install the wiring harness:

Step 1. Plug the CT shorting connectors into terminals #Y01 through #Y18 and #Z01 through #Z18 as appropriate.

Odd-numbered terminals are the polarity terminals.

Step 2. Secure the connector to the relay chassis with the two screws located on each end of the connector.

When you remove the CT shorting connector, pull straight away from the relay rear panel.

As you remove the connector, internal mechanisms within the connector separately short each power system current transformer.

You can install these connectors in only one orientation.

Step 3. Plug the PT voltage connectors into terminals #Y19 to #Y24 for the VV inputs, and #Z19 to #Z24 for the VZ inputs, as appropriate.

Odd-numbered terminals are the polarity terminals. You can install these connectors in only one orientation.

Control Circuit Connections

You can configure the SEL-400G with many combinations of control inputs and control outputs. See *IRIG-B Inputs on page 2.9* and *I/O Interface Boards on page 2.10* for information about I/O configurations. This section provides details about connecting these control inputs and outputs. Refer to *Figure 2.2–Figure 2.5* for representative rear-panel screw-terminal connector locations.

Control Inputs

NOTE: The combined voltages applied to the INnnn and OUTnnn terminals must not exceed 600 V (rms or dc).

Table 2.2 lists the control inputs available with the relay.

Optoisolated

Optoisolated control inputs are not polarity sensitive. These inputs respond to voltage of either polarity, and can be used with ac control signals when properly configured.

Note that INTC and INTD I/O interface boards have two sets of nine inputs that share a common leg (see *Figure 2.10*).

Assigning

To assign the functions of the control inputs, see *Operating the Relay Inputs and Outputs on page 3.55 in the SEL-400 Series Relays Instruction Manual* for more details. You can also use SEL Grid Configurator Software to set and verify operation of the inputs.

Control Outputs

The SEL-400G has the following three types of outputs:

- Standard outputs
- Hybrid (high-current interrupting) outputs
- High-speed, high-current interrupting outputs (for example: INT4 board OUT01). See *Control Outputs on page 2.6* for more information.

You can connect the standard outputs in either ac or dc circuits. Connect the hybrid (high-current interrupting) and high-speed, high-current interrupting outputs to dc circuits only. The screw-terminal connector legends alert you about these requirements by showing polarity marks on the hybrid contacts and HS marks on the high-speed, high-current interrupting contacts.

Alarm Output

The relay monitors internal processes and hardware in continual self-tests. Also see *Relay Self-Tests on page 10.19 in the SEL-400 Series Relays Instruction Manual*. If the relay senses an out-of-tolerance condition, the relay declares a Status Warning or a Status Failure. The relay signals a Status Warning by pulsing the HALARM Relay Word bit (hardware alarm) to a logical 1 for five seconds. For a status failure, the relay latches the HALARM Relay Word bit at logical 1.

To provide remote alarm status indication, connect the b contact of an output contact to your control system remote alarm input. *Figure 2.35* shows the configuration of the a and b contacts of control output OUT215, using INT2 as an example.

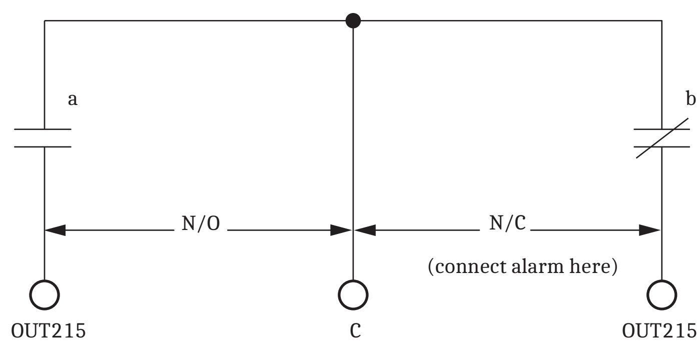


Figure 2.35 Control Output OUT215 (INT2)

Program OUT215 to respond to NOT HALARM by entering the following SELOGIC control equation with a communications terminal, with Grid Configurator.

OUT215 := **NOT HALARM**

When the relay is operating normally, the NOT HALARM signal is at logical 1 and the b contacts of control output OUT215 are open.

When a status warning condition occurs, the relay pulses the NOT HALARM signal to logical 0 and the b contacts of OUT215 close momentarily to indicate an alarm condition.

For a status failure, the relay disables all control outputs and the OUT215 b contacts close to trigger an alarm. Also, when relay power is off, the OUT215 b contacts close to generate a power-off alarm. See *Relay Self-Tests on page 10.19 in the SEL-400 Series Relays Instruction Manual* for information on relay self-tests.

The relay pulses the SALARM Relay Word bit for software programmed conditions; these conditions include settings changes, access level changes, and alarming after three unsuccessful password entry attempts.

The relay also pulses the BADPASS Relay Word bit after three unsuccessful password entry attempts.

You can add the software alarm SALARM to the alarm output by entering the following SELOGIC control equation.

OUT215 := **NOT (HALARM OR SALARM)**

Tripping and Closing Outputs

To assign the control outputs for tripping, see *Setting Outputs for Tripping and Closing on page 3.61 in the SEL-400 Series Relays Instruction Manual*. In addition, you can use the **SET O** command; see *SET on page 9.7* for more details.

IRIG-B Input Connections

The SEL-400G accepts a demodulated IRIG-B signal through two types of rear-panel connectors. These IRIG-B inputs are the BNC connector labeled **IRIG-B** and Pin 4 (+) and Pin 6 (–) of the DB-9 rear-panel serial port labeled **PORT 1**. When you use the **PORT 1** input, ensure that you connect Pins 4 and 6 with the proper polarity. See *Communications Ports Connections on page 2.39* for other DB-9 connector pinouts and additional details.

These inputs accept the dc shift time-code generator output (demodulated) IRIG-B signal with positive edge on the time mark. See *Section 11: Time and Date Management in the SEL-400 Series Relays Instruction Manual* for more information on IRIG-B inputs.

The **PORT 1** IRIG-B input connects to a 2.5 kΩ grounded resistor and goes through a single logic signal buffer. The **PORT 1** IRIG-B is equipped with robust ESD and overvoltage protection but is not optically isolated. When you are using the **PORT 1** input, ensure that you connect Pin 4 (+) and Pin 6 (–) with the proper polarity.

The IRIG network should be properly terminated with an external termination resistor (SEL 240-1802, BNC Tee, and SEL 240-1800, BNC terminator, 50 Ω) placed on the unit that is farthest from the source. This termination provides impedance matching of the cable for the best possible signal-to-noise ratio.

Where distance between the SEL-400G and the IRIG-B sending device exceeds the cable length recommended for conventional EIA-232 metallic conductor cables, you can use transceivers to provide isolation and to establish communication to remote locations.

Conventional fiber-optic and telephone modems do not support IRIG-B signal transmission. The SEL-2810 Fiber-Optic Transceiver/Modem includes a channel for the IRIG-B time code. These transceivers enable you to synchronize time precisely from IRIG-B time-code generators (such as the SEL-2032 Communications Processor) over a fiber-optic communications link.

For ease of connection or for runs as long as 91.44 m (300 ft) between the IRIG-B generator and the SEL-400G, use the BNC IRIG-B input to connect the IRIG-B input of the SEL-400G to the IRIG-B generation equipment. Make this connection with a 50 Ω coaxial cable assembly.

Communications Ports Connections

The SEL-400G has three rear-panel EIA-232 serial communications ports labeled **PORT 1**, **PORT 2**, and **PORT 3** and one front-panel port, **PORT F** (see *Section 10: Communications Interfaces*). In addition, the rear panel features **PORT 5** for an optional factory-installed Ethernet communications card. For additional information about communications topologies and standard protocols that are available in the SEL-400G, see *Section 10: Communications Interfaces*, *DNP3 Communication on page 10.8*, *IEC 61850 Communication on page 10.30*, and *Modbus TCP Communication on page 10.63*.

Serial Ports

The SEL-400G serial communications ports use EIA-232 standard signal levels in a DB-9 connector. To establish communication between the relay and a DTE device (a computer terminal, for example) with a DB-9 connector, use an SEL-C234A cable. Alternatively, you can use an SEL-C662 cable to connect to a USB port.

Figure 2.33 shows the configuration of an SEL-C234A cable that you can use for basic ASCII and binary communication with the relay. A properly configured ASCII terminal, terminal emulation program, or Grid Configurator along with the SEL-C234A cable provide communication with the relay in most cases.

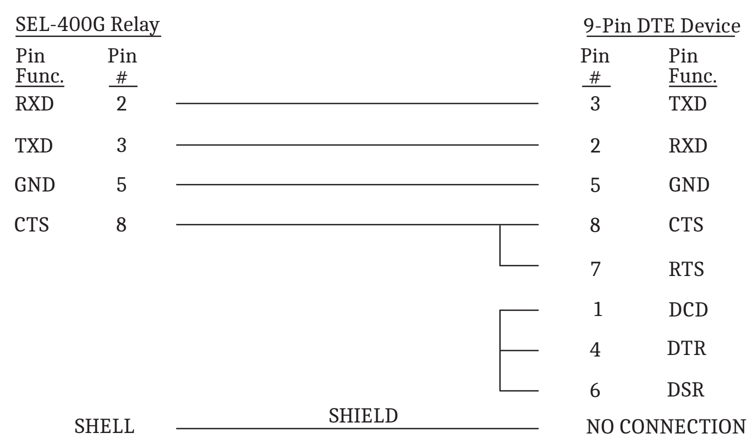


Figure 2.36 SEL-400G to Computer DB-9 Connector Diagram

Serial Cables

⚠CAUTION
Severe power and ground problems can occur on the communications ports of this equipment as a result of using non-SEL cables. Never use standard null-modem cables with this equipment.

Using an improper cable can cause numerous problems or failure to operate, so you must be sure to specify the proper cable for application of your SEL-400G. Several standard SEL communications cables are available for use with the relay. The following list provides additional rules and practices you should follow for successful communication using EIA-232 serial communications devices and cables.

- Route communications cables well away from power and control circuits. Switching spikes and surges in power and control circuits can cause noise in the communications circuits if power and control circuits are not adequately separated from communications cables.
- Keep the length of the communications cables as short as possible to minimize communications circuit interference and also to minimize the magnitude of hazardous ground potential differences that can develop during abnormal power system conditions.

- ➤ Ensure that EIA-232 communications cable lengths never exceed 15.25 m (50 ft), and always use shielded cables for communications circuit lengths greater than 13.05 m (10 ft).
- ➤ Modems provide communication over long distances and give isolation from ground potential differences that are present between device locations (examples are the SEL-2800 series transceivers).
- ➤ Lower data speed communication is less susceptible to interference and will transmit greater distances over the same medium than higher data speeds. Use the lowest data speed that provides an adequate data transfer rate.

Ethernet Network Connections

⚠CAUTION
Use of controls or adjustments, or performance of procedures other than those specified herein, may result in hazardous radiation exposure.

⚠WARNING
Do not look into the fiber ports/connectors.

NOTE: The five-port Ethernet card uses SFP ports for its fiber-optic connections. SFP transceivers are not included with the card and must be ordered separately. See Table 15.7 in the SEL-400 Series Relays Instruction Manual or selinc.com/products/sfp/ for a list of compatible SFP transceivers.

The optional Ethernet card for the SEL-400G is available with four or five Ethernet ports. These ports can work together to provide a primary and backup interface. Other operating modes are also available. The following list describes the Ethernet card port options.

- ➤ **10/100BASE-T**. 10 Mbps or 100 Mbps communications through the use of Cat 5 cable (Category 5 twisted-pair) and RJ45 connector (four-port Ethernet card only)
- ➤ **100BASE-FX.** 100 Mbps communications over multimode fiber-optic cable through the use of an LC connector
- ➤ **1000BASE-X.** 1 Gbps communication over fiber-optic cable through the use of an LC connector (PORT 5A and PORT 5B on the five-port Ethernet card only)

Ethernet Card Rear-Panel Layout

⚠WARNING
Do not perform any procedures or adjustments that this instruction manual does not describe.

⚠WARNING
During installation, maintenance, or testing of the optical ports, use only test equipment qualified for Class 1 laser products.

⚠WARNING
Incorporated components, such as LEDs, transceivers, and laser emitters, are not user serviceable. Return units to SEL for repair or replacement.

Rear-panel layouts for the Ethernet card port configurations are shown in *Figure 2.37–Figure 2.40*.

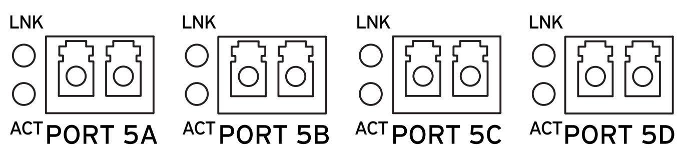


Figure 2.37 Four 100BASE-FX Port Configuration

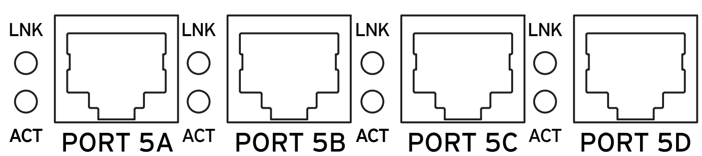


Figure 2.38 Four 10/100BASE-T Port Configuration

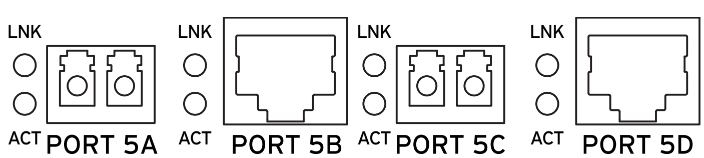


Figure 2.39 100BASE-FX and 10/100BASE-T Port Configuration

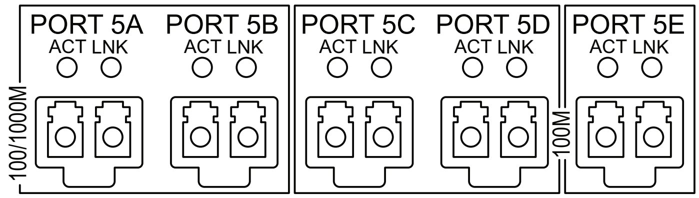


Figure 2.40 Two 100/1000BASE and Three 100BASE SFP Ports

Twisted-Pair Networks

NOTE: Use caution with UTP cables as these cables do not provide adequate immunity to interference in electrically noisy environments unless additional shielding measures are employed.

While Unshielded Twisted Pair (UTP) cables dominate office Ethernet networks, Shielded Twisted Pair (STP) cables are often used in industrial applications. The four-port Ethernet card is compatible with standard UTP cables for Ethernet networks as well as STP cables for Ethernet networks.

Typically UTP cables are installed in relatively low-noise environments including offices, homes, and schools. Where noise levels are high, you must either use STP cable or shield UTP using grounded ferrous raceways such as steel conduit.

Several types of STP bulk cable and patch cables are available for use in Ethernet networks. If noise in your environment is severe, you should consider using fiber-optic cables. We strongly advise against using twisted-pair cables for segments that leave or enter the control house.

If you use twisted-pair cables, you should use care to isolate these cables from sources of noise to the maximum extent possible. Do not install twisted-pair cables in trenches, raceways, or wireways with unshielded power, instrumentation, or control cables. Do not install twisted-pair cables in parallel with power, instrumentation, or control wiring within panels; rather, make them perpendicular to the other wiring.

You must use a cable and connector rated as Category 5 (Cat 5) to operate the twisted-pair interface (10/100BASE-T) at 100 Mbps. Because lower categories are becoming rare and because you may upgrade a 10 Mbps network to 100 Mbps, we recommend using all Cat 5 components.

Some industrial Ethernet network devices use 9-pin connectors for STP cables. The Ethernet card RJ45 connectors are grounded so you can ground the shielded cable using a standard, externally shielded jack with cables terminating at the Ethernet card.

AC/DC Connection Diagrams

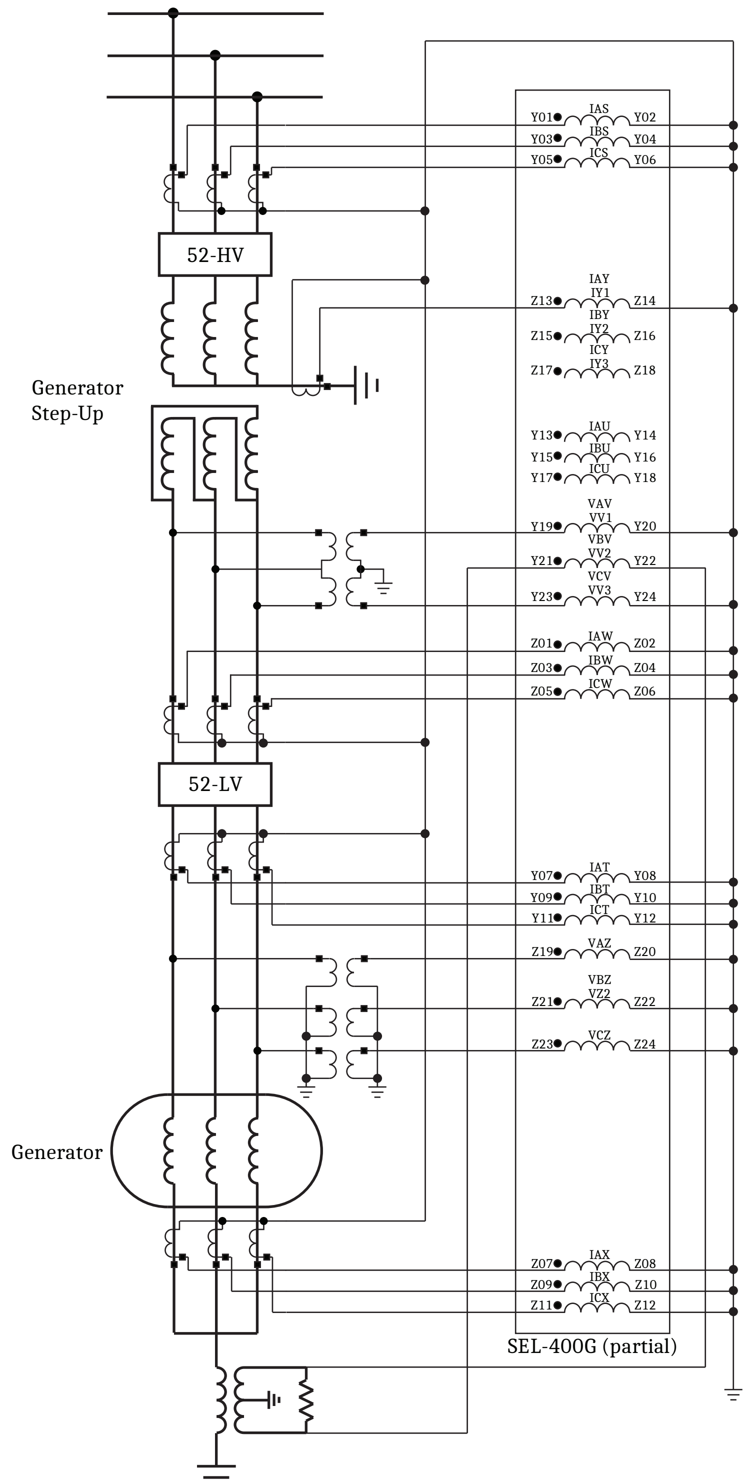


Figure 2.41 Typical AC Connection Diagram

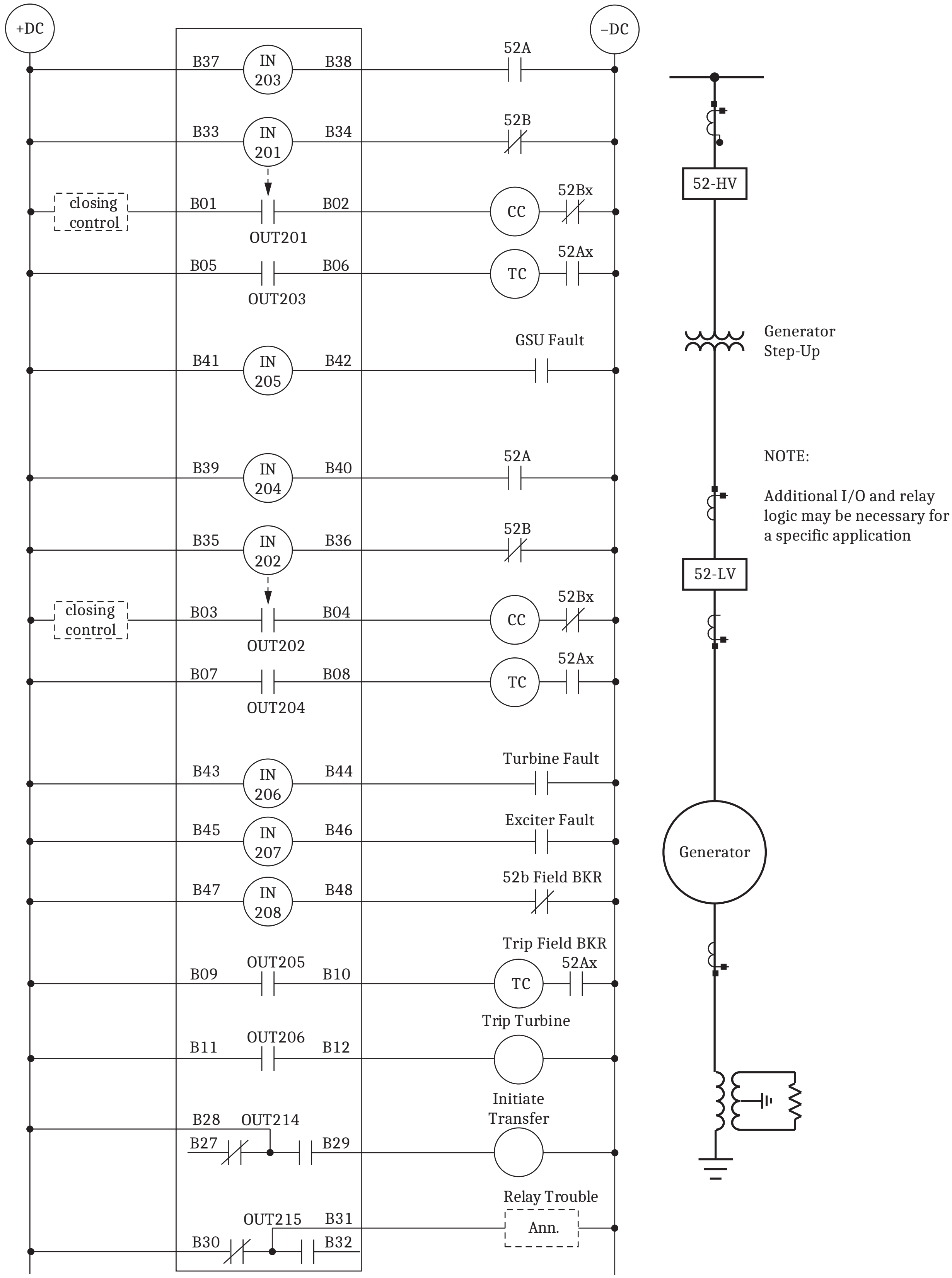


Figure 2.42 Typical DC Connection Diagram

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SECTION 3

Testing

This section provides guidelines for determining and establishing test routines for the SEL-400G Advanced Generator Protection System. Follow the standard practices of your company in choosing testing philosophies, methods, and tools. *Section 10: Testing, Troubleshooting, and Maintenance in the SEL-400 Series Relays Instruction Manual* provides additional information related to testing.

Topics presented in this section include the following:

The SEL-400G is factory-calibrated; this section contains no calibration information. If you suspect that the relay is out of calibration, contact your Technical Service Center or the SEL factory.

Low-Level Test Interface

⚠CAUTION
The relay contains devices sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.

NOTE: The relay front, I/O, and CAL boards are not hot-swappable. Remove all power from the relay before altering ribbon cable connections.

You can test the relay in two ways: by using secondary injection testing or by applying low-magnitude ac voltage signals to the low-level test interface. This section describes the low-level test interface between the calibrated input module and the separately calibrated processing module.

Access the test interface by removing the relay front panel. At the right side of the relay main board is the processing module. Inputs to the processing module are multipin connectors **J6** and **J12**, the analog or low-level test interface connections. Receptacle **J12** is on the right side of the main board, with **J6** located 5 cm (2 in) behind **J12**; see *Figure 2.16* for a locating diagram.

Figure 3.1 shows the **J12** low-level interface connections and signal scaling factors. The **J6** interface has the same scaling factors as the front interface, but with the channel allocation shown in *Figure 3.2*. Remove the ribbon cable between the two modules to access the outputs of the input module and the inputs to the processing module (relay main board). You can test the relay processing module by using signals from a low-level test source, such as the SEL-RTS Low-Level Relay Test System. Never apply voltage signals greater than 6.6 V peak-to-peak to the low-level test interface.

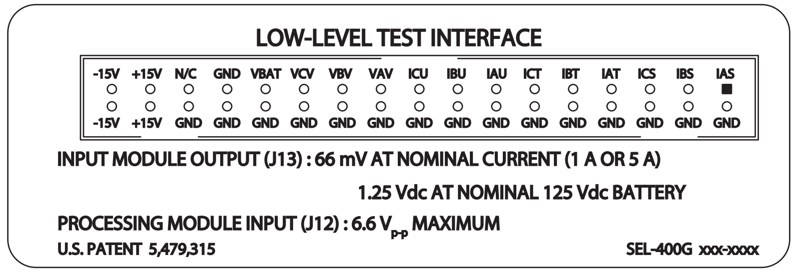


Figure 3.1 Low-Level Test Interface J12

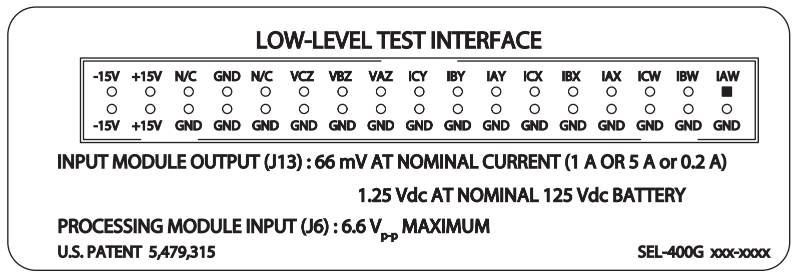


Figure 3.2 Low-Level Test Interface J6

Use signals from the low-level relay test system to test the relay processing module. These signals simulate power system conditions, taking into account PT ratio and CT ratio scaling. Use relay metering to determine whether the applied test voltages and currents produce correct relay operating quantities. The UUT database entries for the SEL-400G in the SEL-5401 Relay Test System Software are shown in *Table 3.1–Table 3.6*.

Table 3.1 UUT Database Entries for SEL-5401 Relay Test System Software (Analog Input Board Y)—5 A Relay

Channel	Label	Scale Factor	Unit
1	IAS	75	A
2	IBS	75	A
3	ICS	75	A
4	IAT	75	A
5	IBT	75	A
6	ICT	75	A
7	IAU	75	A
8	IBU	75	A
9	ICU	75	A
10	VAV	150	V
11	VBV	150	V
12	VCV	150	V

Table 3.2 UUT Database Entries for SEL-5401 Relay Test System Software (Analog Input Board Z)—5 A Relay (Sheet 1 of 2)

Channel	Label	Scale Factor	Unit
1	IAW	75	A
2	IBW	75	A
3	ICW	75	A

Table 3.2 UUT Database Entries for SEL-5401 Relay Test System Software (Analog Input Board Z)—5 A Relay (Sheet 2 of 2)

Channel	Label	Scale Factor	Unit
4	IAX	75	A
5	IBX	75	A
6	ICX	75	A
7	IY1	75	A
8	IY2	75	A
9	IY3	75	A
10	VAZ	150	V
11	VBZ	150	V
12	VCZ	150	V

Table 3.3 UUT Database Entries for SEL-5401 Relay Test System Software (Analog Input Board Y)—1 A Relay

Channel	Label	Scale Factor	Unit
1	IAS	15	A
2	IBS	15	A
3	ICS	15	A
4	IAT	15	A
5	IBT	15	A
6	ICT	15	A
7	IAU	15	A
8	IBU	15	A
9	ICU	15	A
10	VAV	150	V
11	VBV	150	V
12	VCV	150	V

Table 3.4 UUT Database Entries for SEL-5401 Relay Test System Software (Analog Input Board Z)—1 A Relay

Channel	Label	Scale Factor	Unit
1	IAW	15	A
2	IBW	15	A
3	ICW	15	A
4	IAX	15	A
5	IBX	15	A
6	ICX	15	A
7	IY1	15	A
8	IY2	15	A
9	IY3	15	A
10	VAZ	150	V
11	VBZ	150	V
12	VCZ	150	V

Table 3.5 UUT Database Entries for SEL-5401 Relay Test System Software (Analog Input Board Z)—0.2 A (Terminal Y Only) Relay

Channel	Label	Scale Factor	Unit
1	IY1	3	A
2	IY2	3	A
3	IY3	3	A

Relay Test Connections

NOTE: The procedures specified in this section are for initial relay testing only. Follow your company policy for connecting the relay to the power system.

⚠WARNING
Before working on a CT circuit, first apply a short to the secondary winding of the CT.

Figure 3.3 shows the test set and relay connections for three-phase current injection.

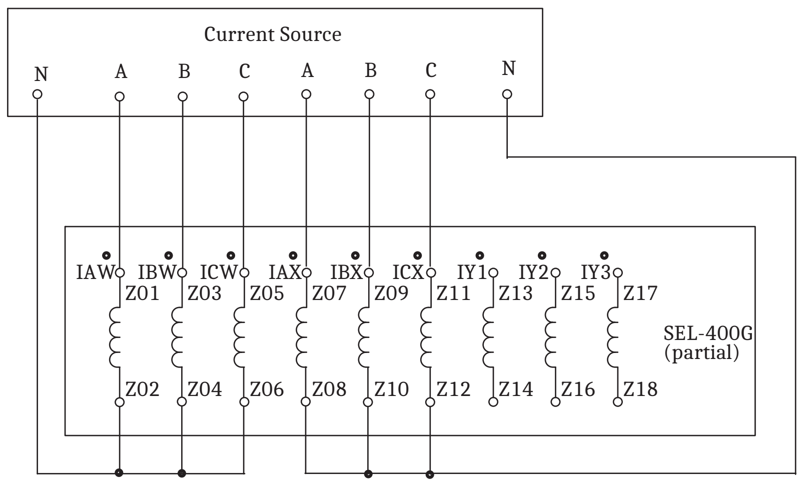


Figure 3.3 Test Connections for Balanced Load With Three-Phase Current Sources

Figure 3.4 shows the test set and relay connections for three-phase voltage injection.

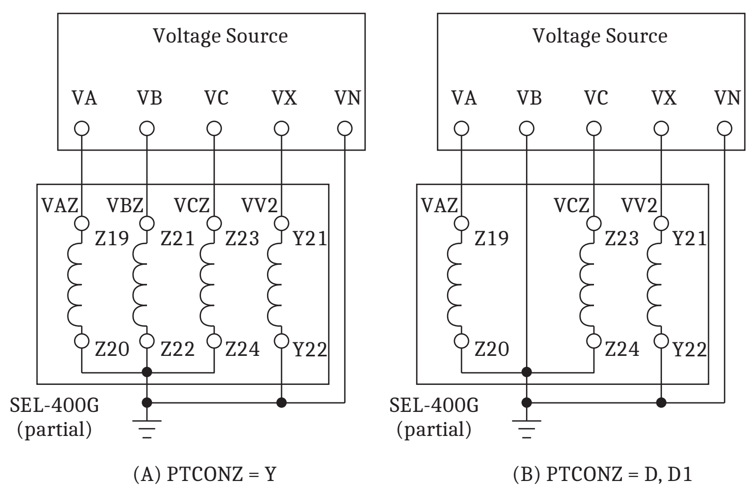


Figure 3.4 Voltage Test Connections

Selected Element Tests

This section discusses tests of selected functions in the SEL-400G. These tests are designed to show a method of testing a function in an easy way while at the same time familiarizing you with other functions such as programming logic functions, Sequential Event Recorder (SER), and the front panel. Each test starts with the default settings to avoid unexpected results from previous programming when testing other functions. This section provides tests for the following relay elements:

- Volts/Hertz elements
- Directional power elements
- Capability-based loss of field elements
- Current unbalance elements
- 100 percent stator ground elements
- Universal differential elements

The following paragraphs describe when each type of test is performed, the goals of testing at that time, and the relay functions that you need to test at each point. This information is intended as a guideline for testing SEL relays.

Volts/Hertz

Although the V/Hz element offers definite-time and user-defined elements, this test shows how to test the user-defined function. For this test, you program a SELOGIC variable to assert LEDs on the front panel to indicate the status of the V/Hz element. You also program the SER to record the status of the V/Hz element, and then use these recorded values to calculate the element operating time(s).

Figure 3.5(A) shows a curve with four points defined, and *Figure 3.5(B)* shows an intermediate point Pt (107,?) between Point 24U1101 and Point 24U1102.

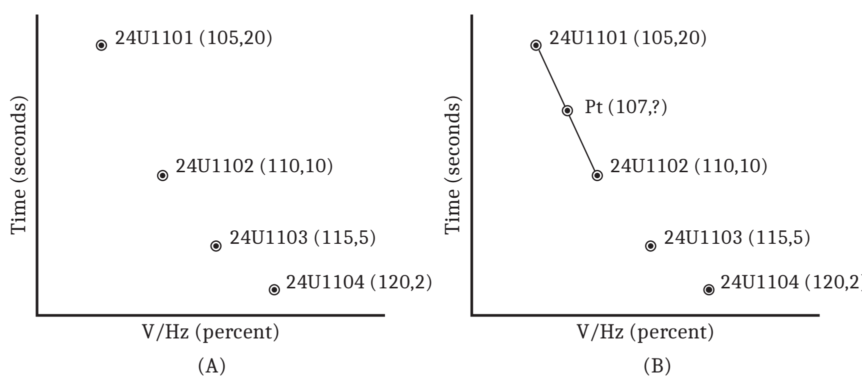


Figure 3.5 User-Defined V/Hz Curve 1

Because the relay linearly interpolates these data points, use *Equation 3.1* to calculate the operating time for a V/Hz value of 107 percent.

$$t = \left[\frac{t1 - t2}{P1 - P2}\right] \bullet \ Pt + \left[\frac{t1 \bullet \ P2 - t2 \bullet \ P1}{P2 - P1}\right]$$

Equation 3.1

where:

t1 = the operate time value of 24U1101 (20)
P1 = the percentage V/Hz value of 24U1101 (105)
t2 = the operate time value of 24U1102 (10)
P2 = the percentage V/Hz value of 24U1102 (110)
Pt = the percentage V/Hz value of 107 percent

$$t = \left[\frac{20 - 10}{105 - 110}\right] \bullet 107 + \left[\frac{20 \bullet 110 - 10 \bullet 105}{110 - 105}\right]$$

$$t = 16 \text{ seconds}$$

Equation 3.2

Table 3.6 Settings to Test the V/Hz Elements

Setting	Setting Category	Comments
E24 = 1	Group	Enable the V/Hz elements
2401 = VPMAXZF	Group	Set the operating quantity equal to the maximum phase-to-phase voltage for Terminal Z
24TC1 = 0	Group	Disable the definite-time V/Hz elements
24CCS1 = UI	Group	Select user-defined curve
24U1TC1 = 1	Group	Enable the logic for user-defined curves
24U1NP1 = 4	Group	Specify a curve with 4 points
24U1101 = 105,20	Group	Coordinates for Point 1
24U1102 = 110,10	Group	Coordinates for Point 2
24U1103 = 115,5	Group	Coordinates for Point 3
24U1104 = 120,2	Group	Coordinates for Point 4
PSV01 = 24RPU1 > 105	Protection Logic (SET L)	PSV01 asserts when V/Hz exceeds 105 percent
PSV02 = 24RPU1 > 107	Protection Logic	PSV02 asserts when V/Hz exceeds 107 percent
PB1_LED = PSV01	Front panel (SET F)	Pushbutton LED 1 reports the status of PSV01
PB1_COL = AG	Front panel	LED is amber when PSV01 asserts, and green when PSV01 deasserts
PB2_LED = PSV02	Front panel	Pushbutton LED 2 reports the status of PSV02
PB2_COL = AG	Front panel	LED is amber when PSV02 asserts, and green when PSV02 deasserts
PSV01,"V/Hz picked up"	Report (SER) (SET R)	Reports and time-stamps when PSV01 asserts
24U1T1,"V/Hz timed out"	Report (SER)	Reports and time-stamps when V/Hz elements times out

Figure 3.6 shows the group settings (Group 1) for this test.

```
=>>SET TE <Enter>
Group 1

Potential Transformer Data

PT connection for Term V (OFF,Y,D,D1,1PH)                        PTCONV  := 1PH    ?Y <ENTER>
PT connection for Term Z (Y,D,D1)                                PTCONZ  := Y      ? <ENTER>
PT Ratio Term V (1.0-10000)                                      PTRV    := 200.0  ?2000 <ENTER>
PT Ratio Term Z (1.0-10000)                                      PTRZ    := 200.0  ?2000 <ENTER>
PT Nominal Voltage (L-L) Term V (30.00-300 V,sec)                VNOMV   := 110.00 ? <ENTER>
PT Nominal Voltage (L-L) Term Z (30.00-300 V,sec)                VNOMZ   := 110.00 ? <ENTER>

Current Transformer Data

CT Connection for Term Y (1PH,Y)                                 CTCONY  := 1PH    ?Y <ENTER>
CT Ratio Term S (OFF,1.0-50000)                                  CTRS    := 4000.0 ?100 <ENTER>
CT Ratio Term T (OFF,1.0-50000)                                  CTRT    := 400.0  ?100 <ENTER>
CT Ratio Term U (OFF,1.0-50000)                                  CTRU    := 12000.0?100 <ENTER>
CT Ratio Term W (OFF,1.0-50000)                                  CTRW    := 4000.0 ?100 <ENTER>
CT Ratio Term X (OFF,1.0-50000)                                  CTRX    := 4000.0 ?100 <ENTER>
CT Ratio Term Y (OFF,1.0-50000)                                  CTRY    := OFF    ?100 <ENTER>

Relay Configuration

Advanced Settings (Y,N)                                          EADVS   := N      ? <ENTER>
En. Pump Storage (OFF or combo of S,T,U,W,X,Y,V,Z)               EPS     := OFF    ? <ENTER>
Enable Sys Volt Term (OFF,V)                                     ESYSPT  := "V1"   ?V <ENTER>
Enable Gen Neut Cur Terms (combo of W,X)                         EGNCT   := "X"    ?W,X <ENTER>
Enable System Cur Terms (OFF or combo of S,T,U,Y)                ESYSCT  := "S,T"  ?S <ENTER>
En. Power Calc Term (OFF or S)                                   EPCAL   := "S"    ?OFF <ENTER>
Enable Volts per Hertz Elements (N,1-2)                          E24     := 2      ?1 <ENTER>
Enable Synch. Check (OFF or S)                                   E25     := "S"    ?OFF <ENTER>
Enable Under Voltage Elements (N,1-6)                            E27     := N      ? <ENTER>
Enable Directional Power (N,1-4)                                 E32     := 1      ?N <ENTER>
Enable Loss of Field (OFF or combo of Z,P)                       E40     := "Z"    ?OFF <ENTER>
Enable Current Unbalance Elements (N, 1-2)                       E46     := 1      ?N <ENTER>
Enable 50 Elements (OFF or S)                                    E50     := OFF    ? <ENTER>
Enable Inverse Time Overcurrent Elements (N,1-12)                E51     := N      ? <ENTER>
Enable Over Voltage Elements (N,1-6)                             E59     := 1      ?N <ENTER>
Enable 60P Split Phase Element (N,T,U,W,X,Y)                     E60P    := N      ? <ENTER>
Enable 60N Split Phase Element (N,Y1,Y2,Y3)                      E60N    := N      ? <ENTER>
Enable 64G Element (OFF or combo of G1,G2,G3)                    E64G    := "G1,G3"?OFF <ENTER>
Enable 64F Field Ground Element (Y,N)                            E64F    := N      ? <ENTER>
Enable 64S Stator Ground Element (Y,N)                           E64S    := N      ? <ENTER>
Enable Out-of-Step Element (N,1B,2B)                             E78     := 1B     ?N <ENTER>
Enable Frequency Elements (N,1-6)                                E81     := 2      ?N <ENTER>
Enable Accumulated Freq Elements (N,1-8)                         E81A    := N      ? <ENTER>
Enable Rate of Change of Freq Elements (N,1-6)                   E81R    := N      ? <ENTER>
Enable Differential Elements (N,1-2)                             E87     := 2      ?N <ENTER>
Enable REF Element (OFF or combo of Y1,Y2,Y3)                    EREF    := "Y1"   ?OFF <ENTER>
Enable Inad. Ener. Prot. (OFF or S)                              EINAD   := "S"    ?OFF <ENTER>
Enable Pole Open (OFF or S)                                      EPO     := "S,T"  ?OFF <ENTER>
Load Encroachment (Y,N)                                          ELOAD   := N      ? <ENTER>
Enable Loss of Potential (OFF or combo of V,Z)                   ELOP    := "Z"    ?OFF <ENTER>
Enable Brkr Fail. Prot. (OFF or S)                               EBFL    := "S,T"  ?OFF <ENTER>
Enable Brkr Flash Ovr. (OFF or S)                                EBFO    := "S"    ?OFF <ENTER>
Enable System Backup Protection (OFF or combo of 51C, 51V, 21P)  EBUP    := 21P    ?N <ENTER>
Enable Demand Metering (N,1-10)                                  EDEM    := N      ? <ENTER>
Enable Max/Min Metering (N,1-30)                                 EMXMN   := 12     ?N <ENTER>

Power System Data

Generator Max. MVA (1-5000 MVA)                                  MVAGEN  := 555    ? <ENTER>
Generator L-L Voltage (1.00-100 kV)                              KVGEN   := 24.00  ? <ENTER>
Generator D-Axis Synch Reactance (0.100-4)                       XDGEN   := 1.810  ? <ENTER>
Transformer Leakage Reactance (0.010-10)                         XTXFR   := 0.042  ? <ENTER>
Equivalent System Reactance (0.010-10)                           XESYS   := 0.200  ? <ENTER>

Frequency Tracking Sources

Frequency Source for Current Term S (G,S)                        FTSRCS  := S      ?G <ENTER>
Frequency Source for Current Term T (G,S)                        FTSRCT  := S      ?G <ENTER>
Frequency Source for Current Term U (G,S)                        FTSRCU  := G      ? <ENTER>
Frequency Source for Current Term W (G)                          FTSRCW  := G      ?
Frequency Source for Current Term X (G)                          FTSRCX  := G      ?
Frequency Source for Current Term Y (G,S)                        FTSRCY  := G      ? <ENTER>
Frequency Source for Voltage Term V (S)                          FTSRCV  := S      ?
Frequency Source for Voltage Term Z (G)                          FTSRCZ  := G      ?
```

Figure 3.6 Group Settings for the V/Hz Test

```
Volts per Hertz Element 1

24 Element 1 Operating Quantity                                  24O1    := VPMAXZF? <ENTER>
24 Element 1 Level 1 Pick Up (100-200%)                          24D1P1  := 110    ? <ENTER>
24 Element 1 Level 1 Time Delay (0.040-6000 s)                   24D1D1  := 10.000 ? <ENTER>
24 Element 1 Torque Control (SELogic Eqn)
24TC1 := 1
?  0 <ENTER>
24 Element 1 Level 2 Comp. Curve (OFF,DD,U1,U2)                  24CCS1  := OFF    ?U1 <ENTER>


Volts per Hertz Element 1 Level 2, User Defined Curve 1

24 Element 1 Curve 1 Torque Control (SELogic Eqn)
24U1TC1 := 1
?
24 Element 1 No. of Point on User 1 Curve (3-20)                 24U1NP1 := 3      ?4 <ENTER>
24 Ele. 1 Cur. 1,Pnt. 01 (100-200%,0.040-6000 s)
24U1101 := 200, 400.000
?  105,20 <ENTER>
24 Ele. 1 Cur. 1,Pnt. 02 (100-200%,0.040-6000 s)
24U1102 := 200, 400.000
?  110,10 <ENTER>
24 Ele. 1 Cur. 1,Pnt. 03 (100-200%,0.040-6000 s)
24U1103 := 200, 400.000
?  115,5 <ENTER>
24 Ele. 1 Cur. 1,Pnt. 04 (100-200%,0.040-6000 s)
24U1104 := 200, 400.000
?  120,2 <ENTER>
24 Element 1 Curve 1 Reset Time (0.010-400 s)                    24U1CR1 := 0.010  ? <ENTER>

Generator Monitoring Logic

Generator Online Logic (SELogic Eqn)
ONLINE := NA
?  END <ENTER>
Group 1

Save settings (Y,N)  ?Y <ENTER>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 3.6 Group Settings for the V/Hz Test (Continued)

Figure 3.7 shows the Protection Logic setting for the test. Protection SELOGIC variable PSV01 asserts when the analog output (24RPU1, see *Equation 5.54*) exceeds 105 percent, and PSV02 asserts when 24RPU1 exceeds 107 percent. Protection math variables PMV01 and PMV02 are included for easy monitoring of the values 24RPU1 and VPMAXZF.

```
=>>SET L TE <Enter>
Protection 1

1: # BREAKER S OPEN AND CLOSE CMD
?  >
21:
?  PSV01:=24RPU1 > 105 <Enter>
22:
?  PSV02:=24RPU1 > 107 <Enter>
23:
?  PMV01:=24RPU1 <Enter>
24:
?  PMV02:=VPMAXZF <Enter>
25:
?  END <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 3.7 Logic Settings for the V/Hz Test

Program the front-panel pushbutton LEDs to indicate the status of PSV01 and PSV02. Set the LED to show amber when PSV01 (PB1_LED) and PSV02 (PB2_LED) are asserted, and to show green when PSV01 and PSV02 are deasserted. *Figure 3.8* shows the front-panel LED programming.

```
=>>SET F TE <Enter>
Front Panel

Front Panel Settings

Front Panel Display Time-Out (OFF,1-60 mins)        FP_TO   := 15     ?
Enable LED Asserted Color (R,G)                     EN_LEDC := G      ?
Trip LED Asserted Color (R,G)                       TR_LEDC := R      ?
Pushbutton LED 1 (SELogic Equation)
PB1_LED := NA
?  PSV01 <Enter>
PB1_LED Assert & Deassert Color (Enter 2: R,G,A,O)   PB1_COL := AO     ?AG <Enter>
Pushbutton LED 2 (SELogic Equation)
PB2_LED := NA
?  PSV02 <Enter>
PB2_LED Assert & Deassert Color (Enter 2: R,G,A,O)   PB2_COL := AO     ?AG <Enter>
Pushbutton LED 3 (SELogic Equation)
PB3_LED := NA
?  END <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 3.8 Front-Panel Settings for the V/Hz Test

Use the SER to record the exact time when PSV01 and PSV02 assert, and when the output from the V/Hz element (24U1T1) asserts. Calculate the operating time of the V/Hz element by finding the difference between these two times. *Figure 3.9* shows the SER programming.

```
=>>SET R TE <Enter>
Report

SER Chatter Criteria

Automatic Removal of Chattering SER Points (Y,N)    ESERDEL := N     ? <Enter>

SER Points
(Relay Word Bit, Reporting Name, Set State Name, Clear State Name, HMI Alarm)

1:
? PSV01,"V/Hz picked up 105" <Enter>
2:
? PSV02,"V/Hz picked up 107" <Enter>
3:
?  24U1T1,"V/Hz timed out" <Enter>
4:
? END <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 3.9 SER Settings for the V/Hz Test

This concludes the settings and programming. At this point, pushbutton PB1_LED and PB2_LED must both show green. Refer to *Equation 5.54* to see the logic that determines 24RPU and *Figure 5.111* to see the logic that determines output 24U1T1. Notice that *Equation 5.54* compares the maximum phase-to-phase voltage with the nominal phase-to-phase voltage. To monitor 24RPU1 and VPMAXZF, perform a **MET PMV** command while running the test conditions below.

Step 1. Connect an injection set as shown in *Figure 3.4* to the PT Z terminals.

Step 2. Calculate the line-to-line voltage for the nominal line-to-neutral voltage of 63.5 V (63.5 • (√3) = 110). Next, calculate 105 percent and 107 percent of 110 V to determine the magnitude of VPMAXZF that will cause PSV01 and PSV02 to assert. Start off by injecting the voltage values shown in the Initial Voltage (105%) column in *Table 3.7*.

Step 3. Slowly increase the A-Phase voltage until PB1_LED changes from green to amber. Record this voltage value in *Table 3.7*. Perform a **MET PMV** command and record the values of PMV01 and PMV02 in the table.

Step 4. Turn off the injection set.

Step 5. Clear the SER by typing **SER C <Enter>**. Enter **Y <Enter>** at the prompt: `Are you sure (Y/N)?`

Table 3.7 Voltage Values

Initial Voltage (105%)	Recorded Voltage	Initial Voltage (107%)	Recorded Voltage
VA = 68 ∠0°	VA = PMV01 = % PMV02 = V	VA = 71∠0°	VA = PMV01 = % PMV02 = V
VB = 63.5∠–120°	VB = 63.5∠–120°	VB = 63.5∠–120°	VB = 63.5∠–120°
VC = 63.5∠120°	VC = 63.5∠120°	VC = 63.5∠120°	VC = 63.5∠120°

Step 6. Inject the relay with the recorded voltages for at least 22 seconds (verify that PB1_LED is amber, and PB2_LED is green).

Step 7. Stop the injection and turn the test set off. Type **SER <Enter>** to see the element assert and operate times, as shown in *Figure 3.10*.

```
=>>SER <Enter>

Relay 1                                   Date: 12/16/2019  Time: 11:45:25.880
Station A                                 Serial Number: 1181300592

FID=SEL-400G-X581-V0-Z001001-D20191209

#      DATE        TIME           ELEMENT              STATE
2    12/16/2019  11:45:02.6000   V/Hz picked up 105   Asserted
1    12/16/2019  11:45:22.5850   V/Hz timed out       Asserted

=>>
```

Figure 3.10 Element Assert and Operate Times (105%)

Because we are testing point (105,20), we expect the V/Hz element to assert after 20 seconds. Calculate the trip time as follows:

Trip time = 11:45:22.5850 – 11:45:02.6000 = 19.985 seconds.

This result is within the tolerance range of the V/Hz element.

Step 8. With the test set connected, repeat *Step 1* through *Step 5*, noting the voltage when PB2_LED changes from green to amber in *Step 3* (PB1_LED also changes from green to amber).

Step 9. Inject the relay with the recorded voltages for at least 18 seconds (verify that both PB1_LED and PB2_LED are amber).

Step 10. Stop the injection and turn the test set off. Type **SER <Enter>** to see the element assert and operate times, as shown in *Figure 3.11*.

```
=>>SER <Enter>

Relay 1                                          Date: 12/16/2019  Time: 11:51:05.099
Station A                                        Serial Number: 1181300592

FID=SEL-400G-X581-V0-Z001001-D20191209

#      DATE        TIME           ELEMENT              STATE
3    12/16/2019  11:50:41.4550   V/Hz picked up 105   Asserted
2    12/16/2019  11:50:41.4550   V/Hz picked up 107   Asserted
1    12/16/2019  11:50:57.3800   V/Hz timed out       Asserted

=>>
```

Figure 3.11 Element Assert and Operate Times (107%)

Because we are testing point (107,16), we expect the V/Hz element to assert after 16 seconds. Calculate the trip time as follows:

Trip time = 11:50:57.3800 – 11:50:41.4550 = 15.925 seconds

This result is within the tolerance range of the V/Hz element. This concludes the V/Hz tests for this example; use similar tests to test more points on the curve.

Directional Power Element

This section provides a test to verify the operation of the directional power element. You can use the test connections of *Figure 3.3* and *Figure 3.4(a)*.

In this example, Element 1 is configured for a generator motoring application. This element operates from a three-phase, real or reactive power quantity that is calculated by the relay in secondary VA. The equations for three-phase real and reactive power are:

$$P = 3 \bullet V_{L-N} \bullet I \bullet \cos\theta$$

$$Q = 3 \bullet V_{L-N} \bullet I \bullet \sin\theta$$

where:

θ = the angle between V_{L-N} and I

The settings for this test are shown in *Table 3.8*.

Table 3.8 Settings to Test the Directional Power Element

Setting	Category	Comments
E32 = 1	Group	Enable Element 1
32O01 = 3PGF	Group	Use generator real power as the operating signal
32MOD01 = O	Group	Set the element for overpower operation
32BIA01 = 0	Group	Disable the biased characteristic
32ANG01 = 1	Group	Set the bias angle to 1 degree
32PP01 = –10	Group	Set the pickup to be negative
32RS01 = Y	Group	Set the timer reset to instantaneous
32PD01 = 2.0	Group	Set the timer delay to 2 seconds
32TC01 = 1	Group	Assert torque control

```
=>>SET TE <Enter>
Group 1

Potential Transformer Data

PT connection for Term V (OFF,Y,D,D1,1PH)                          PTCONV  := 1PH    ?Y <Enter>
PT connection for Term Z (Y,D,D1)                                  PTCONZ  := Y      ? <Enter>
PT Ratio Term V (1.0-10000)                                        PTRV    := 200.0  ?2000 <Enter>
PT Ratio Term Z (1.0-10000)                                        PTRZ    := 200.0  ?2000 <Enter>
PT Nominal Voltage (L-L) Term V (30.00-300 V,sec)                  VNOMV   := 110.00 ? <Enter>
PT Nominal Voltage (L-L) Term Z (30.00-300 V,sec)                  VNOMZ   := 110.00 ? <Enter>

Current Transformer Data

CT Connection for Term Y (1PH,Y)                                   CTCONY  := 1PH    ?Y <Enter>
CT Ratio Term S (OFF,1.0-50000)                                    CTRS    := 4000.0 ?100 <Enter>
CT Ratio Term T (OFF,1.0-50000)                                    CTRT    := 400.0  ?100 <Enter>
CT Ratio Term U (OFF,1.0-50000)                                    CTRU    := 12000.0?100 <Enter>
CT Ratio Term W (OFF,1.0-50000)                                    CTRW    := 4000.0 ?100 <Enter>
CT Ratio Term X (OFF,1.0-50000)                                    CTRX    := 4000.0 ?100 <Enter>
CT Ratio Term Y (OFF,1.0-50000)                                    CTRY    := OFF    ?100 <Enter>

Relay Configuration

Advanced Settings (Y,N)                                            EADVS   := N      ? <Enter>
En. Pump Storage (OFF or combo of S,T,U,W,X,Y,V,Z)                 EPS     := OFF    ? <Enter>
Enable Sys Volt Term (OFF,V)                                       ESYSPT  := "V1"   ?V <Enter>
Enable Gen Neut Cur Terms (combo of W,X)                           EGNCT   := "X"    ?W,X <Enter>
Enable System Cur Terms (OFF or combo of S,T,U,Y)                  ESYSCT  := "S,T"  ?S <Enter>
En. Power Calc Term (OFF or S)                                     EPCAL   := "S"    ? <Enter>
Enable Volts per Hertz Elements (N,1-2)                            E24     := 2      ?N <Enter>
Enable Synch. Check (OFF or S)                                     E25     := "S"    ?OFF <Enter>
Enable Under Voltage Elements (N,1-6)                              E27     := N      ? <Enter>
Enable Directional Power (N,1-4)                                   E32     := 1      ? <Enter>
Enable Loss of Field (OFF or combo of Z,P)                         E40     := "Z"    ?OFF <Enter>
Enable Current Unbalance Elements (N, 1-2)                         E46     := 1      ?N <Enter>
Enable 50 Elements (OFF or S)                                      E50     := OFF    ? <Enter>
Enable Inverse Time Overcurrent Elements (N,1-12)                  E51     := N      ? <Enter>
Enable Over Voltage Elements (N,1-6)                               E59     := 1      ?N <Enter>
Enable 60P Split Phase Element (N,T,U,W,X,Y)                       E60P    := N      ? <Enter>
Enable 60N Split Phase Element (N,Y1,Y2,Y3)                        E60N    := N      ? <Enter>
Enable 64G Element (OFF or combo of G1,G2,G3)                      E64G    := "G1,G3"?OFF <Enter>
Enable 64F Field Ground Element (Y,N)                              E64F    := N      ? <Enter>
Enable 64S Stator Ground Element (Y,N)                             E64S    := N      ? <Enter>
Enable Out-of-Step Element (N,1B,2B)                               E78     := 1B     ?N <Enter>
Enable Frequency Elements (N,1-6)                                  E81     := 2      ?N <Enter>
Enable Accumulated Freq Elements (N,1-8)                           E81A    := N      ? <Enter>
Enable Rate of Change of Freq Elements (N,1-6)                     E81R    := N      ? <Enter>
Enable Differential Elements (N,1-2)                               E87     := 2      ?N <Enter>
Enable REF Element (OFF or combo of Y1,Y2,Y3)                      EREF    := "Y1"   ?OFF <Enter>
Enable Inad. Ener. Prot. (OFF or S)                                EINAD   := "S"    ?OFF <Enter>
Enable Pole Open (OFF or S)                                        EPO     := "S,T"  ?OFF <Enter>
Load Encroachment (Y,N)                                            ELOAD   := N      ? <Enter>
Enable Loss of Potential (OFF or combo of V,Z)                     ELOP    := "Z"    ?OFF <Enter>
Enable Brkr Fail. Prot. (OFF or S)                                 EBFL    := "S,T"  ?OFF <Enter>
Enable Brkr Flash Ovr. (OFF or S)                                  EBFO    := "S"    ?OFF <Enter>
Enable System Backup Protection (OFF or combo of 51C, 51V, 21P)    EBUP    := 21P    ?N <Enter>
Enable Demand Metering (N,1-10)                                    EDEM    := N      ? <Enter>
Enable Max/Min Metering (N,1-30)                                   EMXMN   := 12     ?N <Enter>

Power System Data

Generator Max. MVA (1-5000 MVA)                                    MVAGEN  := 555    ? <Enter>
Generator L-L Voltage (1.00-100 kV)                                KVGEN   := 24.00  ? <Enter>
Generator D-Axis Synch Reactance (0.100-4)                         XDGEN   := 1.810  ? <Enter>
Transformer Leakage Reactance (0.010-10)                           XTXFR   := 0.042  ? <Enter>
Equivalent System Reactance (0.010-10)                             XESYS   := 0.200  ? <Enter>

Frequency Tracking Sources

Frequency Source for Current Term S (G,S)                          FTSRCS  := S      ?G <Enter>
Frequency Source for Current Term T (G,S)                          FTSRCT  := S      ?G <Enter>
Frequency Source for Current Term U (G,S)                          FTSRCU  := G      ?
Frequency Source for Current Term W (G)                            FTSRCW  := G      ?
Frequency Source for Current Term X (G)                            FTSRCX  := G      ?
Frequency Source for Current Term Y (G,S)                          FTSRCY  := G      ?
Frequency Source for Voltage Term V (S)                            FTSRCV  := S      ?
Frequency Source for Voltage Term Z (G)                            FTSRCZ  := G      ?
```

Figure 3.12 Group 1 SET Command

```
Current Transformer Polarity Terminal Selection

CT Polarity For Terminal S (P,N)                                 CTPS    := P      ? <Enter>

Directional Power (32) Element 01

Dir Power Element 01 Operating Quantity                          32O01   := 3PGF   ? <Enter>
Dir Power Element 01 Operating Mode (U,O)                        32MOD01 := O      ? <Enter>
Dir Power Element 01 Bias (SELogic Eqn)
32BIA01 := NA
?  0 <Enter>
Dir Power Element 01 Bias Angle (-5.00 to 5 deg)                 32ANG01 := 1.00   ? <Enter>
Dir Power Element 01 PU (-400.00 to 400 VA,sec)                  32PP01  := -10.00 ? <Enter>
Dir Power Element 01 Inst Reset (Y,N)                            32RS01  := y      ? <Enter>
Dir Power Element 01 Time Delay (0.000-400 s)                    32PD01  := 2.000  ? <Enter>
Dir Power Element 01 Torque Cont (SELogic Eqn)
32TC01 := 1
? <Enter>

Generator Monitoring Logic

Generator Online Logic (SELogic Eqn)
ONLINE := 52CLS
?  END <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 3.12 Group 1 SET Command (Continued)

In a similar manner to *Volts/Hertz on page 3.5*, you can program SELOGIC variables to assert LEDs on the front panel to indicate the status of the directional power element. You can also program the SER to record the status of the element, and then use these recorded values to calculate the element operating time(s). The active Relay Word bits for this test are the following.

32P01	Directional Power Element 1 Picked Up
32T01	Directional Power Element 1 Timed Out

Generator power for this example is calculated by the relay by using the W terminal current and the Z terminal voltage input. The default value of the Z input line-to-line nominal voltage, VNOMZ, is 110 volts. Nominal line-to-neutral voltage is therefore, 110 V / $\sqrt{3}$ = 63.51 V.

Unity Power Factor Test

At unity power factor and for a line-to-line voltage magnitude of VNOMZ, the element should pick up for a secondary current magnitude of:

$$I = \frac{-10\ \text{VA}}{3 \bullet 63.51\ \text{V} \bullet \cos 0°} = 0.052\ \text{A}\angle 180°$$

Test Steps

Step 1. Inject a balanced three-phase voltage with a magnitude of 63.51 V.

Step 2. Inject a balanced three-phase current with a magnitude of 0.025 A and an angle, θ, of 180°. The element should not operate.

Step 3. Increase the three-phase current magnitude until the element picks up. Record this value as the measured pickup.

Step 4. Maintain the current until the element times out. Record the difference between the Timed Out and Picked Up Relay Word bits as the measured time delay.

Step 5. Deassert and reassert torque control. Confirm that the element resets and picks up again.

Rated Power Factor Test (32BIA = 0)

Assuming a rated power factor of 0.85, the reactive power in secondary VA is:

$$Q = 3 \bullet 63.51\ \text{V} \bullet 5\ \text{A} \bullet \sqrt{1^2 - 0.85^2} = 501.84\ \text{VA}$$

At the pickup setting, the corresponding angle θ is:

$$\theta = 180° + \tan^{-1}\left(\frac{501.84}{-10}\right) = 91.14°$$

At rated power factor and for a line-to-line voltage magnitude of VNOMZ, the element should pick up for a secondary current of:

$$I = \frac{-10\ \text{VA}}{3 \bullet 63.51\ \text{V} \bullet \cos 91.14°} = 2.638\ \text{A}$$

Test Steps

Step 1. Inject a balanced three-phase voltage with a magnitude of 63.51 V.

Step 2. Inject a balanced three-phase current with a magnitude of 2.638 A and angle, θ, of 0°. The element should not operate.

Step 3. Rotate the angle, θ, until the element picks up. Record this value as the measured pickup angle.

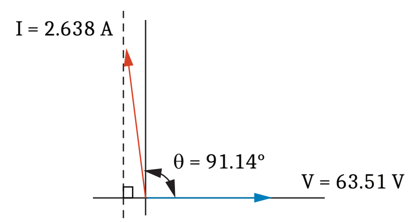


Figure 3.13 Voltage/Current Relationship for 32BIA = 0

Step 4. Maintain the current until the element times out. Record the difference between the Timed Out and Picked Up Relay Word bits as the measured time delay.

Rated Power Factor Test (32BIA01 = 1)

In this test, the biasing feature of the directional power element is enabled. We assume that the bias angle is equal to 1 degree.

Assuming a rated power factor of 0.85, the reactive power in secondary VA is:

$$Q = 3 \bullet 63.51\ \text{V} \bullet 5\ \text{A} \bullet \sqrt{1^2 - 0.85^2} = 501.84\ \text{VA}$$

At this value, the value of P for which the element is expected to pick up is:

$$P = -10 + \frac{501.84}{\tan(90 - 1)} = -1.24\ \text{VA}$$

At the pickup setting, the corresponding angle θ is:

$$\theta = 180° + \tan^{-1}\left(\frac{501.84}{-1.24}\right) = 90.14°$$

At rated power factor and for a line-to-line voltage magnitude of VNOMZ, the element should pick up for a secondary current of:

$$I = \frac{-1.24\ \text{VA}}{3 \bullet\ 63.51\ \text{V} \bullet\ \cos 90.14°} = 2.664\ \text{A}$$

Test Steps

Step 1. Inject a balanced three-phase voltage with a magnitude of 63.51 V.

Step 2. Inject a balanced three-phase current with a magnitude of 2.664 A and angle, θ, of 0°. The element should not operate.

Step 3. Rotate the angle, θ, until the element picks up. Record this value as the measured pickup angle.

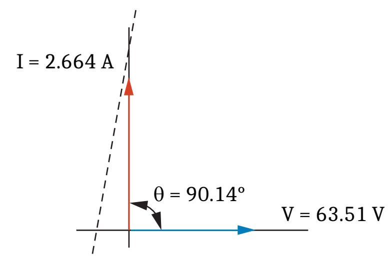


Figure 3.14 Voltage/Current Relationship for 32BIA = 1

Step 4. Maintain the current until the element operates. Record this value as the measured time delay.

Capability-Based Loss of Field (40P)

This section provides a test to verify the operation of the capability-based loss of field element. You can use the test connections of *Figure 3.3* and *Figure 3.4(A)*.

In a similar manner to *Volts/Hertz on page 3.5*, you can program SELOGIC variables to assert LEDs on the front panel to indicate the status of the 40P element. You can also program the SER to record the status of the element, and then use these recorded values to calculate the element operating time(s). The active Relay Word bits for this test are:

40P1	Capability Loss-of-Field Zone 1 picked up
40P1T	Capability Loss-of-Field Zone 1 timed out
40P2	Capability Loss-of-Field Zone 2 picked up
40P2T	Capability Loss-of-Field Zone 2 timed out
40P3	Capability Loss-of-Field Zone 3 picked up
40P3T	Capability Loss-of-Field Zone 3 timed out

In this example, Zones 1, 2, and 3 are enabled. Testing of Zone 4 is similar to testing of Zone 2. Dynamic cooling capability is disabled. The settings for this test are shown in *Table 3.9*.

Table 3.9 Settings to Test the Capability-Based Loss-of-Field Element (Sheet 1 of 2)

Setting	Category	Comments
PTCONZ = Y	Group	Set the PT connection for Terminal Z to Y
PTRZ = 120	Group	Set the Terminal Z PT ratio to 120
VNOMZ = 115	Group	Set the Terminal Z nominal voltage to 13800/120 = 115 V (L-L)

Table 3.9 Settings to Test the Capability-Based Loss-of-Field Element (Sheet 2 of 2)

Setting	Category	Comments
EGNCT = W	Group	Assign the generator current to use Terminal W
CTRW = 1600	Group	Set the Terminal W CT ratio to 8000/5
E40 = P	Group	
MVAGEN = 90	Group	Set the generator nominal MVA to 90
KVGEN = 13.8	Group	Set the generator nominal voltage to 13.8 kV
XDGEN = 1.78	Group	Set the direct-axis synchronous impedance to 1.78 pu on the generator base
XTXFR = 0.08	Group	Set the direct-axis synchronous impedance to 0.08 pu on the generator base
XESYS = 0.32	Group	Set the direct-axis synchronous impedance to 0.32 pu on the generator base

Table 3.10 Zone 1 Settings

Setting	Category	Comments
E40PZ = Z1, Z2, Z3	Group	
40P1P = –312.5	Group	Set the Zone 1 reactive power offset to –312.5 MVA
40P1DIR = –10	Group	Set the Zone 1 characteristic angle to –10°
40P1D = 0.25	Group	Set the Zone 1 delay to 0.25 s
40P1TC = 1	Group	Assert the Zone 1 torque control

Table 3.11 Zone 2 Settings

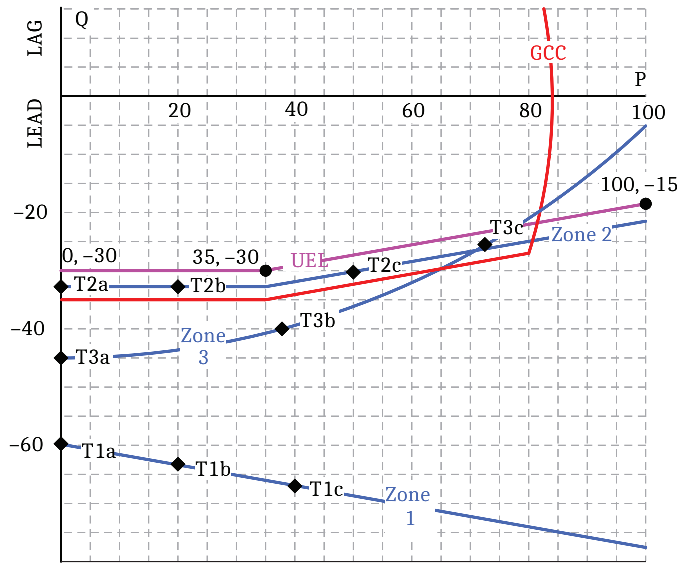
Setting	Category	Comments
40P2SEG = L	Group	Set the Zone 2 characteristic to Linear
40PUP5 = 520.8, 40PUQ5 = –78.1	Group	Set the Zone 2 real/reactive power at Point 5 of the UEL
40PUP6 = 182.3, 40PUQ6 = –156.3	Group	Set the Zone 2 real/reactive power at Point 6 of the UEL
40PUQ7 = –156.2	Group	Set the Zone 2 real/reactive power at Point 7 of the UEL
40PK = 1	Group	Set the Zone 2 voltage coefficient to 1
40P2M = 1.10	Group	Set the Zone 2 margin at 110%
40P2D = 60	Group	Set the Zone 2 UV pickup delay to 60 s
40PZ2TC = 1	Group	Assert the Zone 2 torque control

Table 3.12 Zone 3 Settings

Setting	Category	Comments
40P3D = 10	Group	Set the Zone 3 pickup delay
40P3TC = 1	Group	Assert the Zone 3 torque control

Table 3.13 Undervoltage Acceleration Settings

Setting	Category	Comments
40PUVP = 92	Group	Set the Zone 2 undervoltage supervision at 10%
40PAD = 0.5	Group	Set the UV acceleration delay to 0.5 s



System Parameters

Generator MVA:	90 MVA
Generator Nominal Voltage:	13.8 kV
Direct-Axis Synchronous Reactance (XDGEN):	1.78 pu
Transformer Leakage Reactance (XTXFR):	0.08 pu
System Reactance (XESYS):	0.32 pu

Note: Impedances are in per unit using the generator nominal MVA and voltage.

Figure 3.15 Example Generator Capability Curve

```
=>> SET S TE <Enter>
Group 1

Potential Transformer Data

PT connection for Term V (OFF,Y,D,D1,1PH)                 PTCONV  := 1PH    ? <Enter>
PT connection for Term Z (Y,D,D1)                         PTCONZ  := Y      ? <Enter>
PT Ratio Term Z (1.0-10000)                               PTRZ    := 200.0  ?120 <Enter>
PT Nominal Voltage (L-L) Term Z (30.00-300 V,sec)         VNOMZ   := 110.00 ?115 <Enter>
PT Ratio Term V1 (OFF,1.0-10000)                          PTRV1   := 200.0  ? <Enter>
PT Ratio Term V2 (OFF,1.0-10000)                          PTRV2   := 200.0  ? <Enter>
PT Ratio Term V3 (OFF,1.0-10000)                          PTRV3   := 200.0  ? <Enter>
PT Nominal Voltage Term V1 (30.00-300 V,sec)              VNOMV1  := 110.00 ? <Enter>
PT Nominal Voltage Term V2 (30.00-300 V,sec)              VNOMV2  := 110.00 ? <Enter>
PT Nominal Voltage Term V3 (30.00-300 V,sec)              VNOMV3  := 110.00 ? <Enter>

Current Transformer Data

CT Connection for Term Y (1PH,Y)                          CTCONY  := 1PH    ? <Enter>
CT Ratio Term S (OFF,1.0-50000)                           CTRS    := 4000.0 ? <Enter>
CT Ratio Term T (OFF,1.0-50000)                           CTRT    := 400.0  ? <Enter>
CT Ratio Term U (OFF,1.0-50000)                           CTRU    := 12000.0? <Enter>
CT Ratio Term W (OFF,1.0-50000)                           CTRW    := 4000.0 ?1600 <Enter>
CT Ratio Term X (OFF,1.0-50000)                           CTRX    := 4000.0 ? <Enter>
CT Ratio Term Y1 (OFF,1.0-50000)                          CTRY1   := 100.0  ? <Enter>
CT Ratio Term Y2 (OFF,1.0-50000)                          CTRY2   := 100.0  ? <Enter>
CT Ratio Term Y3 (OFF,1.0-50000)                          CTRY3   := 100.0  ? <Enter>
```

Figure 3.16 Group 1 Setting Command

```
Relay Configuration

Advanced Settings (Y,N)                                           EADVS   := N      ? <Enter>
En. Pump Storage (OFF or combo of S,T,U,W,X,Z)                    EPS     := OFF    ? <Enter>
Enable Gen Neut Volt Term (OFF,V2)                                EGNPT   := V2     ? <Enter>
Enable Sys Volt Term (OFF or combo of V1,V3)                      ESYSPT  := "V1"   ? <Enter>
Enable Gen Neut Cur Terms (combo of W,X)                          EGNCT   := "X"    ?W <Enter>
Enable System Cur Terms (OFF or combo of S,T,U)                   ESYSCT  := "S,T"  ? <Enter>
En. Power Calc Term (OFF or combo of S,T)                         EPCAL   := "S"    ?OFF <Enter>
Enable Volts per Hertz Elements (N,1-2)                           E24     := 2      ?N <Enter>
Enable Synch. Check (OFF or combo of S,T)                         E25     := "S"    ?OFF <Enter>
Enable Under Voltage Elements (N,1-6)                             E27     := N      ? <Enter>
Enable Directional Power (N,1-4)                                  E32     := 1      ?N <Enter>
Enable Loss of Field (OFF or combo of Z,P)                        E40     := "Z"    ?P <Enter>
Enable Current Unbalance Elements (N, 1-2)                        E46     := 1      ?N <Enter>
Enable 50 Elements (OFF or combo of S,T)                          E50     := OFF    ? <Enter>
Enable Inverse Time Overcurrent Elements (N,1-12)                 E51     := N      ? <Enter>
Enable Over Voltage Elements (N,1-6)                              E59     := 1      ?N <Enter>
Enable 60P Split Phase Element (N,U,W)                            E60P    := N      ? <Enter>
Enable 60N Split Phase Element (N,Y1,Y2,Y3)                       E60N    := N      ? <Enter>
Enable 64G Element (OFF or combo of G1,G2,G3)                     E64G    := "G1,G3"?OFF <Enter>
Enable 64F Field Ground Element (Y,N)                             E64F    := N      ? <Enter>
Enable 64S Stator Ground Element (Y,N)                            E64S    := N      ? <Enter>
Enable Out-of-Step Element (N,1B,2B)                              E78     := 1B     ?N <Enter>
Enable Frequency Elements (N,1-6)                                 E81     := 2      ?N <Enter>
Enable Accumulated Freq Elements (N,1-8)                          E81A    := N      ? <Enter>
Enable Rate of Change of Freq Elements (N,1-6)                    E81R    := N      ? <Enter>
Enable Differential Elements (N,1-2)                              E87     := 2      ?N <Enter>
Enable REF Element (OFF or combo of Y1,Y2,Y3)                     EREF    := "Y1"   ?OFF <Enter>
Enable Inad. Ener. Prot. (OFF or combo of S,T)                    EINAD   := "S"    ?OFF <Enter>
Enable Pole Open (OFF or combo of S,T)                            EPO     := "S,T"  ?OFF <Enter>
Load Encroachment (Y,N)                                           ELOAD   := N      ? <Enter>
Enable Loss of Potential (OFF or Z)                               ELOP    := "Z"    ?OFF <Enter>
Enable Brkr Fail. Prot. (OFF or combo of S,T)                     EBFL    := "S,T"  ?OFF <Enter>
Enable Brkr Flash Ovr. (OFF or combo of S,T)                      EBFO    := "S"    ?OFF <Enter>
Enable System Backup Protection (OFF or combo of 51C,51V,21P)     EBUP    := 21P    ?N <Enter>
Enable Demand Metering (N,1-10)                                   EDEM    := N      ? <Enter>
Enable Max/Min Metering (N,1-30)                                  EMXMN   := 12     ?N <Enter>

Power System Data

Generator Max. MVA (1-5000 MVA)                                   MVAGEN  := 555    ?90 <Enter>
Generator L-L Voltage (1.00-100 kV)                               KVGEN   := 24.00  ?13.8 <Enter>
Generator D-Axis Synch Reactance (0.100-4)                        XDGEN   := 1.810  ?1.78 <Enter>
Transformer Leakage Reactance (0.010-10)                          XTXFR   := 0.042  ?0.08 <Enter>
Equivalent System Reactance (0.010-10)                            XESYS   := 0.200  ?0.32 <Enter>

Frequency Tracking Sources

Frequency Source for Current Term S (G,S)                         FTSRCS  := S      ? <Enter>
Frequency Source for Current Term T (G,S)                         FTSRCT  := S      ? <Enter>
Frequency Source for Current Term U (G,S)                         FTSRCU  := G      ? <Enter>
Frequency Source for Current Term W (G)                           FTSRCW  := G      ? <Enter>
Frequency Source for Current Term X (G,S)                         FTSRCX  := G      ? <Enter>
Frequency Source for Current Term Y1 (G,S)                        FTSRCY1 := S      ? <Enter>
Frequency Source for Current Term Y2 (G,S)                        FTSRCY2 := G      ? <Enter>
Frequency Source for Current Term Y3 (G,S)                        FTSRCY3 := G      ? <Enter>
Frequency Source for Voltage Term Z (G)                           FTSRCZ  := G      ? <Enter>
Frequency Source for Voltage Term V1 (S)                          FTSRCV1 := S      ? <Enter>
Frequency Source for Voltage Term V2 (G)                          FTSRCV2 := G      ? <Enter>
Frequency Source for Voltage Term V3 (G,S)                        FTSRCV3 := G      ? <Enter>
```

Figure 3.16 Group 1 Setting Command (Continued)

```
Generator Capability Based Loss of Field (40P) Element

Enable 40P Zones (Combo of Z1,Z2,Z3,Z4)                          E40PZ   := "Z1,Z2"?Z1,Z2,Z3 <Enter>
Enable Zone 2 Dynamic Capability (Y,N)                           E40P2D  := N      ? <Enter>
40P Zone 1 Pickup (-2000.00 to -1 VA,sec)                        40P1P   := -100.00?-312.5 <Enter>
40P Zone 1 Time Delay (0.000-400 s)                              40P1D   := 0.250  ? <Enter>
40P Zone 1 Torque Cont (SELogic Eqn)
40P1TC := NOT LOPZ
?  1 <Enter>
40P Zone 1 Directional Sup Ang (-30.0 to 30 deg)                 40P1DIR := 10.0   ?-10 <Enter>
40P Zone 2 Segment shape (C,L)                                   40P2SEG := C      ?L <Enter>
40P Zone 2 P Power Pt 5 (1.00-2000 VA,sec)                       40PUP5  := 80.00  ?520.8 <Enter>
40P Zone 2 Q Power Pt 5 (-2000.00 to 2000 VA,sec)                40PUQ5  := -60.00 ?-78.1 <Enter>
40P Zone 2 P Power Pt 6 (1.00-2000 VA,sec)                       40PUP6  := 40.00  ?182.3 <Enter>
40P Zone 2 Q Power Pt 6 (-2000.00 to 0 VA,sec)                   40PUQ6  := -80.00 ?-156.3 <Enter>
40P Zone 2 Q Power Pt 7 (-2000.00 to -1 VA,sec)                  40PUQ7  := -100.00?-156.2 <Enter>
40P Zone 2 Margin from UEL (1.05-1.25)                           40P2M   := 1.20   ?1.10 <Enter>
40P Zone Voltage Coefficient (0-2)                               40PK    := 2      ?1 <Enter>
40P Zone 2 Time Delay (0.000-400 s)                              40P2D   := 0.500  ?60 <Enter>
40P Zone 2 Torque Cont (SELogic Eqn)
40P2TC := NOT LOPZ
?  1 <Enter>
40P Zone 3 Time Delay (0.000-400 s)                              40P3D   := 10.000 ? <Enter>
40P Zone 3 Torque Cont (SELogic Eqn)
40P3TC := NOT LOPZ
?  1 <Enter>
40P U/V Element PU (OFF,2.00-300 V,sec)                          40PUVP  := OFF    ?92 <Enter>
40P Accelerated Time Delay (0.000-400 s)                         40PAD   := 10.000 ?0.5 <Enter>

Generator Monitoring Logic

Generator Online Logic (SELogic Eqn)
ONLINE := 52CLS
?  END <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 3.16 Group 1 Setting Command (Continued)

The scaling factor between primary MVA and secondary VA is:

$$\mathrm{SF} = \frac{10^6}{\mathrm{PTRZ} \bullet \mathrm{CTRG}} = \frac{10^6}{120 \bullet 1600} = 5.208$$

Zone 1 Test

Zone 1 will be tested at Points T1a, T1b, and T1c, as shown in *Figure 3.15*. The test will be carried out at nominal voltage. The operating equation of Zone 1 at nominal voltage can be written as:

$$\mathrm{Z1\_OP} = \mathrm{Q} < (\mathrm{40P1P} + \mathrm{P} \bullet \tan \mathrm{40P1DIR})$$

Therefore, the secondary current at nominal voltage at each test point is given by:

$$\mathrm{I} = \frac{\mathrm{P} - j(\mathrm{40P1P} + \mathrm{P} \bullet \tan(\mathrm{40P1DIR}))}{\sqrt{3} \bullet \mathrm{VNOMZ}} = \frac{\mathrm{P} - j(-312.5 + \mathrm{P} \bullet \tan(-10°))}{\sqrt{3} \bullet 115}$$

Table 3.14 lists the expected pickup current for each test and the corresponding real and reactive power at nominal voltage.

Table 3.14 Zone 1 Expected Pickup Currents and Corresponding Real and Reactive Power

Test	Real Power—P		Reactive Power—Q		Current Magnitude (Secondary A)	Current Angle (Degrees)
	(Primary MVA)	(Secondary VA)	(Primary MVA)	(Secondary VA)		
T1a	0	0.00	–60	–312.50	1.569	90
T1b	20	104.17	–63.53	–330.83	1.74	72.52
T1c	40	208.33	–67.05	–349.22	2.04	59.2

Test Steps

Step 1. Inject a balanced three-phase voltage with a phase-to-phase magnitude of 115 V.

Step 2. Inject a balanced three-phase current with a magnitude of 0.1 A and current angle shown for T1a. Zone 1 should not operate.

Step 3. Increase the current magnitude until Zone 1 picks up. Record this value as the measured pickup.

Step 4. Maintain the current until Zone 1 times out. Record the difference between the Timed Out and Picked Up Relay Word bits as the measured time delay.

Step 5. Deassert and reassert torque control. Confirm that Zone 1 resets and picks up again.

Step 6. Repeat *Step 2*, *Step 3*, and *Step 4* for tests T1b and T1c.

Zone 2 Test

Zone 2 will be tested at Points T2a, T2b, and T2c, as shown in *Figure 3.18*. The operating equation of Zone 2 at nominal voltage can be written as:

$$\text{Z2\_OP} = Q < (\text{40PUQ7} + (P - \text{40PUP6}) \bullet \tan\varnothing) \bullet \text{40P2M}$$

where Ø accounts for the sloped section of the UEL and can be calculated as:

$$\varnothing = \tan^{-1}\left(\frac{\text{40PUQ5} - \text{40PUQ6}}{\text{40PUP5} - \text{40PUP6}}\right) = \tan^{-1}\left(\frac{-78.1 - (-156.3)}{520.8 - 182.3}\right) = 13.01°$$

The secondary current at nominal voltage at each test point is given by:

$$I = \frac{P - j(\text{40PUQ7} + (P - \text{40PUP6}) \bullet \tan\varnothing) \bullet \text{40P2M}}{\sqrt{3} \bullet \text{VNOMZ}}$$

$$= \frac{P - j(-156.2 + (P - 182.3) \bullet \tan(9.6°)) \bullet 1.1}{\sqrt{3} \bullet 115}$$

Table 3.15 lists the expected pickup current for each test and the corresponding real and reactive power.

Table 3.15 Zone 2 Expected Pickup Currents and Corresponding Real and Reactive Power

Test	Real Power—P		Reactive Power—Q		Current Magnitude (Secondary A)	Current Angle (Degrees)
	(Primary MVA)	(Secondary VA)	(Primary MVA)	(Secondary VA)		
T2a	0	0.00	–33	–171.88	1.09	90
T2b	20	104.17	–33	–171.88	1.09	61.5
T2c	50	260.42	–29.18	151.97	1.51	30.27

Test Steps

Step 1. Inject a balanced three-phase voltage with a phase-to-phase magnitude of 115 V.

Step 2. Inject a balanced three-phase current with a magnitude of 0.1 A and the current angle shown for T2a. Zone 2 should not operate.

Step 3. Increase the current magnitude until Zone 2 picks up. Record this value as the measured pickup.

Step 4. Maintain the current until Zone 2 times out. Record the difference between the Timed Out and Picked Up Relay Word bits as the measured time delay.

Step 5. Deassert and reasserted torque control. Confirm that Zone 2 resets and picks up again.

Step 6. Repeat *Step 2*, *Step 3*, and *Step 4* for tests T2b and T2c.

Zone 3 Test

The element will be tested at Points T3a, T3b and T3c as shown in *Figure 3.18*. The operating equation of Zone 3 at nominal voltage can be written as:

$$Z3_{OP} = S < (\cos\theta + j\sin\theta) \bullet SR + SC$$

where:

$$SR = \frac{1}{2}\left(\frac{1}{XS} + \frac{1}{XD}\right) \bullet MVAGEN \bullet SF$$

$$SC = j\frac{1}{2}\left(\frac{1}{XS} - \frac{1}{XD}\right) \bullet MVAGEN \bullet SF$$

The current at nominal voltage at each test point is given by:

$$I = \frac{(\cos\theta - j\sin\theta) \bullet SR + SC}{\sqrt{3} \bullet 115}$$

Table 3.16 lists the expected pickup current for three values of θ and the corresponding real and reactive power.

Table 3.16 Zone 3 Expected Pickup Currents and Corresponding Real and Reactive Power

Test	ϕ	Real Power—P		Reactive Power—Q		Current Magnitude (Secondary A)	Current Angle (Degrees)
	(Degrees)	(Primary MVA)	(Secondary VA)	(Primary MVA)	(Secondary VA)		
T3a	–90	0.00	0.00	–50.56	–263.34	1.32	90.0
T3b	–75	35.66	185.73	–45.87	–238.89	1.52	52.1
T3c	–60	68.89	358.80	–32.10	–167.20	1.99	25.0

Test Steps

Step 1. Inject a balanced three-phase voltage with a phase-to-phase magnitude of 115 V.

Step 2. Inject a balanced three-phase current with a magnitude of 0.1 A and angle shown for T3a. The element should not operate.

Step 3. Increase the current magnitude until Zone 3 picks up. Record this value as the measured pickup.

Step 4. Maintain the current until Zone 3 times out. Record the difference between the Timed Out and Picked Up Relay Word bits as the measured time delay.

Step 5. Deassert and reasserted torque control. Confirm that Zone 3 resets and picks up again.

Step 6. Repeat *Step 2*, *Step 3*, and *Step 4* for tests T3b and T3c.

Undervoltage Test

Zone 2 operates via the accelerated tripping path when the positive-sequence secondary voltage is less than the 40PUVP setting. The Zone 2 characteristic can shift dynamically with voltage depending on the 40P2K setting.

For this test, a voltage that is 1 volt less than the 40PUVP setting (92 volts) will be applied. The Zone 2 voltage coefficient, 40P2K, equals 1. The secondary current is given by:

$$I = \frac{(P + j(40UQ7 + P \bullet \tan\varnothing)) \bullet 40P2M \bullet \left(\frac{91}{VNOMZ}\right)^{1}}{\sqrt{3} \bullet 91} = \frac{P + j(-156.2 + P \bullet \tan(13°)) \bullet 1.1}{\sqrt{3} \bullet 115}$$

Table 3.17 lists the expected pickup current for each test and the corresponding real and reactive power. Note that because 40P2K = 1, the current is the same as that of the test carried out at nominal voltage but the corresponding power is reduced by a factor of 91/115.

Table 3.17 Zone 2 Undervoltage Expected Pickup Currents and Corresponding Real and Reactive Power

Test	ϕ (Degrees)	Real Power–P (Primary VA)	Reactive Power–Q (Primary VA)	Current Magnitude (Secondary A)	Current Angle (Degrees)
T2d	0	0	–26.11	0.863	90
T2e	0	15.83	–26.11	1.009	58.78
T2f	13	39.65	–23.37	1.519	30.57

Table 3.18 Undervoltage Expected Pickup Currents and Corresponding Real and Reactive Power

Test	Real Power–P		Reactive Power–Q		Current Magnitude (Secondary A)	Current Angle (Degrees)
	(Primary MVA)	(Secondary VA)	(Primary MVA)	(Secondary VA)		
T2a	0	0.00	–33	–171.88	0.86	–90
T2b	20	104.17	–33	–171.88	1.01	–58.8
T2c	50	260.42	–30.21	–157.34	1.53	–31.1

Test Steps

Step 1. Inject a balanced three-phase voltage with a phase-to-phase magnitude of 52.0 V.

Step 2. Inject a balanced three-phase current with a magnitude of 0.1 A and the current angle shown for T2d. Zone 2 should not operate.

Step 3. Increase the current magnitude until Zone 2 picks up. Record this value as the measured pickup.

Step 4. Maintain the current until Zone 2 times out. Record the difference between the Timed Out and Picked Up Relay Word bits as the measured time delay.

Step 5. Deassert and reasserted torque control. Confirm that Zone 2 resets and picks up again.

Step 6. Repeat *Step 2*, *Step 3*, and *Step 4* for tests T2e and T2f.

Zone 3 Undervoltage Test

The Zone 3 characteristic shifts dynamically with the square of the voltage using the 40PK.

Table 3.19 lists the expected pickup current for three values of θ and the corresponding real and reactive power. Note the current magnitude is reduced by a factor of (91/115) of the value the nominal voltage test and the corresponding power is reduced by a factor of $(91/115)^2$.

Table 3.19 Zone 3 Undervoltage Expected Pickup Currents and Corresponding Real and Reactive Power

Test	ϕ (Degrees)	Real Power–P (Primary VA)	Reactive Power–Q (Primary VA)	Current Magnitude (Secondary A)	Current Angle (Degrees)
T3d	–90	0	–10.17	0.931	90
T3e	–75	8.51	–9.05	1.137	46.77
T3f	–60	16.43	–5.76	1.595	19.33

Test Steps

Step 1. Inject a balanced three-phase voltage with a magnitude of 91 V.

Step 2. Inject a balanced three-phase current with a magnitude of 0.1 A and current angle shown for T3d. Zone 3 should not operate.

Step 3. Increase the current magnitude until Zone 3 picks up. Record this value as the measured pickup.

Step 4. Maintain the current until Zone 3 times out. Record the difference between the Timed Out and Picked Up Relay Word bits as the measured time delay.

Step 5. Deassert and reasserted torque control. Confirm that Zone 3 resets and picks up again.

Step 6. Repeat *Step 2*, *Step 3*, and *Step 4* for tests T3e and T3f.

Current Unbalance

This section provides a test to verify the operation of the current unbalance element. The test connections of *Figure 3.3* reference current connection circuit and can be used.

In this example, Element 1 is enabled and configured to include harmonics. The harmonic weighting factors for selected harmonics and sequence components. The settings for this test are shown in *Table 3.20*.

Table 3.20 Settings to Test the Directional Power Element (Sheet 1 of 2)

Setting	Category	Comments
MVAGEN = 95	Group	Set the generator nominal MVA to 90
KVGEN = 13.8	Group	Set the generator nominal KV to 13.8
EGNCT = X	Group	Set the generator neutral current to Terminal X
CTRX = 1000	Group	Set Terminal X CT ratio to 5000/5
E46 = 1	Group	Enable Element 1

Table 3.20 Settings to Test the Directional Power Element (Sheet 2 of 2)

Setting	Category	Comments
46Q1P1 = 2.0%	Group	Set Level 1 to pick up at 2.0% of INOMGS or 0.08 A
46QOP1 = I2GPEQ	Group	Use the operating signal that includes harmonics
46Q1D1 = 30 sec	Group	Set the Level 1 timer delay to 2 seconds
46Q1P2 = 5%	Group	Set Level 2 to pick up at 5% of INOMGS or 0.2 A
46Q1K2 = 10	Group	Set the Level 2 time multiplier to 10
46Q1TC = 1	Group	Assert torque control

The SEL-400G calculates the nominal generator current INOMGS as:

$$\text{INOMGS} = \frac{\text{MVAGEN} \bullet 1000}{\sqrt{3} \bullet \text{KVGEN} \bullet \text{CTRX}} = \frac{90 \bullet 1000}{\sqrt{3} \bullet 13.8 \bullet 1000} = 3.765$$

```
=>>SET TE <Enter>

Group 1

Potential Transformer Data

PT connection for Term V (OFF,Y,D,D1,1PH)                       PTCONV  := 1PH    ? <Enter>
PT connection for Term Z (Y,D,D1)                               PTCONZ  := Y      ? <Enter>
PT Ratio Term Z (1.0-10000)                                     PTRZ    := 200.0  ? <Enter>
PT Nominal Voltage (L-L) Term Z (30.00-300 V,sec)               VNOMZ   := 110.00 ? <Enter>
PT Ratio Term V1 (OFF,1.0-10000)                                PTRV1   := 200.0  ? <Enter>
PT Ratio Term V2 (OFF,1.0-10000)                                PTRV2   := 200.0  ? <Enter>
PT Ratio Term V3 (OFF,1.0-10000)                                PTRV3   := 200.0  ? <Enter>
PT Nominal Voltage Term V1 (30.00-300 V,sec)                    VNOMV1  := 110.00 ? <Enter>
PT Nominal Voltage Term V2 (30.00-300 V,sec)                    VNOMV2  := 110.00 ? <Enter>
PT Nominal Voltage Term V3 (30.00-300 V,sec)                    VNOMV3  := 110.00 ? <Enter>

Current Transformer Data

CT Connection for Term Y (1PH,Y)                                CTCONY  := 1PH    ? <Enter>
CT Ratio Term S (OFF,1.0-50000)                                 CTRS    := 4000.0 ? <Enter>
CT Ratio Term T (OFF,1.0-50000)                                 CTRT    := 400.0  ? <Enter>
CT Ratio Term U (OFF,1.0-50000)                                 CTRU    := 12000.0? <Enter>
CT Ratio Term W (OFF,1.0-50000)                                 CTRW    := 4000.0 ? <Enter>
CT Ratio Term X (OFF,1.0-50000)                                 CTRX    := 4000.0 ?1000 <Enter>
CT Ratio Term Y1 (OFF,1.0-50000)                                CTRY1   := 100.0  ? <Enter>
CT Ratio Term Y2 (OFF,1.0-50000)                                CTRY2   := 100.0  ? <Enter>
CT Ratio Term Y3 (OFF,1.0-50000)                                CTRY3   := 100.0  ? <Enter>
```

Figure 3.17 46 Element Testing Group Settings

```
Relay Configuration

Advanced Settings (Y,N)                                           EADVS   := N       ? <Enter>
En. Pump Storage (OFF or combo of S,T,U,W,X,Z)                    EPS     := OFF     ? <Enter>
Enable Gen Neut Volt Term (OFF,V2)                                EGNPT   := V2      ? <Enter>
Enable Sys Volt Term (OFF or combo of V1,V3)                      ESYSPT  := "V1"    ? <Enter>
Enable Gen Neut Cur Terms (combo of W,X)                          EGNCT   := "X"     ? <Enter>
Enable System Cur Terms (OFF or combo of S,T,U)                   ESYSCT  := "S,T"   ? <Enter>
En. Power Calc Term (OFF or combo of S,T)                         EPCAL   := "S"     ? <Enter>
Enable Volts per Hertz Elements (N,1-2)                           E24     := 2       ?N <Enter>
Enable Synch. Check (OFF or combo of S,T)                         E25     := "S"     ?OFF <Enter>
Enable Under Voltage Elements (N,1-6)                             E27     := N       ? <Enter>
Enable Directional Power (N,1-4)                                  E32     := 1       ?N <Enter>
Enable Loss of Field (OFF or combo of Z,P)                        E40     := "Z"     ?OFF <Enter>
Enable Current Unbalance Elements (N, 1-2)                        E46     := 1       ? <Enter>
Enable 50 Elements (OFF or combo of S,T)                          E50     := OFF     ? <Enter>
Enable Inverse Time Overcurrent Elements (N,1-12)                 E51     := N       ? <Enter>
Enable Over Voltage Elements (N,1-6)                              E59     := 1       ?N <Enter>
Enable 60P Split Phase Element (N,U,X)                            E60P    := N       ? <Enter>
Enable 60N Split Phase Element (N,Y1,Y2,Y3)                       E60N    := N       ? <Enter>
Enable 64G Element (OFF or combo of G1,G2,G3)                     E64G    := "G1,G3"?OFF <Enter>
Enable 64F Field Ground Element (Y,N)                             E64F    := N       ? <Enter>
Enable 64S Stator Ground Element (Y,N)                            E64S    := N       ? <Enter>
Enable Out-of-Step Element (N,1B,2B)                              E78     := 1B      ?N <Enter>
Enable Frequency Elements (N,1-6)                                 E81     := 2       ?N <Enter>
Enable Accumulated Freq Elements (N,1-8)                          E81A    := N       ? <Enter>
Enable Rate of Change of Freq Elements (N,1-6)                    E81R    := N       ? <Enter>
Enable Differential Elements (N,1-2)                              E87     := 2       ?N <Enter>
Enable REF Element (OFF or combo of Y1,Y2,Y3)                     EREF    := "Y1"    ?OFF <Enter>
Enable Inad. Ener. Prot. (OFF or combo of S,T)                    EINAD   := "S"     ?OFF <Enter>
Enable Pole Open (OFF or combo of S,T)                            EPO     := "S,T"   ?OFF <Enter>
Load Encroachment (Y,N)                                           ELOAD   := N       ? <Enter>
Enable Loss of Potential (OFF or Z)                               ELOP    := "Z"     ?OFF <Enter>
Enable Brkr Fail. Prot. (OFF or combo of S,T)                     EBFL    := "S,T"   ?OFF <Enter>
Enable Brkr Flash Ovr. (OFF or combo of S,T)                      EBFO    := "S"     ?OFF <Enter>
Enable System Backup Protection (OFF or combo of 51C,51V,21P)     EBUP    := 21P     ?N <Enter>
Enable Demand Metering (N,1-10)                                   EDEM    := N       ? <Enter>
Enable Max/Min Metering (N,1-30)                                  EMXMN   := 12      ?N <Enter>

Power System Data

Generator Max. MVA (1.0-5000 MVA)                                 MVAGEN  := 555.0   ?95 <Enter>
Generator L-L Voltage (1.00-100 kV)                               KVGEN   := 24.00   ?13.8 <Enter>
Generator D-Axis Synch Reactance (0.100-4)                        XDGEN   := 1.810   ? <Enter>
Transformer Leakage Reactance (0.010-10)                          XTXFR   := 0.042   ? <Enter>
Equivalent System Reactance (0.010-10)                            XESYS   := 0.200   ? <Enter>

Frequency Tracking Sources

Frequency Source for Current Term S (G,S)                         FTSRCS  := S       ? <Enter>
Frequency Source for Current Term T (G,S)                         FTSRCT  := S       ? <Enter>
Frequency Source for Current Term U (G,S)                         FTSRCU  := G       ? <Enter>
Frequency Source for Current Term W (G,S)                         FTSRCW  := G       ? <Enter>
Frequency Source for Current Term X (G)                           FTSRCX  := G       ? <Enter>
Frequency Source for Current Term Y1 (G,S)                        FTSRCY1 := S       ? <Enter>
Frequency Source for Current Term Y2 (G,S)                        FTSRCY2 := G       ? <Enter>
Frequency Source for Current Term Y3 (G,S)                        FTSRCY3 := G       ? <Enter>
Frequency Source for Voltage Term Z (G)                           FTSRCZ  := G       ? <Enter>
Frequency Source for Voltage Term V1 (S)                          FTSRCV1 := S       ? <Enter>
Frequency Source for Voltage Term V2 (G)                          FTSRCV2 := G       ? <Enter>
Frequency Source for Voltage Term V3 (G,S)                        FTSRCV3 := G       ? <Enter>

Current Transformer Polarity Terminal Selection

CT Polarity For Terminal S (P,N)                                  CTPS    := P       ? <Enter>

Current Unbalance (46) Element 1

46 Element 1 Operate Quantity                                     46QO1   := I2GP    ?I2GPEQ <Enter>
46 Element 1 Level 1 PU (OFF,2.0-100 %)                           46Q1P1  := 8.0     ?2.0 <Enter>
46 Element 1 Level 2 PU (OFF,2.0-100 %)                           46Q1P2  := 8.0     ?5.0 <Enter>
46 Element 1 Level 1 Delay (0.000-1000 s)                         46Q1D1  := 30.000 ? <Enter>
46 Element 1 Level 2 Time Dial (1-100 s)                          46Q1K2  := 10      ? <Enter>
46 Element 1 Torque Control (SELogic Eqn)
46Q1TC := 1
?   <Enter>

Generator Monitoring Logic

Generator Online Logic (SELogic Eqn)
ONLINE := 52CLS
?  END <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 3.17 46 Element Testing Group Settings (Continued)

In a similar manner to *Volts/Hertz on page 3.5*, you can program SELOGIC variables to assert LEDs on the front panel to indicate the status of the current unbalance element. You also program the SER to record the status of the element, and then use these recorded values to calculate the element operating time(s). The active Relay Word bits for this test are as follows:

46Q11	Current Unbalance 1 Level 1 picked up
46Q1T1	Current Unbalance 1 Level 1 timed out
46Q12	Current Unbalance 1 Level 2 1 picked up
46Q1T2	Current Unbalance 1 Level 2 timed out

Element 1, Level 1 Test

Test Steps

Step 1. Inject a balanced three-phase current with the sequence (positive or negative) and frequency shown for the tests shown in *Table 3.21*. Swap two phases of the current when injecting a negative-sequence quantity.

Step 2. Increase the three-phase current magnitude until Level 1 picks up. Note that harmonic quantities are updated every 5 seconds so the signal should be ramped slowly to account for the update rate. Record this value as the measured pickup. No operation is expected for Test 1.

Table 3.21 Element 1, Level 1 Tests

Test	Expected Pickup (A sec)	Injected Quantity	Frequency of the Current (Hz)	Harmonic (n)	i	Weighting Factor $\sqrt{(n+i)/2}$	I2GPEQ
1	No Op	fund pos	60	1	–1	0.000	0
2	0.214	fund neg	60	1	+1	1.000	0.020
3	0.303	2nd pos	120	2	–1	0.707	0.020
4	0.174	2nd neg	120	2	+1	1.225	0.020
5	0.151	5th pos	300	5	–1	1.414	0.020
6	0.123	5th neg	300	5	+1	1.732	0.020
7	0.096	11th pos	660	11	–1	2.236	0.020
8	0.088	11th neg	660	11	+1	2.450	0.020
9	0.081	13th pos	780	13	–1	2.450	0.020
10	0.075	13th neg	780	13	+1	2.646	0.020

Step 3. Maintain the current until Level 1 times out. Record the difference between the Timed Out and Picked Up Relay Word bits as the measured time delay.

Step 4. Deassert and reasserted torque control. Confirm that Level 1 resets and picks up again.

Step 5. Set 46QO1 = I2GP. Repeat Test 3 from *Table 3.21*. Confirm that Level 1 does not pick up. Set 46QO1 = I2GPEQ again.

Element 1, Level 2 Test

Test Steps

Step 1. Inject a balanced three-phase current with the sequence and frequency shown for Test 1 shown in *Table 3.22*. Swap two phases of the current when injecting a negative-sequence quantity.

Step 2. Increase the three-phase current magnitude until Level 2 picks up. Note that harmonic quantities are updated every 5 seconds so the signal should be ramped slowly to account for the update rate. Record this value as the measured pickup.

Step 3. Deassert and reasserted torque control. Confirm that Level 1 resets and picks up again.

Step 4. Set 46QO1 = I2GP. Repeat Test 3 from *Table 3.22*. Confirm that Level 1 does not pick up. Set 46QO1 = I2GPEQ again.

Table 3.22 Element 1, Level 2 Tests

Test	Expected Pickup (A sec)	Injected Quantity	Frequency of the Current (Hz)	Harmonic (n)	i	Weighting Factor $\sqrt{(n+i)/2}$	I2GPEQ
1	No Op	fund pos	60	1	–1	0.000	0
2	0.085	fund neg	60	1	+1	1.000	0.020
3	0.120	2nd pos	120	2	–1	0.707	0.020

Step 5. Inject a balanced three-phase current with the sequence, magnitude, and frequency shown for the tests shown in *Table 3.23*. Swap two phases of the current when injecting a negative-sequence quantity.

Step 6. Record the difference between the Timed Out and Picked Up Relay Word bits as the measured time delay.

Table 3.23 Sequence, Magnitude, and Frequency

Test	Injected Magnitude (A sec)	Injected Quantity	Frequency of the Current (Hz)	Harmonic (n)	i	Weighting Factor $\sqrt{(n+i)/2}$	Expected Operate Time (s)
1	2.125	fund neg	60	1	+1	1.000	40
2	3.007	2nd pos	120	2	–1	0.707	40
3	4.250	fund neg	60	1	+1	1.000	10

Third-Harmonic Tests

This section provides a test to verify the operation of the 64G2 and 64G3 elements. This test uses the test connection of *Figure 3.4(A)*.

Because these elements operate from the third-harmonic component of the voltage, we must inject a composite voltage with a fundamental component (50 or 60 Hz) and a third harmonic into the Z terminal.

Note that the third-harmonic component should be injected into all three phases with an angle of zero between each phase.

Note also that the element asserts 64GAAL when the angle between the third-harmonic voltage drops at the generator terminals and neutral is outside the setting range 64GANCH and 64GANCL. For a secondary injection test that uses the circuit of *Figure 3.4(A)*, this angle will be in the range of 180 degrees.

The common settings are shown in *Table 3.24*.

Table 3.24 Third Harmonic Common Settings

Setting	Category	Comments
E64G = G2	Group	Enable the 64G2 element
PTCONZ = Y	Group	Set the PT connection for Terminal Z to Y
PTRZ = 120	Group	Set the Terminal Z PT ratio to 120
VNOMZ = 115	Group	Set the Terminal Z nominal voltage to 13800 / 120 = 115
PTCONV = 1PH	Group	Set the PT connection for Terminal V to single-phase
PTRV2 = 57	Group	Set the V2 terminal PT ratio to 57
VNOMV2 = 115	Group	

The SEL-400G calculates the generator total third harmonic, VG3F, as:

$$\mathrm{VG3F} = \mathrm{VN3F} + \frac{\mathrm{PTRZ}}{3 \bullet \mathrm{PTRV2}} \bullet \mathrm{3V0Z3F}$$

VG3FM = mag(VG3F)

VG3FA = angle(VG3F)

64G2 Third-Harmonic Test

In a similar manner to *Volts/Hertz on page 3.5*, you can program SELOGIC variables to assert LEDs on the front panel to indicate the status of the 64G2 element. You can also program the SER to record the status of the element, and then use these recorded values to calculate the element operating time(s). The active Relay Word bits for this test are:

64GAAL	Third-harmonic angle check alarm
64GALT	Alternative settings selected
64G2DEN	Third-harmonic differential is enabled
64G2DIF	Third-harmonic differential asserted
64G2	Third-harmonic Element 2 pickup
64G2T	Third-harmonic Element 2 delayed pickup
64G2TC	64G2 torque control bit
RB01, RB02	Remote bits

The settings for the 64G2 are shown in *Table 3.25*.

Table 3.25 Settings to Test the Third Harmonic 64G2 Element

Setting	Category	Comments
64GALT = RB01	Group	Set the switch to Level 2 Settings (SV) to RB01
64G2P1 = 2	Group	Set the 64G2 Level 1 Pickup to 1
64G2R1 = 1.0	Group	Set the 64G2 Level 1 Ratio to 1.0
64G2P2 = 2.5	Group	Set the 64G2 Level 2 Pickup to 2
64G2R2 = 1.1	Group	Set the 64G2 Level 2 Ratio to 1.1
64G2D = 0.05	Group	Set the 64G2 Time Delay to 0.05
64G2TC = RB02	Group	Set the 64G2 Torque Control to RB02

```
==>>SET S TE <Enter>
Group 1

Potential Transformer Data

PT connection for Term V (OFF,Y,D,D1,1PH)                       PTCONV  := 1PH    ? <Enter>
PT connection for Term Z (Y,D,D1)                               PTCONZ  := Y      ? <Enter>
PT Ratio Term Z (1.0-10000)                                     PTRZ    := 200.0  ?120 <Enter>
PT Nominal Voltage (L-L) Term Z (30.00-300 V,sec)               VNOMZ   := 110.00 ?115 <Enter>
PT Ratio Term V1 (OFF,1.0-10000)                                PTRV1   := 200.0  ? <Enter>
PT Ratio Term V2 (OFF,1.0-10000)                                PTRV2   := 200.0  ?57 <Enter>
PT Ratio Term V3 (OFF,1.0-10000)                                PTRV3   := 200.0  ? <Enter>
PT Nominal Voltage Term V1 (30.00-300 V,sec)                    VNOMV1  := 110.00 ? <Enter>
PT Nominal Voltage Term V2 (30.00-300 V,sec)                    VNOMV2  := 110.00 ?115 <Enter>
PT Nominal Voltage Term V3 (30.00-300 V,sec)                    VNOMV3  := 110.00 ? <Enter>

Current Transformer Data

CT Connection for Term Y (1PH,Y)                                CTCONY  := 1PH    ? <Enter>
CT Ratio Term S (OFF,1.0-50000)                                 CTRS    := 4000.0 ?100 <Enter>
CT Ratio Term T (OFF,1.0-50000)                                 CTRT    := 400.0  ?100 <Enter>
CT Ratio Term U (OFF,1.0-50000)                                 CTRU    := 12000.0?100 <Enter>
CT Ratio Term W (OFF,1.0-50000)                                 CTRW    := 4000.0 ?100 <Enter>
CT Ratio Term X (OFF,1.0-50000)                                 CTRX    := 4000.0 ?100 <Enter>
CT Ratio Term Y1 (OFF,1.0-50000)                                CTRY1   := 100.0  ? <Enter>
CT Ratio Term Y2 (OFF,1.0-50000)                                CTRY2   := 100.0  ? <Enter>
CT Ratio Term Y3 (OFF,1.0-50000)                                CTRY3   := 100.0  ? <Enter>

Relay Configuration

Advanced Settings (Y,N)                                         EADVS   := N      ? <Enter>
En. Pump Storage (OFF or combo of S,T,U,W,X,Z)                  EPS     := OFF    ? <Enter>
Enable Gen Neut Volt Term (OFF,V2)                              EGNPT   := V2     ? <Enter>
Enable Sys Volt Term (OFF or combo of V1,V3)                    ESYSPT  := "V1"   ?OFF <Enter>
Enable Gen Neut Cur Terms (combo of W,X)                        EGNCT   := "X"    ? <Enter>
Enable System Cur Terms (OFF or combo of S,T,U)                 ESYSCT  := "S,T"  ?S <Enter>
En. Power Calc Term (OFF or S)                                  EPCAL   := "S"    ?OFF <Enter>
Enable Volts per Hertz Elements (N,1-2)                         E24     := 2      ?N <Enter>
Enable Under Voltage Elements (N,1-6)                           E27     := N      ? <Enter>
Enable Directional Power (N,1-4)                                E32     := 1      ?N <Enter>
Enable Loss of Field (OFF or combo of Z,P)                      E40     := "Z"    ?OFF <Enter>
Enable Current Unbalance Elements (N, 1-2)                      E46     := 1      ?N <Enter>
Enable 50 Elements (OFF or S)                                   E50     := OFF    ? <Enter>
Enable Inverse Time Overcurrent Elements (N,1-12)               E51     := N      ? <Enter>
Enable Over Voltage Elements (N,1-6)                            E59     := 1      ?N <Enter>
Enable 60P Split Phase Element (N,T,U,X)                        E60P    := N      ? <Enter>
Enable 60N Split Phase Element (N,Y1,Y2,Y3)                     E60N    := N      ? <Enter>
Enable 64G Element (OFF or combo of G1,G2,G3)                   E64G    := "G1,G3"?G2 <Enter>
Enable 64F Field Ground Element (Y,N)                           E64F    := N      ? <Enter>
Enable 64S Stator Ground Element (Y,N)                          E64S    := N      ? <Enter>
Enable Out-of-Step Element (N,1B,2B)                            E78     := 1B     ?N <Enter>
Enable Frequency Elements (N,1-6)                               E81     := 2      ?N <Enter>
Enable Accumulated Freq Elements (N,1-8)                        E81A    := N      ? <Enter>
Enable Rate of Change of Freq Elements (N,1-6)                  E81R    := N      ? <Enter>
Enable Differential Elements (N,1-2)                            E87     := 2      ?N <Enter>
Enable REF Element (OFF or combo of Y1,Y2,Y3)                   EREF    := "Y1"   ?OFF <Enter>
Enable Inad. Ener. Prot. (OFF or S)                             EINAD   := "S"    ?OFF <Enter>
Enable Pole Open (OFF or S)                                     EPO     := "S,T"  ?OFF <Enter>
Load Encroachment (Y,N)                                         ELOAD   := N      ? <Enter>
Enable Loss of Potential (OFF or Z)                             ELOP    := "Z"    ?OFF <Enter>
Enable Brkr Fail. Prot. (OFF or S)                              EBFL    := "S,T"  ?OFF <Enter>
Enable Brkr Flash Ovr. (OFF or S)                               EBFO    := "S"    ?OFF <Enter>
Enable System Backup Protection (OFF or combo of 51C,51V,21P)   EBUP    := 21P    ?N <Enter>
Enable Demand Metering (N,1-10)                                 EDEM    := N      ? <Enter>
Enable Max/Min Metering (N,1-30)                                EMXMN   := 12     ?N <Enter>

Power System Data

Generator Max. MVA (1-5000 MVA)                                 MVAGEN  := 555    ? <Enter>
Generator L-L Voltage (1.00-100 kV)                             KVGEN   := 24.00  ? <Enter>
Generator D-Axis Synch Reactance (0.100-4)                      XDGEN   := 1.810  ? <Enter>
Transformer Leakage Reactance (0.010-10)                        XTXFR   := 0.042  ? <Enter>
Equivalent System Reactance (0.010-10)                          XESYS   := 0.200  ? <Enter>
```

Figure 3.18 64G2 Settings

```
Frequency Tracking Sources

Frequency Source for Current Term S (G)                             FTSRCS  := G      ? <Enter>
Frequency Source for Current Term T (G)                             FTSRCT  := G      ? <Enter>
Frequency Source for Current Term U (G)                             FTSRCU  := G      ? <Enter>
Frequency Source for Current Term W (G)                             FTSRCW  := G      ? <Enter>
Frequency Source for Current Term X (G)                             FTSRCX  := G      ? <Enter>
Frequency Source for Current Term Y1 (G)                            FTSRCY1 := G      ? <Enter>
Frequency Source for Current Term Y2 (G)                            FTSRCY2 := G      ? <Enter>
Frequency Source for Current Term Y3 (G)                            FTSRCY3 := G      ? <Enter>
Frequency Source for Voltage Term Z (G)                             FTSRCZ  := G      ? <Enter>
Frequency Source for Voltage Term V1 (G)                            FTSRCV1 := G      ? <Enter>
Frequency Source for Voltage Term V2 (G)                            FTSRCV2 := G      ? <Enter>
Frequency Source for Voltage Term V3 (G)                            FTSRCV3 := G      ? <Enter>

Stator Ground (64G) Element

64G Alternate Setting (SELogic Eqn)
64GALT := NA
?  RB01 <Enter>
64G Angle Check Low (-179.99 to 180 deg)                            64GANCL := 45.00  ? <Enter>
64G Angle Check High (-179.99 to 180 deg)                           64GANCH := -135.00? <Enter>
64G2 Ratio Correction [2] (0.10-10)                                 64G2R1  := 1.00   ? <Enter>
64G2 Ratio Correction [2] (0.10-10)                                 64G2R2  := 1.00   ?1.1 <Enter>
64G2 Voltage Pickup 1 (0.10-150 V,sec)                              64G2P1  := 2.00   ? <Enter>
64G2 Voltage Pickup 2 (0.10-150 V,sec)                              64G2P2  := 2.00   ?2.5 <Enter>
64G2 Element Delay (0.000-400 s)                                    64G2D   := 1.000  ?0.05 <Enter>
64G2 Element Torque Cont (SELogic Eqn)
64G2TC := 1
?  RB02 <Enter>
64G Normal Trip Input (SELogic Eqn)
64GTIN := 64G1T OR 64G2T OR 64G3T
?   <Enter>
64G Accelerated Input (SELogic Eqn)
64GAIN := 64G1 OR 64G2 OR 64G3
?   <Enter>
64G Accelerated Torque Cont (SELogic Eqn)
64GATC := NA
?   <Enter>
64G Accelerated PU Delay (0.000-400 s)                              64GAPU  := 0.200  ? <Enter>
64G Accelerated DO Delay (0.000-400 s)                              64GADO  := 15.000 ? <Enter>

Generator Monitoring Logic

Generator Online Logic (SELogic Eqn)
ONLINE := 52CLS
?  END <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

==>>
```

Figure 3.18 64G2 Settings (Continued)

The operating equation for Level 1 is:

$$64G2 = V3DIF > 64G2P1$$

where:

$$V3DIF = \frac{PTRZ}{3 \bullet PTRV2} \bullet 3V03FM \bullet 64R1 - VN3FM$$

Table 3.26 shows the test values and expected results. 64G2DEN asserts when there is enough third harmonic for the element to operate, and 64G2DIF asserts when V3DIF is greater than the pickup setting.

Table 3.26 64G2 Level 1 Test Values

Test	Terminal Z 3rd Harmonic Voltage	Terminal V2 3rd Harmonic Voltage	3V03ZM	VN3FM	V3DIF	64G2DEN	64G2DIF
1	0	2.05	0	2.04	–2.04	ON	OFF
2	3.0	2.05	2.99	2.04	0.00	ON	OFF
3	5.79	2.05	5.77	2.04	2.01	ON	ON

Test Steps

Step 1. Issue the **CON 01 C** and **CON 02 S** commands to the relay. Check that 64GALT is not asserted by issuing **TAR 64GALT**. Also, confirm that the torque bit is asserted by issuing **TAR 64G2TC**.

Step 2. Inject a balanced three-phase voltage with a magnitude of 66.39 V at the fundamental frequency into the A-Phase of the Z terminal.

Step 3. Inject the voltage with the magnitude shown for Test 1 into the V2 terminal at the third-harmonic frequency.

Step 4. Confirm that V3DIF has the value shown for Test 1 and that the operands assert as shown.

Step 5. Add a third-harmonic component to the voltage injected into the B-phase of the Z terminal with the value shown in Test 2.

Step 6. Confirm that (V3DIF + VN3FM) / VT3FM is equal to the 64G2R1 setting.

Step 7. Increase the magnitude of the Terminal 2 third-harmonic component until the element picks up as indicated by assertion of 64G2DIF.

Step 8. Confirm that the value of V3DIF is equal to the 64G2P1 setting.

Step 9. Maintain the voltage until 64G2D times out and 64G2T asserts. Record the difference between 64G2T and 64G2 as the measured time delay, 64G2D.

Step 10. Deassert and reassert the torque control by issuing the **CON 02 C** and then **CON 02 S** commands to the relay. Confirm that the element resets and picks up again.

Step 11. Set 64GALT to 1 by issuing the **CON 01 S** command and repeat *Step 3* through *Step 10* to test Level 2.

64G3 Test

In a similar manner to *Volts/Hertz on page 3.5*, you can program SELOGIC variables to assert LEDs on the front panel to indicate the status of the 64G3 element. You can also program the SER to record the status of the element, and then use these recorded values to calculate the element operating time(s). The active Relay Word bits for this test are as follows:

64GAAL	64G3 Third-harmonic voltage angle alarm
64G3EN	64G3 Third-harmonic ratio is enabled
64G3	64G3 Third-harmonic ratio pickup
64G3T	64G3 Third-harmonic ratio timed out
RB03	Remote bit

The common settings are shown in *Table 3.27*.

Table 3.27 Settings to Test the Third Harmonic 64G3 Element

Setting	Category	Comments
E64G = G3	Group	Enable the 64G3 element
PTCONZ = Y	Group	Set the PT connection for Terminal Z to Y
PTRZ = 120	Group	Set the Terminal Z PT ratio to 120
VNOMZ = 115	Group	Set the Terminal Z nominal voltage to 13800 / 120 = 115
PTCONV = 1PH	Group	Set the PT connection for Terminal Y to single-phase
PTRV2 = 57	Group	Set the Terminal V2 PT ratio to 57

Table 3.28 shows the settings for 64G3.

Table 3.28 64G3 Settings

Setting	Category	Comments
64G3P1 = 2	Group	64G3 voltage pickup
64G3R1 = 0.15	Group	64G3 ratio pickup
64G3R2 = 0.2	Group	Alternative ratio pickup
64G3D = 0.05	Group	64G3 time delay
64G3TC = RB03	Group	64G3 torque control (SV)
64GALT = RB01	Group	Deassert the switch to Level 2 settings (SV)

```
=>>SET E64G TE <Enter>
Group 1

Relay Configuration

Enable 64G Element (OFF or combo of G1,G2,G3)        E64G    := "G2"   ?G3 <Enter>
Enable 64F Field Ground Element (Y,N)                E64F    := N      ?END <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>

=>>SET 64GALT TE <Enter>
Group 1

Stator Ground (64G) Element

64G Alternate Setting (SELogic Eqn)
64GALT := RB01
?  <Enter>
64G Angle Check Low (-179.99 to 180 deg)             64GANCL := 45.00  ? <Enter>
64G Angle Check High (-179.99 to 180 deg)            64GANCH := -135.00? <Enter>
64G3 Ratio Correction 1 (0.01-1)                     64G3R1  := 0.15   ? <Enter>
64G3 Ratio Correction 2 (0.01-1)                     64G3R2  := 0.15   ?0.2 <Enter>
64G3 Voltage Pickup 1 (0.10-150 V,sec)               64G3P1  := 2.00   ? <Enter>
64G3 Element Delay (0.000-400 s)                     64G3D   := 1.000  ?0.05
   <Enter>
64G3 Element Torque Cont (SELogic Eqn)
64G3TC := 1
?  RB03 <Enter>
64G Normal Trip Input (SELogic Eqn)
64GTIN := 64G1T OR 64G2T OR 64G3T
?  END <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 3.19 64G3 Settings

The operating equation for this function is:

$$64G3 = V3RAT < 64G3R1$$

where:

$$V3RAT = \frac{VN3FM}{VG3FM}$$

The test values and expected results are shown in *Table 3.29*. Note that 64G3 uses the total third harmonic. 64GAAL asserts when the angle between 3V03ZM and VN3F is outside the setting range 64GANCH and 64GANCL. 64G3EN asserts when there is sufficient third harmonic for the element to operate, and 64G3 asserts when the element has picked up.

Table 3.29 64G3 Level 1 Test Values

Test	Terminal Z 3rd Harmonic Voltage	Terminal V2 3rd Harmonic Voltage	3V0ZM	VN3FM	V3RAT	64GAAL	64G3EN	64G3
1	0	2.05	0	2.04	1	OFF	ON	OFF
2	10	2.05	9.97	2.04	0.23	OFF	ON	OFF
3	16.6	2.05	16.52	2.04	0.15	OFF	ON	ON

Test Steps

Step 1. Issue the **CON 01 C** and **CON 03 S** commands to the relay. Check that 64GALT is not asserted by issuing **TAR 64GALT**. Also, confirm that the torque bit is asserted by issuing **TAR 64G3TC**.

Step 2. Inject a balanced three-phase voltage with a magnitude of 66.39 V at the fundamental frequency into the A-Phase of the Z terminal.

Step 3. Inject the voltage into the V2 terminal at the third-harmonic frequency. Increase the magnitude until 64G3EN asserts.

Step 4. Confirm that the 64GAAL is deasserted and that V3RAT = 1.

Step 5. Confirm that the value of VN3FM is slightly greater than 64G3P1.

Step 6. Add a third-harmonic component to the voltage injected into the B-Phase of the Z terminal. Increase the magnitude until the 64G3 asserts.

Step 7. Confirm that 64GAAL is not asserted.

Step 8. Record that the value of V3RAT is equal to 64G3R1.

Step 9. Maintain the voltage until 64G3D times out and 64G3T asserts. Record the difference between 64G3T and 64G3 as the measured time delay, 64G3D.

Step 10. Deassert and reassert the torque control by issuing the **CON 03 C** and then **CON 03 S** commands to the relay. Confirm that the element resets and picks up again.

Step 11. Set 64GALT to 1 by issuing the **CON 01 S** command and repeat *Step 3* through *Step 10* to test Level 2.

87RA, 87RB, and 87RC Restrained Differential Elements

This section provides tests to show the operation of the restraint differential element under the following system conditions (for ease of testing consider only two terminals [Terminal S and Terminal T]):

- Internal fault
- External fault with heavy CT saturation
- Evolving fault, causing the relay to trip on Slope 2

In general, the relay uses *Equation 3.3* and *Equation 3.4* to calculate the operational operating current (IOP_{OP}) and the restraint current (IRT).

$$IOP_{OP} = \left|\overrightarrow{IAS} + \overrightarrow{IAT}\right|$$

Equation 3.3

$$IRT = |IAS| + |IAT|$$

Equation 3.4

Equation 3.3 calculates the absolute value of the vector sum of $\overrightarrow{IAS}$ and $\overrightarrow{IAT}$, and *Equation 3.4* calculates the sum of the absolute values of $\overrightarrow{IAS}$ and $\overrightarrow{IAT}$.

Equation 3.5 is the third equation that the differential element uses to make a trip/no trip decision.

$$IOP(IRT) = \frac{SLP}{100} \bullet IRT$$

Equation 3.5

Equation 3.5 provides the reference value (from the slope setting) for various restraint values, as shown in *Figure 3.21*.

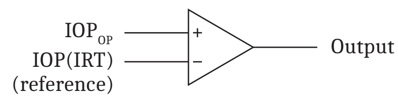


Figure 3.20 Differential Element Comparator

Each processing interval, the relay calculates IRT (*Equation 3.4*), uses this calculated IRT value to calculate IOP(IRT) (*Equation 3.5*), and compares this calculated IOP(IRT) value with the result of *Equation 3.3* (IOP_{OP}).

Figure 3.21 shows the characteristic of the differential element, together with IOP_{OP}. In *Figure 3.21*, the shaded area (area below the SLP line) is the non-operating or restraint area, and the area above the SLP line is the operating or tripping area.

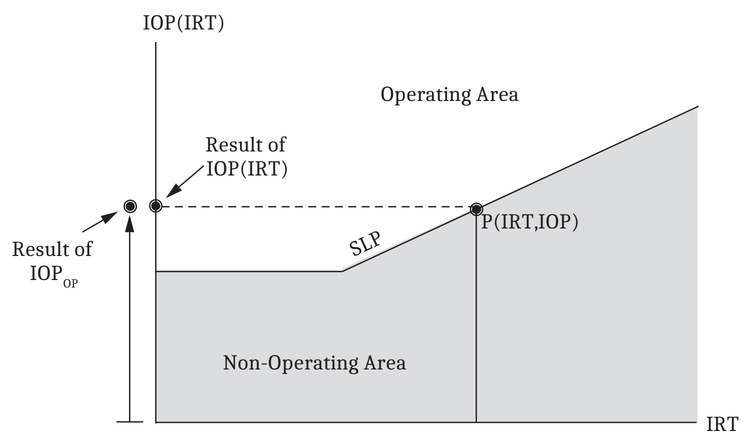


Figure 3.21 Differential Element Characteristic

To simplify *Equation 3.3*, consider a fixed angular relationship of 180 degrees between $\overline{IAS}$ and $\overline{IAT}$, i.e., $\overline{IAS} = IAS\angle 0°$ and $\overline{IAT} = IAT\angle 180°$. With this relationship, both IAS and IAT are real numbers, and *Equation 3.3* becomes:

$$IOP_{OP} = IAS - IAT$$

Equation 3.6

or

$$IAS = IOP_{OP} + IAT$$

Equation 3.7

Also, from *Equation 3.4*,

$$IAS = IRT - IAT$$

Equation 3.8

Combine *Equation 3.7* and *Equation 3.8* to solve for IAT as follows:

$$IAT = \frac{IRT - IOP_{OP}}{2}$$

Equation 3.9

With this value, use *Equation 3.8* to calculate IAS as follows:

$$IAS = \frac{IRT + IOP_{OP}}{2}$$

Equation 3.10

Connect a three-phase test set to the SEL-400G as shown in *Figure 3.3*. Change the following settings, as shown in *Table 3.30* and *Figure 3.22*.

Table 3.30 Differential Element Settings

Setting	Setting Category	Comment
E87Z2 = S, T	Group	Include Terminals S and T for the differential element
87P11 = 0.3	Group	Restraint differential element pickup
87SLP12 = 30	Group	Set Slope 1 to 30 percent
87SLP22 = 60	Group	Set Slope 2 to 60 percent

```
=>>SET TE <Enter>
Group 1


Potential Transformer Data

PT connection for Term V (OFF,Y,D,D1,1PH)                       PTCONV  := 1PH    ? <Enter>
PT connection for Term Z (Y,D,D1)                               PTCONZ  := Y      ? <Enter>
PT Ratio Term Z (1.0-10000)                                     PTRZ    := 200.0  ? <Enter>
PT Nominal Voltage (L-L) Term Z (30.00-300 V,sec)               VNOMZ   := 110.00 ? <Enter>
PT Ratio Term V1 (OFF,1.0-10000)                                PTRV1   := 200.0  ? <Enter>
PT Ratio Term V2 (OFF,1.0-10000)                                PTRV2   := 200.0  ? <Enter>
PT Ratio Term V3 (OFF,1.0-10000)                                PTRV3   := 200.0  ? <Enter>
PT Nominal Voltage Term V1 (30.00-300 V,sec)                    VNOMV1  := 110.00 ? <Enter>
PT Nominal Voltage Term V2 (30.00-300 V,sec)                    VNOMV2  := 110.00 ? <Enter>
PT Nominal Voltage Term V3 (30.00-300 V,sec)                    VNOMV3  := 110.00 ? <Enter>
Current Transformer Data

CT Connection for Term Y (1PH,Y)                                CTCONY  := 1PH    ? <Enter>
CT Ratio Term S (OFF,1.0-50000)                                 CTRS    := 4000.0 ?100 <Enter>
CT Ratio Term T (OFF,1.0-50000)                                 CTRT    := 400.0  ?100 <Enter>
CT Ratio Term U (OFF,1.0-50000)                                 CTRU    := 12000.0? <Enter>
CT Ratio Term W (OFF,1.0-50000)                                 CTRW    := 4000.0 ? <Enter>
CT Ratio Term X (OFF,1.0-50000)                                 CTRX    := 4000.0 ? <Enter>
CT Ratio Term Y1 (OFF,1.0-50000)                                CTRY1   := 100.0  ? <Enter>
CT Ratio Term Y2 (OFF,1.0-50000)                                CTRY2   := 100.0  ? <Enter>
CT Ratio Term Y3 (OFF,1.0-50000)                                CTRY3   := 100.0  ? <Enter>
```

Figure 3.22 Group Settings for the Differential Test

```
Relay Configuration

Advanced Settings (Y,N)                                       EADVS   := N      ? <Enter>
En. Pump Storage (OFF or combo of S,T,U,W,X,Z)                EPS     := OFF    ? <Enter>
Enable Gen Neut Volt Term (OFF,V2)                            EGNPT   := V2     ?OFF <Enter>
Enable Sys Volt Term (OFF or combo of V1,V2,V3)               ESYSPT  := "V1"   ?OFF <Enter>
Enable Gen Neut Cur Terms (combo of W,X)                      EGNCT   := "X"    ? <Enter>
Enable System Cur Terms (OFF or combo of S,T,U)               ESYSCT  := "S,T"  ? <Enter>
En. Power Calc Term (OFF or combo of S,T)                     EPCAL   := "S"    ?OFF <Enter>
Enable Volts per Hertz Elements (N,1-2)                       E24     := 2      ?N <Enter>
Enable Under Voltage Elements (N,1-6)                         E27     := N      ? <Enter>
Enable Directional Power (N,1-4)                              E32     := 1      ?N <Enter>
Enable Loss of Field (OFF or combo of Z,P)                    E40     := "Z"    ?OFF <Enter>
Enable Current Unbalance Elements (N, 1-2)                    E46     := 1      ?N <Enter>
Enable 50 Elements (OFF or combo of S,T)                      E50     := OFF    ? <Enter>
Enable Inverse Time Overcurrent Elements (N,1-12)             E51     := N      ? <Enter>
Enable Over Voltage Elements (N,1-6)                          E59     := N      ? <Enter>
Enable 60P Split Phase Element (N,U,X)                        E60P    := N      ? <Enter>
Enable 60N Split Phase Element (N,Y1,Y2,Y3)                   E60N    := N      ? <Enter>
Enable 64F Field Ground Element (Y,N)                         E64F    := N      ? <Enter>
Enable 64S Stator Ground Element (Y,N)                        E64S    := N      ? <Enter>
Enable Out-of-Step Element (N,1B,2B)                          E78     := 1B     ?N <Enter>
Enable Frequency Elements (N,1-6)                             E81     := 2      ?N <Enter>
Enable Accumulated Freq Elements (N,1-8)                      E81A    := N      ? <Enter>
Enable Rate of Change of Freq Elements (N,1-6)                E81R    := N      ? <Enter>
Enable Differential Elements (N,1-2)                          E87     := 2      ? <Enter>
Enable REF Element (OFF or combo of Y1,Y2,Y3)                 EREF    := "Y1"   ?OFF <Enter>
Enable Inad. Ener. Prot. (OFF or combo of S,T)                EINAD   := "S"    ?OFF <Enter>
Enable Pole Open (OFF or combo of S,T)                        EPO     := "S,T"  ?OFF <Enter>
Load Encroachment (Y,N)                                       ELOAD   := N      ? <Enter>
Enable Loss of Potential (OFF or Z)                           ELOP    := "Z"    ?OFF <Enter>
Enable Brkr Fail. Prot. (OFF or combo of S,T)                 EBFL    := "S,T"  ?OFF <Enter>
Enable Brkr Flash Ovr. (OFF or combo of S,T)                  EBFO    := "S"    ?OFF <Enter>
Enable System Backup Protection (OFF or combo of 51C,51V,21P) EBUP    := 21P    ?N <Enter>
Enable Demand Metering (N,1-10)                               EDEM    := N      ? <Enter>
Enable Max/Min Metering (N,1-30)                              EMXMN   := 12     ?N <Enter>

Power System Data

Generator Max. MVA (1-5000 MVA)                               MVAGEN  := 555    ? <Enter>
Generator L-L Voltage (1.00-100 kV)                           KVGEN   := 24.00  ? <Enter>
Generator D-Axis Synch Reactance (0.100-4)                    XDGEN   := 1.810  ? <Enter>
Transformer Leakage Reactance (0.010-10)                      XTXFR   := 0.042  ? <Enter>
Equivalent System Reactance (0.010-10)                        XESYS   := 0.200  ? <Enter>

Frequency Tracking Sources

Frequency Source for Current Term S (G)                       FTSRCS  := G      ? <Enter>
Frequency Source for Current Term T (G)                       FTSRCT  := G      ? <Enter>
Frequency Source for Current Term U (G)                       FTSRCU  := G      ? <Enter>
Frequency Source for Current Term W (G)                       FTSRCW  := G      ? <Enter>
Frequency Source for Current Term X (G)                       FTSRCX  := G      ? <Enter>
Frequency Source for Current Term Y1 (G)                      FTSRCY1 := G      ? <Enter>
Frequency Source for Current Term Y2 (G)                      FTSRCY2 := G      ? <Enter>
Frequency Source for Current Term Y3 (G)                      FTSRCY3 := G      ? <Enter>
Frequency Source for Voltage Term Z (G)                       FTSRCZ  := G      ? <Enter>
Frequency Source for Voltage Term V1 (G)                      FTSRCV1 := G      ? <Enter>
Frequency Source for Voltage Term V2 (G)                      FTSRCV2 := G      ? <Enter>
Frequency Source for Voltage Term V3 (G)                      FTSRCV3 := G      ? <Enter>

Zone 1 Differential Element Configuration

87 Zone 1 Terminals (Combo of S,T,W,X)                        E87Z1   := "W,X"  ? <Enter>
87 Zone 1 In-Zone Transformer (Y,N)                           E87XFR1 := N      ? <Enter>
87 Zone 1 En. Unres. Diff. (OFF or combo of F)                E87U1   := OFF    ? <Enter>
87 Zone 1 Term. W Current Tap (0.50-175 A,sec )               87WTAP1 := 1.00   ? <Enter>
87 Zone 1 Term. X Current Tap (0.50-175 A,sec )               87XTAP1 := 1.00   ? <Enter>
87 Zone 1 External Fault Detect DO (0.0200-1.2 s)             87EFDO1 := 1.0000 ? <Enter>
87 Zone 1 Oper. Current Sensitive PU (0.10-4)                 87P11   := 0.25   ? <Enter>
87 Zone 1 Oper. Current Secure PU (0.10-4)                    87P21   := 0.50   ? <Enter>
87 Zone 1 Slope 1 Percentage (5.00-90%)                       87SLP11 := 10.00  ? <Enter>
87 Zone 1 Slope 2 Percentage (5.00-90%)                       87SLP21 := 75.00  ? <Enter>
87 Zone 1 Switch to Secure (SELogic Eqn)
87ASEC1 := CONA1
?   <Enter>
87 Zone 1 Switch to Secure (SELogic Eqn)
87BSEC1 := CONB1
?   <Enter>
87 Zone 1 Switch to Secure (SELogic Eqn)
87CSEC1 := CONC1
?   <Enter>
87 Zone 1 Restrained Element TC (SELogic Eqn)
87RTC1 := 1
?  0 <Enter>
87 Zone 1 RMS Element PU (OFF,1.00-20)                        87RMP1  := OFF    ? <Enter>
```

Figure 3.22 Group Settings for the Differential Test (Continued)

```
Zone 2 Differential Element Configuration

87 Zone 2 Terminals (Combo of S,T,W,X)                          E87Z2   := "S,T"  ? <Enter>
87 Zone 2 In-Zone Transformer (Y,N)                             E87XFR2 := Y      ? <Enter>
87 Zone 2 Harm. Blk. & Restr. (Combo of B,BW,R,RW)              E87H2   := "B"    ?R <Enter>
87 Zone 2 En. Unres. Diff. (OFF or combo of F,R,W)              E87U2   := OFF    ?F <Enter>
87 Zone 2 Enable Neg. Seq. Differential (Y,E,N)                 E87Q2   := N      ?Y <Enter>
87 Zone 2 Term. S CT Conn. Compensation (0-13)                  87SCTC2 := 0      ?12 <Enter>
87 Zone 2 Term. T CT Conn. Compensation (0-13)                  87TCTC2 := 0      ?12 <Enter>
87 Zone 2 Transformer Max. MVA (OFF,1-5000 MVA)                 MVA2    := OFF    ?100 <Enter>
87 Zone 2 Term. S L-L Voltage (1.00-1000 kV)                    VTERMS2 := 275.00 ? <Enter>
87 Zone 2 Term. T L-L Voltage (1.00-1000 kV)                    VTERMT2 := 275.00 ?132 <Enter>
87 Zone 2 Term. S Current Tap (0.50-175 A,sec )                 87STAP2 := 2.10   ? <Enter>
87 Zone 2 Term. T Current Tap (0.50-175 A,sec )                 87TTAP2 := 4.37   ? <Enter>
87 Zone 2 External Fault Detect DO (0.0200-1.2 s)               87EFDO2 := 1.0000 ? <Enter>
87 Zone 2 Oper. Current Sensitive PU (0.10-4)                   87P12   := 0.25   ?0.3 <Enter>
87 Zone 2 Oper. Current Secure PU (0.10-4)                      87P22   := 0.50   ? <Enter>
87 Zone 2 Slope 1 Percentage (5.00-90%)                         87SLP12 := 10.00  ?30 <Enter>
87 Zone 2 Slope 2 Percentage (5.00-90%)                         87SLP22 := 75.00  ?60 <Enter>
87 Zone 2 Switch to Secure (SELogic Eqn)
87ASEC2 := CONA2
?   <Enter>
87 Zone 2 Switch to Secure (SELogic Eqn)
87BSEC2 := CONB2
?   <Enter>
87 Zone 2 Switch to Secure (SELogic Eqn)
87CSEC2 := CONC2
?   <Enter>
87 Zone 2 Restrained Element TC (SELogic Eqn)
87RTC2 := 1
?   <Enter>
87 Zone 2 Unrestrained Element PU (1.00-20)                     87UP2   := 8.00   ? <Enter>
87 Zone 2 Unrestrained Element TC (SELogic Eqn)

87UTC2 := 1
?   <Enter>
87 Zone 2 RMS Element PU (OFF,1.00-20)                          87RMP2  := OFF    ? <Enter>
87 Zone 2 2nd-Harmonic Percentage (OFF,5-100%)                  87PCT22 := OFF    ?15 <Enter>
87 Zone 2 4th-Harmonic Percentage (OFF,5-100%)                  87PCT42 := OFF    ?15 <Enter>
87 Zone 2 5th-Harmonic Percentage (OFF,5-100%)                  87PCT52 := OFF    ?35 <Enter>
87 Zone 2 5th-Harmonic Alarm PU (OFF,0.02-3.2)                  87TH5P2 := OFF    ? <Enter>
87 Zone 2 Neg. Seq. Operate Current PU (0.05-1)                 87QP2   := 0.30   ? <Enter>
87 Zone 2 Neg. Seq. Slope (5-100%)                              87QSLP2 := 25     ? <Enter>
87 Zone 2 Neg. Seq. Delay (0.0000-200 s)                        87QD2   := 0.2000 ? <Enter>
87 Zone 2 Neg. Seq. TC (SELogic Eqn)
87QTC2 := NOT 87QB2 AND NOT CON2
?  END <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 3.22 Group Settings for the Differential Test (Continued)

With arbitrary values IRT = 3 per unit, SLP1 = 30, and SLP2 = 60 percent, use *Equation 3.12* and *Equation 3.13* to calculate IOP(IRT) values for Slope 1 and Slope 2:

$$\mathrm{IOP(IRT)} = \frac{30}{100} \cdot 3 = 0.9 \text{ pu (Slope 1)}$$

Equation 3.11

$$\mathrm{IOP(IRT)} = \frac{60}{100} \cdot 3 = 1.8 \text{ pu (Slope 2)}$$

Equation 3.12

Case 1: Internal Fault

Select an $\mathrm{IOP_{OP}}$ value greater than 1.8 to ensure that the relay will operate, such as 3 per unit. *Figure 3.23* shows the selected point P(3,3), which is well within the tripping area (shaded area).

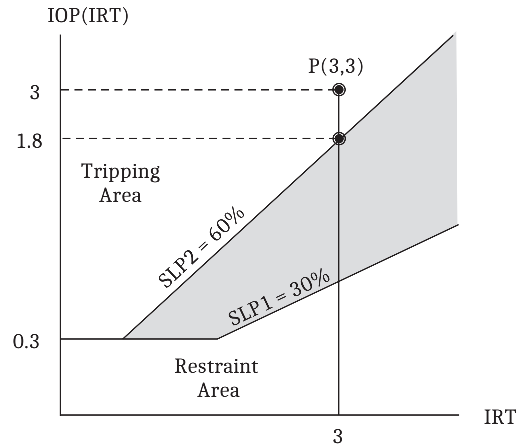


Figure 3.23 Values for Case 1

For this test, inject current into Terminal S only, i.e., I*n*T (*n* = A, B, C) = 0, and I*n*S = 3 per unit. Convert per-unit values (pu) to ampere values, by multiplying the per-unit values with the TAPS value (2.1), as shown in *Table 3.31*.

Table 3.31 Calculate the Current Values in Amperes (Case 1)

Current (per unit)	Current (Amperes)
IAS = 3∠0°pu • 2.1	IAS = 6.3∠0°A
IBS = 3∠–120°pu • 2.1	IBS = 6.3∠–120°A
ICS = 3∠120°pu • 2.1	ICS = 6.3∠120°A

Step 1. Inject balanced 6.3 A into Terminal S for 100 ms, then stop.

Step 2. Verify that LEDs 3, 4, and 5 are illuminated.

Step 3. Press the **TARGET RESET** button to reset the LEDs.

Case 2: External Fault With Heavy CT Saturation

This test simulates an external fault that eventually results in extreme CT saturation that would have caused the relay to trip if the relay were still operating on Slope 1. However, because the relay switched to Slope 2, the relay does not operate for this fault for less than one second. This test will be run in two stages, the first stage simulating an external fault without CT saturation and the second stage introducing heavy CT saturation.

Step 1. For Stage 1, select a large IRT value that will simulate an external fault without CT saturation (IOP_{OP} is zero); a good value for IRT is 3 pu. *Figure 3.24* shows the selected point P1(3,0).

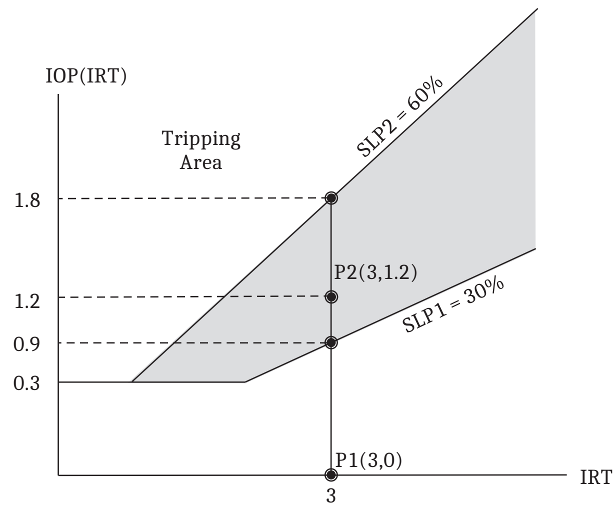


Figure 3.24 Values for Case 2

Step 2. Calculate IAS and IAT for the point P1(3,0):

$$IAS = \frac{IRT + IOP_{OP}}{2} = \frac{3 + 0}{2} = 1.5$$

Equation 3.13

$$IAT = \frac{IRT - IOP_{OP}}{2} = \frac{3 - 0}{2} = 1.5$$

Equation 3.14

Convert per-unit values (pu) to ampere values by multiplying the per-unit values with the TAP values, as shown in *Table 3.32*.

Table 3.32 Calculate the Current Values in Amperes (Case 2, Stage 1)

Current (per unit)	Current (Amperes)
IAS = 1.5∠0°pu • 2.1	IAS = 3.15∠0°A
IBS = 1.5∠–120°pu • 2.1	IBS = 3.15∠–120°A
ICS = 1.5∠120°pu • 2.1	ICS = 3.15∠120°A
IAT = 1.5∠180°pu • 4.37	IAT = 6.56∠180°A
IBT = 1.5∠60°pu • 4.37	IBT = 6.56∠60°A
ICT = 1.5∠–60°pu • 4.37	ICT = 6.56∠–60°A

Step 3. For Stage 2, select an IOP_{OP} value between 0.9 pu and 1.8 pu that will simulate CT saturation. Accounting for the group settings of the relay, a good choice for IOP_{OP} would be 1.2 pu. *Figure 3.24* shows the selected point P2(3,1.2) and the area between the two slopes (shaded area).

Step 4. Calculate IAS and IAT for the point P2(3,1.2):

$$IAS = \frac{IRT + IOP_{OP}}{2} = \frac{3 + 1.2}{2} = 2.1$$

Equation 3.15

$$IAT = \frac{IRT - IOP_{OP}}{2} = \frac{3 - 1.2}{2} = 0.9$$

Equation 3.16

As before, convert the pu values to ampere values by multiplying by the appropriate TAP values, as shown in *Table 3.33*.

Table 3.33 Calculate the Current Values in Amperes (Case 2, Stage 2)

Current (per unit)	Current (Amperes)
IAS = 2.1∠0°pu • 2.1	IAS = 4.41∠0°A
IBS = 2.1∠–120°pu • 2.1	IBS = 4.41∠–120°A
ICS = 2.1∠120°pu • 2.1	ICS = 4.41∠120°A
IAT = 0.9∠180°pu • 4.37	IAT = 3.93∠180°A
IBT = 0.9∠60°pu • 4.37	IBT = 3.93∠60°A
ICT = 0.9∠–60°pu • 4.37	ICT = 3.93∠–60°A

Step 5. Inject the currents for Stage 1 shown in *Table 3.32* into Terminal S and Terminal T for 1.8 cycles, and then inject the currents for Stage 2 shown in *Table 3.33* into Terminal S and Terminal T for 800 ms.

Step 6. Verify that LEDs 3, 4, and 5 are NOT illuminated, i.e., the relay did not trip.

Case 3: Evolving Fault, Causing the Relay to Trip on Slope 2

This test is for a fault that starts out as an external fault (causing the relay to switch to Slope 2), but then evolves into an in-zone fault. The worst case for this fault is when there is only one source, i.e., when the fault moves to an internal fault, the side where the external fault was, does not contribute any fault current.

This test is in two stages: Stage 1 for the external fault (no saturation) and Stage 2 for the evolved fault.

Table 3.34 Current Values in Amperes (Case 3)

Current (Amperes) Stage 1	Current (Amperes) Stage 2
IAS = 4.2∠0°A	IAS = 4.2∠0°A
IBS = 4.2∠–120°A	IBS = 4.2∠–120°A
ICS = 4.2∠120°A	ICS = 4.2∠120°A
IAT = 8.74∠180°A	IAT = 0
IBT = 8.74∠60°A	IBT = 0
ICT = 8.74∠–60°A	ICT = 0

Step 1. Enable an overcurrent element for Terminal T, and set the pickup value to 0.5 A, as shown in *Figure 3.25*.

```
=>>SET S TE E50 <Enter>
Group 1

Relay Configuration

Enable 50 Elements (OFF or combo of S,T)                          E50     := OFF    ?T <Enter>
Enable Inverse Time Overcurrent Elements (N,1-12)                 E51     := N      ? <Enter>
Enable Over Voltage Elements (N,1-6)                              E59     := N      ? <Enter>
Enable 60P Split Phase Element (N,U,X)                            E60P    := N      ? <Enter>
Enable 60N Split Phase Element (N,Y1,Y2,Y3)                       E60N    := N      ? <Enter>
Enable 64F Field Ground Element (Y,N)                             E64F    := N      ? <Enter>
Enable 64S Stator Ground Element (Y,N)                            E64S    := N      ? <Enter>
Enable 67 Dir. Elements (OFF or T)                                E67     := OFF    ? <Enter>
Enable Out-of-Step Element (N,1B,2B)                              E78     := N      ? <Enter>
Enable Frequency Elements (N,1-6)                                 E81     := N      ? <Enter>
Enable Accumulated Freq Elements (N,1-8)                          E81A    := N      ? <Enter>
Enable Rate of Change of Freq Elements (N,1-6)                    E81R    := N      ? <Enter>
Enable Differential Elements (N,1-2)                              E87     := 2      ? <Enter>
Enable REF Element (OFF or combo of Y1,Y2,Y3)                     EREF    := OFF    ? <Enter>
Enable Inad. Ener. Prot. (OFF or combo of S,T)                    EINAD   := OFF    ? <Enter>
Enable Pole Open (OFF or combo of S,T)                            EPO     := OFF    ? <Enter>
Load Encroachment (Y,N)                                           ELOAD   := N      ? <Enter>
Enable Loss of Potential (OFF or Z)                               ELOP    := OFF    ? <Enter>
Enable Brkr Fail. Prot. (OFF or combo of S,T)                     EBFL    := OFF    ? <Enter>
Enable Brkr Flash Ovr. (OFF or combo of S,T)                      EBFO    := OFF    ? <Enter>
Enable System Backup Protection (OFF or combo of 51C,51V,21P)     EBUP    := N      ? <Enter>
Enable Demand Metering (N,1-10)                                   EDEM    := N      ? <Enter>
Enable Max/Min Metering (N,1-30)                                  EMXMN   := N      ? <Enter>

Power System Data

Generator Max. MVA (1-5000 MVA)                                   MVAGEN  := 555    ? <Enter>
Generator L-L Voltage (1.00-100 kV)                               KVGEN   := 24.00  ? <Enter>
Generator D-Axis Synch Reactance (0.100-4)                        XDGEN   := 1.810  ? <Enter>
Transformer Leakage Reactance (0.010-10)                          XTXFR   := 0.042  ? <Enter>
Equivalent System Reactance (0.010-10)                            XESYS   := 0.200  ? <Enter>

Frequency Tracking Sources

Frequency Source for Current Term S (G)                           FTSRCS  := G      ? <Enter>
Frequency Source for Current Term T (G)                           FTSRCT  := G      ? <Enter>
Frequency Source for Current Term U (G)                           FTSRCU  := G      ? <Enter>
Frequency Source for Current Term W (G)                           FTSRCW  := G      ? <Enter>
Frequency Source for Current Term X (G)                           FTSRCX  := G      ? <Enter>
Frequency Source for Current Term Y1 (G)                          FTSRCY1 := G      ? <Enter>
Frequency Source for Current Term Y2 (G)                          FTSRCY2 := G      ? <Enter>
Frequency Source for Current Term Y3 (G)                          FTSRCY3 := G      ? <Enter>
Frequency Source for Voltage Term Z (G)                           FTSRCZ  := G      ? <Enter>
Frequency Source for Voltage Term V1 (G)                          FTSRCV1 := G      ? <Enter>
Frequency Source for Voltage Term V2 (G)                          FTSRCV2 := G      ? <Enter>
Frequency Source for Voltage Term V3 (G)                          FTSRCV3 := G      ? <Enter>

Zone 1 Differential Element Configuration

87 Zone 1 Terminals (Combo of S,T,W,X)                            E87Z1   := "W,X"  ? <Enter>
87 Zone 1 In-Zone Transformer (Y,N)                               E87XFR1 := N      ? <Enter>
87 Zone 1 En. Unres. Diff. (OFF or combo of F)                    E87U1   := OFF    ? <Enter>
87 Zone 1 Term. W Current Tap (0.50-175 A,sec )                   87WTAP1 := 1.00   ? <Enter>
87 Zone 1 Term. X Current Tap (0.50-175 A,sec )                   87XTAP1 := 1.00   ? <Enter>
87 Zone 1 External Fault Detect DO (0.0200-1.2 s)                 87EFDO1 := 1.0000 ? <Enter>
87 Zone 1 Oper. Current Sensitive PU (0.10-4)                     87P11   := 0.25   ? <Enter>
87 Zone 1 Oper. Current Secure PU (0.10-4)                        87P21   := 0.50   ? <Enter>
87 Zone 1 Slope 1 Percentage (5.00-90%)                           87SLP11 := 10.00  ? <Enter>
87 Zone 1 Slope 2 Percentage (5.00-90%)                           87SLP21 := 75.00  ? <Enter>
87 Zone 1 Switch to Secure (SELogic Eqn)
87ASEC1 := CONA1
?   <Enter>
87 Zone 1 Switch to Secure (SELogic Eqn)
87BSEC1 := CONB1
?   <Enter>
87 Zone 1 Switch to Secure (SELogic Eqn)
87CSEC1 := CONC1
?   <Enter>
87 Zone 1 Restrained Element TC (SELogic Eqn)
87RTC1 := 0
?   <Enter>
87 Zone 1 RMS Element PU (OFF,1.00-20)                            87RMP1  := OFF    ? <Enter>
```

Figure 3.25 Enable Overcurrent Element for Terminal T

```
Zone 2 Differential Element Configuration

87 Zone 2 Terminals (Combo of S,T,W,X)                          E87Z2   := "S,T"  ? <Enter>
87 Zone 2 In-Zone Transformer (Y,N)                             E87XFR2 := Y      ? <Enter>
87 Zone 2 Harm. Blk. & Restr. (Combo of B,BW,R,RW)              E87H2   := "R"    ? <Enter>
87 Zone 2 En. Unres. Diff. (OFF or combo of F,R,W)              E87U2   := "F"    ? <Enter>
87 Zone 2 Enable Neg. Seq. Differential (Y,E,N)                 E87Q2   := Y      ? <Enter>
87 Zone 2 Term. S CT Conn. Compensation (0-13)                  87SCTC2 := 12     ? <Enter>
87 Zone 2 Term. T CT Conn. Compensation (0-13)                  87TCTC2 := 12     ? <Enter>
87 Zone 2 Transformer Max. MVA (OFF,1-5000 MVA)                 MVA2    := 100    ? <Enter>
87 Zone 2 Term. S L-L Voltage (1.00-1000 kV)                    VTERMS2 := 275.00 ? <Enter>
87 Zone 2 Term. T L-L Voltage (1.00-1000 kV)                    VTERMT2 := 132.00 ? <Enter>
87 Zone 2 Term. S Current Tap (0.50-175 A,sec )                 87STAP2 := 2.10   ? <Enter>
87 Zone 2 Term. T Current Tap (0.50-175 A,sec )                 87TTAP2 := 4.37   ? <Enter>
87 Zone 2 External Fault Detect DO (0.0200-1.2 s)               87EFDO2 := 1.0000 ? <Enter>
87 Zone 2 Oper. Current Sensitive PU (0.10-4)                   87P12   := 0.30   ? <Enter>
87 Zone 2 Oper. Current Secure PU (0.10-4)                      87P22   := 0.50   ? <Enter>
87 Zone 2 Slope 1 Percentage (5.00-90%)                         87SLP12 := 30.00  ? <Enter>
87 Zone 2 Slope 2 Percentage (5.00-90%)                         87SLP22 := 60.00  ? <Enter>
87 Zone 2 Switch to Secure (SELogic Eqn)
87ASEC2 := CONA2
?   <Enter>
87 Zone 2 Switch to Secure (SELogic Eqn)
87BSEC2 := CONB2
?   <Enter>
87 Zone 2 Switch to Secure (SELogic Eqn)
87CSEC2 := CONC2
?   <Enter>
87 Zone 2 Restrained Element TC (SELogic Eqn)
87RTC2 := 1
?   <Enter>
87 Zone 2 Unrestrained Element PU (1.00-20)                     87UP2   := 8.00   ? <Enter>
87 Zone 2 Unrestrained Element TC (SELogic Eqn)
87UTC2 := 1
?  <Enter>
87 Zone 2 RMS Element PU (OFF,1.00-20)                          87RMP2  := OFF    ? <Enter>
87 Zone 2 2nd-Harmonic Percentage (OFF,5-100%)                  87PCT22 := 15     ? <Enter>
87 Zone 2 4th-Harmonic Percentage (OFF,5-100%)                  87PCT42 := 15     ? <Enter>
87 Zone 2 5th-Harmonic Percentage (OFF,5-100%)                  87PCT52 := 35     ? <Enter>
87 Zone 2 5th-Harmonic Alarm PU (OFF,0.02-3.2)                  87TH5P2 := OFF    ? <Enter>
87 Zone 2 Neg. Seq. Operate Current PU (0.05-1)                 87QP2   := 0.30   ? <Enter>
87 Zone 2 Neg. Seq. Slope (5-100%)                              87QSLP2 := 25     ? <Enter>
87 Zone 2 Neg. Seq. Delay (0.0000-200 s)                        87QD2   := 0.2000 ? <Enter>
87 Zone 2 Neg. Seq. TC (SELogic Eqn)
87QTC2 := NOT 87QB2 AND NOT CON2
?   <Enter>

Overcurrent Elements Terminal T

Type of O/C Elems Enabled Term. T (Combo of P,Q,G)              E50T    := "P"    ? <Enter>

Terminal T Phase Overcurrent Element Level 1

Phase Inst O/C Pickup Lvl 1 (OFF,0.25-100 A,sec)                50TP1P  := OFF    ?0.5 <Enter>
Phase Inst O/C Lvl 1 Torque Ctrl (SELogic Eqn)
67TP1TC := 1
?   <Enter>
Phase Inst O/C Lvl 1 Delay (0.000-400 s)                        67TP1D  := 0.000  ? <Enter>

Terminal T Phase Overcurrent Element Level 2

Phase Inst O/C Pickup Lvl 2 (OFF,0.25-100 A,sec)                50TP2P  := OFF    ?END <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 3.25 Enable Overcurrent Element for Terminal T (Continued)

Step 2. Enter the setting in *Figure 3.26* to include the overcurrent element in the SER.

```
=>>SET R TE <Enter>
Report

SER Chatter Criteria

Automatic Removal of Chattering SER Points (Y,N)     ESERDEL := N      ?

SER Points
(Relay Word Bit, Reporting Name, Set State Name, Clear State Name, HMI Alarm)

1:
?  50TP1 <Enter>
2:
?  TR01 <Enter>
3:
?  END <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 3.26 Enter Overcurrent Element in the SER

Step 3. Inject the current shown in the Stage 1 column of *Table 3.34* into Terminal S and Terminal T for 200 ms, then inject the Stage 2 currents for 200 ms.

Step 4. Issue the **SER** command and calculate the time difference between the deassertion of 50TP1 and the assertion of TR01. This must be less than two cycles.

Autosynchronizer

This section provides a commissioning example for the autosynchronizer, which includes steps for determination of autosynchronizer settings that govern control pulse slope, period, and duration (25AVSLP, 25AVPER, 25AVDUR, 25AFSLP, 25AFPER, and 25AFDUR).

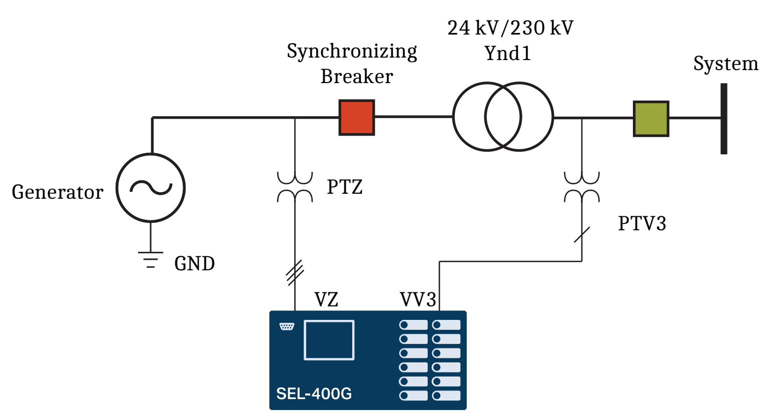


Figure 3.27 Autosynchronizer Commissioning Example

This section assumes that the Breaker S synchronism-check element will be used. The settings for this function are shown in *Table 3.35*. In this example, an autosynchronism operation is configured to start (25ASTS) through use of IN201 and is configured to cancel (25ACNS) through use of IN202. Alternatively, front-panel pushbuttons can be assigned to these settings.

Table 3.35 Settings to Test the Autosynchronizer Element

Setting	Category	Comments
SYNCP = VABZ	Group	Use AB-Phase voltage
SYNCSS = VV3	Group	Use A-Phase voltage
KSSM = 1	Group	No magnitude mismatch assumed
KSSA = 0	Group	No angle mismatch assumed
25VLS = 55	Group	Allow synchronizing to a minimum of 55 V
25VHS = 75	Group	Allow synchronizing to a maximum of 75 V
25VDIFS = 5	Group	Allow a maximum voltage difference of 5%
25GVHIS = Y	Group	Generator voltage high is required
25SFBKS = 0.067	Group	Allow maximum slip frequency of 0.067 Hz
25ANGS = 10	Group	Max. ang. diff. uncompensated angle of 10 degrees
25ADS = 0.016	Group	Require an uncompensated sync for 10 cycles
25ANGCS = 5	Group	Allow a max. ang. diff. compensated of 5 degrees
TCLSBKS = 0.083	Group	Breaker S close time is 5 cycles
25GFHIS = Y	Group	Generator frequency high is required
25AFMOD = PW	Group	Pulse width frequency control selected for this example
25AVMOD = PW	Group	Pulse width voltage control selected for this example
BSYNBKS = 52A_S	Group	Block synchronism check when breaker is closed
CFANGS = 10	Group	Close failure angle at 10 degrees

Settings for the pulse control characteristics for frequency and voltage matching are often made in the field. The generator controls (governor and voltage regulator) and their associated systems (prime mover and field) constitute a complex electromechanical system with multiple gains and time constants. Often, information is not available to determine settings in advance. Measurements made in the field during initial setup can be used to tune the system.

NOTE: This procedure does not replace your company's procedures and safe work practices.

Optimal tuning of the settings for the pulse control characteristic is important to performance of the system. Too aggressive settings can increase the time it takes to synchronize a generator because the control overshoots the sync acceptance bands and causes the control to hunt. On the opposite side, setting the control characteristic too low causes the control to take a long time to move the controlled parameter into the sync acceptance band.

Circuit Breaker Timing Test

The close time of the breaker is used by the synchronism-check element to ensure making of the breaker primary contacts at the instant that the generator and system come into synchronism. SEL recommends that this setting be confirmed as part of the commissioning of the autosynchronizer. This setting can be determined from a traditional offline breaker timing test.

Autosynchronizer Test Setup

- ➤ The generator must be offline and operating at nominal frequency and voltage.
- ➤ The frequency and voltage on the system-side of the breaker must be at nominal values.

- Because the generator is energized, all protection functions must be in service.
- The breaker closing circuit must be isolated from the breaker close coil to ensure that the generator breaker cannot be inadvertently closed.
- In the following procedure, we assume that synchronism-check Element S is used to supervise the breaker and that the SEL-400G outputs are configured as shown in *Table 3.36*. Make the necessary substitutions for applications that use different synchronism-check elements or output contacts.

Table 3.36 Output Configuration

OUT201 :=	25AFR
OUT202 :=	25AFL
OUT203 :=	25AVR
OUT204 :=	25AVL
OUT205 :=	CLSS

- Ensure that the Event Reporting Analogs (ERAQ) include the following values:
  - 25SLIPS
  - FREQPG
  - FREQPS
  - 25DIFVS
  - 25VPFM
  - 25VPSA
- Ensure that the Event Reporting Digitals (ERDG) include the following values:
  - 59VPS
  - 59VSS
  - BSYNBKS
  - 25ENBKS
  - SFZBKS
  - SFBKS
  - FASTS
  - SLOWS
  - 25AS
  - 25CS
  - GENVHIS
  - GENVLOS
  - 25VDIFS
  - 52CLS
- Ensure that the Event Report (ER) trigger includes the TESTPUL OR CLOSES values

Frequency Control Step Response Test

This procedure determines the gain and time constant for a first-order equivalent representation of the governor systems.

To carry out this procedure, place the `BREAKER` jumper on the main board of the SEL-400G in the `ON` position. This allows the **PULSE** command to be used to pulse the control outputs. Return this jumper to its original state when testing is completed.

Step 1. Go to Access Level 2.

Step 2. Issue the **MET SYN S 5** command. This will return the measurements associated with the Breaker S synchronism-check function. Five sets of measurements will be returned at a rate of approximately twice a second. Confirm that the slip (SLIPS) is stable and in the range of ±0.1 Hz.

Step 3. Issue the **PULSE OUT201** command to cause a frequency raise pulse of 1-second duration.

Step 4. Issue the **FILE READ** command to retrieve the event report triggered by *Step 2*, as shown in *Figure 3.28*.

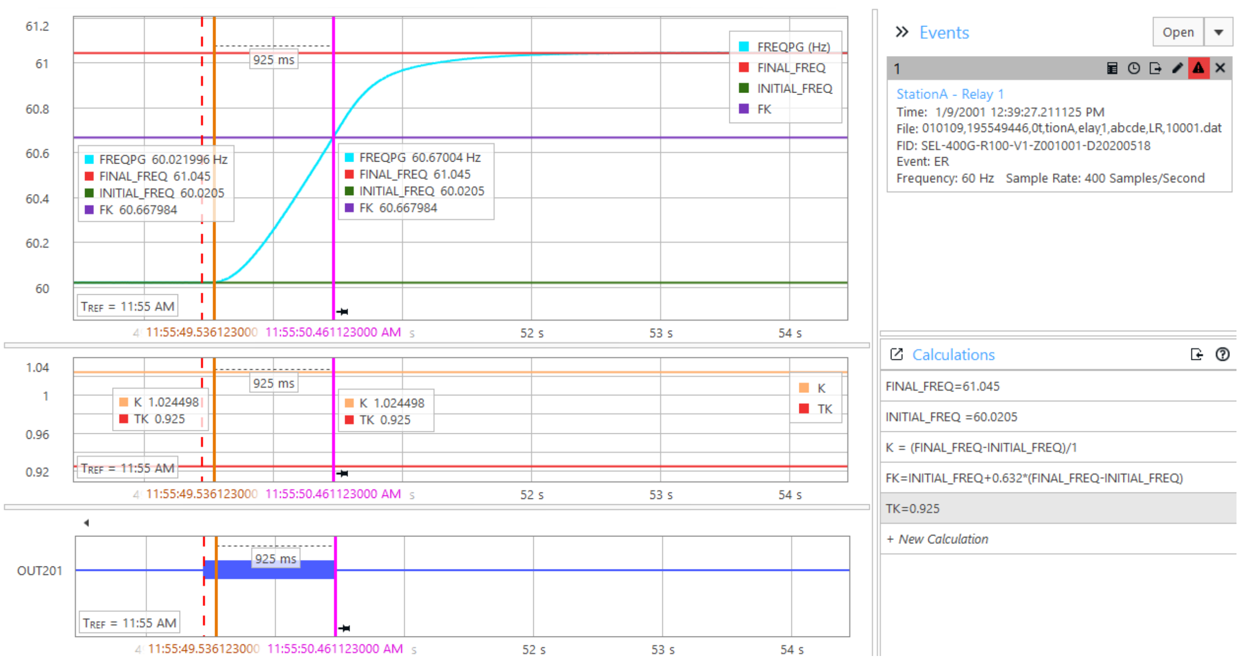


Figure 3.28 PULSE OUT201 Event Report

Step 5. Record K as 1.024 Hz/s and T as 0.925 s for this event.

Step 6. Repeat *Step 3* through *Step 5* three more times.

Step 7. Issue the **PULSE OUT202** command to cause a frequency lower pulse of 1-second duration.

Step 8. Issue the **FILE READ** command to retrieve the event report triggered by *Step 7* as shown in *Figure 3.29*.

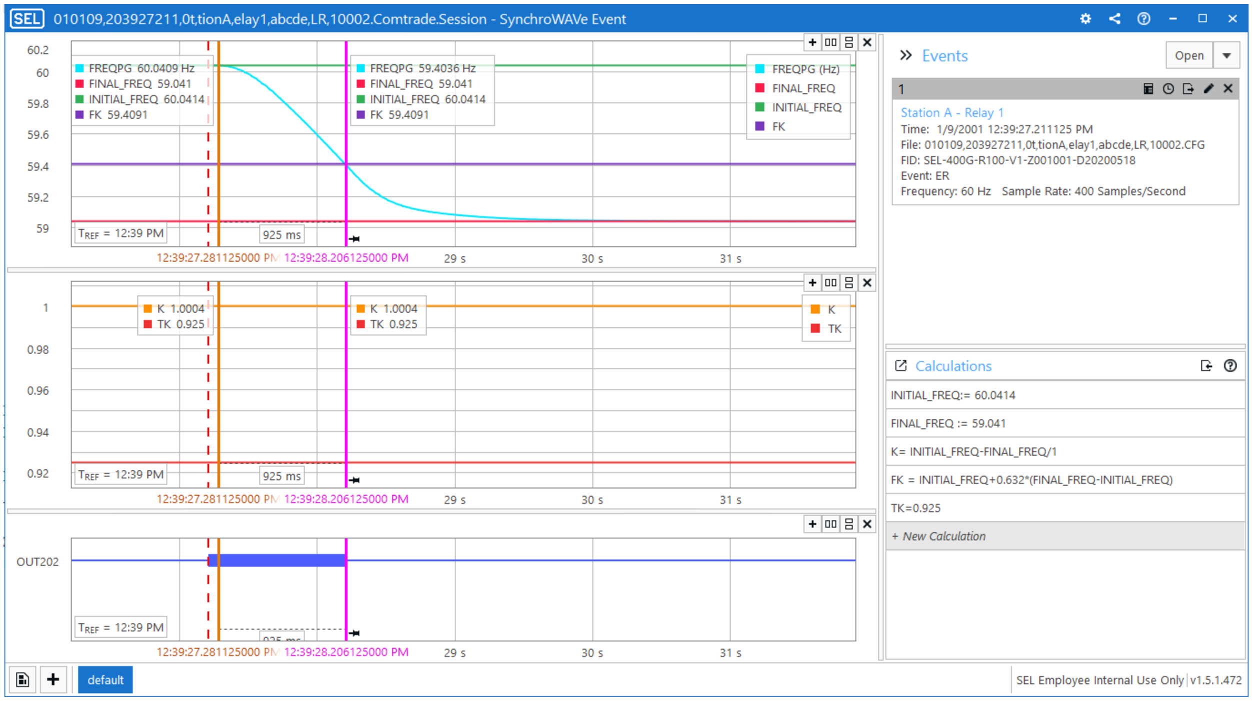


Figure 3.29 PULSE OUT202 Event Report

Step 9. Record K as 1 Hz/s and T as 0.925 s for this event.

Step 10. Repeat *Step 7* through *Step 9* three more times.

Step 11. Calculate K and T as the average of the eight events.

Step 12. Use *Table 5.61* to calculate the 25AFDUR, 25AFPER, and 25AFSLP settings.

Voltage Control Step Response Test

This procedure determines the gain and timer constant for a first-order equivalent representation of the AVR/exciter systems.

To carry out this procedure, place the **BREAKER** jumper on the main board of the SEL-400G in the **ON** position. This allows the **PULSE** command to be used to pulse the control outputs. Return this jumper to its original state when testing is completed.

Step 1. Go to Access Level 2.

Step 2. Issue the **MET SYN S 5** command. This will return the measurements associated with the Breaker S synchronism-check function. Five sets of measurements will be returned at a rate of approximately twice a second. Confirm that the voltage different (VDIFS) is stable and in the range of ±1.%.

Step 3. Issue the **PULSE OUT203** command to cause a voltage raise pulse of 1-second duration.

Step 4. Issue the **FILE READ** command to retrieve the event report triggered by *Step 3* as shown in *Figure 3.30*.

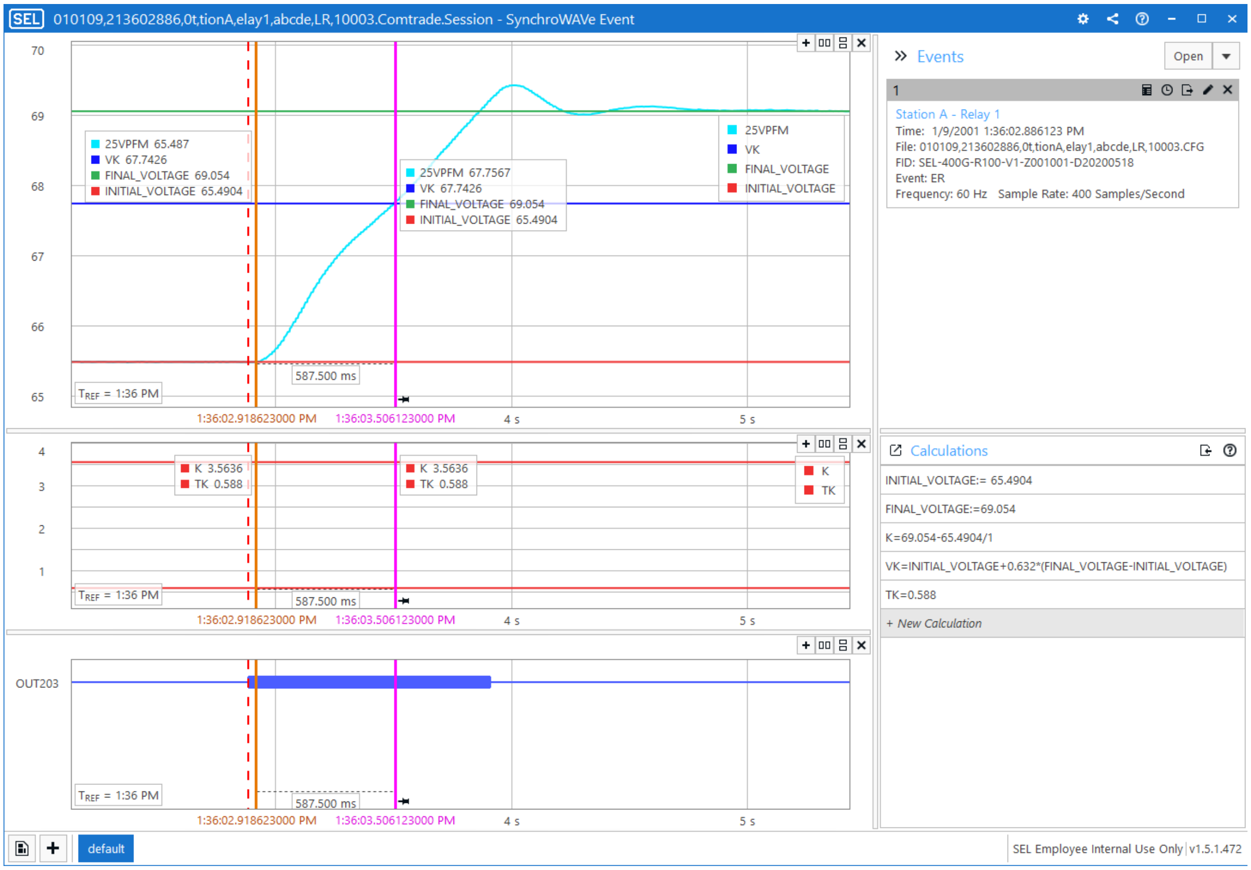


Figure 3.30 PULSE OUT203 Event Report

Step 5. Record K as 3.56 V/s and T as 0.588 s for this event.

Step 6. Repeat *Step 3* through *Step 5* three more times.

Step 7. Issue the **PULSE OUT204** command to cause a voltage lower pulse of 1-second duration.

Step 8. Issue the **FILE READ** command to retrieve the event report triggered by *Step 7*, as shown in *Figure 3.31*

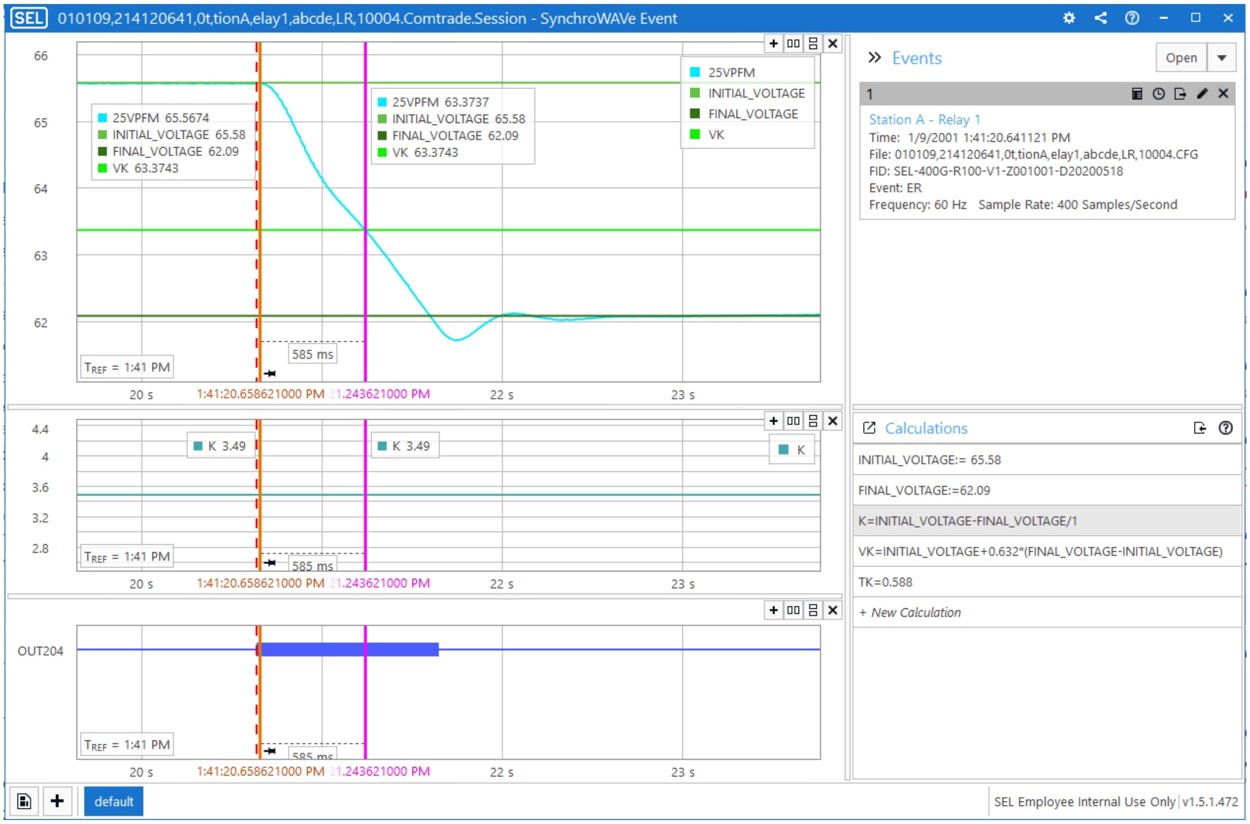


Figure 3.31 PULSE OUT204 Event Report

Step 9. Record K as 3.49 V/s and T as 0.588 s for this event.

Step 10. Repeat *Step 7* through *Step 9* three more times.

Step 11. Calculate K and T as the average of the eight events.

Step 12. Use *Table 5.61* to calculate the 25AVDUR, 25AVPER, and 25AVSLP settings.

Autosynchronizer Isolated Close Test

This test confirms operation of the autosynchronizer pulse control and synchronism-check functions.

We assume that the control pulse settings have been adjusted as required by the results from the frequency and voltage control step response tests.

The disturbance report will be used to capture the close operation by using the settings shown in *Table 3.37*.

Table 3.37 Disturbance Report Settings

EDR = Y	Enable the disturbance report
DRLER = 300	Set the record length to 300 seconds
DRPRE = 100	Set the predisturbance length to 100 seconds

The state of the system will be the same as that of previous tests. Namely, the generator must be offline and operating at nominal frequency and voltage, the frequency and voltage on the system-side of the breaker must be at nominal values, and the breaker closing circuit must be isolated from the breaker close coil to allow the relay to issue a close command without inadvertently closing the generator breaker.

Step 1. If possible, adjust the generator voltage and frequency to be outside the acceptance windows of the synchronism-check element.

Step 2. Use the **TAR** command to confirm that BSYNBKS is deasserted. This is a supervisory input that blocks a normal autosynchronization operation.

Step 3. Initiate an autosynchronization operation via the operator interface. Use the **TAR** command to confirm that 25AACT asserts immediately.

Step 4. The autosynchronization operation will terminate once the 25ACD timer expires. Use the **FILE READ** command to retrieve the disturbance report from *Step 3*. This report will be generated from the assertion of the CLSS Relay Word bit.

Step 5. From the report, confirm that 25AVR and/or 25AVL pulses were generated while the voltage difference was outside the synchronism-check voltage-difference acceptance window. Matching of voltage should occur in a reasonable time frame and with no tendency for hunting.

Step 6. From the report, confirm that 25AFR and/or 25AFL pulses were generated while the frequency difference was outside the synchronism-check slip acceptance window. Matching of frequency should occur in a reasonable time frame and with no tendency for hunting. Note in this example that the autosynchronizer is configured for biased operation.

Step 7. From the report, confirm that the 25CS asserted in advance of the generator and system coming into synchronism. The time of advance closing should agree with the measured slip and TCLSBK*n* setting.

Step 8. From the report, confirm that CFS asserts. This is expected because the breaker does not close for this test.

Step 9. Use the **SER** command to confirm that 25ASTO asserts and the scheme resets (25AACT deasserts). This is also expected since the breaker does not close for this test.

Synchronism-Check Final Phasing Confirmation

Prior to allowing the synchronism-check function to supervise breaker closing, it is critical to confirm the overall correctness of the phase relationships between the primary system and the secondary voltage circuits. This could, for instance, entail opening an upstream breaker and then closing the generator breaker to safely apply the generator voltages to both sides of the breaker. The secondary phasing can then be confirmed. Follow your company’s operating practices to make these final checks.

Autosynchronizer Final Close Test

On completion of all the preceding tests, the autosynchronizer can be used to carry out synchronized closing of the breaker.

The breaker closing circuit is connected to the breaker close coil to allow the relay to issue a close to the generator breaker.

Step 1. Initiate an autosynchronization operation via the operator interface.

Step 2. The autosynchronization operation will terminate when the breaker closes (assertion of 52CLS). Use the **FILE READ** command to retrieve the event report from *Step 1*. This report will be generated either from the assertion of the CLSS Relay Word bit or from the expiration of the 25ACD timer (25ASTO).

Step 3. From the report, confirm the making of the breaker primary contacts at the instant of the generator and system coming into synchronism. There may be some disturbance in the instantaneous voltages and currents because of pole scatter, but the effect should be minimal.

Step 4. From the report, confirm that CFS does not assert.

Step 5. Use the **SER** command to confirm that 25ASTO also does not assert.

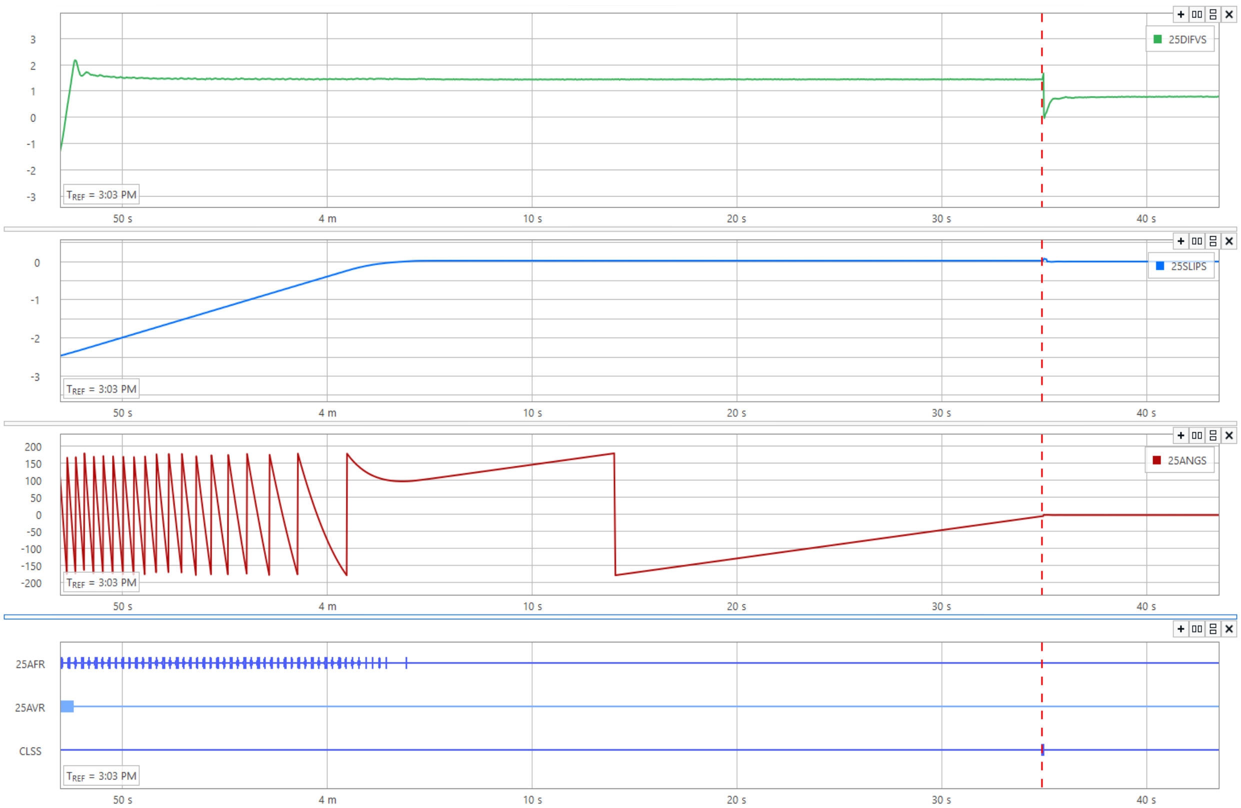


Figure 3.32 Close Test

Technical Support

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

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Fax: +1.509.332.7990
Internet: selinc.com/support
Email: info@selinc.com

SEL-400G Relay Commissioning Test Worksheet

System Information

System Settings

RID (Relay identification) =												
TID (Terminal identification) =												
MVA (Maximum transformer rating) =												
	Terminal S[a]		Terminal T[a]		Terminal U[a]		Terminal W[a]		Terminal X[a]		Terminal Y[a]	
Current transformer ratio:	CTRS =		CTRT =		CTRU =		CTRW =		CTRX =		CTRY =	
Connection compensation:	87SCTC*n* =		87TCTC*n* =		87UCTC*n* =		87WCTC*n* =		87XCTC*n* =		87YCTC*n* =	
Nominal line-to-line voltage (kV):	VTERMS*n* =		VTERMT*n* =		VTERMU*n* =		VTERMW*n* =		VTERMX*n* =		VTERMY*n* =	
TAP calculation:	87STAP*n* =		87TTAP*n* =		87UTAP*n* =		87WTAP*n* =		87XTAP*n* =		87YTAP*n* =	

[a] n = 1, 2.

Differential Settings

87P1*n* =		87SLP1*n* =		87SLP2*n* =		87UP*n* =	

Metered Load (Data taken from substation panel meters, not the SEL-400G)

± Readings from meters	Terminal S		Terminal T		Terminal U		Terminal W		Terminal X		Terminal Y	
Megawatts:	MWS =		MWT =		MWU =		MWW =		MWX =		MWY =	
MVARs:	MVARS =		MVART=		MVARU=		MVARW =		MVARX =		MVARY =	
MVA calculation:	MVAS =		MVAT =		MVAU =		MVAW =		MVAX =		MVAY =	

MVA calculation:

$$MVAn = \sqrt{MWn^2 + MVARn^2}$$

Calculated Relay Load

	Terminal S		Terminal T		Terminal U		Terminal W		Terminal X		Terminal Y	
Primary Amperes calculation:	ISpri =		ITpri =		IUpri =		IWpri =		IXpri =		IYpri =	
Secondary Amperes calculation:	ISsec =		ITsec =		IUsec =		IWsec =		IXsec =		IYsec =	

Primary amperes calculation:

$$\text{Inpri} = \frac{\text{MVAn} \bullet 1000}{\sqrt{3} \bullet \text{VTERMn}}$$

Secondary amperes calculation:

$$\text{In sec} = \frac{\text{Inpri}}{\text{CTRn}}$$

Connection Check

System load conditions should be higher than 0.1 A secondary. 0.5 A secondary is recommended for the best results.

Differential Connection (Issue MET DIF <Enter> to Serial Port or Front Panel)

Operate Current:	IOPA =		IOPB =		IOPC =	
Restraint Current:	IRTA =		IRTB =		IRTC =	
Mismatch Calculation:	MMA =		MMB =		MMC =	

Check individual current magnitudes, phase angles, and operate and restraint currents in an event report if mismatch is not less than 0.10.

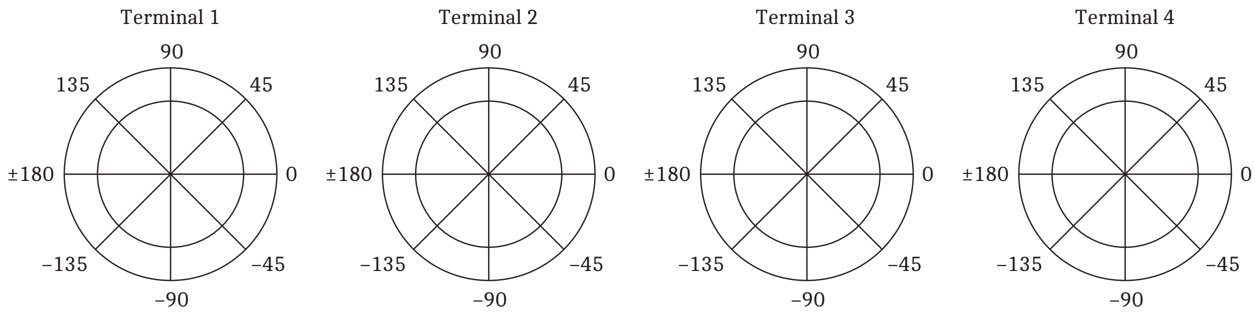
Mismatch calculation:

$$\text{MMn} = \frac{\text{IOPn}}{\text{IRTn}}$$

Magnitude, Angle, and Phase Rotation Check

Issue **MET SEC <Enter>** to the serial port or front panel.

	Terminal S		Terminal T		Terminal U		Terminal W		Terminal X		Terminal Y	
A-Phase Secondary Amperes:	IAS =		IAT =		IAU =		IAW =		IAX =		IAY =	
A-Phase Angle:												
B-Phase Secondary Amperes:	IBS =		IBT =		IBU =		IBW =		IBX =		IBY =	
B-Phase Angle:												
C-Phase Secondary Amperes:	ICS =		ICT =		ICU =		ICW =		ICX =		ICY =	
C-Phase Angle:												



1. Calculated relay amperes match MET SEC amperes?
2. Phase rotation is as expected for each terminal?
3. Do angular relationships among terminals correspond to expected results? (Remember that secondary current values for load current flowing out of a terminal will be 180° out-of-phase with the reference phase position for that terminal. The reason is that CT polarity marks normally face away from the transformer on all terminals.)

S E C T I O N 4

Front-Panel Operations

There are two prominent functions of the front panel, i.e., front-panel operations and the bay controller. This section describes the front-panel operations, and *Bay Control Front-Panel Operations on page 5.12 in the SEL-400 Series Relays Instruction Manual* describes the bay controller. Using the front panel, you can analyze power system operating information, view and change relay settings, collect power system data, and perform relay control functions. For ease of navigation, the front-panel menu is a straightforward menu driven control structure presented on the front-panel LCD. Front-panel targets and other LED indicators give a quick look at SEL-400G Advanced Generator Protection System operation status. You can perform often-used control actions rapidly by using the large direct-action pushbuttons. All of these features help you operate the relay from the front panel and include:

➤ Reading metering
➤ Inspecting targets
➤ Accessing settings
➤ Controlling relay operations

This section includes the following:

Front-Panel LCD Default Displays

The SEL-400G has two screen scrolling modes: autoscrolling and manual scrolling. After front-panel time-out, the relay enters the autoscrolling mode, and the LCD presents each of the display screens in this sequence:

➤ Any active (filled) alarm points screens
➤ Any active (filled) display points screens
➤ One-line diagrams
➤ Enabled metering screens

Table 4.1 through *Table 4.5* show the screens available for display on the front panel in the autoscrolling mode.

Table 4.1 Bay Control

Screen	Description
ONELINE	Bay Control screen

Table 4.2 RMS Quantities

Screen	Description
RMSZV	Generator line-to-line rms voltage screen
RMSGVI	Generator rms current and voltage screen

Table 4.3 Fundamental Quantities

Screen	Description
FUNVV	System fundamental line-to-line voltage, frequency, and VDC screen
FUNZV	Generator fundamental line-to-line voltage, frequency, and VDC screen
FUN1VV	Fundamental single-phase voltage screen
FUN*m*VI[a]	Terminal *m* fundamental phase current and voltage screen
FUN1YI	Fundamental single-phase current screen
FUN*m*SQ[a]	Terminal *m* fundamental sequence voltage and current screens
FUN*m*PQ[a]	Terminal *m* fundamental real (P) and reactive (Q) screen
FUN*m*VA[a]	Terminal *m* fundamental apparent power and power factor screen

[a] m = S, T, U, Y, G.

Table 4.4 Energy Quantities

Screen	Description
ENRMET*m*[a]	Terminal *m* energy screen

[a] m = S, T, U, Y, G.

Table 4.5 Differential Quantities

Screen	Description
DIFFMET	Differential quantities screen

Table 4.6 Stator Ground Quantities

Screen	Description
STRGNDM	Stator ground meter screen

Table 4.7 Insulation

Screen	Description
INSMET	Stator and field insulation resistance and capacitance meter screen

Use the front-panel settings (the **SET F RDD** command from a communications port or the Front Panel settings in SEL Grid Configurator Software) to select which screens to enable. Enter each of the screens you need on a separate line. The relay will display the screens in the sequence that you enter. *Figure 4.1* shows a sample ROTATING DISPLAY consisting of an example alarm points screen (see *Alarm Points on page 4.7 in the SEL-400 Series Relays Instruction Manual*), an example display points screen (see *Display Points on page 4.10 in the SEL-400 Series Relays Instruction Manual*), and the metering screen FUNGVI (see *Table 4.2*).

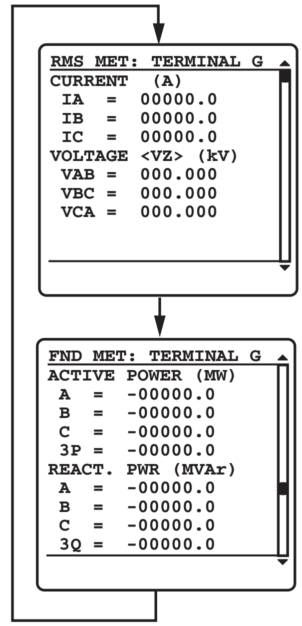


Figure 4.1 Sample ROTATING DISPLAY

Front-Panel Menus and Screens

Operate the SEL-400G front panel through a sequence of menus that you view on the front-panel display. The `MAIN MENU` is the introductory menu for other front-panel menus. These additional menus allow you onsite access to metering, control, and settings for configuring the SEL-400G to your specific application needs. Use the following menus and screens to set the relay, perform local control actions, and read metering:

- Support Screens
  - `Contrast`
  - `Password`
- `MAIN MENU`
  - `METER`
  - `EVENTS`
  - `BREAKER MONITOR`
  - `RELAY ELEMENTS`
  - `LOCAL CONTROL`
  - `SET/SHOW`
  - `RELAY STATUS`
  - `VIEW CONFIGURATION`
  - `DISPLAY TEST`
  - `RESET ACCESS LEVEL`
  - `ONELINE DIAGRAM`

See *Section 4: Front-Panel Operations in the SEL-400 Series Relays Instruction Manual* for information on most of these screens. The following screen descriptions are unique to the SEL-400G.

Meter

The SEL-400G displays metering screens on the LCD. Highlight METER on the MAIN MENU screen to select these screens. The METER MENU, shown in *Figure 4.2*, allows you to choose the following metering screens corresponding to the relay metering modes:

- RMS METER
- FUNDAMENTAL METER
- DEMAND METER
- ENERGY METER
- METER MIN/MAX
- SYNCHRONOUS CHECK
- DIFFERENTIAL METER
- STATOR GROUND METER
- INSULATION METER

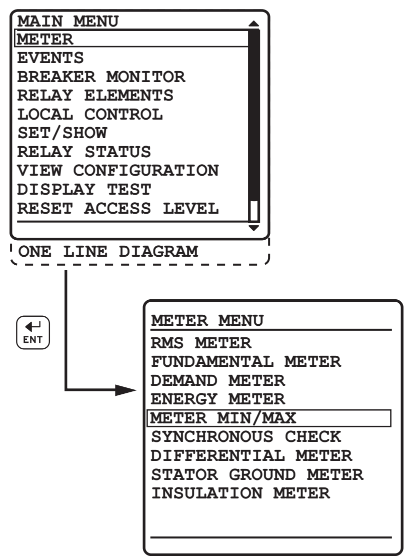


Figure 4.2 METER Menus

Figure 4.2 shows the nine categories of meter screens available in the SEL-400G. *Table 4.8* summarizes the conditions under which these categories are displayed and also states how the FTSRC*m* (*m* = S, T, U, W, X, Y), PTCON*k* (*k* = V, Z), CTCONY, EPCAL, ESYSPT, and ESYSCT settings influence the displays.

Table 4.8 Meter Availability Conditions (Sheet 1 of 2)

Meter	Dependencies
RMS Meter	None
Fundamental Meter	None
Demand Meter	EDEM ≠ N
Energy Meter	None
Meter Min/Max	EMXMN ≠ N
Synchronous Check	E25 ≠ OFF
Differential Meter	E87 ≠ N
Stator Ground Meter	E64G ≠ OFF
Insulation Meter	E64S ≠ N and E64F ≠ N

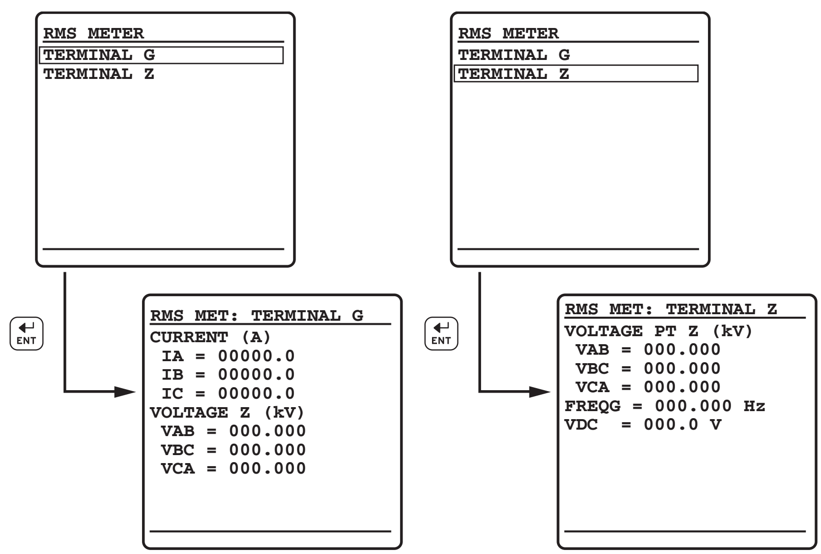
Table 4.8 Meter Availability Conditions (Sheet 2 of 2)

Meter	Dependencies
FTSRC*m*[a]	Voltage Terminal Z is associated with Current Terminal *m* when FTRC*m* = G.
ESYSPT	Voltage Terminal V is associated with Current Terminal *m* when FTRC*m* = S and ESYSPT = V. Voltage Terminal Z is associated with Current Terminal *m* when FTSRC*m* = S and ESYSPT ≠ V.
ESYSCT	Fundamental metering screens are shown only for terminals included in the ESYSCT setting. Terminal G screens are always shown.
EPCAL	Power and energy screens are shown only for terminals included in the EPCAL setting. Terminal G screens are always shown.
PTCON*k*[b]	Zero-sequence voltage is available when PTCON*k* = Y. Single-phase voltages are available when PTCON*k* = 1PH.
CTCONY	Single-phase currents are available when CTCONY = 1PH.

[a] If CTCONY = 1PH, m = S, T, U, W, X. If CTCONY = Y, m = S, T, U, W, X, Y.
[b] k = V, Z.

RMS Meter

To view the rms meter values, select METER from the main menu and press **ENT**, then press **ENT** with RMS METER highlighted. This shows the screen with the TERMINAL G and TERMINAL Z options. With TERMINAL G highlighted, press **ENT** to see the generator currents and voltages, as shown in *Figure 4.3(A)*. With TERMINAL Z highlighted, press **ENT** to see the generator line-to-line voltages, as shown in *Figure 4.3(B)*.



(A) (B)

Figure 4.3 RMS Metering Screens

Fundamental Meter

The fundamental meter provides a phase voltage and current screen. As well as sequence component, active, reactive, and apparent power screens as shown in *Figure 4.4*. *Figure 4.4(b)* shows the fundamental metering screen for Terminal S.

Notice that the fundamental meter includes the angular relationships, using the positive-sequence voltage of Terminal Z as reference. Press the down arrow to move to the Terminal S sequence screen. This screen shows the positive, negative, and zero-sequence voltage and currents for Terminal S. Zero-sequence voltages are not shown when the PTs are connected in delta. Press the down arrow to move to Screens *(d)* and *(e)*. They show the fundamental real, reactive and apparent power, and the power factors.

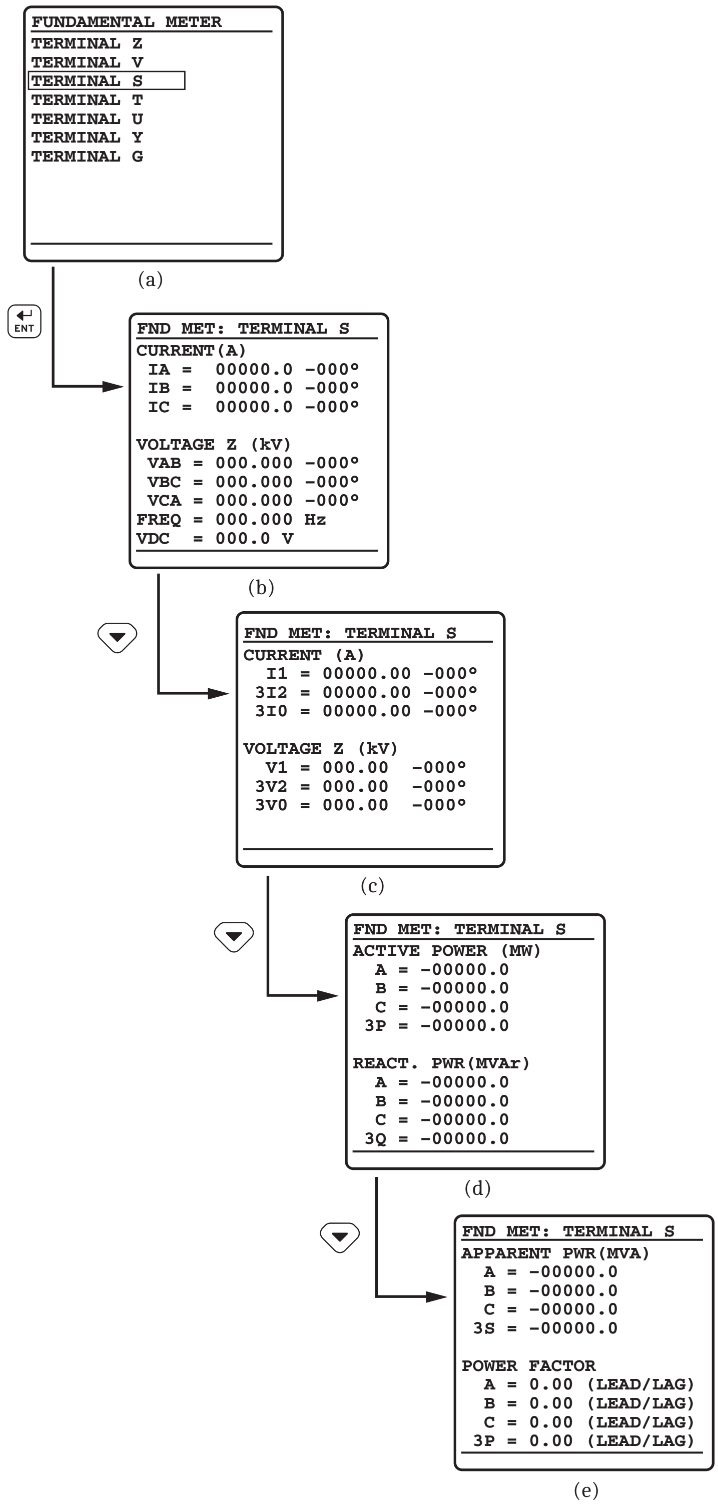


Figure 4.4 Fundamental Metering Screens

Figure 4.5 shows the single-phase currents for Terminal Y when CTCONY = 1PH.

```
FND MET: TERMINAL Y
CURRENT (A)

IY1 = 00000.0  -000°
IY2 = 00000.0  -000°
IY3 = 00000.0  -000°
```

Figure 4.5 Fundamental Terminal Y Single-Phase Screen

Figure 4.6 shows the single-phase voltages for Terminal V when PTCONV = 1PH.

```
FND MET: TERMINAL V
VOLTAGE PT V (kV)
 VV1 = 000.000  -000°
 VV2 = 000.000  -000°
 VV3 = 000.000  -000°
```

Figure 4.6 Fundamental Terminal V Single-Phase Screen

Demand Meter

In the SEL-400G, the demand meter operate quantities are not fixed. Instead of fixed operating quantities, select a suitable operating quantity (see *Section 12: Analog Quantities*) for each of the 10 demand elements (see *Demand Meter on page 7.8* for more information).

Because you can select the number of demand elements, there will be either one or two sets of demand meter screens. If you select five or fewer demand elements, then there is only one screen; for greater than five demand elements, there are two screens. *Figure 4.7* shows the demand screens. Screen *(A)* shows the selected demand element operating quantities (a second screen is shown only if more than five operating quantities are selected). Also, each operating quantity can be either a rolling or a thermal calculation. This selection is shown by `ROLL PK` or `THERM PK` following the operating quantity in Screen *(A)*. Screen *(B)* and Screen *(C)* show reset options for demand and maximum demand quantities. Use the left arrow and right arrow pushbuttons to select a `NO` or `YES` response to the reset prompt, and then press **ENT** to reset all of the metering quantities.

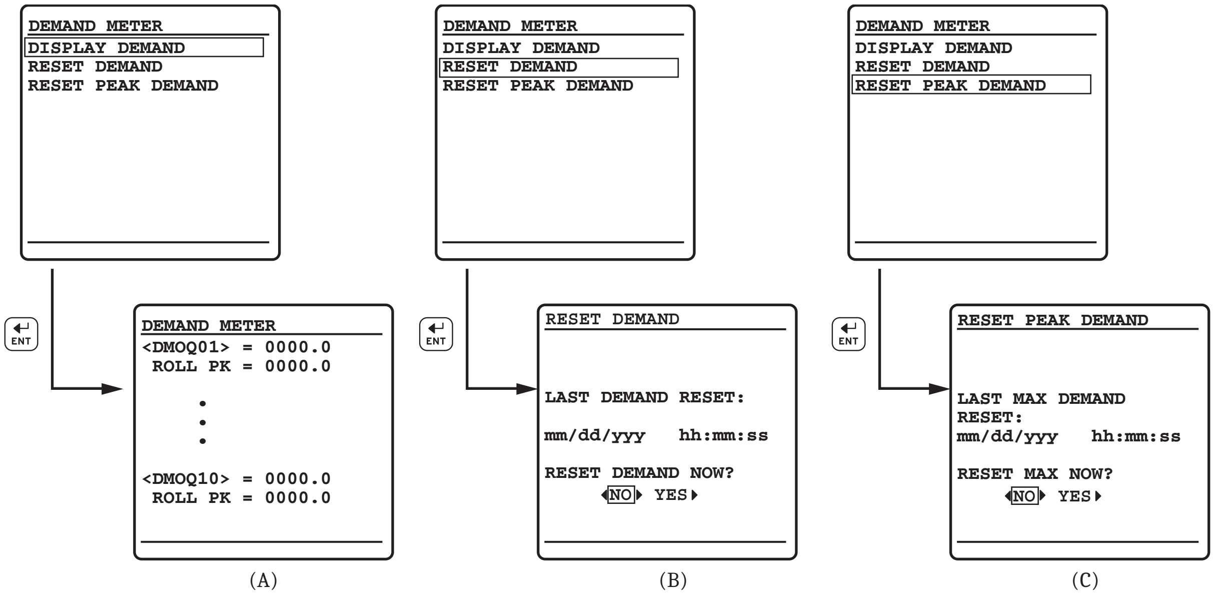


Figure 4.7 Demand Meter Screens

Energy Meter

Energy metering screens follow the demand meter screens. *Figure 4.8(A)* shows the screen for Terminal S, *Figure 4.8(B)* the energy reset screen. Use the left arrow and right arrow pushbuttons to select a NO or YES response to the reset prompt, and then press **ENT** to reset all of the metering quantities.

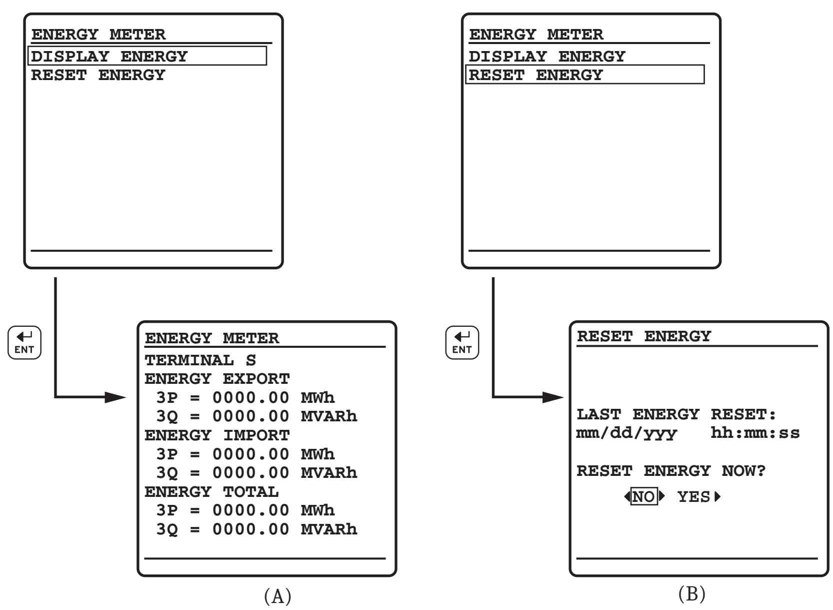


Figure 4.8 Energy Meter Screens

Min/Max Meter

In the SEL-400G, the min/max meter operate quantities are not fixed. Instead of fixed operating quantities, select a suitable operating quantity (see *Section 12: Analog Quantities*) for each of the 30 min/max elements (see *Metering on page 7.2* for more information).

Because you can select the number of demand elements, there will be as many as 30 meter min/max screens. *Figure 4.9(A)* shows the selected min/max element operating quantity, the minimum and maximum values and associated time-stamps. *Figure 4.9(B)* is for resetting. Use the left arrow and right arrow pushbuttons to select a NO or YES response to the reset prompt, and then press **ENT** to reset the minimum and maximum values.

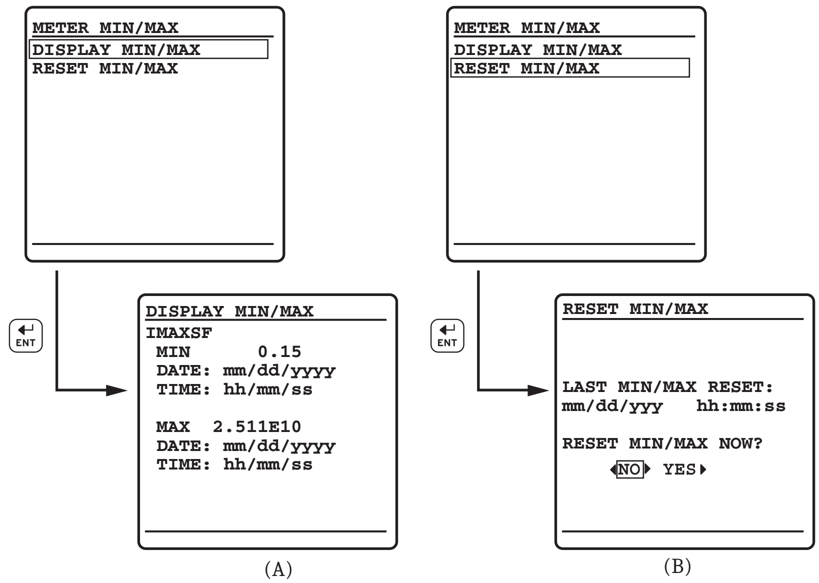


Figure 4.9 Min/Max Meter Screens

Synchronous Check Meter

Following the meter min/max screens are the synchronous check meter screens. The SEL-400G provides a synchronism check element for each breaker (S, T, U, and Y), and a screen is provided for each enabled element as shown in *Figure 4.10(A)*.

The screen of *Figure 4.10(B)* shows the status of the breaker (open or closed) according to the 52CL*n* status. Also shown is the magnitude of the generator voltage (VPFM), the system voltage (VSFM), the percentage voltage difference (DIFV), the angle difference (ANG), the frequency difference (SLIP), and the generator and system frequencies (FREQG and FREQS).

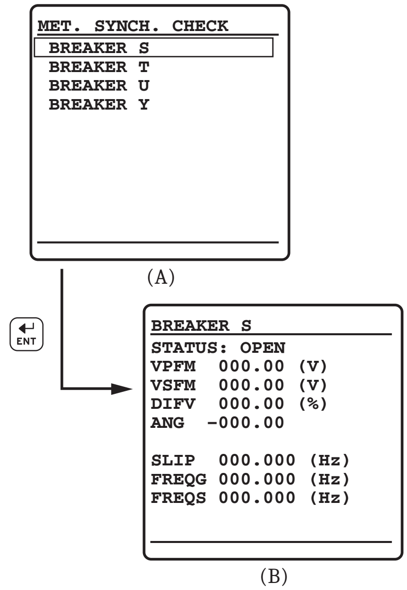


Figure 4.10 Synchronous Check Meter Screens

Differential Meter

Differential operate and restraint current are metered for each enabled zone, as shown in *Figure 4.11*. The SEL-400G provides a differential metering screen for two possible zones, according to the E87 setting.

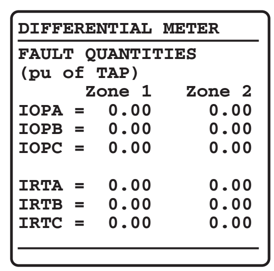


Figure 4.11 Differential Meter Screen

Stator Ground Meter

The SEL-400G provides a stator ground metering screen, as shown in *Figure 4.12*, to monitor the protection analogs used in the stator ground element. See *One Hundred Percent Stator Ground Elements on page 5.62* for more information. *Table 4.9* summarizes the setting prerequisites for some of the ground metering quantities.

Table 4.9 Stator Ground Metering Quantity Visibility Conditions

Metering Quantity	Prerequisite
VN	E64G includes G1
VN3, VG3, and V3DIF	E64G includes G2 or G3
Polarity Check[a]	(E64G includes G2 or G3) and PTCONZ ≠ D

[a] Polarity Check = OK when 64GAAL is deasserted and FAIL when 64GAAL is asserted. See Third-Harmonic Voltage Elements (64G2 and 64G3) on page 5.65 for more information on 64GAAL.

```
STATOR GROUND METER
VOLTAGE (kV)
VN      0.00      0.0°
VN3     0.00      0.0°
VG3     0.00      0.0°
3V03    0.00      0.0°

V3DIF    0.00  (V,sec)
V3RAT    0.000 (pu)

POLARITY CHECK OK
```

Figure 4.12 Stator Ground Meter Screen

Insulation Meter

Insulation metering is the final front-panel display screen. The SEL-400G provides stator and field insulation metering, as shown in *Figure 4.13*, which displays the measured insulation resistances, stator insulation capacitance, and measurement quality.

```
INSULATION METER
STATOR:
 RES.       0.00 (kΩ)
 CAP.       0.00 (uF)
 QUAL.       OK

FIELD:
 RES.       0.00 (kΩ)
 QUAL.       OK
```

Figure 4.13 Insulation Meter Screen

Events

The SEL-400G front panel features summary event reporting, which simplifies post-fault analysis. These summary event reports include the items shown in *Table 4.10*.

Table 4.10 Event Elements

Event	Description
87 ZONE 1, 87 ZONE 2, REF	Differential elements involvement for event reports generated by 87A, 87B, or 87C of Zones 1 and 2. REF is the OR combination of REFF1, REFF2, and REFF3
EX TRIP	Rising edge of TRIPEX (Excitation TRIP)
PM TRIP	Rising edge of TRIPPM (Prime Mover TRIP)
AUX TRIP	Rising edge of TRIPAUX
TRIP	Rising edge of Relay Word bit TRIP
ER (event report trigger)	Rising edge of ER (SELOGIC control equation)
TRIG	Execution of the **TRIGGER** (**TRI**) command (manually triggered)

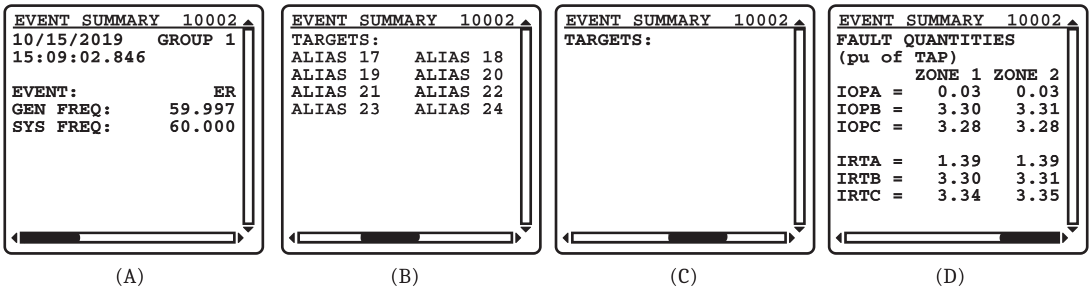


Figure 4.14 EVENT SUMMARY Screen

To assist with fault analysis, the SEL-400G displays the targets that asserted during the event on the front panel. Use the right arrow pushbutton to move from Screen *(A)* to Screen *(B)* in *Figure 4.14*. There are 24 alias items (ALIAS 01 through ALIAS 24), one for each of the front-panel LEDs. Use the **SET T** command to enter alias settings for Relay Word bits TLED_1 through TLED_24. If no alias is defined for a particular TLED_*x* (*x* = 1 through 24), then the TLED_*x* Relay Word bit name is displayed. Also, if the particular TLED_*x* target is not set to be a tripping target, (i.e., T*x*LEDL setting is N), then it is not displayed. *Figure 4.14(D)* shows the differential quantities for the event.

Breaker Monitor

The SEL-400G features an advanced circuit breaker monitor. Select BREAKER MONITOR screens from the MAIN MENU to view circuit breaker monitor alarm data on the front-panel display. *Figure 4.15* shows the case where Monitor setting EBMON = S T U, i.e., three breakers are enabled. (If only one breaker is enabled [e.g., EBMON = S], then *Figure 4.15(b)* is not shown, and *Figure 4.15(c)* appears directly). Use the navigation pushbuttons to choose between BREAKER S, BREAKER T, or BREAKER U. Press **ENT** to view the selected circuit breaker monitor information, as shown in *Figure 4.15(c)*. The BKR n ALARM COUNTER screen displays the number of times the circuit breaker exceeded certain alarm thresholds (see *Circuit Breaker Monitor on page 7.18*).

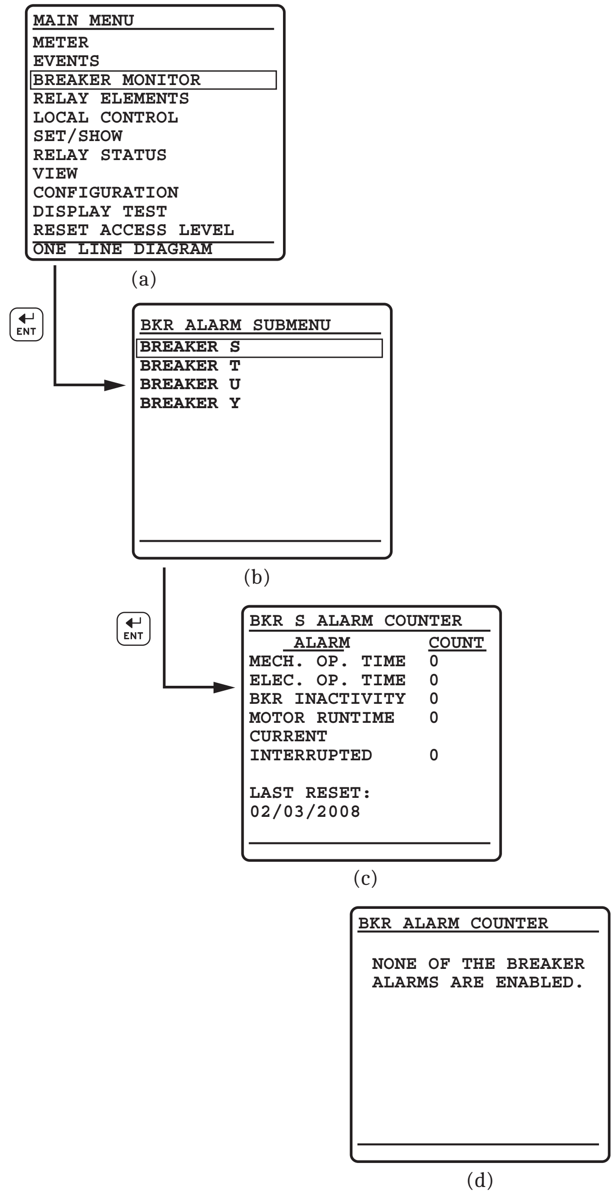


Figure 4.15 BREAKER MONITOR Report Screens

Figure 4.15(d) shows the screen when no breaker monitors are enabled (EBMON = OFF).

View Configuration

You can use the front panel to view detailed information about the configuration of the firmware and hardware components in the SEL-400G. In the MAIN MENU, highlight the VIEW CONFIGURATION option by using the navigation pushbuttons and press **ENT**. The relay presents seven screens in the order shown in *Figure 4.16*. Use the navigation pushbuttons to scroll through these screens. When finished viewing these screens, press **ESC** to return to the MAIN MENU.

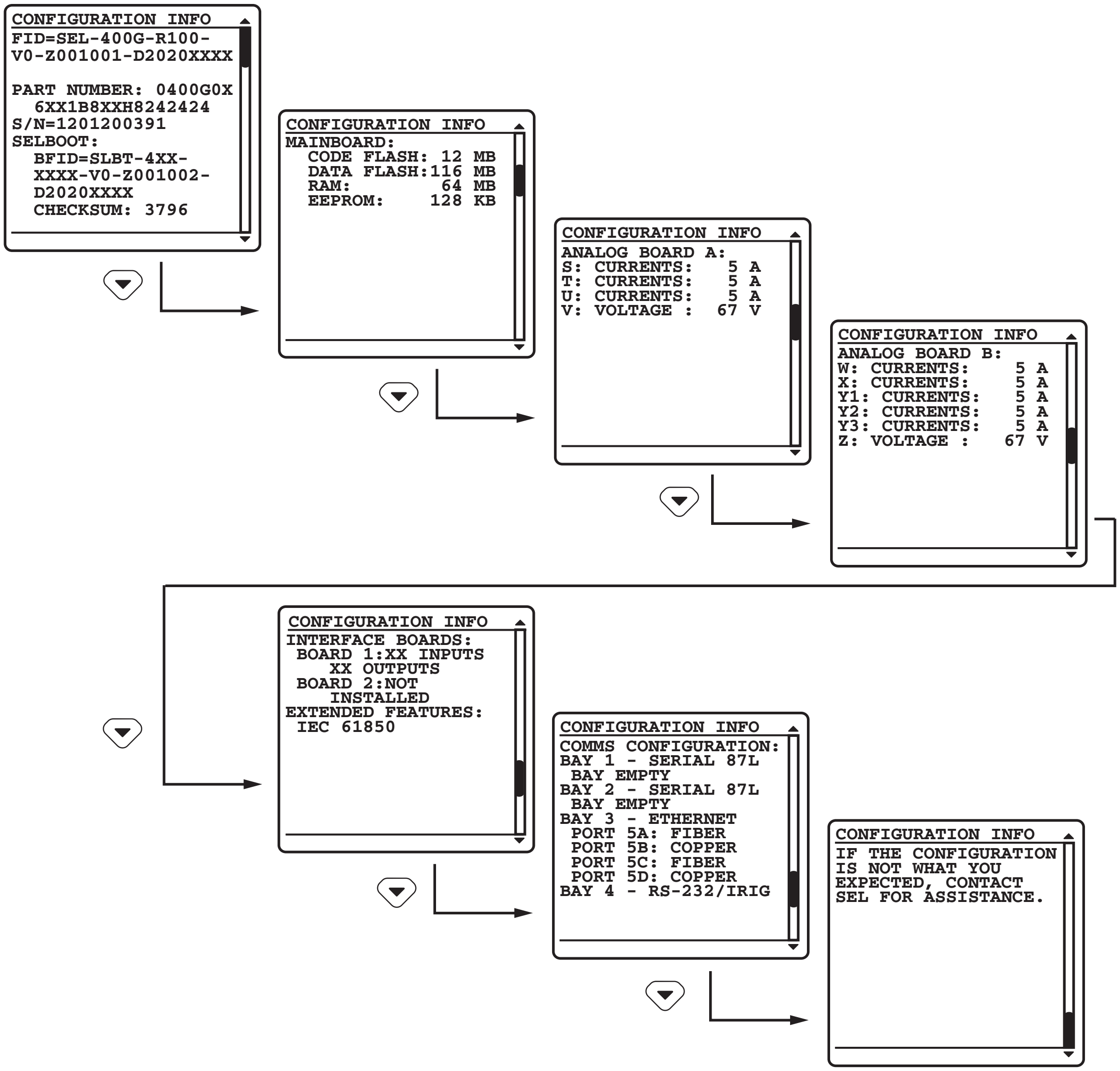


Figure 4.16 VIEW CONFIGURATION Sample Screens

Target LEDs

The SEL-400G gives you at-a-glance confirmation of relay conditions via 24 color-programmable operation and target LEDs, located in the middle of the relay front panel, as shown in *Figure 4.17*. To provide clear visual indication, choose between red and green for the **ENABLED** and **TRIP** LED colors. For the remaining LEDs, choose among red, green, or amber.

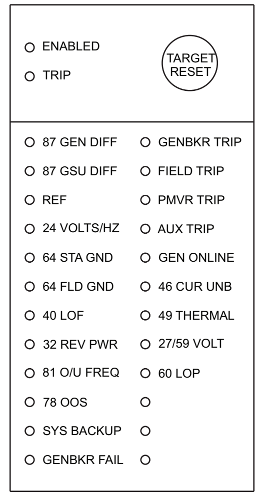


Figure 4.17 Factory-Default Front-Panel Target LEDs

A description of the general operation and configuration of these LEDs is provided in *Section 4: Front-Panel Operations in the SEL-400 Series Relays Instruction Manual*. Note that the SEL-400G has alternative behavior on the T*n*_LED bits: they latch independent of the trip condition.

Table 4.11 shows the LED labels (top to bottom in *Figure 4.17*) and the actual settings.

Table 4.11 LED Settings

LED Label	Settings	Comment
87 GEN DIFF	87Z1	Zone 1 differential element asserted
87 GSU DIFF	87Z2	Zone 2 differential element asserted
REF	REF	Restricted earth fault
24 VOLTS/HZ	24D1T1 OR 24D2T1	Volts/hertz
64 STA GND	64GT	Stator ground element asserted
64 FLD GND	64F1T OR 64F2T	Field ground element asserted
40 LOF	40Z1T OR 40Z2T OR 40P1T OR 40P2T	Loss-of-field element asserted
32 REV PWR	32T01	Directional power Element 1 asserted
81 O/U FREQ	81D1T OR 81D2T OR 81D3T OR 81D4T OR 81D5T OR 81D6T	Over- or underfrequency element asserted
78 OOS	78OST	Out-of-step detected
SYS BACKUP	51CT OR 51VT OR 21PZ1T OR 21PZ2T	Backup protection element asserted
GENBKR FAIL	FBFS	Breaker failure, Terminal S
GENBKR TRIP	TRIPS	Trip logic asserted, Terminal S
FIELD TRIP	TRIPEX	Generator exciter trip
PMVR TRIP	TRIPPM	Generator prime mover trip
AUX TRIP	TRIPAUX	Generator auxiliary trip
GEN ONLINE	ONLINE	Generator online logic asserted
46 CUR UNB	46Q1T1 OR 46Q1T2 OR 46Q2T1 OR 46Q2T2	Current unbalance element asserted
49 THERMAL	THRLT1 OR THRLT2 OR THRLT3	IEC thermal element asserted
27/59 VOLT	271P1T OR 591P1T	Over- or undervoltage element asserted
60 LOP	LOPZ	Loss of potential, Terminal Z

You can reprogram all of these indicators except the **ENABLED** and **TRIP** LEDs to reflect other operating conditions than the factory-default programming described in this section. Settings T*n*_LED are SELOGIC control equations that, when asserted during a relay trip event, light the corresponding LED. Parameter *n* is a number from 1 through 24 that indicates each LED.

Program settings T*n*LEDL := Y to latch the LEDs when the T*n*_LED SELOGIC control equation is true, regardless of the status of TRIP. The LEDs will reset with a subsequent **TRIP** or a **TARGET RESET** via the front panel or the **TAR R** command. When you set T*n*LEDL := N, the trip latch supervision has no effect and the LED follows the state of the T*n*_LED SELOGIC control equation. The relay reports these targets in event report summaries. The asserted and deasserted colors for the LED are determined with settings T*n*LEDC. Options include red, green, amber, or off.

After setting the target LEDs, issue the **TAR R** command or press the **TARGET RESET** button on the front panel to reset the target LEDs.

Use the slide-in labels to mark the LEDs with custom names. Download the word processor configurable label templates for printing slide-in labels from selinc.com.

Front-Panel Operator Control Pushbuttons

The SEL-400G front panel features large operator control pushbuttons coupled with color-programmable annunciator LEDs for local control. *Figure 4.18* shows this region of the relay front panel with configurable front-panel labels.

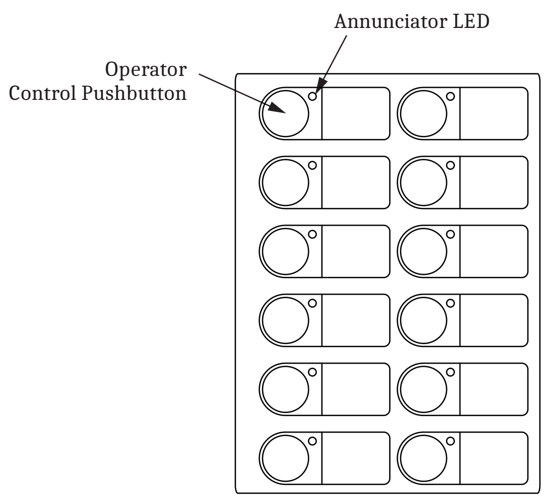


Figure 4.18 Operator Control Pushbuttons and LEDs

There are two ways to program the operator control pushbuttons. The first is through front-panel settings PB*nn*_HMI (*nn* = 1–12). These settings allow any of the operator control pushbuttons to be programmed to display a particular HMI screen category. The HMI screen categories available are Alarm Points, Display Points, Event Summaries, SER, and Bay Control. Front-panel setting NUM_ER allows the user to define the number of event summaries that are displayed via the operator control pushbutton; it has no effect on the event summaries automatically displayed or the event summaries available through the main menu. Each HMI screen category can be assigned to a single pushbutton.

Attempting to program more than one pushbutton to a single HMI screen category will result in an error. After assigning a pushbutton to an HMI screen category, pressing the pushbutton will jump to the first available HMI screen in that particular category. If more than one screen is available, a navigation scroll bar will be displayed. Pressing the navigation arrows will scroll through the available screens. Subsequent pressing of the operator control pushbutton will advance through the available screens, behaving the same as the right arrow or down arrow pushbutton. Pressing the **ESC** pushbutton will return the user to the ROTATING DISPLAY. The second way to program the operator control pushbutton is through SELOGIC control equations, using the pushbutton output as a programming element.

Using SELOGIC control equations, you can readily change the default LED functions. Use the slide-in labels to mark the pushbuttons and pushbutton LEDs with custom names to reflect any programming changes that you make. The labels are keyed; you can insert each Operator Control Label in only one position on the front of the relay. Download the word processor configurable label templates for printing slide-in labels from selinc.com. See the instructions included in the Configurable Label kit for more information on changing the slide-in labels.

The SEL-400G has two types of outputs for each of the front-panel pushbuttons. Relay Word bits represent the pushbutton presses. One set of Relay Word bits follows the pushbutton and another set pulses for one processing interval when the button is pressed. Relay Word bits PB1–PB12 are the “follow” outputs of operator control pushbuttons. Relay Word bits PB1_PUL–PB12PUL are the pulsed outputs.

Annunciator LEDs for each operator control pushbutton are PB1_LED–PB12LED. The asserted and deasserted colors for the LED are determined with settings PB*nn*COL. Options include red, green, amber, or off. You can change the LED indications to fit your specific control and operational requirements. This programmability allows great flexibility and provides operator confidence and safety, especially in indicating the status of functions that are controlled both locally and remotely.

One-Line Diagrams

One-line diagrams are fully explained in *Section 5: Control in the SEL-400 Series Relays Instruction Manual*. The SEL-400G supports as many as ten scrollable single-line diagrams from the HMI, with the first single-line diagram appearing in the rotating display.

By using Grid Configurator, you can include the bay control screens in the rotating display. Select ONELINE (found under Front Panel settings), selectable screens, as shown in *Figure 4.19*.

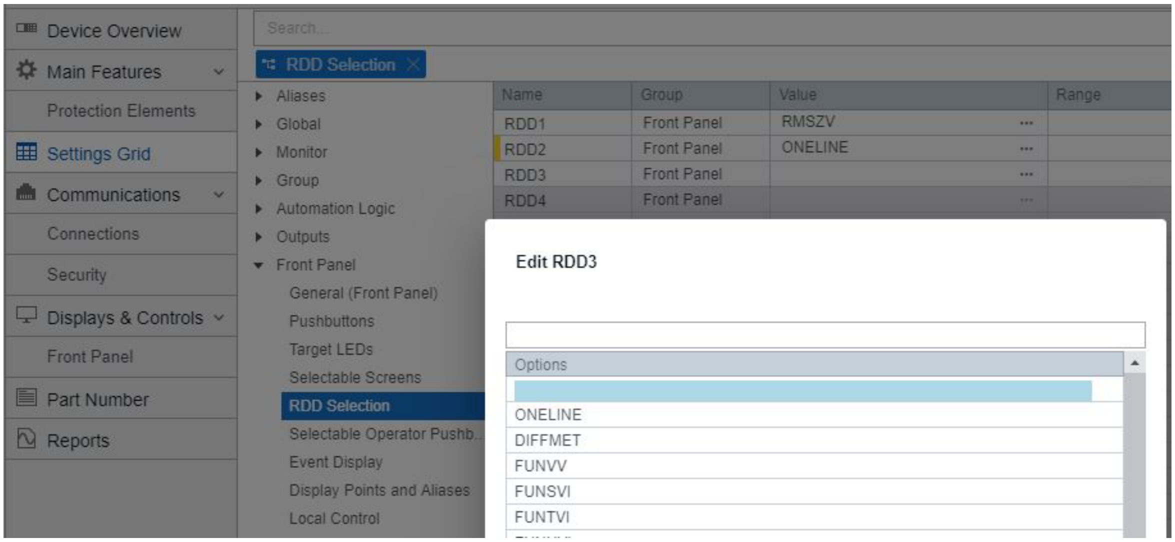


Figure 4.19 Bay Control Screen Selected for Rotating Display

You can also configure an HMI pushbutton to give you direct access to the bay control screen. *Figure 4.20* shows an example of how to configure HMI Pushbutton 3 to provide this access by selecting the BC option from the drop-down menu.

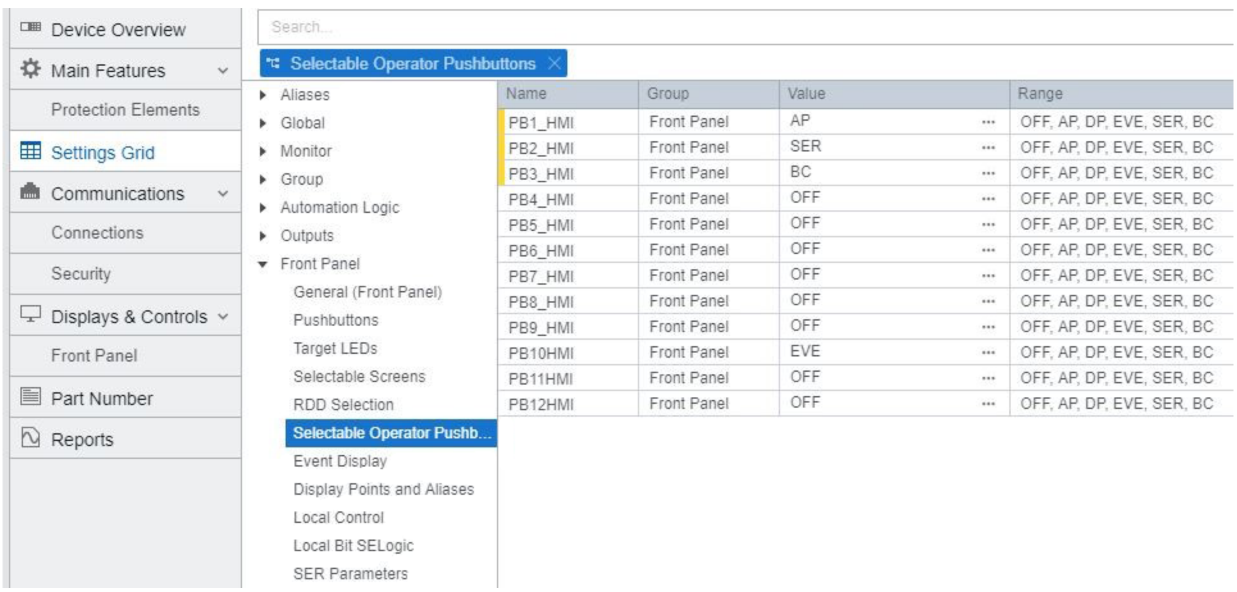


Figure 4.20 Configuring PB1_HMI for Direct Bay Control Access

Panning

When you specify a custom layout that is too large for one screen, you can take advantage of the panning feature to display sections not visible in the present screen view. *Figure 4.21* and *Figure 4.22* show an example station with a breaker-and-a-half application.

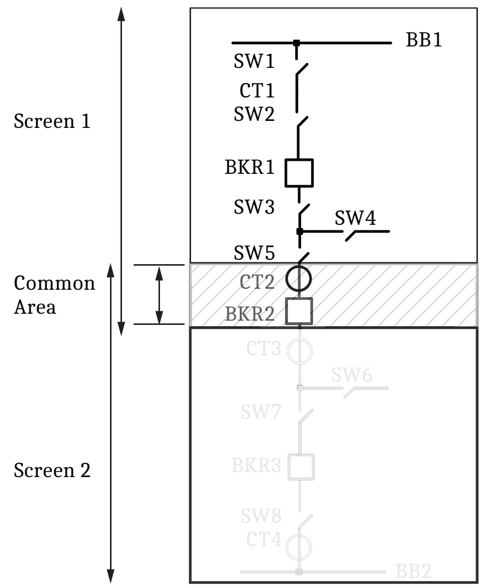


Figure 4.21 Screen 1

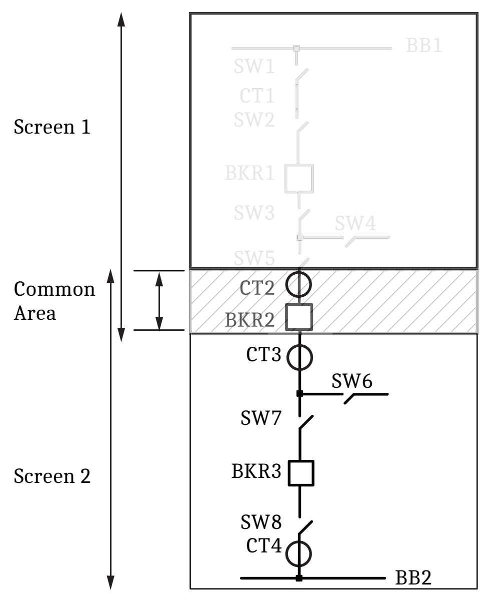


Figure 4.22 Screen 2

Panning is discontinuous and necessitates your toggling between two front-panel screens.

- ➤ Screen 1 plus the common area (*Figure 4.21*)
- ➤ Screen 2 plus the common area (*Figure 4.22*)

When you specify a custom screen, be sure to separately specify these three areas.

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SECTION 5

Protection Functions

This section provides a detailed explanation of the SEL-400G Advanced Generator Protection System protection functions. Each section provides an explanation of the function, along with a list of the corresponding settings and Relay Word bits. Logic diagrams and other figures are included. The following functions are discussed in this section:

NOTE: Each SEL-400G is shipped with default factory settings. Calculate the settings for your application to ensure secure and dependable protection. Document and enter the settings (see Section 8: Settings).

➤ *Injection-Based Stator Ground Protection on page 5.192*
➤ *Over- and Undervoltage Elements on page 5.195*
➤ *Overcurrent Elements on page 5.199*
➤ *Selectable Time-Overcurrent Element on page 5.206*
➤ *Trip Logic on page 5.219*
➤ *Close Logic on page 5.221*

Application Data

It is faster and easier for you to calculate the settings for the SEL-400G if you collect the following information before you begin:

- ➤ Generator/transformer data
- ➤ System phase rotation and nominal frequency
- ➤ Highest expected load current
- ➤ Current transformer primary and secondary ratings and connections
- ➤ Voltage transformer ratios and connections,
- ➤ Type and location of resistance temperature devices (RTDs), if used
- ➤ Expected fault current magnitudes for ground and three-phase faults

Inverting Polarity of Current and Voltage Inputs

The relay can change the polarity of the CT and PT inputs. This ability allows the user to change CT and PT polarity digitally to correct for incorrect wiring to the input on the back of the relay. You can change the polarity on a per-terminal or per-phase basis, but you must practice extreme caution when using this function. The change of polarity applies directly to the input terminal and is carried throughout all calculations, metering, and protection logic.

The EINVPOL setting is always hidden on the front-panel HMI.

Table 5.1 Inverting Polarity Setting

Setting	Prompt	Range	Default
EINVPOL	Enable Invert Polarity (Off or combo of terminals)	OFF, Combo of S*p*[a], T*p*, U*p*, W*p*, X*p*, Y*n*[b], V*p*, and Z*p*	OFF

[a] Where p = A, B, C. Entering a terminal without specifying a phase designation applies the setting to all phases of that terminal. For example, EINVPOL := SA, SB, X inverts the polarity of the A- and B-Phases for Terminal S and all phases for Terminal X.

[b] Where n = 1, 2, 3. For example, EINVPOL := Y1, Y3 inverts the polarity of the Y1 and Y3 terminals.

If redundant entries of terminals are used, such as [W, WA], [X, XC], [Y, Y1], or [Y,YB], the relay displays the following error message: `Redundant entries for terminal [m]`.

Inverse Polarity in Event Reports

In raw or high-resolution COMTRADE event reports, terminals that have EINVPOL enabled do not show the polarity as inverted. The raw COMTRADE must display the values as they are applied to the back of the relay. This also ensures that when you use an event playback, the setting is applied to the signals coming in the back of the relay and recreates the event properly.

Filtered or low-resolution and disturbance COMTRADE show the polarity as inverted. The filtered and disturbance events display the analogs as the relay uses them in processed logic; therefore, the inverted polarity is shown.

Configuration of Voltage Inputs

The SEL-400G has six voltage inputs that are arranged into two groups: V and Z. The voltage inputs are configurable, which allow them to be applied in a wide variety of applications as described in *Figure 5.2* through *Figure 5.6*.

The Z terminal is dedicated to measuring the voltage at the generator terminals. The Z terminal can be configured for wye or open-delta PTs. Protection elements associated with the generator, such as 21, 32, 40, 51V/C, and 78, use the Z inputs for voltage. Accordingly, the SEL-400G derives the generator frequency source from the Z terminal.

The V terminal is available for measuring the power system voltage in synchronizing applications but can be used for other purposes. The V terminal can be configured for wye, open-delta, or single-phase PTs.

Voltage Input Connections

Figure 5.1 shows the SEL-400G voltage rear connections and internal naming convention.

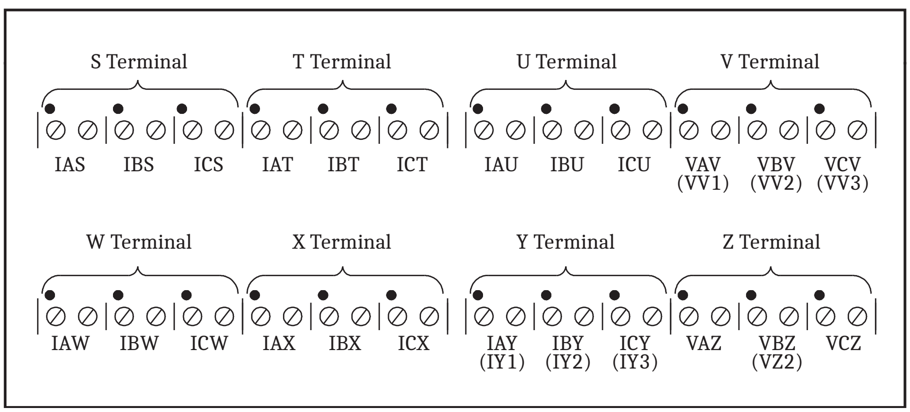


Figure 5.1 SEL-400G Voltage Connections and Naming Convention

When PTCON*k* = Y (*k* = V or Z), a three-phase voltage can be connected as shown in *Figure 5.2*. The voltage signals are named internally as VA*k*, VB*k*, and VC*k*.

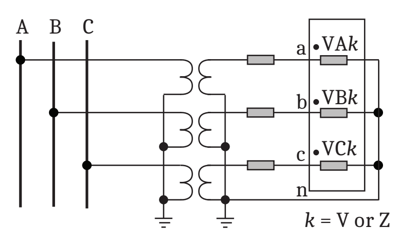


Figure 5.2 Connection of a Three-Phase Voltage for PTCONk = Y

When PTCONk = D or D1, a three-phase voltage can be connected as shown in *Figure 5.3*. The voltage signals are named internally as VAk and VCk. Note that the VBk input is not used in *Figure 5.3* and this input is named internally as Vk2.

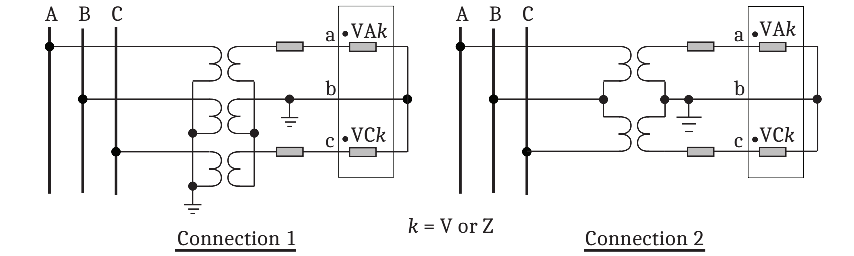


Figure 5.3 Connection of a Three-Phase Voltage for PTCONk = D or PTCONk = D1

When PTCONk = D, a neutral or single-phase voltage can be connected as shown in *Figure 5.4*. This allows the Vk2 input to be applied to protection applications that use the generator neutral voltage or in single-phase voltage applications.

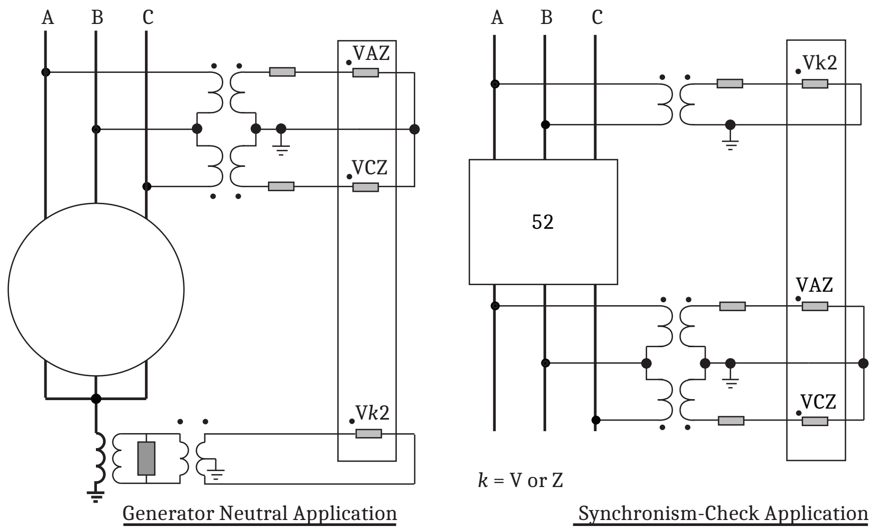


Figure 5.4 Connection of a Neutral or Single-Phase Voltage for PTCONk = D

When PTCONk = D1, an open-corner delta voltage can be connected as shown in *Figure 5.5*. This allows the zero-sequence voltage and third-harmonic voltage to be measured.

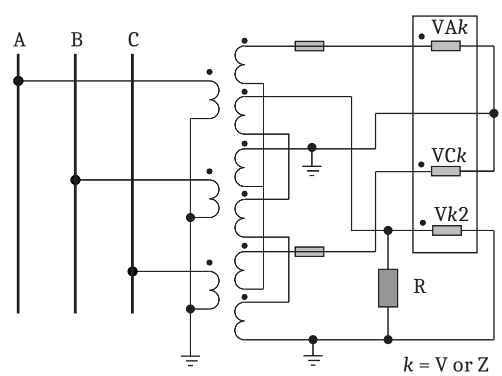


Figure 5.5 Connection of an Open-Corner Delta Voltage for PTCONk = D1

When PTCONV = 1PH, three single-phase voltages can be connected to the relay by using the V input. The voltage signals are named internally as VV1, VV2, and VV3. *Figure 5.6* shows an example connection when PTCONZ = Y and PTCONV = 1PH.

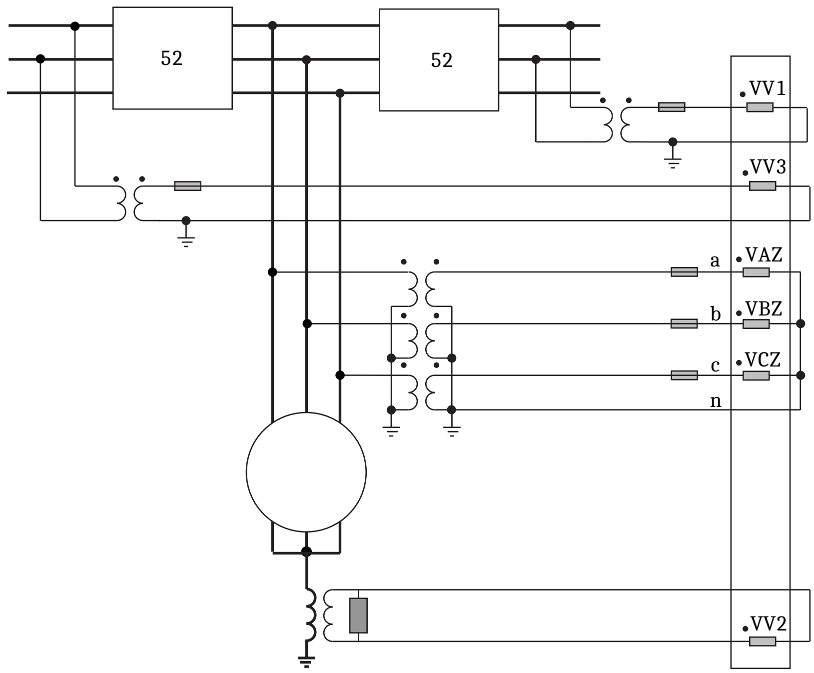


Figure 5.6 Connection Using One Three-Phase Voltage, Two Single-Phase and the Generator Neutral Voltage for PTCONZ = Y and PTCONV = 1PH

NOTE: Set the nominal voltage (VNOMb) to its minimum value when the voltage input is assigned to measure the generator neutral voltage. This ensures that the displayed values of small voltages are not forced to zero.

Table 5.2 Voltage Input Settings

Setting	Prompt	Range	Default	Category
PTCONV	PT connection for Term V	OFF, Y, D, D1, 1PH	1PH	Group
PTCONZ	PT connection for Term Z	Y, D, D1	Y	Group
PTR*k*[a]	PT Ratio Term *k*	1.0–10000	200	Group
VNOM*k*[a]	PT Nominal Voltage (L-L) Term. *k* (V, sec)	30–300	110	Group
PTR*b*[b]	PT Ratio Term *b*	OFF, 1.0–10000	200	Group
VNOM*b*[b]	PT Nominal Voltage Term *b* (V, sec)	30–300	110	Group
EGNPT	Enable Gen Neut Volt Term	OFF, V2, Z2	V2	Group
ESYSPT	Enable Sys Volt Term	OFF, V, or combo of V1, V2, V3	OFF	Group

[a] k = V, Z.
[b] b = V1, V2, V3, Z2.

PTCON*k* determines the quantities which are calculated by the relay. These are summarized in *Table 5.3*. *Figure 5.2–Figure 5.6* show the voltage connections corresponding to the PTCON*k* setting.

Table 5.3 PTCONk Internal Signals and Calculated Voltages

PTCONk	Available Internal Signals	Calculated Voltages
Y	VA*k*, VB*k*, VC*k*	Phase-to-phase, phase-to-neutral, positive-, negative-, and zero-sequence voltages for terminals V and Z Third-harmonic voltage for terminal Z
D	VA*k*, V*k*2, VC*k*	Phase-to-phase, positive-, and negative-sequence voltages
D1	VA*k*, V*k*2, VC*k*	Phase-to-phase, positive-, negative- and zero-sequence voltages
1PH	VV1, VV2, VV3	

NOTE: Neither VV2 nor VZ2 is assignable if PTCONV = Y or PTCONZ = Y. Once assigned, this voltage is used by the generator ground fault elements.

EGNPT defines the generator neutral voltage. Either of the B-Phase voltage inputs (VV2 or VZ2) can be assigned to this input.

The relay uses the potential transformer ratio settings (PTR*k* and PTR*b*) to convert measured secondary phase-to-neutral voltages into primary phase-to-phase voltages for display in the meter report. These settings are also used in certain protection functions.

NOTE: If PTCONV = Y, PTRV2 and VNOMV2 are not available. If PTCONZ = Y, PTRZ2 and VNOMZ2 are not available. Similarly PTRV1, VNOMV1, PTRV3, VNOMV3, are available only if PTCONV = 1PH.

VNOM*k* and VNOM*b* are the nominal system line-to-line voltage in secondary volts.

For example, for a PT with a nominal line-to-line voltage of 13.8 kV and a secondary nominal line-to-line voltage of 115 V (VNOM), the PTR = 13.8 kV/115 V = 120.

System Frequency Source

ESYSPT defines the system frequency source. Enabling the system frequency source allows the relay to independently track the generator frequency and system frequency. This is important in synchronism-check applications or in applications with a breaker on the LV side of the generator step-up (GSU) where the generator and system frequency can be different. Valid settings are:

ESYSPT :=	Available when PTCONV :=
V	Y, D, D1
V2	D
V1, V2, V3	1PH

For more information on frequency tracking, see *Frequency Tracking on page 5.12*.

Voltage Configuration Examples

The SEL-400G provides considerable flexibility when configuring voltage inputs. Specific settings depend on the primary system layout, VT connections, and protection requirements. The following section provides several examples.

Third-Harmonic Comparison and Voltage-Balance LOP

This example shows a typical application with a grounded-wye VT at the generator terminals. The protection functions identified with an * always use the Z input for voltage. Other functions such as voltage and frequency have selectable operating signals. This example also uses a third-harmonic comparison scheme (64G2/3) and a voltage-balance loss-of-protection (LOP) (60) scheme. Third-harmonic comparison schemes use voltage drops at the neutral and terminals of the generator. In this application, the terminal measurement is calculated from the three phase-to-ground Z voltage measurements. The voltage-balance LOP scheme compares the positive-sequence voltages from two VT windings. The V input is configured as D, which allows the positive and negative voltage to be derived using the A and C inputs, allowing the V2 input to be used to measure the generator neutral voltage. See *Configuration of Voltage Inputs on page 5.3* for wiring details.

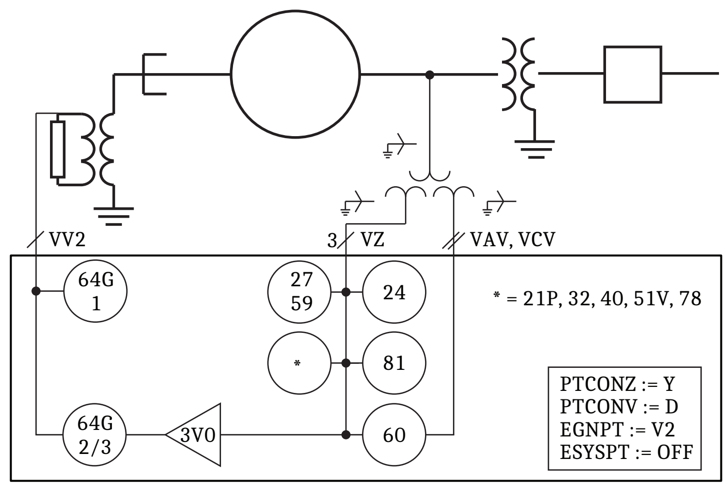


Figure 5.7 Third-Harmonic Comparison and Voltage-Balance LOP Example

Synchronism Check and Voltage-Based LOP

This example shows a typical application with an open-delta VT at the generator terminals. The protection functions identified with an * always use the Z input for voltage. Other functions such as voltage and frequency have selectable operating signals. This example also uses a synchronism-check element (25) and a voltage-balance LOP (60) scheme. Both voltage inputs are configured as D, allowing the Z2 input to measure the generator neutral voltage and the V2 input to be used for synchronism-check. The voltage-balance LOP scheme compares the positive-sequence voltages from two VT windings. Because ESYSPT = V2, the relay measures the system frequency by using V2, and this input will be frequency-tracked by using the system frequency. See *Configuration of Voltage Inputs on page 5.3* for wiring details.

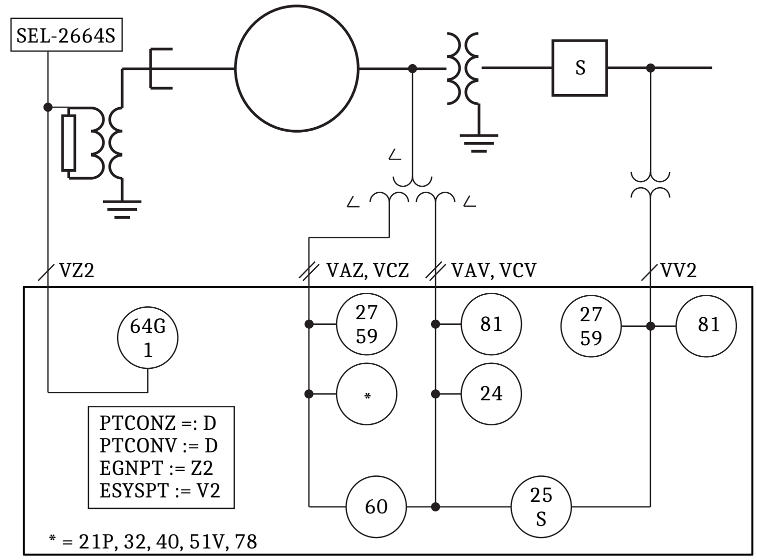


Figure 5.8 Synchronism Check and Voltage-Based LOP

Iso-Phase Bus (IPB) Ground Fault Protection and Synchronism Check

This example shows a typical application with a low-voltage generator breaker. The protection functions identified with an * always use the Z input for voltage. Other functions such as voltage and frequency have selectable operating signals. This example also uses a synchronism-check element (25) and IPB (590) protection. The Z voltage input is configured as D, allowing the Z2 input to measure the generator neutral voltage. The V input is configured as D1, allowing the V2 input to be connected to the open-corner delta winding on the system-side VT. Because ESYSPT = V, the relay measures the system frequency by using VA and VC. This allows V/Hz protection to be applied on both sides of the generator breaker. Also, three-phase voltage checks can be carried out on both sides of the breaker. These checks reduce the possibility of an out-of-phase synchronism event caused by a VT wiring error (see *Synchronism-Check Element on page 5.148*).

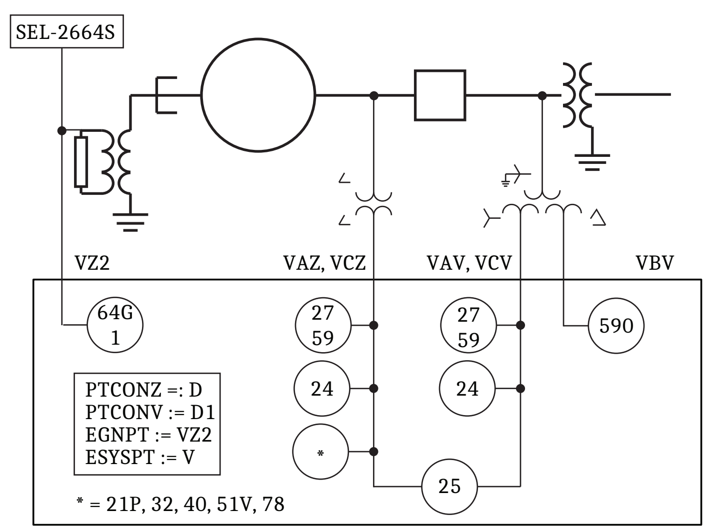


Figure 5.9 IPB Ground Fault Protection and Synchronism Check

Configuration of Current Inputs

The SEL-400G has 18 current inputs that are arranged into 6 groups: S, T, U, W, X, and Y. The current inputs are configurable, allowing them to be applied in a wide variety of applications as described in this section.

The SEL-400G implements a virtual terminal denoted as G. This is the current at the neutral side of the generator. Either the W, X, or a combination of the W and X terminals can be assigned as the generator current. The 21, 40, 46, 51V/C, and 78 use the generator current.

The S, T, and U terminals are available for measuring current at the terminals of the generator or HV terminals of the GSU. A variety of overcurrent, breaker failure and inadvertent energization functions can use these currents.

The Y terminal can be configured as a three-phase terminal or three single-phase terminals. When they are configured as single phase (CTCONY = 1PH), neutral overcurrent and restricted earth fault (REF) functions can use these terminals.

All of the current terminals are assignable to either differential zone including Y [depending on the current channel options (see *Current Channel Options on page 1.12*) and when CTCONY = Y].

Table 5.4 Current Input Settings

Setting	Prompt	Range	Default	Category
EGNCT	Enable Gen Neut Cur Terms	Combo of W, X	X	Group
ESYSCT	Enable System Cur Terms	OFF or combo of S, T, U, Y	S	Group
EPCAL	Enable Power Calc Terms	OFF or combo of S, T, U, Y	S	Group
CTCONY	CT Connection for Term Y	1PH, Y	1PH	Group
CTR*m*[a]	CT Ratio Term *m*	OFF, 1.0–50000	12000	Group
CTRY*n*[b]	CT Ratio Term Y*3*	OFF, 1.0–50000	100	Group

[a] m = S, T, U, W, X, Y.
[b] n = 1, 2, 3.

The EGNCT setting is used to define the three-phase current on the neutral side of the generator (G). Protection elements associated with the generator (21P, 40, 46, 51V/C, and 78) use this current. Valid selections for this setting are W, X, and the combination of W and X (for generators with two neutrals).

Considerations for Generators With Two Neutrals

The stators of some generators are comprised of several parallel branches for each phase. These may be combined into two groups, each brought to its own neutral. You can assign the W and X inputs to CTs on each of these groups as shown in *Figure 5.12*. Setting EGNCT to W, X causes the SEL-400G to sum the W and X inputs to derive the total generator secondary current (IG).

Usually, the branches are grouped such that 50 percent of the generator current will flow in each group. Both groups typically have CTs with the same CT ratio because these CTs should be sized for the nominal current carried by each group. If current distribution is different than 50 percent, the CT ratios could be different. If different, the SEL-400G scales the currents by using the maximum values of CTRW and CTRX. Accordingly, the following equations are used to derive the total generator secondary quantities.

$$IG = K_W \bullet IW + K_X \bullet IX$$

Equation 5.1

$$SG = K_W \bullet SW + K_X \bullet SX$$

Equation 5.2

where:

K_W = CTRW / CTRX when CTRW < CTRX; otherwise, $K_W = 1$

K_X = CTRX / CTRW when CTRX < CTRW; otherwise, $K_X = 1$

IG are the total generator secondary currents (fundamental, RMS, and harmonic)

SG is the total generator complex power (PG + j • QG = SG)

Furthermore, the calculations for secondary generator current (INOMGS in *Equation 5.12*) and secondary generator impedance (ZNOMGS in *Equation 5.13*) are calculated using the maximum values of CTRW and CTRX. Refer to *Power System Data on page 5.16* for details.

The ESYSCT setting determines the terminals at the output of the generator. The overcurrent and breaker failure elements use these currents.

Currents do not need to be assigned to EGNCT to be used by the differential elements.

Power calculations are carried out for any terminals included in the EPCAL setting. Note that power calculations are always carried out for the generator neutral current (terminal G).

The Y current input can be configured either as a three-phase or a single-phase input by using the CTCONY setting. If CTCONY := Y, the Y terminal is available for the differential element. If CTCONY := 1PH, the individual Y terminals are available for single-phase current and REF elements, but it is unavailable for phase/sequence current elements, breaker failure, differential elements, and power calculations.

CTRY is unavailable if CTCONY := 1PH. Similarly, CTRY1, CTRY2, and CTRY3 are unavailable if CTCONY := Y.

Always enter the CTR*m* and CTRY*3* settings with reference to a 1 A secondary. For example, if the S-terminal CT ratio is 600/5 CT, enter CTRS = 120.

Current Configuration Examples

The SEL-400G provides considerable flexibility when configuring current inputs. Specific settings depend on the primary system layout and protection requirements. The following section provides several examples.

Generator Differential and Overall Differential

In this example, generator and overall differentials are implemented. The generator differential primarily provides an indication that a fault is internal or external to the generator. Various overcurrent and breaker failure elements are available on the S, T, U, and Y current terminals.

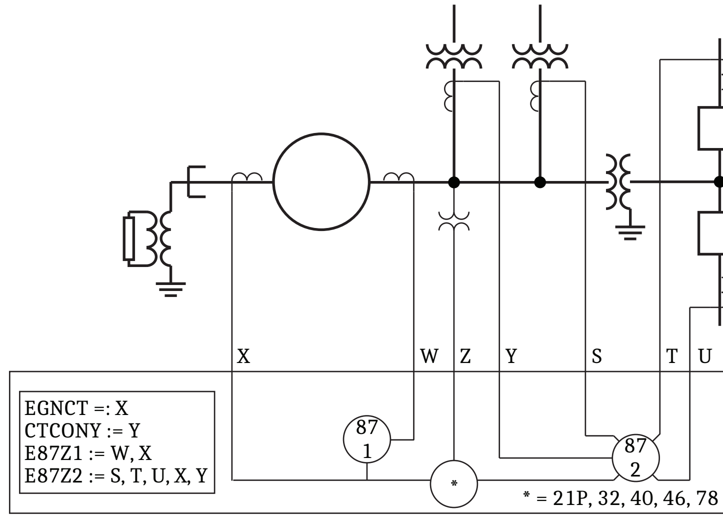


Figure 5.10 Generator Differential and Overall Differential

Generator and Transformer Differential

NOTE: The SEL-400G allows the directional power element to be fed from a dedicated CT. Some CTs may have both a protection class and a metering class rating. If CT does not have a protection class rating, it should not be used for protection functions other than the directional power element.

There is a low-voltage breaker in this application. Each differential is overlapping this breaker. The S, T, U, and Y current terminals are frequency-tracked at the system frequency. The X and W inputs are frequency-tracked at the generator frequency. See *Frequency Tracking on page 5.12* for configuration details. In this example, the directional power element is fed from a dedicated metering class CT.

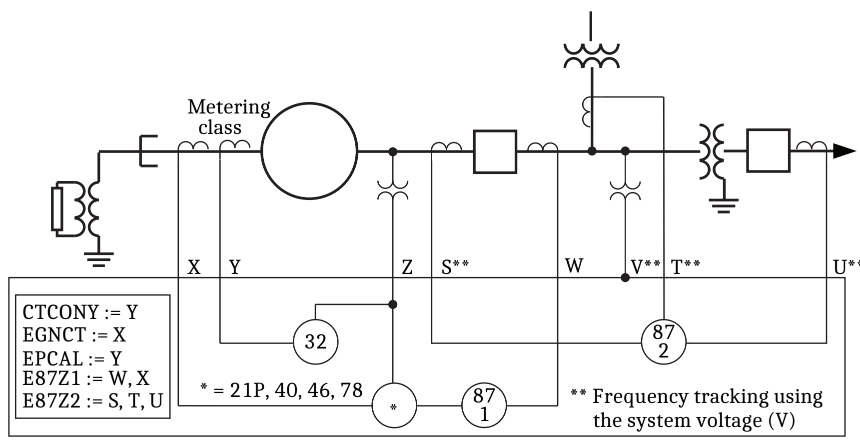


Figure 5.11 Generator and Transformer Differential

Transverse Differential and Overall Differential

In this example, the generator has two parallel branches. This uses one differential to provide fast and secure protection for turn faults and the second to provide overall differential. Balancing the transverse differential is accomplished using the winding compensation feature of the differential protection (see *Differential Element Operating Characteristic on page 5.21*). The Y current terminal is configured as three single-phase inputs. This allows the Y1 input to provide sensitive split-phase protection by using an inter-neutral CT and Y2 to provide REF protection for the transformer (not shown). The W and X terminals are internally summed to provide the generator neutral current.

See *Considerations for Generators With Two Neutrals on page 5.9* for a discussion on CT ratios for generators with two neutrals.

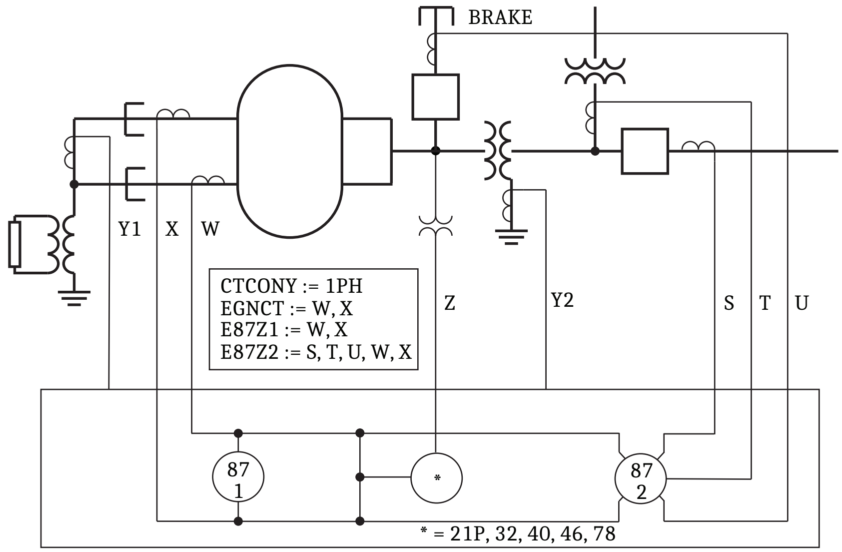


Figure 5.12 Transverse Differential and Overall Differential

Frequency Tracking

Table 5.5 Frequency Tracking Settings

Setting	Prompt	Range	Default	Category
FTSRC*m*[a]	Frequency Source for Current Term *m*	G, S	G	Group
FTSRCY*n*[b]	Frequency Source for Current Term Y*n*	G, S	G	Group
FTSRC*k*[c]	Frequency Source for Voltage Term *k*	G, S	G	Group
FTSRCV*n*	Frequency Source for Voltage Term V*n*	G, S	G	Group

[a] m = S, T, U, W, X, Y.
[b] n = 1, 2, 3.
[c] k = V, Z.

The SEL-400G can track the frequency of both the generator (G) and system (S) independently. The Z voltage input is used for tracking the generator frequency (FREQPG). The ESYSPT setting determines the voltage used for tracking the system frequency (FREQPS). This is a subgroup of the V voltage inputs (see *System Frequency Source on page 5.6*). If ESYSPT is set to OFF, the relay does not calculate the system frequency.

The frequency source settings (FTSRC*m*) define which frequency source is used to track a particular input. If ESYSPT = OFF, all inputs are frequency-tracked using the generator frequency. *Table 5.6* describes the available assignments. In the case of single-phase inputs, individual assignments can be made for each phase.

Table 5.6 Available Assignments (Sheet 1 of 2)

Input	Frequency Tracking Source
Z Voltage, W and X Currents	FREQPG is always used.
V Voltage	If ESYSPT =V, FREQPS is used; otherwise it is assignable to FREQPG or FREQPS by using FTSRCV.

Table 5.6 Available Assignments (Sheet 2 of 2)

Input	Frequency Tracking Source
V1, V2, and V3 Inputs	If ESYSPT includes V1 or V2 or V3, FREQPS is used for the included inputs. If EGNPT = V2, FREQPG is used for that input. Otherwise each input is assignable using FTSRCV1, FTSRCV2, and FTSRCV3.
S, T, U, and Y Currents	Each input is assignable using FTSRCS, FTSRCT, FTSRCU, and FTSRCY.

As noted in the previous table, the Z, W, and X terminals always use FREQPG as the frequency tracking source. The FTSRC setting is viewable for these terminals but cannot be changed from G.

For many applications, all frequency source assignments can be left at their default assignments and all frequency tracking will be carried out using FREQPG.

Tracking of the system frequency is primarily used when a synchronism-check function is enabled or when there is a breaker on the low side of the transformer and the generator can be operated at an off-nominal frequency; for example, a combustion gas turbine that uses static starting. In this case, all the inputs to each differential zone can be tracked at the same frequency.

If a system frequency has been defined, independent V/Hz operating signals can also be configured. See *Volt/Hertz Elements on page 5.107* for more details.

System Frequency Tracking Using Single-Phase Voltages

When the V voltage input is configured as single phase (PTCONV = 1PH), the system frequency is tracked from one of the three voltages: VV1, VV2, or VV3 based on ESYSPT setting. For example, if ESYSPT is set to V2 only, VV2 is used for system frequency tracking.

For applications that require synchronizing more than one circuit breaker (such as *Example 2 on page 5.159*), the SELOGIC variables FTSSV1, FTSSV2, and FTSSV3 are used to select which of the three voltages is used to track the system frequency. The SEL-400G prioritizes the checks in the following order: FTSSV1, FTSSV2, FTSSV3, such that only one voltage is ever selected (see *Table 5.7*). Note that if none of the SELOGIC variables assert, system frequency tracking is suspended, and the system frequency is forced to the nominal frequency (50 or 60 Hz). Therefore, ensure one of the SELOGIC variables is always asserted.

Table 5.7 Frequency Source Voltage Terminal Selection Settings

Setting	Prompt	Range	Default	Category
FTSSV*x*[a, b]	Select Term V*x* Source for Sys Freq	SELOGIC Variable	0	Group

[a] x = 1, 2, 3

[b] The SELOGIC variable is hidden and forced to 0 if the corresponding single-phase voltage is not included in the ESYSPT setting value.

Table 5.8 Frequency Tracking Voltage Quantity (Sheet 1 of 2)

Generator Frequency Tracking		
PTCONZ := Y		Vtr = VAZ – VBZ / 2 – VCZ / 2
PTCONZ := D, D1		Vtr = (VAZ – VCZ) / 2

Table 5.8 Frequency Tracking Voltage Quantity (Sheet 2 of 2)

System Frequency Tracking		
PTCONV := Y	ESYSPT := V	Vtr = VAV – VBV / 2 – VCV / 2
PTCONV := D	ESYSPT := V	Vtr = (VAV – VCV) / 2
	ESYSPT := V2	V = VV2
PTCONV := 1PH[a]	(ESYSPT = V1) OR (((ESYSPT = V1, V2) OR (ESYSPT = V1, V3)) AND FTSSV1 = TRUE)	Vtr = VV1
	(ESYSPT = V2) OR (((ESYSPT = V1, V2) OR (ESYSPT = V2, V3)) AND FTSSV2 = TRUE)	Vtr = VV2
	(ESYSPT = V3) OR (((ESYSPT = V1, V3) OR (ESYSPT = V2, V3)) AND FTSSV3 = TRUE)	Vtr = VV3
PTCONV := D1	ESYSPT := V	Vtr = (VAV – VCV) / 2
All other cases		Vtr = 0

[a] When PTCONV is configured as 1PH, VV1 corresponds to VAV, VV2 corresponds to VBV, and VV3 corresponds to VCV.

Undervoltage Supervision Logic

Relay Word bits 27B81*a* and 27B81R*a* (where *a* = G or S), the output of the logic in *Figure 5.13*, supervises the associated frequency elements (those mapped to the same frequency source) for system undervoltage conditions. In the logic, the comparator compares the absolute value of the tracking voltage quantity (Vtr) against the 81UVSP or 81RUVSP setting value. *Table 5.8* shows the various equations used to calculate the generator and system tracking voltage quantities in various cases.

Relay Word bit 27B81*a* asserts if Vtr falls lower than the 81UVSP setting value for longer than a cycle at the associated frequency. Relay Word bit 27B81R*a* asserts if Vtr falls below the 81RUVSP setting value for longer than a cycle at the associated frequency.

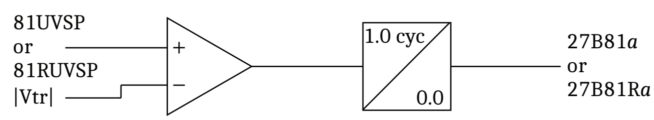


Figure 5.13 Undervoltage Supervision Logic

Calculate the 81UVSP and 81RUVSP Setting Values

Because the relay accepts voltage input from the PTs in any combination, Valpha can have different values, depending on the voltage inputs. In general, the following examples use the average (60 percent) of the 50–70 percent undervoltage range that the IEEE C37.117 Guide recommends. Also, the calculations are based on an rms phase-to-neutral value of 67 V for the PT inputs, although the 81UVSP setting is a peak value and not an rms value. The following calculations only show 81UVSP, same can be used for 81RUVSP.

Case 1: Wye-Connected PT

In this case, VA, VB, and VC are three-phase phase-to-neutral voltages. Use *Equation 5.3* to calculate the nominal value of the tracking voltage quantity as follows:

$$\text{Vtr} = \sqrt{2} \bullet 1.5 \bullet 67\ \text{V}$$

Equation 5.3

$$\text{Vtr} = 142.13\ \text{V}$$

Equation 5.4

Set 81UVSP to 60 percent of this value:

$$81\text{UVSP} = 0.6 \bullet 142.13\ \text{V}$$

Equation 5.5

$$81\text{UVSP} = 85.28\ \text{V}$$

Equation 5.6

Case 2: Delta-Connected PT

In this case, Terminal A measures VAB and Terminal C measures VCB.

$$\text{Vtr} = \frac{\text{VAB} - \text{VCB}}{2} = \frac{\text{VCA}}{2}$$

Equation 5.7

$$\text{Vtr} = \sqrt{3} \bullet \sqrt{2} \bullet \frac{67}{2} = 82.0579\ \text{V}$$

Equation 5.8

Set 81UVSP to 60 percent of *Equation 5.8*.

$$81\text{UVSP} = 0.6 \bullet 82.06 = 49.23\ \text{V}$$

Equation 5.9

Case 3: Single-Phase PT Input, Connected to the B-Phase Input

In this case, the B-Phase input voltage is used for tracking frequency.

$$\text{Vtr} = \sqrt{2} \bullet 67 = 94.7523\ \text{V}$$

Equation 5.10

Set 81UVSP to 60 percent of *Equation 5.10*.

$$81\text{UVSP} = 0.6 \bullet 94.75 = 56.85\ \text{V}$$

Equation 5.11

Generator Monitoring

Use the ONLINE setting (see *Table 8.78*) to indicate that the generator is connected to the power system. The condition(s) that defines the ONLINE status varies for each application. For example, if the generator connects to the power system through a ring bus, the closed indication of each breakers may be ORed to derive the ONLINE status.

The default setting is the Breaker S closed indication (52CLS). See the *Circuit Breaker Monitor on page 7.18* for details on this logic. Note that using the default setting requires that breaker monitoring is enabled (EBMON = S) and configured.

If no breaker status indication is available in the relay, the inverted open-phase indication (NOT OPH*n*) may be considered as a replacement. This is a current-based detector with an operating threshold of about 0.2 A secondary. Therefore, OPH*n* asserts if the generator is online but at no load. The ESYSCT setting enables the open-phase detector for the current terminal associated with the circuit breaker. See *Open-Phase Detection Logic on page 5.175* for details.

Use the FLDENRG setting (see *Table 8.78*) to indicate that the generator field winding is energized. The condition(s) that defines the online status varies depending on the application. You can use a field breaker status wired to the relay (e.g., NOT 52FB) if available. The FLDENRG is used by the LOP logic.

Power System Data

SEL-400G calculates various quantities internally by using the manufacturer data entered by the user. These data are used to set the steady-state stability limit (SSSL) element, i.e., the Zone 3 element of a generator capability-based loss-of-field (LOF) element (40P3). It also is used by the relay to calculate the rated current of the generator for the current unbalance element (46). This approach can reduce the setting errors while minimizing the setting effort. SEL Grid Configurator Software also uses these settings in addition to the existing protection settings to plot the characteristics of the LOF elements (40P, 40Z) in both the R-X plane and P-Q plane, phase distance element (21P), and out-of-step (78) element.

Table 5.9 Power System Data Settings (Sheet 1 of 2)

Setting	Prompt	Range	Default	Category
MVAGEN	Generator Max, MVA	1–5000	555	Group
KVGEN	Generator L-L Voltage, kV	1.00–100	24	Group
XDGEN	Generator D-Axis Synch Reactance, p.u	0.100–4	1.81	Group
XTXFR	Transformer Leakage Reactance, p.u	0.010–10	0.042	Group
XESYS	Equivalent System Reactance, p.u	0.010–10	0.2	Group
XQGEN[a]	Generator Q-Axis Synch Reactance, p.u	0.100–4	1.81	Group
XDPGEN[a]	Generator D-Axis Trans Reactance, p.u	0.100–4	0.17	Group
Z1MAG[a]	Positive Sequence System Impedance for Plots, p.u	0.010–10	0.15	Group
Z1ANG[a]	Positive Sequence System Impedance Angle for Plots, deg	45.0–90	84	Group
CRITANG[a]	Critical Clearing angle, deg	80.0–170	120	Group
RLP[a]	Relay Active Power Loadability Limit, p.u	0.01–2	0.8	Group
RLQ[a]	Relay Reactive Power Loadability Limit, p.u	–2.00 to 2	0.8	Group

Table 5.9 Power System Data Settings (Sheet 2 of 2)

Setting	Prompt	Range	Default	Category
RLV[a]	Relay Voltage Loadability Limit, p.u	0.50–1.25	0.95	Group
RLM[a]	Relay Loadability Limit Margin, %	0.1–100	15	Group
UPSRVR[a]	UPSR voltage ratio[b]	0.50–1.5	0.7	Group
PV1PU[a]	Generator Positive Sequence Voltage for Plots, p.u	0.50–1.5	1	Group
PQPLOT[a]	P-Q Plane in Primary Or Secondary for Plots	P, S	P	Group

[a] These settings are available for data visualization in SEL Grid Configurator.
[b] UPSR = Unstable Power Swing Region (future).

INOMGS, the rated current of the generator is calculated as:

$$\text{INOMGS} = \left(\text{MVAGEN} \bullet \frac{1000}{\sqrt{3} \bullet \text{KVGEN} \bullet \text{CTRG}}\right)$$

Equation 5.12

where:

CTRG = CTRW if EGNCT has W
CTRG = CTRX if EGNCT has X
CTRG = Max(CTRW, CTRX) if EGNCT has W, X

Note that the MVAGEN value entered should be the rated MVA of the generator. If the generator MW rating at a rated lagging power factor is given, MVAGEN should be obtained by dividing the MW rating by the PF. Incorrect MVAGEN value will effect the current unbalance element calculations.

XDGEN, XQGEN, XDPGEN, XTXFR, XESYS, and Z1MAG all must be in pu and must be referred to generator base.

If the system equivalent reactance is given in ohms at the GSU HV side, it should be converted to generator base as in *Equation 5.13*.

$$\text{XESYS (pu)} = \left(\frac{\text{XESYS }\Omega}{\text{ZNOMGS}}\right) \bullet \left(\frac{\text{KVLVGSU}}{\text{KVHVGSU}}\right)^2$$

Equation 5.13

where:

KVHVGSU = GSU high-voltage side L-L voltage
KVLVGSU = GSU low-voltage side L-L voltage
ZNOMGS = the impedance-base value and is calculated as follows:
ZNOMGS = $(\text{KVGEN}^2 / \text{MVAGEN}) \bullet (\text{CTRG} / \text{PTRZ})$

The relay internally calculates ohmic values by multiplying the pu quantities with ZNOMGS variable. 40P3 uses the ohmic values to provide SSSL protection for the generator. The 40P3 implementation details are given in a capability curve-based LOF element.

Grid Configurator Plots

The theoretical dynamic stability limit (TDSL) plot can be seen in the loss-of-field plots. This limit is derived from a solution of the two-axis, synchronous generator model in the transient state (J.H. Walker, *Operating characteristics of salient pole machines*).

This plot requires XDGEN, XQGEN, and XDPGEN settings. The PQPLOT setting enables the user to view the LOF elements in P-Q plane either in primary (Setting P) or secondary (Setting S) quantities. Setting P enables the user to see all the LOF elements in the manufacture generator capability curve (GCC) while Setting S eases the testing of the LOF elements.

The 78 plot uses the Z1MAG setting, which is the Thevenin equivalent of a positive-sequence impedance of a power system from the GSU terminals. The 78 plot uses a setting CRITANG (critical clearing angle), and the default value is 120 degrees.

Grid Configurator also provides relay loadability operating point in the 21P plot to observe if this point encroaches inside the load-responsive protective elements, e.g., 21P. Necessary settings adjustments can be done based on this plot. This operating point requires the settings in pu of RLP, RLQ, RLV, and RLM. The relay loadability can be calculates as follows:

$$\mathrm{ZRLSEC} = (1 + \mathrm{RLM}) \bullet \mathrm{RLV}^2 \bullet \frac{\mathrm{ZNOMGS}}{\mathrm{RLP} - \mathrm{RLQ} \bullet 1j}$$

Equation 5.14

PV1PU, the generator positive-sequence voltage, can be varied from 0.50–1.5 pu to observe the voltage coordination of the 40P and 40Z elements in both the R-X plane and the P-Q plane. The plots can also display underexcitation limiter (UEL) and GCC characteristics. Using the PV1PU setting, the necessary coordination can also be ensured among UEL and the 40P/40Z elements.

Pumped Storage

Table 5.10 Pumped-Storage Settings

Setting	Prompt	Range	Default	Category
EPS	En. Pump Storage	OFF or combo of S, T, U, W, X, Y, V, Z	OFF	Group
PSMODE	Pumped Storage Mode Active	SELOGIC Variable	NA	Group
PSPHREV	Transposed Phases	AB, BC, CA	BC	Group

The pumped-storage logic corrects the transposition introduced by the reversing switch in a pumped-storage scheme. The logic is equivalent to the method used with EM relays that use external switches.

NOTE: Phase rotation is always defined by the power system.

The EPS setting enables the logic and identifies the affected voltage and current terminals. These will be the downstream terminals (on the machine side) of the reversing switch. Terminals that are configured as single phase are not transposed. PSPHREV defines which phases are transposed when the machine switches to motor mode.

PSMODE is a SELOGIC control equation that determines when the machine is operating in motor mode. This will be primarily driven by the reversing switch status, but it also allows the user to build additional security for this indication. For example, a transition from generator to motor only occurs when the machine is offline

The following is an example. The 25, 32, 40, 46, 78, and 87 are all impacted by the reversing switch. The generator is converted from generator to motor operation by transposing the B- and C-Phases, as shown in *Figure 5.14*. However, we only need to identify the terminals downstream from the reversing switch. However, because the Z terminal is transposed for the other generator elements, the W terminal (not shown) also needs to be transposed.

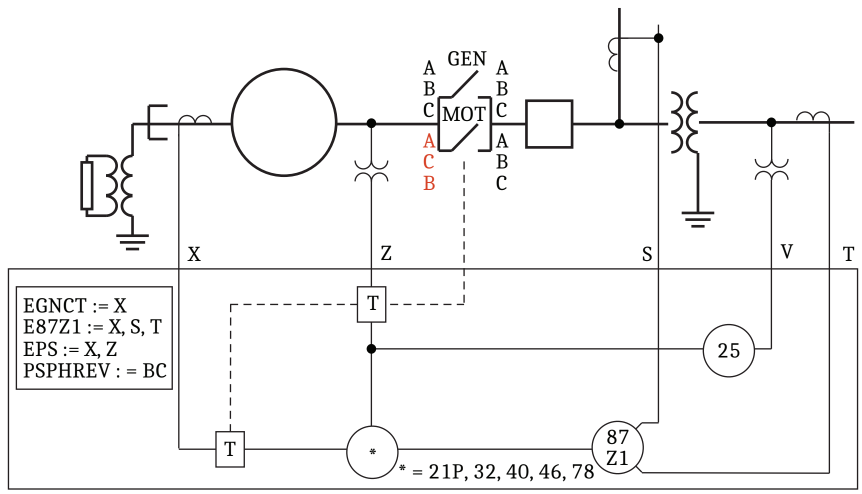


Figure 5.14 Pumped-Storage Example

In pumped-storage applications, the direction of real power flow in motor-mode is opposite to that during generator-mode. To ensure correct behavior in both operating modes, the element responds to the absolute value of real power. This makes the characteristics shown in the previous figure symmetrical about the vertical (Q) axis.

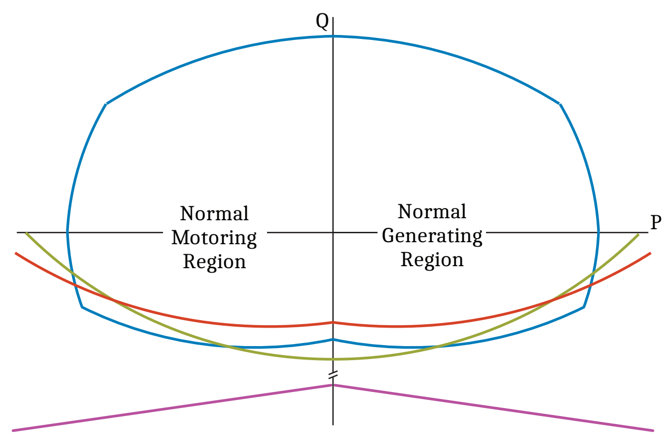


Figure 5.15 40P Element Behavior During Pumped-Storage Operation

Universal Differential Elements

Introduction

The SEL-400G provides two universal differential elements for selective, high-speed protection for internal faults. Use these elements in conjunction with the 100 percent stator ground protection, restricted earth-fault protection, and negative-sequence differential protection to provide comprehensive protection for the generator and GSU.

The differential elements use an adaptive-slope percentage differential characteristic, as opposed to a dual-slope characteristic. Using an advanced adaptive-slope algorithm that includes filtered differential elements as well as instantaneous differential elements, the SEL-400G operates substantially faster than relays that use legacy differential characteristic. The external/internal fault detection supervision adds security during external faults with CT saturation.

The first step in configuring a zone is the selection of the currents that make up the zone by using the E87Z*n* setting. The same current terminal can be shared by both zones. Note that terminals within a zone must use the same frequency tracking source. See *Frequency Tracking on page 5.12* for more information.

Each element can be configured with or without an in-zone transformer. When the in-zone transformer setting, E87XFR*n*, is set to Y, the element becomes a fully featured transformer differential element with the following added functions:

- Connection compensation
- Waveshape-based inrush detection
- Harmonic inrush blocking and restraint
- Raw unrestrained differential
- Negative-sequence differential

If E87XFR*n* = N, the E87H*n* and E87Q*n* settings are forced to their default values and hidden.

See *Section 6: Protection Application Examples* for application examples.

Compensation Calculations

The relay carries out tap and winding compensation calculations on the currents that make up the zone to ensure that they sum to zero under normal operation. See *Table 5.16* for a summary of these settings. Currents not included in a zone are forced to zero.

Tap compensation accounts for differences in current magnitude caused by an in-zone transformer or caused by differing CT ratios. The relay uses the following equation to automatically calculate the tap values. In this case, the tap settings are visible but cannot be changed.

$$87\text{kTAPn} = \frac{\text{MVAn} \bullet 1000}{\sqrt{3} \bullet \text{VTERMmn} \bullet \text{CTRm}}$$

Equation 5.15

where:

MVA*n* = Transformer maximum MVA
VTERM*mn* = Terminal line-to-line voltage of the winding (kV)
CTR*m* = CT ratio

When no transformer exists in the zone or MVA*n* is set to OFF, the automatic tap calculation is not done and the 87*m*TAP*n* settings must be entered manually. Use *Equation 5.15* along with the generator MVA and generator line-to-line voltage. This gives a tap value for each CT that is the nominal current of the machine in secondary amperes.

The relay checks that the currents making up the zone are not severely mismatched by checking that the ratio of the largest TAP (87*m*TAP*n* / INOM*m*) to the smallest (87*m*TAP*n* / INOM*m*) is less than or equal to 35. If not, the last setting entry is rejected.

Connection compensation takes the form of a 3 x 3 matrix with elements determined according to the winding connection associated with the particular current. If E87XFR*n* = N, the identity matrix is used, which is equivalent to no connection compensation. See *Discussion on CT Connection Compensation on page 5.45* for additional details on connection compensation.

Figure 5.16 shows how tap and connection compensations are carried out by the relay.

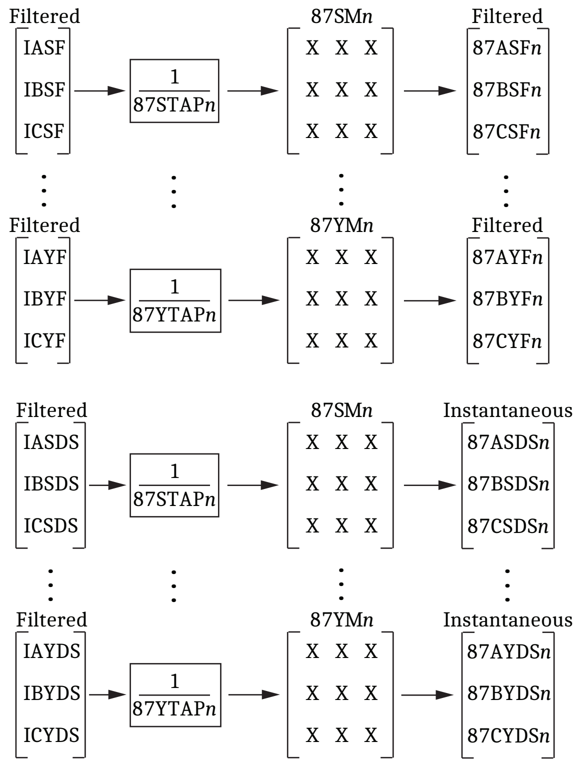


Figure 5.16 Tap and Connection Compensation

Refer to *Winding Compensation Settings for In-Zone Transformers on page 5.44* for details.

Differential Element Operating Characteristic

The relay calculates the filtered differential current (87*p*OPF*n*) and the filtered restraint current (87*p*RTF*n*) by using the following definitions:

$$87p\mathrm{OPF}n = \left| \Sigma_m \, 87pm\mathrm{F}n \right|$$

$$87p\mathrm{RTF}n = c \bullet \Sigma_m \left| 87pm\mathrm{F}n \right|$$

NOTE: Factor c is 0.5 in the SEL-387 and SEL-587 relays. Take this into consideration when calculating the slope setting.

where:

p = Phases A, B, and C

n = Differential zones (1 and 2)

m = The current terminals making up the zone (S, T, U, W, X, and Y) as defined by the E87Z*n* setting

c = 1

87*pm*F*n* The fundamental value of the terminal currents making up the zone

For operating quantities (87*p*OPF*n*) exceeding the pickup level and falling in the operate region of *Figure 5.17*, the filtered differential element issues an output. There are two slope settings: Slope 1 (87SLP1*n*) and Slope 2 (87SLP2*n*) and two pickup settings: Pickup 1 (87P1*n*) and Pickup 2 (87P2*n*). Slope 1 and Pickup 1 are effective during normal operating conditions. Assertion of the external fault detector, CON*pn*, puts the element into a secure mode to avoid possible misoperation resulting from an external fault with CT saturation. Slope 2 is effective at this time. See *AC and DC External Fault Detection Logic on page 5.22* for a description of the external fault detector.

Additional security is provided by the second pickup setting, 87P2*n* during black-starting applications. Switchover to this pickup is controlled by the 87*p*SEC*n* Relay Word bit.

See *Setting Guidelines for 87 Phase Differential on page 5.42* for additional details on setting the pickup and slope.

NOTE: By default, 87pSECn is set to the external fault detector (CONpn). This setting is fine for the majority of applications. The addition of this setting offers the capability to create custom logic to further condition the transition to high-security mode.

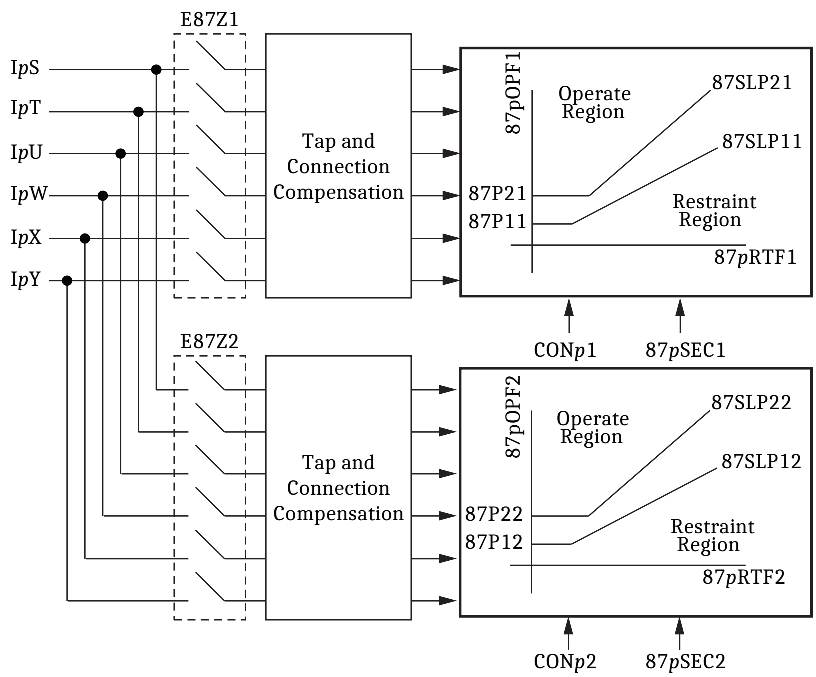


Figure 5.17 Adaptive Differential Elements

AC and DC External Fault Detection Logic

The ac external fault detector anticipates fast ac saturation that occurs because of high-magnitude currents. The logic uses the principle that operating and restraint currents increase simultaneously for internal faults but that only the restraint current increases for external faults (if there is no CT saturation). Instantaneous differential current (87*p*OPI*n*) and restraint current (87*p*RTI*n*) are calculated from the instantaneous terminal currents. The relay uses the following definitions:

$$87p\mathrm{OPI}n = \Sigma_m\ 87pm\mathrm{DS}n$$

$$87p\mathrm{RTI}n = \Sigma_m\ |\ 87pm\mathrm{DS}n\ |$$

where:

p = Phases A, B, and C

n = Differential zones (1 and 2)

m = The current terminals making up the zone (S, T, U, W, X, and Y) as defined by the E87Z*n* setting

87*pm*DS*n* = The instantaneous sample values of the terminal currents making up the zone

One-cycle delta quantities are derived from these values. The ac external fault detector asserts for a change in restraint current without a corresponding change in differential current. 87KRD*n* and 87DIRT*n* are calibration settings. The logic requires approximately 1/8 cycle of saturation-free current to operate. *Figure 5.18* shows the logic.

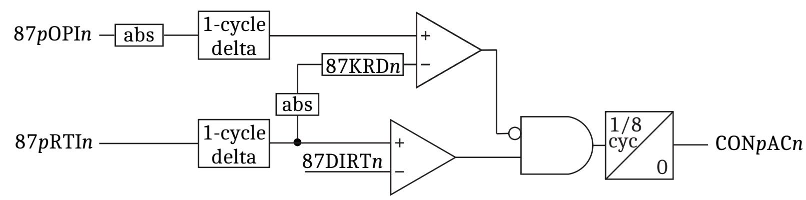


Figure 5.18 AC External Fault Detector

NOTE: Timers that are associated with sample-based logic are shown in cycles. Other timers are shown in seconds or milliseconds.

The dc external fault detector anticipates slower dc saturation that occurs because of low-magnitude currents that contain long-lasting dc components. The dc components of the individual terminal currents are calculated by averaging the instantaneous values over one cycle.

Figure 5.19 shows the dc external fault detector logic. The output asserts when a significant dc component is present in any of the currents that make up the zone, and there is relatively little differential current. Once the output is asserted, a spurious differential current exceeding the slope (87KRD*n*) will not reset the output.

Assertion of DC*pn* is controlled by calibration settings that are factory-set at 0.05 and 0.3, meaning the dc component must be greater than 5 percent of Inom and also greater than 30 percent of the fundamental component.

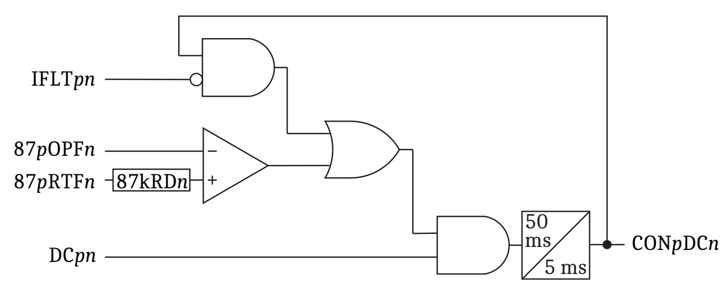


Figure 5.19 DC External Fault Detector

After some time, a saturated CT erases the dc component from its output, but the CON*pn* Relay Word bit asserts for a minimum of three cycles. The dropout is further extended by the fault reset timer (87EFDO*n*). This timer has a default value of 1 second. If there is an evolving internal fault (WFLT*pn*), the external fault reset timer is forced to drop out immediately, forcing the element out of high-security mode. WFLT*pn* is described in following sections.

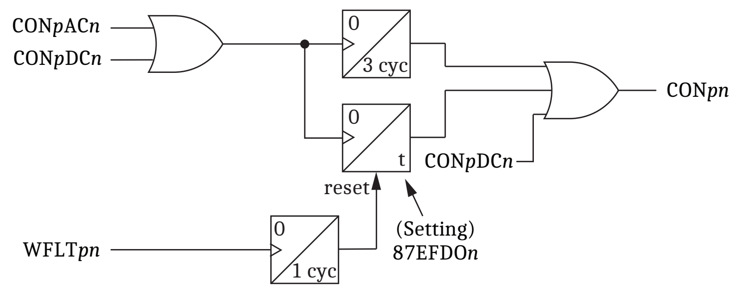


Figure 5.20 External Fault Detector Combined Logic

Internal Fault Detection Logic

While the high-security mode provides satisfactory security for through faults, this mode can cause the relay to operate slower for evolving faults (where the fault starts as an external fault and then develops into an internal fault).

Figure 5.21 shows the logic. The comparator in the upper left corner of the figure asserts when the instantaneous differential current exceeds the product of the instantaneous restraint current and a slope setting. The raw operate quantity, 87*p*OPI*n*, must also exceed the setting 87P*n* before this comparator can assert. The slope switches to the secure value (87SLP2*n*) if there is an external fault (CON*pn*) and switches back to the more sensitive value (87SLP1*n*) if there is no indication of CT saturation in the differential current for 0.5 seconds (CTU*pn*). CTU*pn* is described in a following section.

The upper path provides instantaneous fault detection. This path is conditioned by a timer. This delay prevents a pickup because of operation of an in-zone surge arrestor. The timer delay is factory-set at 1/4 of a power system cycle. Relay Word bit GFLT*pn* asserts when the instantaneous fault detection logic detects an internal fault. This path is supervised by CON*pn* and therefore will not assert IFLT*pn* if the element is already in high-security mode.

The lower path is conditioned by the moving window fault detection logic. During a fault with CT saturation, the CT is expected to come out of saturation in the second half-cycle. Therefore, this logic checks that differential current still exists on a consecutive measurement one-half cycle after RDIFF*pn* asserts. Relay Word bit WFLT*pn* asserts when the moving window fault detector logic declares an internal fault. This path is not supervised by CON*pn* and therefore will assert IFT*pn* if the element is already in high-security mode.

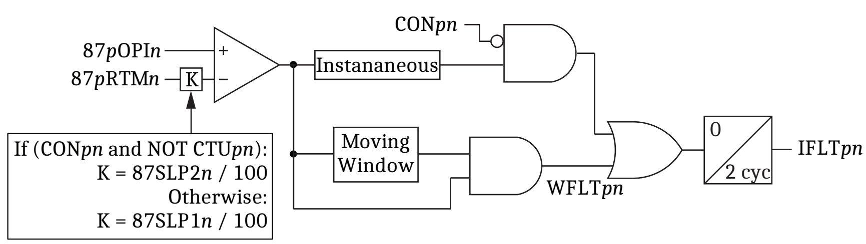


Figure 5.21 Internal Fault Detector Logic

Insignificant Restraint Detection

The element uses the logic of *Figure 5.22* to check that there is essentially no restraint current. This will be the case for a generator prior to synchronizing or a transformer prior to energization.

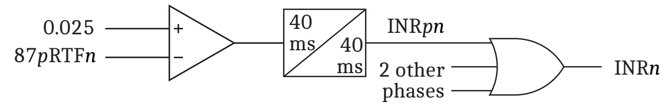


Figure 5.22 Insignificant Restraint Detection

RMS Differential Logic

The relay calculates the rms differential current (87*p*OPR*n*) from the currents making up the zone. This rms filter has a length of 160 ms. Consequently, it ramps more slowly than the filtered differential current (at nominal frequency) but remains accurate in situations where the generator frequency may differ significantly from nominal and the relay is unable to track frequency, for example, a hydro generator during dynamic braking. It is not supervised by any logic other than its own torque-control Relay Word bit (87RMTC*n*).

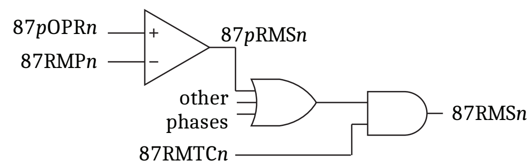


Figure 5.23 RMS Differential Logic

Unrestrained Logic

The unrestrained differential detects high-magnitude internal faults. It provides three mechanisms for tripping: a filtered-unrestrained logic (87UF*n*), a raw-unrestrained logic (87UR*n*, and the waveshape-based, bipolar high-set logic (87BPH*n*). Note that only the filtered, unrestrained element is available when there is no in-zone transformer.

The filtered-unrestrained logic operates when the filtered differential current exceeds the unrestrained pickup setting.

The raw-unrestrained logic can be substantially faster than the filtered logic. It uses the 1-cycle change in the raw differential current (see *AC and DC External Fault Detection Logic on page 5.22*). The pickup setting is scaled by k, which is a calibration with a factory setting of 2 • √2. The √2 accounts for the difference between peak and rms and the two accounts for dc offset in the raw waveform.

The bipolar high-set function is more sensitive that either the filtered- or raw-unrestrained functions because it can differentiate between inrush and internal fault current. See *Waveshape-Based Inrush Detection Logic on page 5.28* for details.

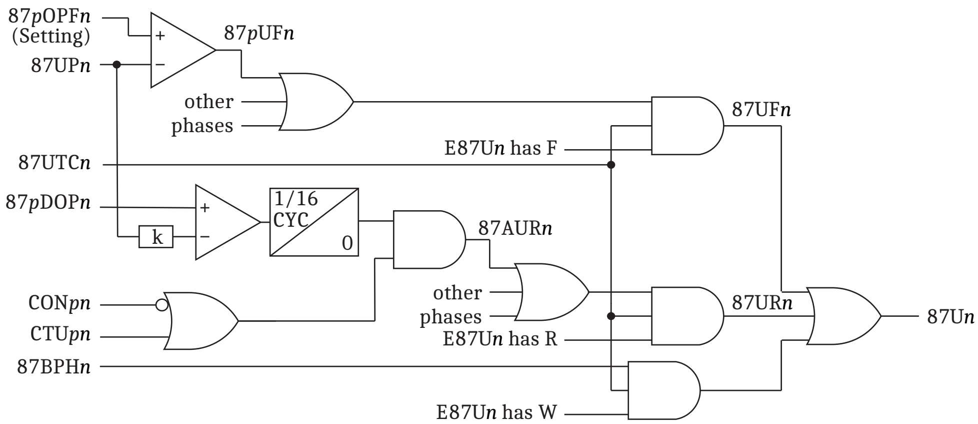


Figure 5.24 Unrestrained Differential Logic

Overall Logic (No In-Zone Transformer)

For applications without an in-zone transformer (E87XFR*n* = N), the overall logic is represented in *Figure 5.25*. The restrained differential Relay Word bit (87R) asserts when the operate current exceeds the pickup setting and also exceeds the product of the restraint current and the slope setting. The CON*pn* Relay Word bit controls the application of the secure slope setting. Assertion is supervised by the internal fault detector.

A dynamic security timer shown in the figure delays operation by 7.5 ms if either the CON*pn* or INR*pn* Relay Word bits are asserted. Operation is delayed by 15 ms if both Relay Word bits are asserted. The timer output is ANDed with the restrained torque-control Relay Word bit (87RTC*n*) to produce the restrained differential output 87R*n*. The restrained, unrestrained and rms Relay Word bits are then combined to produce the differential output 87Z*n*.

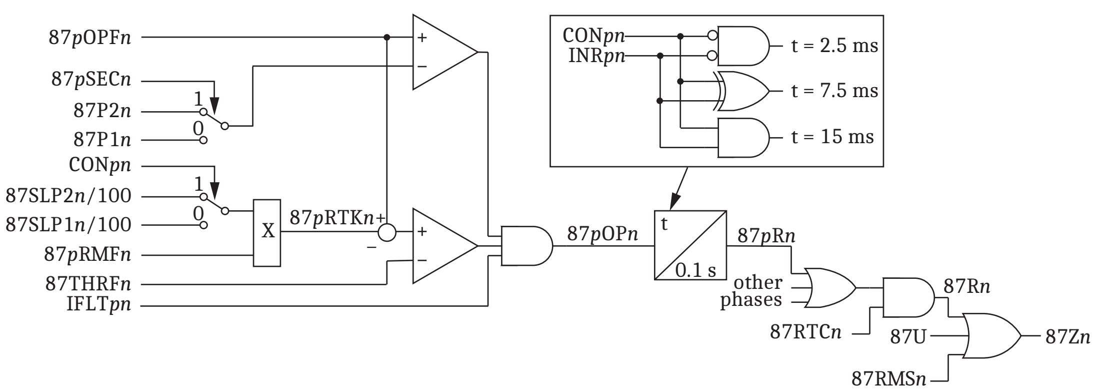


Figure 5.25 Overall Logic With No In-Zone Transformer

In-Zone Transformer Applications

Transformer inrush appears as differential current. The SEL-400G provides harmonic logic and waveshape logic to detect this condition and prevent a potential misoperation.

Harmonic logic is active when E87XFR*n* =Y. Inrush detection is enabled by using the E87H*n* setting, as indicated in *Table 5.11*.

Table 5.11 E87Hn Settings

E87H Setting	Description
R, RW	Harmonic restraint is enabled
B, BW	Harmonic blocking is enabled
RW, BW	Waveshape-based inrush detection is enabled

Harmonic Restraint and Harmonic Blocking

The harmonic-blocking functions always operate in cross-blocking mode, whereby the relay blocks all phases when the harmonic magnitude of any phase exceeds the harmonic setting. By contrast, the harmonic restraint functions always operate in independent blocking mode, i.e., there is no cross blocking between phases.

The second- and fourth-harmonic quantities shown in *Figure 5.26* are also used to boost the restraint signal.

Harmonic components are filtered from the differential currents. Even-numbered harmonics (second and fourth) provide security during energization, while fifth-harmonic blocking provides security for overexcitation conditions. These values are scaled using the 87PCT2*n*, 87PCT4*n*, and 87PCT5*n* settings and then compared with the filtered differential current to produce Relay Word bits for use by the harmonic blocking and restraint logic. After scaling the values, the relay compares each harmonic value against the fundamental quantity 87*p*OPF*n*. Output 87XB2*n* (cross blocking) is the OR combination of the second or fourth-harmonic blocking values from the other phases. 87XB2*n*, together with fifth-harmonic blocking, 87*p*B5*n*, are used in the harmonic blocking path of the overall logic as shown in *Figure 5.40*.

Output 87XB2*n* is also used to block the negative-sequence differential element during inrush conditions (see *Figure 5.26*).

The harmonic integrity timers prevent differential element misoperation when harmonic content momentarily drops below the harmonic threshold setting. The control input at the bottom of the timer means that the DO timer is not timing if the input picks up. If the input picks up continuously for 25 ms, the harmonic integrity timer activates the 15 ms dropout timer. After activation, the dropout timer keeps the output asserted for 15 ms after timer input deasserts. However, if the input picks up again, the DO timer stalls, i.e., does not continue to count until the input has dropped out again. For example, if the input drops out for 5 ms, picks up and then drops out a second time, the timer output resets after 10 ms. Note that the integrity timer for the fifth harmonic is disabled when 87UBL*pn* asserts.

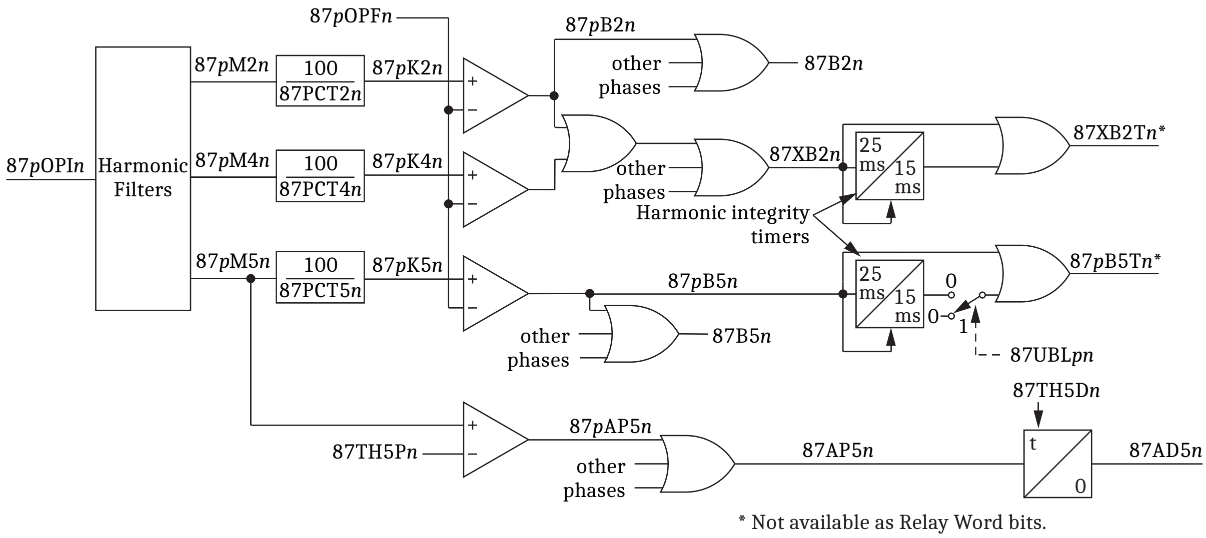


Figure 5.26 Harmonic Blocking and Restraint

Waveshape-Based Inrush Detection Logic

Although inrush currents are typically rich in even-numbered harmonics (the second harmonic in particular), some power transformers, especially the new designs with the core material improved for lower losses, produce low levels of these harmonics. These low harmonic levels can challenge the effectiveness of traditional harmonic-blocking and harmonic-restraint schemes.

The waveshape-based inrush detection element addresses inrush conditions that contain low second- and fourth-harmonic content by using a dwell-time algorithm. The magnetizing currents of a three-phase, three-legged transformer exhibit intervals where the currents are both small and flat (see *Figure 5.27*), called dwell times, which coincide with one another in each phase. The dwell-time algorithm uses this small and flat interval to detect transformer inrush and supervise the percentage-restrained differential elements. For three-phase transformers built from single-phase units or four- or five-legged cores, the dwell times still exist in each phase but do not necessarily coincide. Thus the dwell-time algorithm requires information about the transformer construction, established via the 87COREn setting before it can activate the appropriate logic.

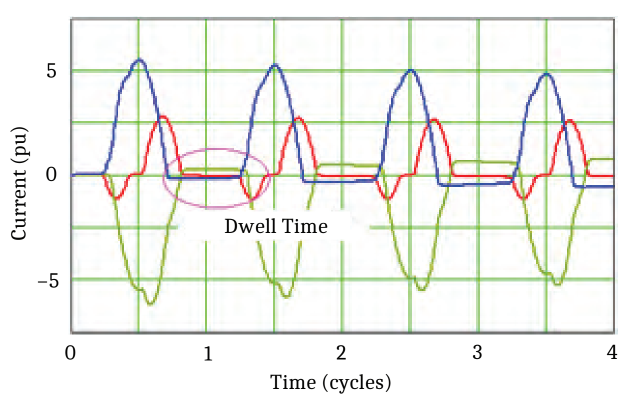


Figure 5.27 Dwell-Time Intervals in the Inrush Currents

Dwell-Time Algorithm for Three-Legged, Three-Phase Transformers

Setting 87COREn = T enables the dwell-time algorithm for three-legged, three-phase transformers.

The dwell-time logic first performs a supervisory check whereby it confirms that there is sufficient differential current to activate the dwell-time algorithm. If either the filtered A-Phase operate current or the negative-sequence operate current is above half of their respective pickup thresholds, 87TMA*n* asserts to indicate sufficient operate current magnitude, as shown in *Figure 5.28*. If any phase has sufficient operate current, the three-legged operate current magnitude check, 87TM*n*, asserts. Assertion of 87TM*n* is a required condition for operation of the three-legged dwell-time logic, as shown in *Figure 5.29*.

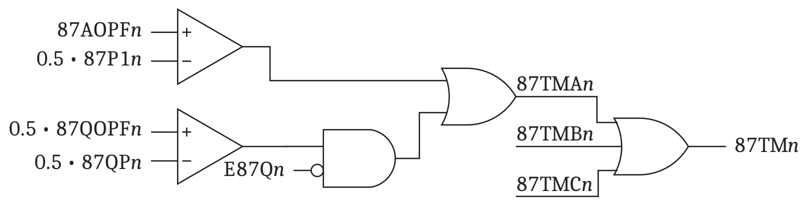


Figure 5.28 Sufficient Operate Current Check

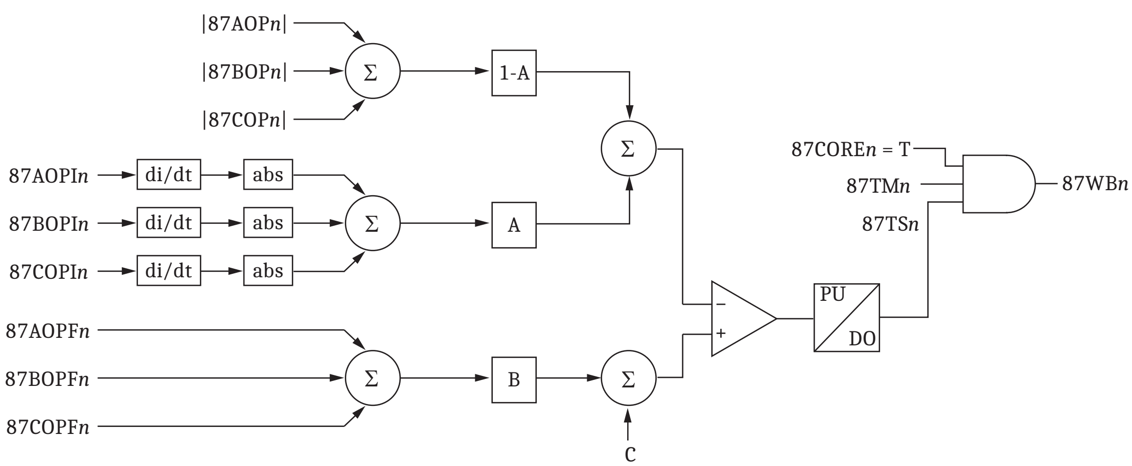


Figure 5.29 Waveshape Dwell-Time Inrush Detection Logic for Three-Legged, Three-Phase Transformers

The three-legged dwell-time algorithm executes on a sample-by-sample basis and works as follows:

- The relay adds the absolute values of the raw (unfiltered) differential current in all three phases (87AOPI*n*, 87BOPI*n*, and 87COPI*n*) (see *Figure 5.29*) to form a portion of the dwell-time identifier signal. During inrush conditions, this signal is low for the duration of the dwell-time periods because all three differential currents exhibit their dwell periods at the same time.
- To provide resiliency against gradual CT saturation that may occur during inrush, the relay forms a second measure of the dwell-time pattern by summing the absolute values of the derivatives of the raw differential currents. Because all three inrush currents are coincidentally flat during the dwell-time periods, this signal is low during the dwell-time periods of the inrush currents.

➤ The two portions of the dwell-time identifier signal are multiplied by a scaling factor and added together. The resulting signal is low during the dwell-time periods, high during internal faults, and resilient to gradual CT saturation during inrush.

➤ The relay creates an adaptive threshold by taking a fraction of the three-phase sum of the filtered operating currents (87AOPF*n*, 87BOPF*n*, and 87COPF*n*) (see *Figure 5.29*). A comparator checks if the level of the dwell-time identifier signal is below the adaptive threshold for the duration of the pickup time (PU). If so, then 87TWB*n* asserts, indicating that the relay has identified an inrush condition through use of waveshape recognition. The dropout time (DO) is set for one power system cycle and is necessary to keep 87TWB*n* continually asserted until the dwell-time of the next subsequent cycle, maintaining reliable inrush detection.

Dwell-Time Algorithm for Single-Phase Units, or Four- or Five-Legged Three-Phase Transformers

When a three-phase transformer is constructed with single-phase transformers or with a four- or five-legged core, the individual phase dwell-time intervals are not aligned in time. In a transformer built with single-phase units or with a four- or five-legged core, the flux in each core can be independent, meaning the three cores go in and out of saturation independently. Therefore, one instance of the dwell-time algorithm is required for each phase of the transformer.

Setting 87CORE*n* = S segregates the inrush detection dwell-time logic into individual phases, such as in the A-Phase logic shown in *Figure 5.30*. The logic is identical to the three-legged core logic shown in *Figure 5.29*, except that it only uses a single-phase current rather than a three-phase sum.

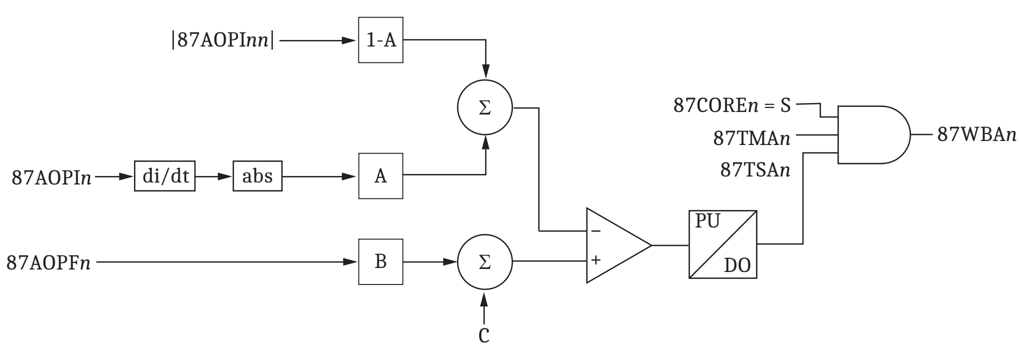


Figure 5.30 Waveshape Dwell-Time Inrush Detection Logic for A-Phase

NOTE: For a more detailed discussion and analysis of the waveshape inrush detection method, refer to the technical paper, Low Second-Harmonic Content in Transformer Inrush Currents – Analysis and Practical Solutions for Protection Security by Steven Hodder, Bogdan Kasztenny, Normann Fischer, and Yu Xia (available at selinc.com).

Figure 5.31 shows the waveshape-based inrush blocking logic used by the differential elements. If the logic identifies magnetizing inrush current through use of waveshape recognition, the 87WB*n* Relay Word bit asserts. The logic uses phase-specific Relay Word bits (87WBA*n*, 87WBB*n*, and 87WBC*n*) to block the percentage-restrained differential elements, as shown in *Figure 5.31*. The negative-sequence differential element is blocked by the 87WB*n* Relay Word bit, as shown in *Figure 5.46*.

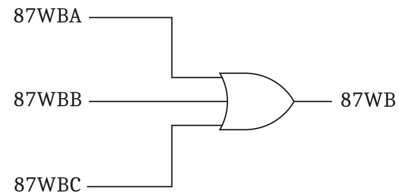


Figure 5.31 Waveshape Blocking Logic

Waveshape-Based Bipolar Unblocking Logic

A waveshape-based bipolar differential overcurrent element allows for improvements in the operation of the restrained and unrestrained differential elements. *Figure 5.32* shows the differential currents for an internal transformer fault that develops during transformer energization. The first part of the figure shows the unipolar characteristic of the differential currents during an inrush condition. When the internal fault occurs on one phase, the resulting waveform has a bipolar characteristic as shown in blue.

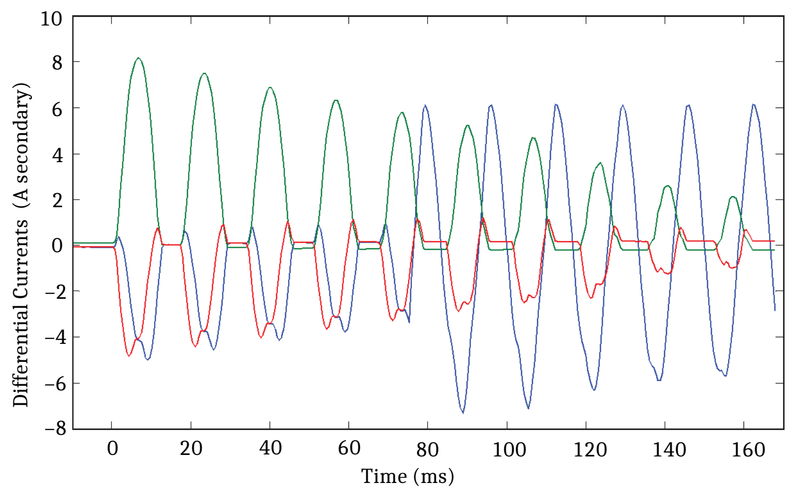


Figure 5.32 Differential Currents for an Internal Fault During Inrush Conditions

Figure 5.33 shows the differential current of the faulted phase of *Figure 5.32* superimposed on two thresholds. Note that during inrush conditions (the first 72 milliseconds), the current is negative and it repeatedly crosses the negative threshold (the dashed blue line in *Figure 5.33*). The current during this time does not cross the symmetrically placed positive threshold (the dashed red line). When the internal fault occurs, the current crosses the negative threshold and then crosses the positive threshold shortly afterwards. Using this information, we create a pair of bipolar differential overcurrent elements: a low-set element that we can use to unblock the inrush blocking functions of the relay and a high-set element that we can use for unrestrained differential protection. Because the elements work on a bipolar principle, we set the thresholds relatively sensitively and still ensure security during inrush conditions.

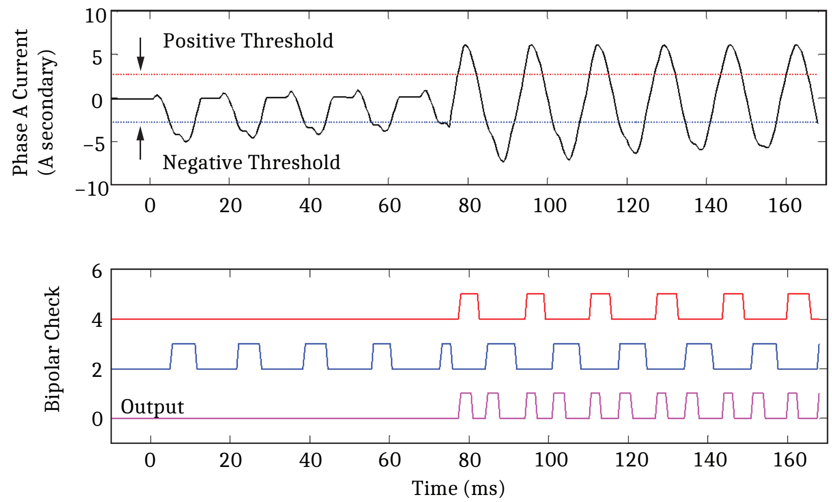


Figure 5.33 Fault Current During Energization (Black) Compared With Positive (Red) and Negative (Blue) Thresholds

As shown in *Figure 5.34*, the A-Phase, low-set bipolar differential overcurrent element compares the unfiltered (raw) operate current, 87AOPI*n* (see *Figure 5.34*), against positive (+L) and negative (–L) thresholds. The B- and C-Phase logic is similar. If the current exceeds the positive threshold for a short duration (PKPBP timer), a window equal to the DPOBP timer opens to wait for the current to decrease below the negative threshold. If it does, the relay declares the current to be symmetrical and not an inrush current. Mirrored logic covers the negative polarity. The magenta trace in *Figure 5.33* is the output of the bipolar low-set overcurrent element, shown in *Figure 5.34* as 87TBL*n*.

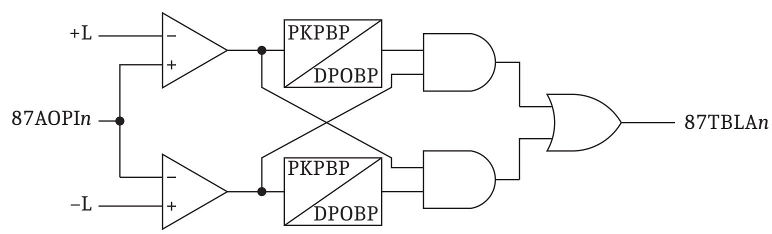


Figure 5.34 A-Phase Bipolar Low-Set Signature Detection Logic

Prior to using the low-set bipolar overcurrent element as an unblocking function, the relay performs additional security checks, as shown in *Figure 5.35*, to ensure that the bipolar logic is asserting properly. The first is a sudden change detection logic, which confirms that the bipolar nature of the differential current is caused by an internal short circuit rather than by gradual CT saturation occurring during inrush conditions. The sudden change detection logic monitors the absolute value of the per-cycle difference of the operate current and checks that this difference is significant (above the +L threshold). The output of the comparator passes through a pickup timer (PKPS) for security, and a dropout timer (DPOS) ensures that the sudden change detection logic coordinates with the input from the unsupervised bipolar low-set logic, 87TBL*n*.

To distinguish between a sudden change in current because of transformer energization or an internal short circuit, perform a second security check by using the filtered restraint current. An internal short circuit during normal operating conditions has a measurable amount of restraint current prior to the fault, whereas there is zero restraint current prior to energization. The pickup timer (PKPR) and dropout timer (DPOR) ensure a sufficient amount of time has passed since energization so that a sudden change in current can be properly identified.

The third security check (shown in *Figure 5.35*) ensures that the bipolar logic does not assert because of CT saturation when an external fault condition is detected (CONA*n* must be deasserted, see *Figure 5.35*). However, if the CT is deemed to be in an unsaturated state following the external fault, as indicated by CTUA*n* asserting, the bipolar logic can assert. When the bipolar low-set logic, 87TBLA*n*, asserts, along with the security checks, the bipolar low-set element, 87BPLA*n*, asserts. The B- and C-Phase supervised low-set logic is similar to the A-Phase logic.

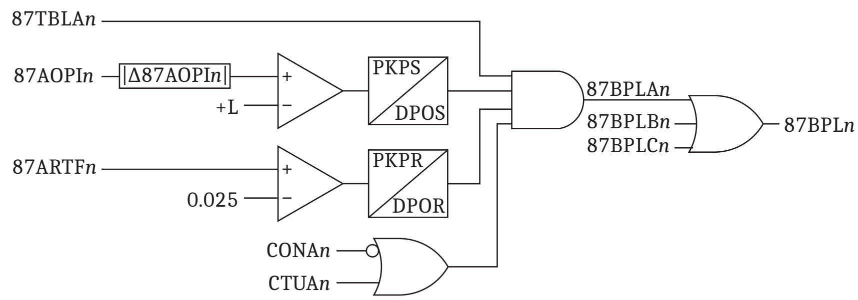


Figure 5.35 A-Phase Bipolar Low-Set Logic

The unblocking logic makes direct use of the bipolar low-set element, as shown in *Figure 5.36*. When you enable the unblocking logic via the E87UNB*n* setting, the unblocking Relay Word bit, 87UBLA*n*, asserts for one cycle following the assertion of the bipolar low-set element, 87BPLA*n*. The B- and C-Phase unblocking logic is similar to the A-Phase logic.

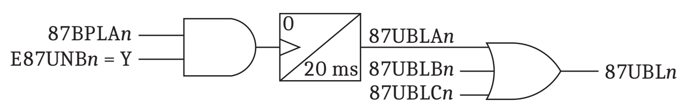


Figure 5.36 A-Phase Unblocking Logic

When the unblocking logic asserts, the following changes occur to the phase-restrained differential elements, as shown in *Figure 5.36*:

- The second- and fourth-harmonic cross blocking, 87XB2*n*, and waveshape-based inrush blocking, 87WBA*n*, are canceled in the harmonic-blocked differential element.
- The waveshape-based inrush blocking, 87WBA*n*, is canceled in the harmonic-restrained differential element.
- The second- and fourth-harmonic magnitudes are removed from the restraint current, 87ARTH*n*, of the harmonic-restrained differential element.
- The fifth-harmonic integrity timer used by the phase-restrained elements is bypassed (although direct assertions of the 87AB5*n* Relay Word bit still block the elements).
- The delay time of the adaptive security timer decreases.

The following changes are made to the negative-sequence differential element when the unblocking logic asserts, as shown in *Figure 5.45* and *Figure 5.46*:

- The second- and fourth-harmonic cross blocking, 87XB2*n*, and waveshape-based inrush blocking, 87WB*n*, are canceled.
- The negative-sequence differential element delay timer, 87QD*n*, is bypassed.

A high-set version of the bipolar differential overcurrent element is available for use as an unrestrained differential element and is identical to the low-set version except that it uses a threshold that is a multiple (m) of the low-set threshold (L), as shown in *Figure 5.37* and *Figure 5.38*.

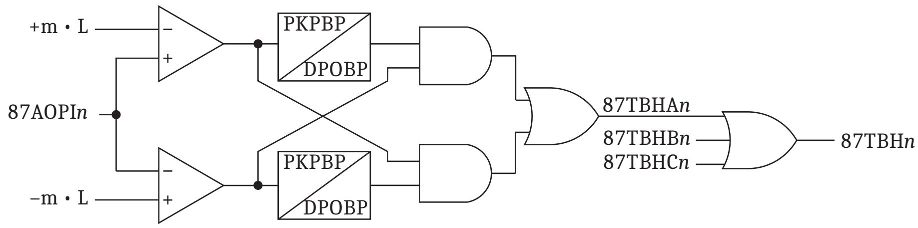


Figure 5.37 A-Phase Bipolar High-Set Signature Detection Logic

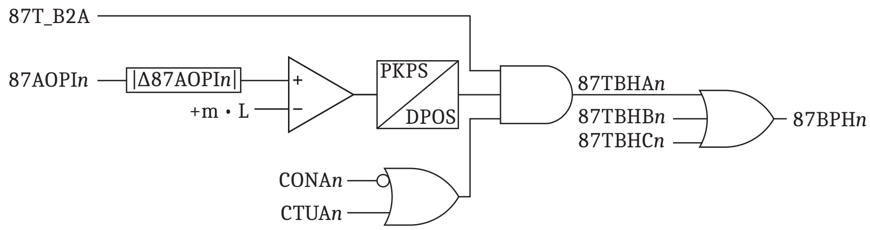


Figure 5.38 A-Phase Bipolar High-Set Logic

As shown in *Figure 5.38*, the unrestrained differential element can use the bipolar high-set element, 87BPHA, for unrestrained tripping.

Using Harmonic and Waveshape Logic in the Differential Elements

NOTE: Consider enabling all of the harmonic and waveshape functions through the **E** and **W** settings options for the settings E87HB, E87HR, and E87Q as well as setting E87UNBL = Y to gain the best security and speed performance from the differential elements.

The enable settings options for the various percentage-restrained differential elements (E87H*n* and E87Q) allow for each element to provide inrush security by using only the harmonic-based method (setting option B or R), by using either the harmonic- or waveshape-based blocking methods for the harmonic-blocked differential element and negative-sequence differential element (setting option BW), or by adding waveshape-based blocking to the harmonic-restrained differential element (setting option RW). As shown in *Figure 5.39* and *Figure 5.46*, the appropriate inrush blocking methods are activated or deactivated depending on the enable settings option.

The waveshape-based unblocking logic is separate from the inrush blocking logic and is enabled in all the percentage-restrained differential elements (87HB, 87HR, and 87Q) when setting E87UNBL = Y (see *Waveshape-Based Bipolar Unblocking Logic on page 5.31*). Should the unblocking logic assert, indicating that the logic detected an internal fault, the relay cancels the inrush security checks and modifies the security timers in the differential elements (see *Figure 5.39*, *Figure 5.45*, and *Figure 5.46*), allowing for improved element operating times. Consider enabling the unblocking logic to gain speed improvements for all internal fault types and conditions.

CT Unsaturate Logic

The CT unsaturate logic ensures that the internal fault detector switches out of secure mode if there are no signs of CT saturation. The relay uses the harmonic components from the differential current. The CTU*pn* Relay Word bit asserts following an assertion of CON*pn* when the differential current is less than 10 percent of the restraint current, the total harmonic current is less than 10 percent of the restraint, and there are no appreciable dc components in the currents making up the zone (see *Figure 5.39*). Note that if there is no in-zone transformer (E87XFR*n* = N), the harmonic calculation is not carried out and the harmonic currents are forced to zero.

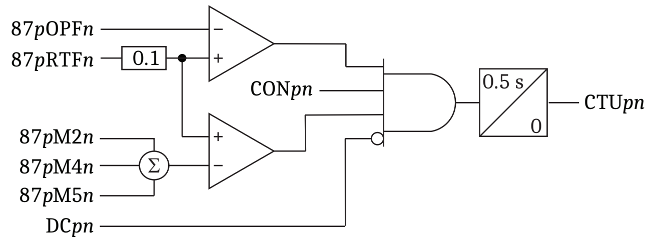


Figure 5.39 CT Unsaturated Logic

Overall Logic for In-Zone Transformer Applications

For applications with an in-zone transformer (E87XFR*n* = Y), the overall logic is represented in *Figure 5.40*. The logic can be divided into three sections: the harmonic blocking path, the harmonic restraint path, and the dynamic security timer.

The logic restrained Relay Word bit (87R) asserts via either path when the operate differential current exceeds the pickup setting and also exceeds the product of the restraint current and the slope setting. The CON*pn* Relay Word bit controls the application of the secure slope setting. Assertion is supervised by the internal fault detector.

The harmonic blocking path asserts the 87*p*RHB*n* Relay Word bit. This path is disabled if E87H*n* does not include B or BW. This path is blocked by the cross blocking Relay Word bit, and also by a high fifth harmonic.

The harmonic restraint path asserts the 87*p*RHR*n* Relay Word bit. This path is disabled if E87H*n* does not include R or RW. This path uses the second and fourth harmonics to boost the restraint signal 87*p*RTH*n*. It is blocked by a high fifth harmonic.

Both paths are blocked by waveshape inrush detection, if enabled. Waveshape unblocking overrides waveshape blocking. It also overrides cross blocking and removes harmonic boosting from the restraint signal.

A dynamic security timer shown in the figure adds a delay in a similar manner to that shown in *Figure 5.40*, but is augmented by waveshape-based unblocking (87UBL*pn*). Operation is delayed by 7.5 ms if either the CON*pn* or INR*pn* Relay Word bits are asserted. Operation is delayed by 15 ms if both Relay Word bits are asserted. However, if INR*pn* is asserted and 87UBL*pn* subsequently asserts, then the delay is reduced from 7.5 ms to 2.5 ms. Similarly, If both CON*pn* and INR*pn* Relay Word bits are asserted and then 87UBL*pn* subsequently asserts, the delay is reduced from 15 ms to 7.5 ms.

The timer output is ANDed with the restrained torque-control Relay Word bit (87RTC*n*) to produce the restrained differential output 87R*n*. The restrained, unrestrained, and rms Relay Word bits are then combined to produce the differential output 87Z*n*.

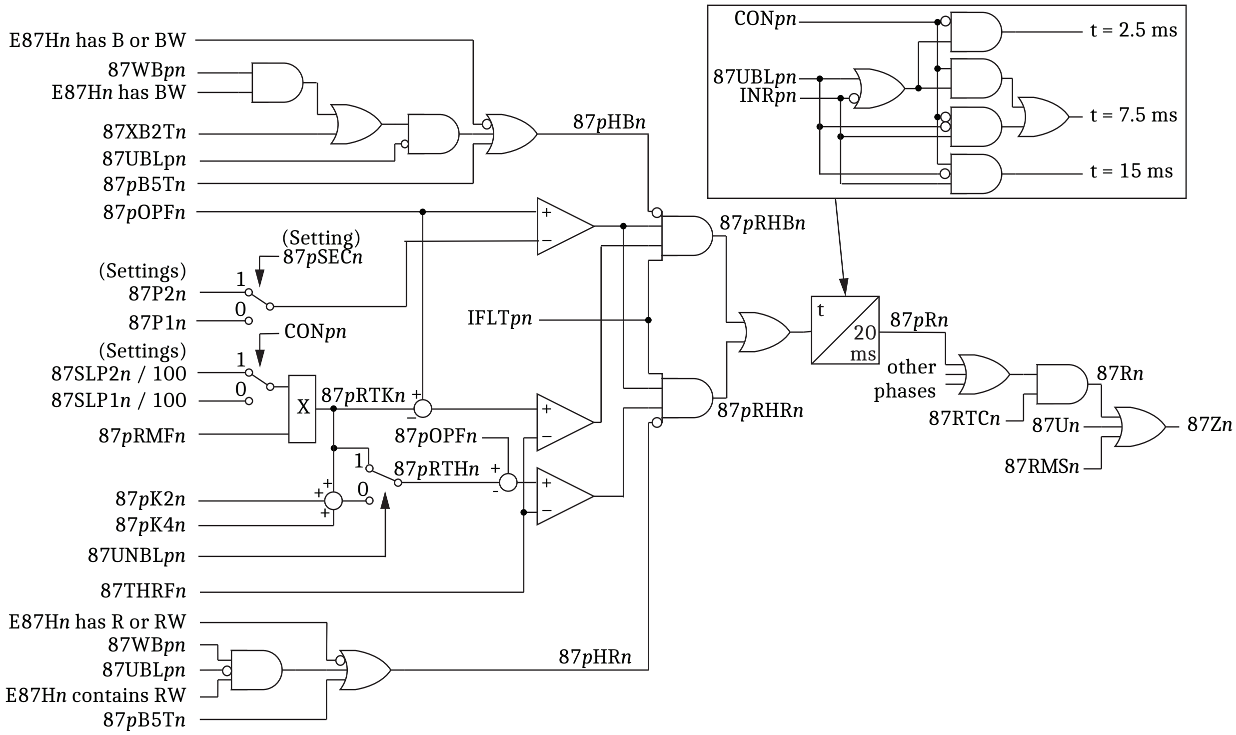


Figure 5.40 Overall Logic For an In-Zone Transformer

CT Selection

CT selection criteria in the SEL-400G are defined in terms of the saturation factor (K_S) for ANSI applications, and the transient dimensioning factor (K_{TD} in IEC 61869) shown in *Table 5.12*. Remanence is considered via the remanence over-dimensioning factor (K_{REM}) which is consistent with both IEEE C37.110 and IEC 61869, as shown in *Equation 5.16*. The CT selection guidance is only applicable when 87UNBL = N.

$$K_{REM} = \frac{1}{1 - \text{Remanence}}$$

Equation 5.16

For example, a low remanence CT type, such as IEC TPY, that holds a maximum remanence of 10 percent has a K_{REM} of 1.1. The remanence level considered is based on industry guidance on expected worst-case levels of remanence, as high as 80 percent.

Table 5.12 Minimum CT Sizing Requirements for the SEL-400G Differential Element (Sheet 1 of 2)

CT Specification	Minimum V_{ANSI}, ALF	Minimum VA Rating	K_{REM}	K_S, K_{TD}
ANSI C (60 Hz)	100	N/A	3.0	1.8
IEC 5P, 10P (50 Hz)	20	2.5	5.0	1.6
IEC 5PR, 10PR (50 Hz)	15	2.5	1.1	1.6
IEC PX (50 Hz)	20	2.5	5.0	1.6
IEC PXR (50 Hz)	15	2.5	1.1	1.6

Table 5.12 Minimum CT Sizing Requirements for the SEL-400G Differential Element (Sheet 2 of 2)

CT Specification	Minimum V_{ANSI}, ALF	Minimum VA Rating	K_{REM}	K_S, K_{TD}
IEC TPX (50 Hz)	20	2.5	5.0	1.6
IEC TPY (50 Hz)	15	2.5	1.1	1.6

$$V_{ANSI} > (K_{REM} \bullet K_S) \bullet \left(\frac{I_F}{N}\right) \bullet R_B$$

Equation 5.17

$$ALF > \frac{(K_{REM} \bullet K_{TD}) \bullet \left(\frac{I_F}{N}\right) \bullet (R_B + R_{CT})}{\left(\frac{VA}{I_{RATED}}\right) + (I_{RATED} \bullet R_{CT})}$$

Equation 5.18

where:

V_{ANSI} = the ANSI C voltage rating at the CT terminals (in volts)
ALF = the accuracy limit factor of the CT
I_F = the fault current in primary amperes
I_{RATED} = the CT rated secondary current (in amperes)
N = the CT turns ratio
R_B = the connected burden in ohms including the secondary wiring and relay burden
R_{CT} = the CT resistance in ohms

The values in *Table 5.12* apply for a 87SLP2*n* setting of 90 percent. In many applications, the actual oversizing factor will be greater than that shown in the table. In this case, the 87SLP2 setting may be relaxed, as shown in *Figure 5.41*, to obtain a lower 87SLP2*n* setting.

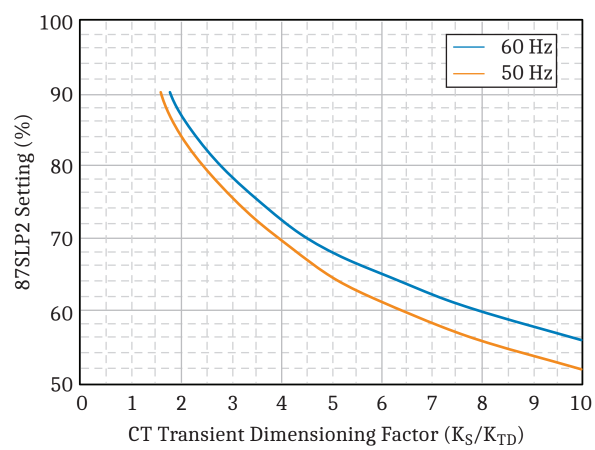


Figure 5.41 87SLP2n Setting as a Function of CT Sizing Factor

CT Selection Example

The following system is used to demonstrate the CT requirements.

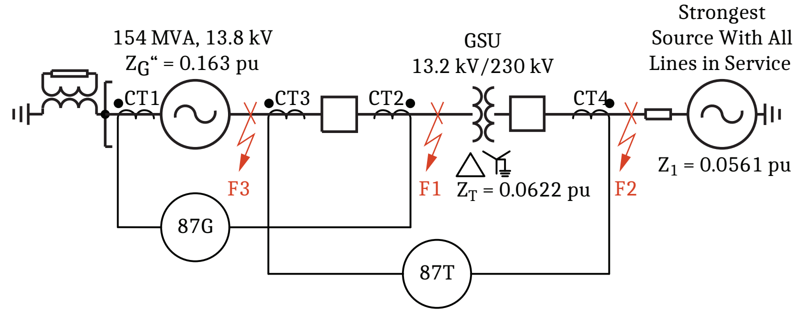


Figure 5.42 Example System for CT Selection

Parameter	Data
Rated current of generator/GSU transformer (including 50% margin)	9,664/555 A
Generator current for three-phase fault at F1	39,530 A
GSU current for three-phase fault at F2	28,610/1,642 A
Generator and GSU transformer current for single-line-to-ground (SLG) fault at F2	21,770/2,164 A
GSU transformer current for 3P fault at F3 with strongest system connected and all lines in service	54,460/3,126 A

ANSI CT Sizing Example

We assume a 60 Hz system with 5 A CT secondary rating. For this example, we assume 300 feet of 10 AWG wire at 75°C. This gives a one-way lead resistance of approximately 0.372 Ω. We also assume a CT resistance of 2.5 mΩ per turn.

CT Ratio Selection for CT1 and CT2 (87G Zone 1)

Select a CT ratio via *Equation 5.19* where I_{FMAX} is the maximum external fault current seen by the CTs.

$$N > (K_{REM} \bullet K_S) \bullet \left(\frac{I_{FMAX}}{100}\right)$$

Equation 5.19

For the example of *Figure 5.42*, the maximum current occurs for a three-phase fault at F1.

$$(K_{REM} \bullet K_S) \bullet \left(\frac{I_{FMAX}}{100\ A}\right) = (3 \bullet 1.8) \bullet \left(\frac{39530\ A}{100\ A}\right) = 2135$$

Equation 5.20

Applying *Equation 5.20*, for CT1 and CT2, we choose a CT ratio of 2400.

Sizing CT Rated Voltage for CT1 and CT2 (87G Zone 1)

The ANSI voltage rating for CTs may be selected via *Equation 5.17*, as shown in *Equation 5.21*.

$$V_{ANSI} > (3 \cdot 1.8) \cdot \left(\frac{39530\ A}{2400}\right) \cdot 0.372\ \Omega = 33.1\ V$$

Equation 5.21

However, according to *Table 5.12*, the minimum V_{ANSI} is 100, therefore we choose a C100 CT. Note that because we sized our CTs larger than required, we can lower the 87SLP2*n* setting. Calculate the CT over-dimensioning by taking the ratio of the saturation voltage of the CT (*Equation 5.22*) compared to the application (*Equation 5.23*), as shown in *Equation 5.24*. Note that RCT is 6 Ω (2400 turns • 0.0025 Ω/turn). If available, use R_{CT} and saturation voltage of the CT (*Equation 5.22*) from the data sheet instead.

$$V_{SAT\_CT} > 100 + 20 \cdot 5\ A \cdot$$

Equation 5.22

$$V_{SAT} > (3 \cdot 1.8) \cdot \left(\frac{39530\ A}{2400}\right) \cdot (0.372\ \Omega + 6\ \Omega) = 566.7\ V$$

Equation 5.23

$$K_{S\_EFF} = \left(\frac{V_{SAT\_CT}}{V_{SAT}}\right) \cdot 1.8 = 2.22$$

Equation 5.24

Both CT1 and CT2 correspond to the 87G Zone. Referring to *Figure 5.41*, we select an 87SLP21 setting for 87G of 85 percent.

CT Ratio Selection for CT3 (87T Zone 2)

Using *Equation 5.19*, the CT ratio for CT3 may be calculated via *Equation 5.25*. The maximum external fault current is for a three-phase fault at F1.

$$(K_{REM} \cdot K_S) \cdot \left(\frac{I_{FMAX}}{100\ A}\right) = (3 \cdot 1.8) \cdot \left(\frac{54460\ A}{100\ A}\right) = 2941$$

Equation 5.25

For CT3, we choose a CT ratio of 3000.

Sizing CT Rated Voltage for CT3 (87T Zone 2)

The ANSI voltage rating for CTs may be selected via *Equation 5.17* as shown in *Equation 5.26*.

$$V_{ANSI} > (3 \cdot 1.8) \cdot \left(\frac{54460\ A}{3000}\right) \cdot 0.372\ \Omega = 36.5\ V$$

Equation 5.26

According to *Table 5.12*, the minimum V_{ANSI} is 100, therefore we choose a C100 CT. Note that because we sized our CTs larger than required, we can lower the 87SLP2*n* setting. Calculate the CT over-dimensioning by taking the ratio of the saturation voltage of the CT (*Equation 5.27*) compared to the application

(*Equation 5.28*), as shown in *Equation 5.29*. Note that RCT is 7.5 Ω (3000 turns • 0.0025 Ω/turn). If available, use R_{CT} and saturation voltage of the CT (*Equation 5.27*) from the data sheet instead.

$$V_{SAT\_CT} > 100 + 20 \bullet 5\ \text{A} \bullet 7.5\ \Omega = 850\ \text{V}$$

Equation 5.27

$$V_{SAT} > (3 \bullet 1.8) \bullet \left(\frac{54460\ \text{A}}{3000}\right) \bullet (0.372\ \Omega + 7.5\ \Omega) = 771.7\ \text{V}$$

Equation 5.28

$$K_{S\_EFF} = \left(\frac{850}{771.7}\right) \bullet 1.8 = 1.98$$

Equation 5.29

CT Ratio Selection for CT4 (87T Zone 2)

The maximum current seen by the HV CT is for a 3P fault at F3 as applied in *Equation 5.30*.

$$(K_{REM} \bullet K_S) \bullet \left(\frac{I_{FMAX}}{100\ \text{A}}\right) = (3 \bullet 1.8) \bullet \left(\frac{3126\ \text{A}}{100\ \text{A}}\right) = 168.8$$

Equation 5.30

For CT4, we obtain a CT ratio of 200.

Sizing CT Rated Voltage for CT4 (87T Zone 2)

The worst-case external 3P fault is at F3 and the worst-case SLG fault is at F2. Applying *Equation 5.17*, the ANSI voltage rating for the HV CT can be calculated via *Equation 5.31* and *Equation 5.32*.

$$V_{ANSI} > (3 \bullet 1.8) \bullet \left(\frac{3126\ \text{A}}{200}\right) \bullet 0.372\ \Omega = 31.4\ \text{V}$$

Equation 5.31

$$V_{ANSI} > (3 \bullet 1.8) \bullet \left(\frac{2164\ \text{A}}{200}\right) \bullet (2 \bullet 0.372\ \Omega) = 43.5\ \text{V}$$

Equation 5.32

According to *Table 5.12*, the minimum V_{ANSI} is 100, therefore we choose a C100 CT. Note that because we sized our CTs larger than required, we can lower the 87SLP2*n* setting. Calculate the CT over-dimensioning by taking the ratio of the saturation voltage of the CT (*Equation 5.33*) compared to the application (*Equation 5.34*), as shown in *Equation 5.35*. Note that RCT is 0.5 Ω (200 turns • 0.0025 Ω/turn). If available, use R_{CT} and saturation voltage of the CT (*Equation 5.33*) from the data sheet instead.

$$V_{SAT\_CT} > 100 + 20 \bullet 5\ \text{A} \bullet 0.5\ \Omega = 150\ \text{V}$$

Equation 5.33

$$V_{SAT} > (3 \bullet 1.8) \bullet \left(\frac{2164\ \text{A}}{200}\right) \bullet (2 \bullet 0.372\ \Omega + 0.5\ \Omega) = 72.7\ \text{V}$$

Equation 5.34

$$K_{S\_EFF} = \left(\frac{150}{72.7}\right) \bullet 1.8 = 3.71$$

Equation 5.35

For the 87T, the LV CT has an effective K_S of 1.98, whereas the HV CT has a higher K_{S_EFF} of 3.71. Choose the lower value (1.98) in this case. Referring to *Figure 5.41*, we select an 87SLP22 setting for 87T of 87 percent.

IEC CT Sizing

We size a 50 Hz 1A Class P 5P CT in this example. We assume 100 m of 2.5 mm^2 wire at 75°C. This gives a one-way lead resistance of approximately 0.841 Ω. We also assume CT winding resistance of 6 mΩ per turn.

VA Rating for All CTs (CT1, CT2, CT3, and CT4)

Because we assumed the same lead length for all CTs, we use the same burden resistance of 0.840 Ω. Choose a VA rating per *Equation 5.36*.

$$VA = 1^2 \bullet 0.841 = 0.841$$

Equation 5.36

Per *Table 5.12*, choose a VA rating of 2.5.

CT Ratio Selection for All CTs (CT1, CT2, CT3, and CT4)

Based on the maximum LV load current of 9664 A, choose 10000:1 CTs for CT1, CT2 and CT3.

Based on the maximum HV load current of 555 A, choose 600:1 for CT4.

ALF for CT1 and CT2 (87G Zone 1)

For the 10000:1 CT, R_{CT} = 60 Ω. ALF, per *Equation 5.18*, through use of values from *Table 5.12*, can be calculated via *Equation 5.37*. The worst-case external fault is at F1.

$$ALF > \frac{(5 \bullet 1.6) \bullet \left(\frac{39530}{10000}\right) \bullet (0.841\ \Omega + 60\ \Omega)}{2.5 + 60} = 30.78$$

Equation 5.37

Choosing the next highest ALF of 40, we choose a 2.5 VA 5P 40 CT for this application. The effective K_{TD} is shown in *Equation 5.38*.

$$K_{TD\_EFF} = \left(\frac{40}{30.78}\right) \bullet 1.6 = 2.08$$

Equation 5.38

We look at *Figure 5.41* for an 87SLP21 of 83 percent.

ALF for CT3 (87T Zone 2)

For the 10000:1 CT, R_{CT} = 60 Ω. E_{AL}, per *Equation 5.18*, through use of values from *Table 5.12*, can be calculated via *Equation 5.39*. The worst-case fault current is the 3P fault at F3.

$$\text{ALF} > \frac{(5 \cdot 1.6) \cdot \left(\frac{54460}{10000}\right) \cdot (0.841\ \Omega + 60\ \Omega)}{2.5 + 60} = 42.41$$

Equation 5.39

Choosing the next highest ALF of 50, we choose a 2.5 VA 5P 50 CT for this application. The effective K_{TD} is shown via *Equation 5.40*.

$$K_{TD\_EFF} = \left(\frac{50}{42.41}\right) \cdot 1.6 = 1.89$$

Equation 5.40

ALF for CT4 (87T Zone 2)

For the 600:1 CT, $R_{CT} = 3.6\ \Omega$. The worst-case 3P external fault and SLG fault are at F2. The ALF for both fault types can be found via *Equation 5.41* and *Equation 5.42*.

$$\text{ALF}_{3P} > \frac{(5 \cdot 1.6) \cdot \left(\frac{3126\ \text{A}}{600}\right) \cdot (0.841\ \Omega + 3.6\ \Omega)}{2.5 + 3.6} = 30.3$$

Equation 5.41

$$\text{ALF}_{SLG} > \frac{(5 \cdot 1.6) \cdot \left(\frac{2164\ \text{A}}{600}\right) \cdot (2 \cdot 0.841\ \Omega + 3.6\ \Omega)}{2.5 + 3.6} = 24.98$$

Equation 5.42

If we use 2.5 VA 5P 40 CT for this application, we get the effective K_{TD} shown in *Equation 5.43*.

$$K_{TD\_EFF} = \left(\frac{40}{30.3}\right) \cdot 1.6 = 2.1$$

Equation 5.43

The minimum over-dimensioning for the 87T zone applying CT3 (1.89 from *Equation 5.40*) and CT4 (2.1 from *Equation 5.43*) is 1.89. This provides us an 87SLP22 of 85 percent.

Setting Guidelines for 87 Phase Differential

Table 5.13 87 Phase Differential Settings

Setting	Prompt	Range	Default	Category
E87Z*n*	87 Zone *n* Terminals	Combo of S, T, U, W, X, Y	W, X	Group
E87XFR*n*	87 Zone *n* In-Zone Transformer	Y, N	N	Group

Use the E87Z*n* setting to enable a zone and to specify which terminals make up the zone. A minimum of two terminals must be selected to enable a zone. Depending on the application, you may not need all of these inputs for the differential protection.

Use the E87XFR*n* setting to specify that a transformer is within the zone. When set to Y, the element carries out TAP and connection compensation. If inrush is possible, then harmonic blocking and harmonic restraint can be enabled.

Table 5.14 Pickup, Slope, and Security Settings

Setting	Prompt	Range	Default	Category
87P1*n*	87 Zone *n* Oper. Current Sensitive PU[a]	0.10–4	0.25	Group
87P2*n*	87 Zone *n* Oper. Current Secure PU[a]	0.10–4	0.5	Group
87SLP1*n*	87 Zone *n* Slope 1 Percentage	5.00–90%	10	Group
87SLP2*n*	87 Zone *n* Slope 2 Percentage	5.00–90%	75	Group
87RTC*n*	87 Zone *n* Restrained Element TC	SELOGIC control equation	1	Group
87*p*SEC*n*	87 Zone *n* Switch to Secure (SELOGIC Equation)	SELOGIC control equation	CON*pn*	Group
87EFDO*n*	87 Zone *n* External Fault Detect DO	0.0200–1.2 s	1	Group

[a] PU is per-unit of the tap setting. See Equation 5.15.

Generator Differential Application

The following settings are suggested for the generator differential relay application.

$$87P1n = \frac{0.25 \bullet \text{Relay Nominal Current}}{TAP} \text{ pu}$$

87SLP1*n* accommodates CT and relay errors under steady-state conditions.

87SLP1*n* = 10%

If the unit is a black-start unit, 87P2*n* should be set higher than 87P1*n*, as shown in the following equation. Otherwise, it can be set the same as 87P1*n*.

$$87P2n = \frac{0.5 \bullet \text{Relay Nominal Current}}{TAP} \text{ pu}$$

Refer to *CT Selection on page 5.36* for guidelines on setting 87SLP2*n*.

Transformer or Overall Differential Application

The following settings are suggested for the unit or transformer differential relay.

$$87P1/2n = \frac{0.20 \bullet \text{Relay Nominal Current}}{TAP} \text{ pu}$$

The relay uses the MVA, terminal voltage, CT ratio, and CT connection settings you have entered and calculates the TAP values automatically. You can view these values by using the Grid Configurator.

In addition to CT and relay errors, 87SLP1*n* accommodates minor errors caused by transformer turns errors and steady-state magnetizing current. This translates to a minimum Slope 1 setting of 20 percent. If the transformer includes a tap-changer, the slope setting is increased using the following calculation.

$$SLPTPCH = 7.5\% \bullet \frac{(\text{TAP Changer }\%)}{10\%}$$

This results in a Slope 1 setting of:

$$87SLP1n = 20\% + SLPTPCH$$

Add another 7.5 percent to 87SLP1*n* for each 10 percent TAP (e.g., if the tap-changer supports a 20 percent change, 87SLP1*n* setting can be set to 20% + (20% / 10%) • 7.5% = 35%.

While 87PCT2/4 settings are intended to provide restraint/blocking because of conditions that excite the transformer magnetizing branch such as inrush, these settings also provide additional security during external fault conditions involving CT saturation. Hence for in-zone transformer applications with default 87PCT2/4 settings, use the following equation to determine 87SLP2 setting irrespective of CT dimensions.

NOTE: The SEL-400G restraint quantity (87pRTFn) calculation differs from the SEL-300G, SEL-587, and SEL-387 by a factor of 2. To achieve the same relative slope for the differential elements in the SEL-400G, SEL-487E, SEL-387, SEL-587, SEL-300G, and SEL-787, this factor of 2 must be accounted for. The relationships between slope settings for the six relays are shown here:

Slope $1_{400G/487E/787}$ = 1/2 • Slope $1_{387/587/300G}$

Slope $2_{400G/487E/787}$ = 1/2 • Slope $2_{387/587/300G}$

87SLP2*n* = max(90%, (SLP2CT + SLPTPCH)) (assuming 87PCT2/4 = 15%)

where SLP2CT is the Slope 2 setting determined during CT selection (see *Figure 5.41*).

87*p*SEC*n*, 87EFDO*n*, and 87RTC*n* can be left at their default values. Alternative settings may be considered in unusual applications—for example, severe CT mismatch.

Table 5.15 Unrestrained and RMS Settings

Setting	Prompt	Range	Default	Category
87UP*n*	87 Zone *n* Unrestrained Element PU	1.00–20 pu	8	Group
87UTC*n*	87 Zone *n* Unrestrained Element TC (SELOGIC Equation)	SELOGIC control equation	1	Group
87RMP*n*	87 Zone *n* RMS Element PU (OFF, 1.00–20)	OFF, 1.00–20 pu	OFF	Group
87RMTC*n*	87 Zone *n* RMS Element TC (SELOGIC Equation)	SELOGIC control equation	1	Group

Set the unrestrained element pickup, 87UP*n*, to operate for very heavy current levels that clearly indicate an internal fault. For in-zone transformer applications, this is typically about 8 times tap. The unrestrained differential element only responds to the fundamental frequency component of the differential operating current. It is unaffected by the slope settings, and there is no harmonic blocking/restraint for this element during inrush conditions. Thus, you must set the element pickup level high enough that the element does not react to large inrush currents.

The rms element is used for instances where the generator operates at an off-nominal frequency but the relay might be unable to track frequency. One example is dynamic braking of a hydro generator. In this case, the generator speed is ramping down but the generator terminals are shorted and the relay cannot measure the correct frequency. The generator is offline so CT saturation for external faults is not a concern. Set the rms element pickup, 87RMP*n* below the minimum expected fault current. Torque-control the element so that it is enabled only when dynamic braking is active.

Winding Compensation Settings for In-Zone Transformers

The SEL-400G provides winding compensation for in-zone transformer applications. For a detailed discussion on the selection of transformer compensation settings see the technical paper *Beyond the Nameplate—Selecting Transformer Compensation Settings for Secure Differential Protection* by Barker Edwards, David G. Williams, Ariana Hargrave, Matthew Watkins, and Vinod K. Yedidi, available at selinc.com.

Table 5.16 Winding Compensation Settings

Setting	Prompt	Range	Default	Category
MVA*n*	87 Zone *n* Transformer Max. MVA	OFF, 1–5000 MVA	OFF	Group
VTERM*mn*	87 Zone *n* Term. *m* L-L Voltage	1.00–1000 kV	275	Group
87*m*CTC*n*	87 Zone *n* Term. *m* CT Conn. Compensation	0–13	0	Group
87*m*TAP*n*[a]	87 Zone *n* Term. *m* Current Tap	0.50 to 175 A, sec	1	Group
87*m*ANG*n*	87 Zone *n* Term. *m* Ang. Comp.	–179.99 to 180.00 deg	30	Group

[a] Automatically calculated when MVAn is not set to OFF. See Equation 5.15.

For MVA*n*, use the highest expected transformer rating, such as the forced oil and air cooled (FOA) rating or a higher emergency rating, when setting the maximum transformer capacity.

For VTERM*nm*, enter the nominal line-to-line transformer terminal voltages. If the transformer differential zone includes a load tap changer, assume that the tap changer is in the neutral position. The setting units are kilovolts.

Discussion on CT Connection Compensation

Setting 87*m*CTC*n* specifies which compensation matrix the differential element is to use. The setting values are 0 through 13. These values physically represent the number of increments of 30 degrees that a balanced set of currents with ABC phase rotation will be rotated in a counterclockwise direction when multiplied by the CTC matrix. For example, setting 87STCS = 1 rotates the Terminal S set of currents counterclockwise by 30 degrees.

If a balanced set of currents with ACB phase rotation undergoes the same exercise, the rotations by the CTC matrices are in the clockwise direction.

The CTC(0) setting value creates no changes in the currents. Referring to *Figure 5.16*:

87A*m*F*n* = IA*m*F

87B*m*F*n* = IB*m*F

87C*m*F*n* = IC*m*F

The 87*n*CTC*m* = 1 setting performs a 30-degree compensation in the counterclockwise direction, as would a delta CT connection of type DAB (Dy1). This connection results from the following relationships:

$$87\mathrm{A}m\mathrm{F}n = \frac{\mathrm{IA}m\mathrm{F} - \mathrm{IB}m\mathrm{F}}{\sqrt{3}}$$

$$87\mathrm{B}m\mathrm{F}n = \frac{\mathrm{IB}m\mathrm{F} - \mathrm{IC}m\mathrm{F}}{\sqrt{3}}$$

$$87\mathrm{C}m\mathrm{F}n = \frac{\mathrm{IC}m\mathrm{F} - \mathrm{IA}m\mathrm{F}}{\sqrt{3}}$$

Setting 87*n*CTC*m* = 1 realizes the above mentioned relationships, and the relay uses the following CTC(1) matrix to compensate the currents:

$$[CTC(1)] = \frac{1}{\sqrt{3}} \bullet \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix}$$

The compensation matrix CTC(12) is similar to CTC(0), in that it produces no phase shift (or, more correctly, 360 degrees of shift) in a balanced set of phasors separated by 120 degrees. However, it removes zero-sequence components from the terminal currents, as do all of the matrices having non-zero values of *m*, i.e., all matrices except CTC(0).

$$[CTC(12)] = \frac{1}{3} \bullet \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix}$$

that is,

$$87AmFn = \frac{2 \bullet IAmF - IBmF - ICmF}{3}$$

$$87BmFn = \frac{-IAmF + 2 \bullet IBmF - ICmF}{3}$$

$$87CmFn = \frac{-IAmF - IBmF - 2 \bullet ICmF}{3}$$

We could use this type of compensation in applications having wye-connected transformer windings (no phase shift) with wye CT connections for each winding. Using 87*m*CTC*n* = 12 for each terminal removes zero-sequence components, just as connection of the CTs in delta would do, but without producing a phase shift. (You could also use 87*m*CTC*n* = 1 or 11 for this same application, yielding compensation similar to that from connection of the CTs on both sides in DAB or DAC.) The effect of each compensation on balanced three-phase currents is to rotate the currents *m* • 30 degrees without a magnitude change. *Table 5.17* shows the complete list of compensation matrices.

Table 5.17 Compensation Matrices (Sheet 1 of 2)

$[CTC(1)] = \frac{1}{\sqrt{3}} \bullet \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix}$	$[CTC(2)] = \frac{1}{3} \bullet \begin{bmatrix} 1 & -2 & 1 \\ 1 & 1 & -2 \\ -2 & 1 & 1 \end{bmatrix}$
$[CTC(3)] = \frac{1}{\sqrt{3}} \bullet \begin{bmatrix} 0 & -1 & 1 \\ 1 & 0 & -1 \\ -1 & 1 & 0 \end{bmatrix}$	$[CTC(4)] = \frac{1}{3} \bullet \begin{bmatrix} -1 & -1 & 2 \\ 2 & -1 & -1 \\ -1 & 2 & -1 \end{bmatrix}$
$[CTC(5)] = \frac{1}{\sqrt{3}} \bullet \begin{bmatrix} -1 & 0 & 1 \\ 1 & -1 & 0 \\ 0 & 1 & -1 \end{bmatrix}$	$[CTC(6)] = \frac{1}{3} \bullet \begin{bmatrix} -2 & 1 & 1 \\ 1 & -2 & 1 \\ 1 & 1 & -2 \end{bmatrix}$

Table 5.17 Compensation Matrices (Sheet 2 of 2)

$[CTC(7)] = \frac{1}{\sqrt{3}} \bullet \begin{bmatrix} -1 & 1 & 0 \\ 0 & -1 & 1 \\ 1 & 0 & -1 \end{bmatrix}$	$[CTC(8)] = \frac{1}{3} \bullet \begin{bmatrix} -1 & 2 & -1 \\ -1 & -1 & 2 \\ 2 & -1 & -1 \end{bmatrix}$
$[CTC(9)] = \frac{1}{\sqrt{3}} \bullet \begin{bmatrix} 0 & 1 & -1 \\ -1 & 0 & -1 \\ 1 & -1 & 0 \end{bmatrix}$	$[CTC(10)] = \frac{1}{3} \bullet \begin{bmatrix} 1 & 1 & -2 \\ -2 & 1 & 1 \\ 1 & -2 & 1 \end{bmatrix}$
$CTC(11)] = \frac{1}{\sqrt{3}} \bullet \begin{bmatrix} 1 & 0 & -1 \\ -1 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix}$	$[CTC(12)] = \frac{1}{3} \bullet \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix}$

If 87*m*CTC*n* is set to 13, the compensation matrix for Terminal *m* is defined using *Equation 5.44*.

$$87m\text{M}n = \frac{2}{3}\begin{pmatrix} \cos(87m\text{ANG}n) & \cos(87m\text{ANG}n + 120°) & \cos(87m\text{ANG}n - 120°) \\ \cos(87m\text{ANG}n - 120°) & \cos(87m\text{ANG}n) & \cos(87m\text{ANG}n + 120°) \\ \cos(87m\text{ANG}n + 120°) & \cos(87m\text{ANG}n - 120°) & \cos(87m\text{ANG}n) \end{pmatrix}$$

Equation 5.44

The setting 87*m*ANG*n* specifies the phase rotation produced by the compensation matrix and has a range of –179.99 to 180.00 degrees.

For example, setting 87SCTC1 = 13 and 87SANG1 = 15 degrees rotates a balanced set of Terminal S currents counterclockwise by 15 degrees in an ABC system. In an ACB system, the rotation is in the clockwise direction.

Upon your entry of an MVA*n* setting (i.e., MVA is not set to OFF), the relay uses the MVA, terminal voltage, CT ratio, and CT connection settings you have entered and calculates the TAP values automatically. You can also enter tap values directly. Set MVA = OFF, and enter the TAPS–TAPX values directly, along with the other pertinent settings. The relay calculates TAP with the following limitations:

➤ The TAP settings are within the range 0.1 • I_{NOM} and 35 • I_{NOM} (I_{NOM} = 1 A or 5 A)

➤ The ratio of the highest (TAPm / $I_{NOM}m$) to the lowest (TAP*m* / $I_{NOM}m$) is less than or equal to 35.

Winding compensation can also be applied for transverse differential protection of generators with parallel branches, as shown in *Figure 5.43*. This scheme can be used as an alternative to conventional split-phase schemes. In this application, the compensation matrices act to balance the differential under normal operation.

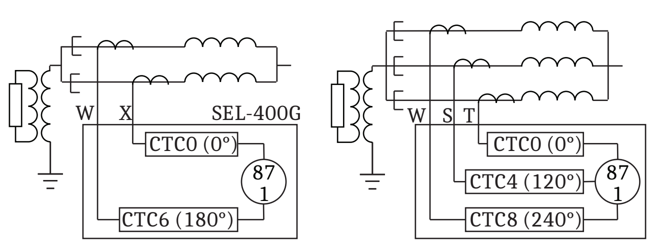


Figure 5.43 Transverse Differential Protection of Parallel-Branch Stator Windings

Table 5.18 Inrush Restraint Settings

Setting	Prompt	Range	Default	Category
E87H*n*	87 Zone *n* Enable Harmonic Block and Restraint	OFF, B, BW, R, RW	B	Group
87CORE*n*	87 Zone *n* XFMR Core Type, Three or Single	T, S	T	Group
E87UNB*n*	87 Zone *n* Enable Wave-Shape Inrush Unblocking	Y, N	N	Group
87PCT2*n*	87 Zone *n* Second-Harmonic Percentage	OFF, 5% to 100%	OFF	Group
87PCT4*n*	87 Zone *n* Fourth-Harmonic Percentage	OFF, 5% to 100%	OFF	Group
87PCT5*n*	87 Zone *n* Fifth-Harmonic Percentage	OFF, 5% to 100%	OFF	Group
87TH5D*n*	87 Zone *n* Fifth-Harmonic Alarm Delay	0.0000 to 200 s	0.5	Group
87TH5P*n*	87 Zone *n* Fifth-Harmonic Alarm Threshold p.u.	OFF, 0.02–3.2	OFF	Group

NOTE: If a transformer is within the zone, 87PCT2n, 87PCT4n, and 87PCT5n must be set properly.

E87Hn (87 Zone n Enable Harmonic Block and Restraint)

Each zone includes harmonic blocking and harmonic restraint functions. Select the element most suited for your application. You can enable harmonic blocking or harmonic restraint by selecting E87H*n* = B or E87H*n* = R, respectively. Both can be enabled simultaneously by selecting E87H*n* = B, R. In addition, either can be employed with waveshape-based detection by selecting BW (versus B) or RW (versus R). The harmonic-blocking element is generally faster, but because of cross blocking, it has reduced dependability when energizing a faulted transformer. Harmonic restraint is generally slower but has improved dependability when energizing a faulted transformer. Also, because the harmonics are summed, harmonic restraint is more secure during inrush conditions if both 87PCT2*n* and 87PCT4*n* are set.

87COREn (Transformer Core Type, Three-Legged or Individual Cores)

The waveshape-based dwell-time algorithm for inrush detection must be adjusted based on the transformer core type. 87CORE*n* defaults to T for three-legged, three-phase transformers. The setting 87CORE*n* = S is for transformers made with single-phase units or with a four- or five-legged core.

E87UNBn (Enable Waveshape Unblocking Logic)

The waveshape-unblocking logic provides sensitive detection of internal faults and cancels the inrush blocking functions used by the phase-restrained and negative-sequence differential elements, improving element operation times for internal faults. Enable the unblocking logic by setting E87UNB*n* = Y.

87PCT2n, 87PCT4n, 87PCT5n (Second-, Fourth-, and Fifth-Harmonic Percentage of Fundamental)

NOTE: The larger the 87PCT2n, 87PCT4n, or 87PCT5n, the smaller the effect of the setting.

The SEL-400G measures the amount of second-, fourth-, and fifth-harmonic current flowing in the transformer. With older transformers, magnetizing inrush current contains high percentages of second and fourth harmonics. However, some types of newer transformers may require setting the threshold as low as 7 percent.

87TH5Pn, 87TH5Dn (Fifth-Harmonic Alarm Threshold and Delay)

When the volt/hertz function is unavailable, use the fifth-harmonic measurement to assert an alarm output during startup. This alarm indicates current in excess of the rated transformer excitation current. At full load, an 87TH5P*n* setting of 0.1 corresponds to 10 percent of the fundamental current. Use Timer 87TH5D*n* to prevent the relay from indicating transient presence of fifth-harmonic currents. You might consider triggering an event report if transformer excitation current exceeds the fifth-harmonic threshold.

There are two criteria for setting 87TH5P*n*:

$$87TH5Pn \bullet TAP_{MIN} \geq 0.05 \bullet I_{NOM}$$

$$87TH5Pn \bullet TAP_{MAX} \leq 35 \bullet I_{NOM}$$

where TAP_{MIN} and TAP_{MAX} are the least and greatest values, respectively, of the tap settings.

Negative-Sequence Percentage-Restrained Differential Element

During heavy load conditions, the resulting increase in restraint current renders the phase-differential element less sensitive, particularly from detecting transformer winding interturn faults. Because negative-sequence currents are unaffected by load in a balanced system, the negative-sequence percentage differential element provides sensitive protection for transformer winding interturn faults. This function is not effective for generator stator winding faults and is disabled when E87XFR*n* = N.

Figure 5.44 shows the trajectory of a fault that shorts out 2 percent of the A-Phase winding of a three-phase transformer. In the phase-differential operation portion of *Figure 5.44*, the transformer is fully loaded, and the phase-differential relay operates when the operate current reaches around 0.43 per unit. *Figure 5.44* also shows the negative-sequence differential element response for the same fault. Because balanced load does not affect negative-sequence current, the negative-sequence element operates when the operate current reaches 0.3 per unit.

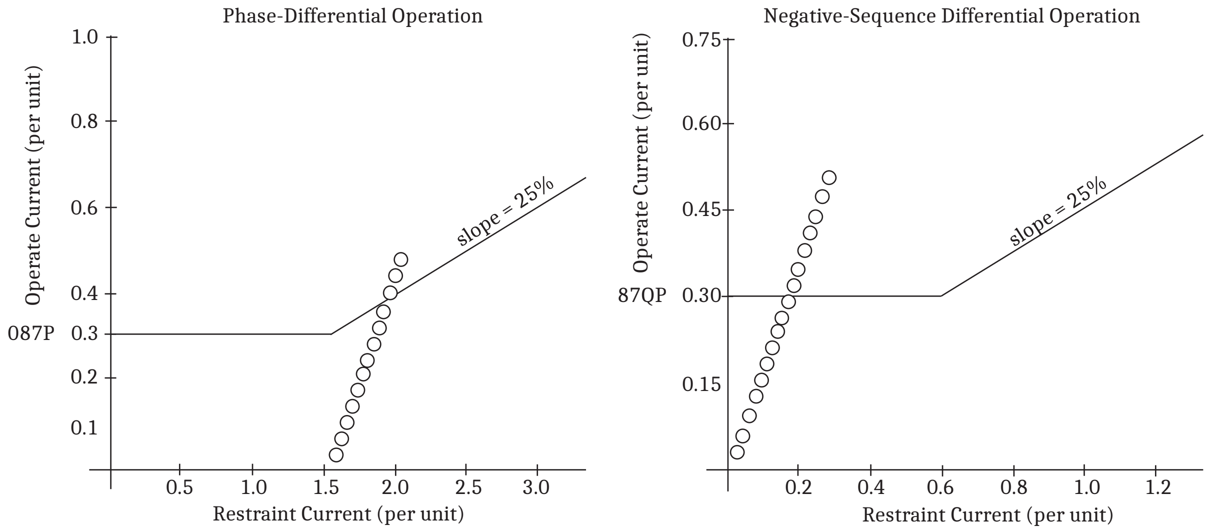


Figure 5.44 Differential Operations

The relay uses filtered compensated currents (see *Figure 5.45*) and *Equation 5.45* to calculate the negative-sequence currents for each terminal included in the differential element (ABC phase rotation) when you have enabled the element through the E87Q setting. The element calculates the negative-sequence operating and restraint current as shown in *Equation 5.46* and *Equation 5.47*, respectively.

NOTE: The 87Q element currents are set in per unit of the 87nAPm values (see Figure 5.16).

$$87QmFn = \begin{bmatrix} 1 & a^2 & a \end{bmatrix} \bullet \begin{bmatrix} 87AmFn \\ 87BmFn \\ 87CmFn \end{bmatrix}$$

Equation 5.45

where:

$$a = e^{j120}$$
$$a^2 = e^{j240}$$

$$87QOPFn = |\Sigma 87QmFn|$$

Equation 5.46

$$87QRTFn = \max(|87QmFn|)$$

Equation 5.47

NOTE: CON is the OR combination of CONAn, CONBn, CONCn (see Figure 5.20).

Figure 5.45 shows the logic that forms the negative-sequence differential element. In the figure, the relay calculates the operating current in a similar manner to that of the phase-restrained differential element. However, the restraint current is the maximum of the negative-sequence currents among the terminals that are part of the differential calculations. After evaluating the operating and restraint currents in the differential element, the relay verifies that torque-control (87QTC*n*) is asserted. This SELOGIC variable has a default value of NOT CON*n* and NOT 87QB*n*. The default assignment checks that the fault is internal and that the negative-sequence blocking logic is deasserted (see *Figure 5.46*).

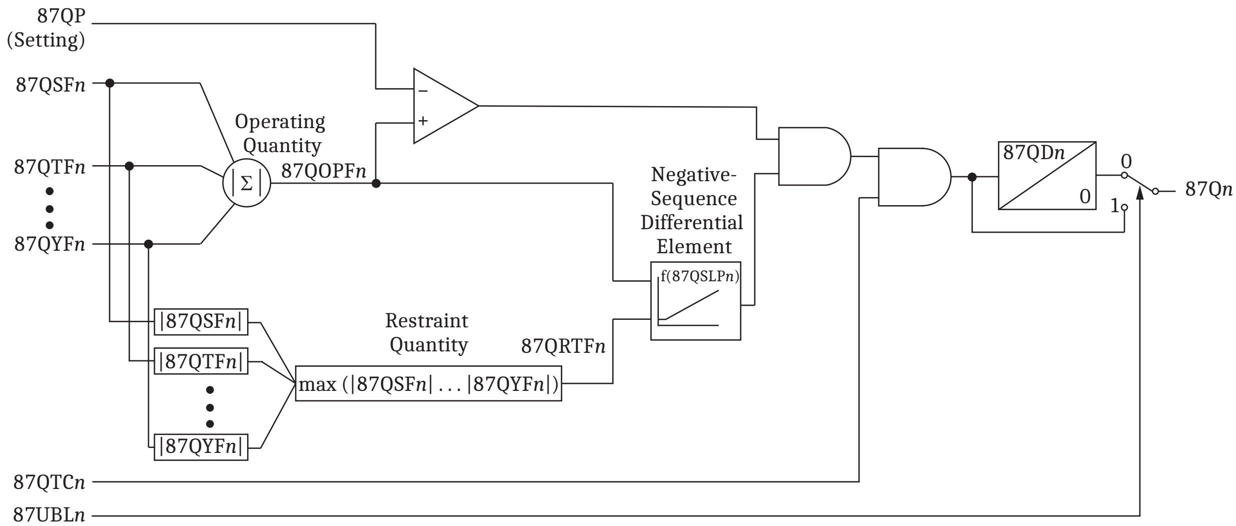


Figure 5.45 Negative-Sequence Percentage-Restrained Differential Element

As shown in *Figure 5.45*, if you have enabled the unblocking logic and 87UBL*n* asserts, the relay bypasses the 87QD*n* timer, allowing the negative-sequence differential element to operate faster.

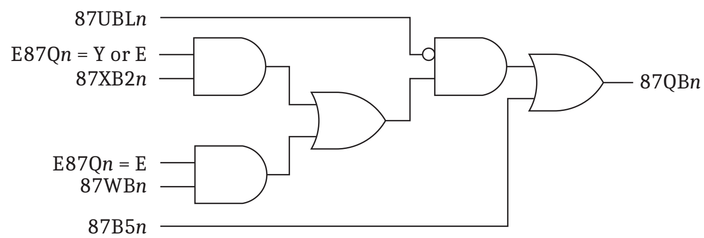


Figure 5.46 Negative-Sequence Differential-Element Blocking Logic

The negative-sequence differential element blocking logic illustrated in *Figure 5.46* secures the element during inrush or overexcitation conditions. Enable or disable the inrush security checks via the negative-sequence differential element enable setting (E87Q*n*). If you have selected harmonic-based inrush security by setting E87Q*n* = Y or E, an assertion of the second- and fourth-harmonic cross-blocking logic, 87XB2*n*, (see *Figure 5.26*) asserts 87QB*n* and blocks the element. If you have also enabled waveshape-based inrush security by setting E87Q*n* = E, an assertion of the waveshape inrush blocking logic, 87WB*n*, (see *Figure 5.31*) asserts 87QB*n* and blocks the element. If you have enabled the unblocking logic and 87UBL*n* asserts (see *Figure 5.36*), indicating detection of an internal fault, the relay cancels the inrush blocking of both the harmonic- and waveshape-based methods. If the fifth-harmonic overexcitation cross-blocking logic (87B5*n*) asserts, 87QB*n* asserts and blocks the element.

E87Qn Enable Negative-Sequence Differential Element

The E87Q*n* setting enables the negative-sequence differential element, and the setting option controls the method of inrush security. Set E87Q*n* = Y to provide inrush blocking that uses only the harmonic-based method. Set E87Q*n* = E to provide inrush blocking from either the harmonic- or waveshape-based methods.

87QPn Negative-Sequence Differential-Element Operating Current Pickup

Set the negative-sequence differential element to improve sensitivity to internal transformer winding turn-to-turn faults during heavy load conditions. 87QP*n* is the negative-sequence pickup threshold of the element, and is set in per unit of the 87*n*TAP*m* values.

87QSLPn Negative-Sequence Differential Slope

The 87QSLP*n* setting defines the slope of the negative-sequence differential element. Unlike the phase-restrained differential elements, there is only one slope to set because the negative-sequence element is blocked if an external fault is detected (when the CON*n* Relay Word bit asserts).

87QDn Negative-Sequence Differential-Element Delay

The output of the negative-sequence differential element can be delayed for added security. Set the negative-sequence differential element 87QDC*n* delay to the recommended delay of 0.2 seconds.

87QTCn Negative-Sequence Differential-Element Torque Control

SELOGIC control equation 87QTC*n* provides a method to externally control the enabling of the 87Q pickup. The default setting is recommended in *Figure 5.46*.

Restricted Earth Fault Element

This function is used to provide selective ground fault protection for a low-impedance grounded generator or for the wye winding of a transformer. In either application, the phase-differential element may only detect faults on the upper portion of the winding. The REF scheme can provide better coverage for faults near the neutral. Historically, two operating principles have been applied for selective ground fault protection: ground differential and REF. The ground differential as implemented in a digital relay is challenged because it will be a low-impedance implementation and could misoperate for CT saturation for a close-in phase-to-phase or three-phase fault. The operating signal of the REF scheme is derived from a CT in the ground connection of the generator or transformer. Therefore, it picks up only in the case of a true ground fault. Operation of the REF scheme is supervised by a zero-sequence directional check. The directional check is more tolerant of CT errors as compared to a conventional zero-sequence differential scheme. However, the REF scheme needs additional logic to ensure that it operates in the case that there is no current for the directional check. This could happen for example, if a ground fault occurs on a generator that is energized but not yet connected to the system.

Figure 5.47 shows the characteristic of the REF element, with the shaded area indicating the tripping area. The operating current is derived from a single-phase input connected to a CT in the ground connection of the generator or transformer. The SEL-400G uses a Y current input as the operating current for an REF element. The reference current is derived from a set of three phase currents (S, T, or U) or another Y input.

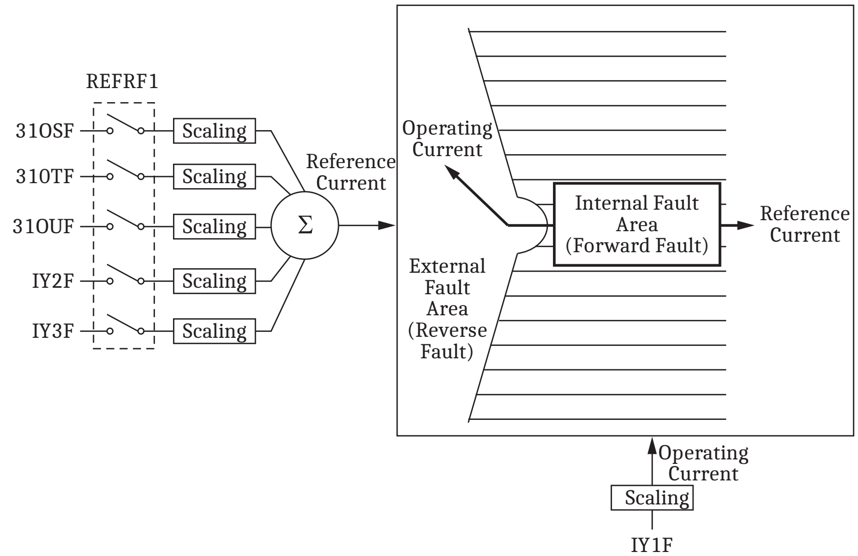


Figure 5.47 REF Directional Element (REF 1 Is Shown)

Because the REF element employs a neutral CT at neutral end of the winding and a set of three CTs at the HV end of the winding, REF protection can detect only ground faults within that particular generator or wye-connected transformer winding. The element is restricted in the sense that protection is limited to ground faults within a zone defined by neutral and reference CT placement.

The REF element uses comparison of zero-sequence currents, so the reference CTs must be connected in wye for the element to function. Delta-connected CTs cancel out all zero-sequence components of the currents, eliminating one of the quantities the REF element needs for comparison.

To enable an REF element, Terminal Y must be configured as three single-phase current inputs (CTCONY := 1PH). In this case, IAY, IBY, and ICY are unavailable and IY1, IY2, and IY3 are available. *Figure 5.48* shows the 24 analog inputs of the SEL-400G.

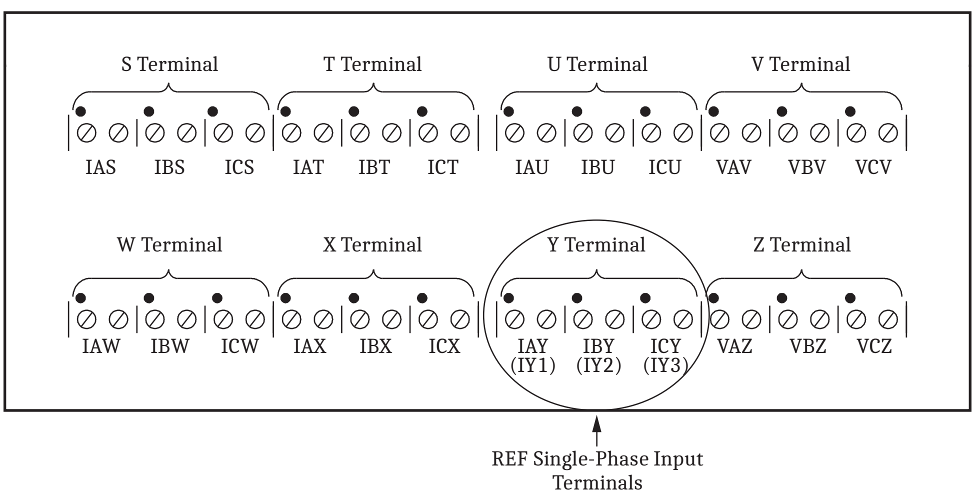


Figure 5.48 REF Terminals

Table 5.19 shows the relationships among the input currents of the Y terminal and the REF elements. These relationships are not settable; they are fixed and must be observed when you use the REF function. For example, if you select REF 1 for your application, wire the input current from the neutral CT to IY1.

Table 5.19 Relationships Among Input Currents and REF Elements

Input Current	REF Element
IY1	REF Element 1
IY2	REF Element 2
IY3	REF Element 3

The reference current is defined using the REFRF*n* setting. This setting allows for several possible configurations of the REF element. *Figure 5.49* shows two examples. In *Figure 5.49(A)*, the REF1 is applied to a low-impedance-grounded generator. At its terminals, the generator is equipped with a core balance CT that is connected to the Y2 input and used as the reference current for the scheme. In *Figure 5.49(B)*, a transformer is feeding a ring bus through two breakers. REF3 provides REF protection. The currents from each breaker are connected to the S and T inputs where they are summated and used as the reference current.

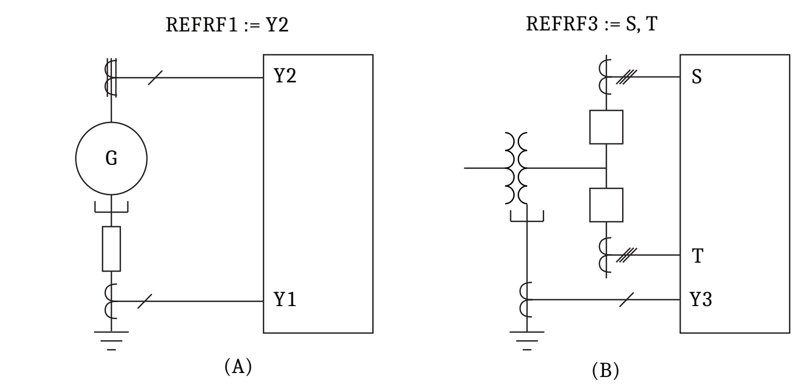
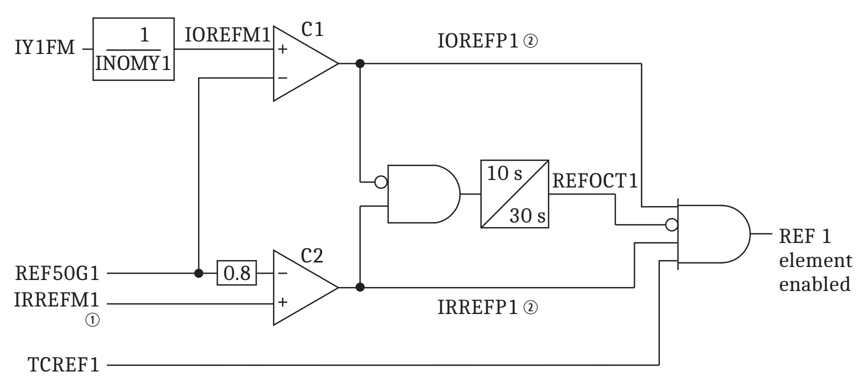


Figure 5.49 Reference Current Configuration Examples

Figure 5.50 shows the REF 1 element logic diagram (REF 2 and REF 3 have similar diagrams) that produces the REF enable output.



① See Figure 5.51.

② Signals are labeled in this figure for ease of discussion. They are not Relay Word bits.

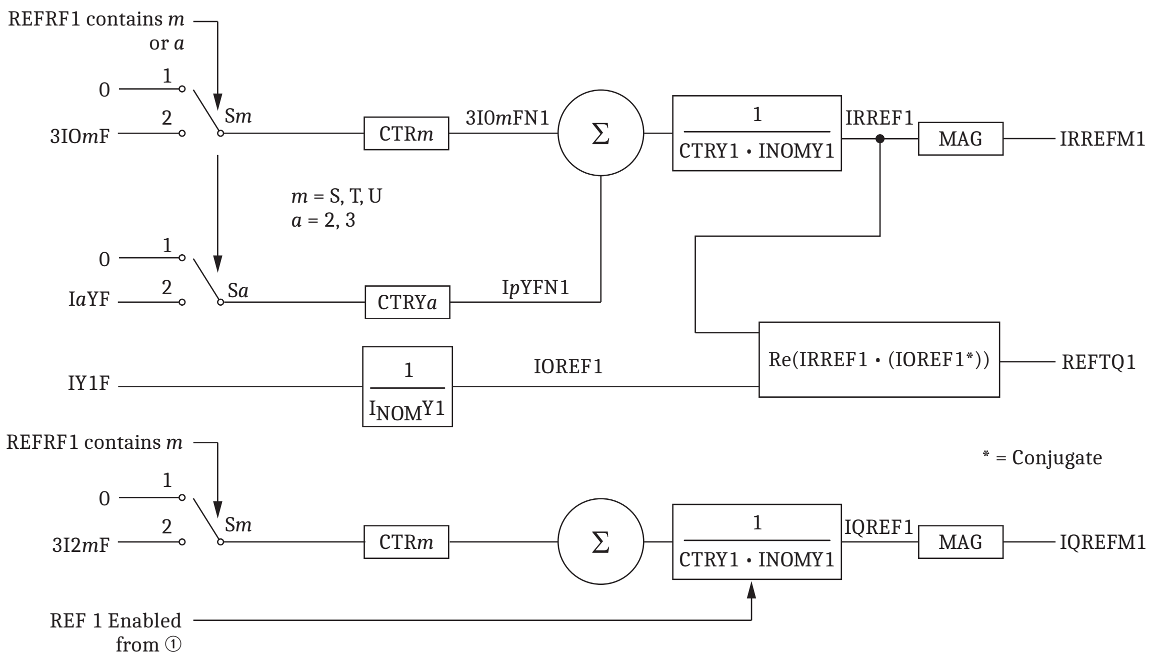
Figure 5.50 REF 1 Element Enable Logic

IY*n*FM is the magnitude of the input current from the neutral CT connected to Terminal IY*n*.

Comparator C1 compares the normalized IY*n*FM value against the REF50G*n* Group setting and asserts if the measured quantity exceeds the threshold. Comparator C2 compares 0.8 of the REF50G*n* setting value against the magnitude of the reference current. The 0.8 multiplier secures the operation of the REFF*n* element. This ensures that the nondirectional output (NDREF*n*) does not assert for an external fault (see *Figure 5.52*).

The output of the comparators, together with the torque-control equation TCREF*n*, enables the REF *n* element, which supervises the directional calculations (see *Figure 5.51*). Note that the REF *n* enable declaration is also secured against an open circuit or a setting error (REF50G) via REFOCT*n*.

Figure 5.51 shows the logic that performs the directional calculations.



① Figure 5.50.

Figure 5.51 Algorithm That Performs the Directional Calculations (REF 1 Is Shown)

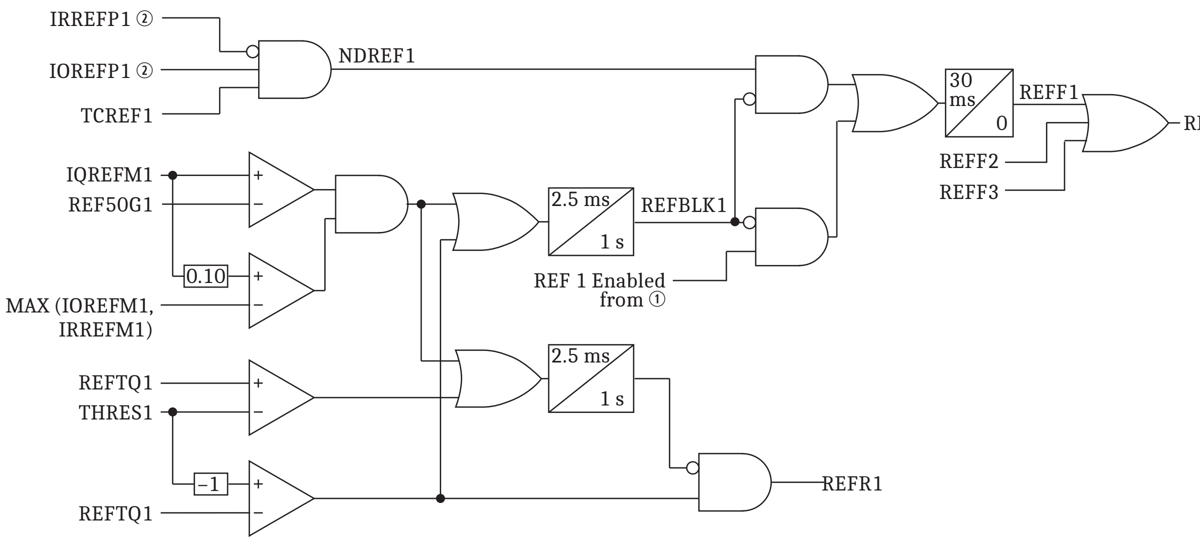
Switch S (S, T, U, 2, 3) selects the zero-sequence and negative-sequence vector currents from those CTs that are part of the REF calculations, as determined by Group setting REFRF*n*, where *m* = S, T, U, and *a* = 2, 3 for REF*n*. For a single-wye winding, the logic requires one neutral CT and one set of line CTs for the REF function. If this set of line CTs is from Terminal S, then Switch SS is in Position 2, while all other cells of Switch S remain in Position 1. Current inputs from those terminals in Position 1 are not included in any REF element calculations.

Next, the currents are converted to primary values by multiplying each current by the appropriate CT ratio. The relay then sums these currents vectorially to produce the reference current. To bring this value to the same base as the neutral CT, the algorithm divides the reference current by the product of the CT ratio and the neutral CT nominal current. These calculations produce the reference current, IRREF*n*. IY*n*F is normalized to produce the operating current, IOREF*n*, in vector form.

When REF *n* enabled asserts, the relay enables the directional calculations. To determine the direction, the algorithm calculates the real part of the product of the reference quantity and the conjugate of the operating quantity. This calculation yields the signed torque quantity REFTQ*n* (this calculation is equivalent to the product of |IOREF*n*|, |IRREF*n*|, and the cosine of the angle between them).

REFTQ*n* is positive if the angle is within ±90 degrees, indicating a forward or internal fault. Otherwise, REFTQ*n* is negative, indicating a reverse or external fault.

Figure 5.52 shows the REF output logic.



① Figure 5.50.

② Signals are labeled in this figure for ease of discussion. They are not Relay Word bits.

Figure 5.52 REF Element Trip Output (REF 1 Is Shown)

REF schemes are generally susceptible to external LLG faults that produce CT saturation. Therefore, the scheme is supervised if the negative-sequence current is greater than the pickup REF50G*n* and also more than 10 times greater than either I0REFM*n* or IRREFM*n*.

If there is current flow at the terminals of the protected device (generator or transformer), the REF forward asserts when REFTQ*n* is greater than THRES*n* and REF reverse asserts when REFTQ*n* is less than THRES*n*. THRES*n* is an adaptive threshold that ensures security for very small currents or for an angle near +90 or –90 degrees. A forward fault is declared when the element is enabled (see *Figure 5.50*) and is not blocked by REFBLK*n*.

The logic declares a forward (internal) fault via the nondirectional path, NDREF*n*, for the condition that current flows in the neutral (IONRFP*n* asserts) but no current flows at the terminals of the generator or transformer (IRREFP*n* is deasserted) and the torque equation (TCREF*n*) is satisfied. Use TCREF*n* to further qualify the nondirectional output by checking, for example, the status of a breaker.

Figure 5.53 shows the need for the nondirectional tripping path. A directional check requires both an operating signal and a reference signal. If Fault F1 occurs with the breaker open, no current flows through the breaker CT, and there is no reference quantity present.

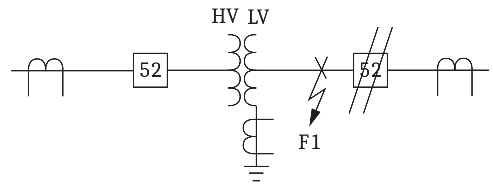


Figure 5.53 Internal Fault With LV Breaker Open

For fast tripping, include REFF*n*, the output of the REF element, into one or more of the trip equations (Group settings TR*k*) as appropriate. If you want additional security, use the programmable 51 element in *Figure 5.54* to delay tripping. In *Figure 5.54*, the overcurrent element uses the neutral current (IY*n*FM) as an input quantity. To avoid inadvertent tripping for external faults, use REFF*n* (see *Figure 5.52*) in the torque-control equation (RF51TC*n*) of the overcurrent element.

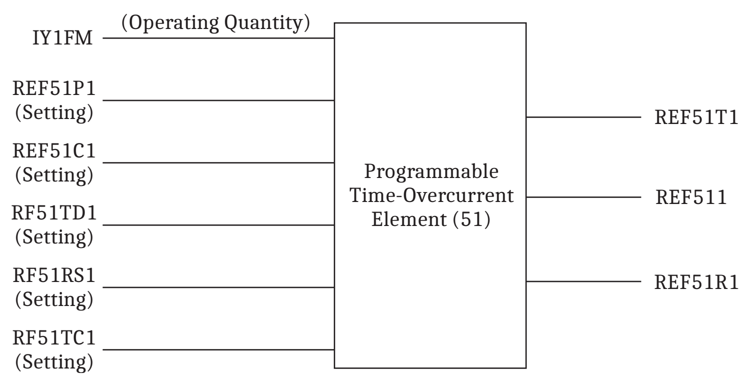


Figure 5.54 Programmable 51 REF Element (REF 1 Is Shown)

Neutral Element

For applications such as frame leakage protection or sustained ground fault protection, the REF element includes a definite-time overcurrent (50) element. *Figure 5.55* shows the REF50 element, with neutral current IY*n*FM as an input quantity. If IY*n*FM exceeds the REF50P*n* setting, REF50*n* asserts and starts the REF Definite-Time Timer. If IY*n*FM exceeds the REF50P*n* setting for a period exceeding the REF50D*n* timer setting, REF50T*n* asserts. Disable this element by setting REF50P*n* = OFF.

NOTE: Identify which of the current inputs the relay processes, excluding the three REF (IY1, IY2, IY3) channels. Although you may have already set ECTTERM while establishing differential protection, the setting appears here as a reminder that the relay only accepts enabled terminals as reference quantities for the REF element.

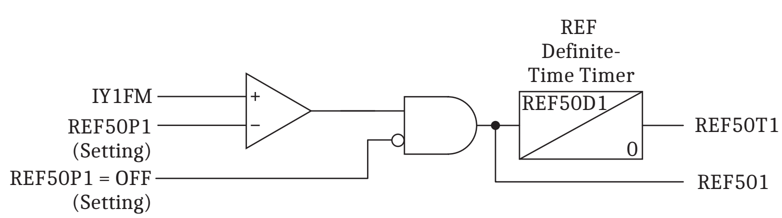


Figure 5.55 REF Neutral Element (REF 1 Is Shown)

Applications and Setting Descriptions

Table 5.20 Restricted Earth Fault Element Settings

Setting	Prompt	Range	Default	Category
EREF	Enable REF Element	OFF or combo of Y1, Y2, Y3	OFF	Group
REFRF*n*[a]	Rest Qty REF *n*	OFF or combo of S, T, U, W, X, Y1, Y2, Y3	OFF	Group
REF50G*n*[a]	Residual Current Sensitivity Pickup	0.05–3 (per unit)	0.25	Group
TCREF*n*[a]	Torque Control REF Element *n*	SV	1	Group
REF50P*n*[a]	REF Op. Current Inst O/C *n* Pickup	OFF, 0.25–100 (A sec)	OFF	Group
REF50D*n*[a]	REF Inst O/C *n* Delay	0.0000–400 (s)	0.2	Group
RF50TC*n*[a]	REF Inst O/C *n* Torque Cont	SV	1	Group
REF51P*n*[a]	REF Inv. Time O/C *n* PU	OFF, 0.25–16 (A sec)	OFF	Group
REF51C*n*[a]	REF Inv. Time O/C *n* Curve	U1–U5, C1–C5	U1	Group
RF51TD*n*[a]	REF Inv. Time O/C *n* Time Dial	0.50–15	0.5	Group
RF51RS*n*[a]	REF Inv. Time O/C *n* EM Reset	Y, N	N	Group
RF51TC*n*[a]	REF Inv. Time O/C *n* Torque Cont	SV	1	Group

[a] n = 1–3.

REF Directional Element Enable (EREF)

Use the EREF setting to enable the number of REF elements appropriate for the application. Setting EREF = N disables all REF elements, but not the neutral element. There are no neutral input current/REF element assignment settings: the relationships are fixed as in *Table 5.19*.

Therefore, when you set EREF = 1, the REF element evaluates only an input connected to Terminal IY1; the element ignores inputs connected to IY2 and IY3.

Restraint (Reference) Quantity (REFRFn)

Setting REFRF*n* (*n* = 1–3) identifies the terminal or combination of terminals the REF element must include when it calculates the reference current (closing the cells of Switch S in *Figure 5.50* and *Figure 5.51*).

Residual Current Sensitivity Threshold (REF50Gn)

You can set the residual current sensitivity threshold to as low as 0.05 times nominal current (0.25 A for 5 A nominal CT current), the minimum residual current sensitivity of the relay. However, the minimum acceptable value of REF50G*n* must be greater than any natural 3I0 unbalance resulting from load conditions.

REF Torque Control (TCREFn)

SELOGIC control equation TCREF*n* provides a method to externally control the enabling of the directional calculations (see *Figure 5.50*).

REF Neutral Element Instantaneous Overcurrent Pickup (REF50Pn)

REF50P*n* is the instantaneous overcurrent pickup setting for the neutral element (see *Figure 5.55*).

REF Neutral Element Overcurrent Time Delay (REF50Dn)

REF50D*n* is the time-delay setting for the instantaneous overcurrent element of the neutral element (see *Figure 5.55*).

REF Neutral Element Overcurrent Torque Control (RF50TCn)

RF50TC*n* is the torque-control setting for the instantaneous neutral overcurrent element (see *Figure 5.54*).

REF TOC (51) Pickup (Plug) (REF51Pn)

REF51P*n* is the time-overcurrent pickup (plug) setting for the programmable 51 element (see *Figure 5.54*).

REF TOC (51) Curve (REF51Cn)

REF51C*n* is the time-overcurrent curve selection setting for the programmable 51 element (see *Figure 5.54*).

REF TOC (51) Time Dial (RF51TDn)

RF51TD*n* is the time-dial (time multiplier) setting for the programmable 51 element (see *Figure 5.54*).

REF TOC (51) Electromechanical Reset (RF51RSn)

RF51RS*n* is the time-dial (time multiplier) electromechanical reset setting for the programmable 51 element (see *Figure 5.54*).

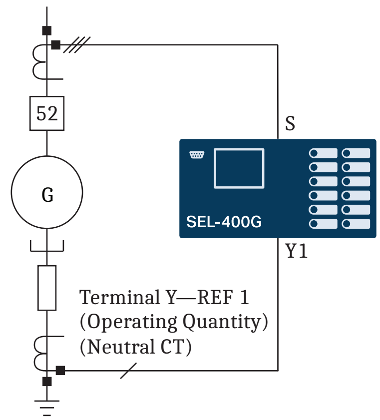
REF TOC (51) Torque Control (RF51TCn)

RF51TC*n* is the torque-control setting for the programmable 51 element (see *Figure 5.54*).

Selection of the Restraint Quantity

The operating quantity/reference quantity relationship is defined by the relay settings (rather than a fixed relationship in hardware), so you can apply the REF elements to any primary plant configuration with the correct CT arrangement. In general, identify all terminals that are electrically connected to the grounded winding that you want to protect with the REF element. Then enter those terminals at the REFRF*n* setting. The following are examples of a few applications.

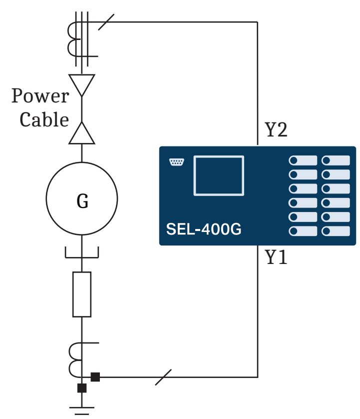
Figure 5.56 shows a low-impedance-grounded generator with a three-phase CT at the generator terminals. Set EREF = Y1 to enable this REF element (this setting dictates that we connect the neutral CT to Terminal IY1) and set REFRF1 = S.



EREF	Y1
REFRF1	S

Figure 5.56 Low-Impedance-Grounded Generator With a Three-Phase Reference CT

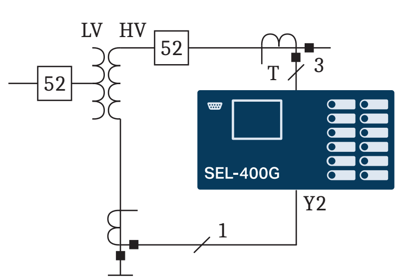
Figure 5.57 shows a low-impedance-grounded generator connected to the system by using a high-voltage cable. A core-balance CT is located at the power cable system-side termination. Set EREF = Y1 to enable this REF element and set REFRF1 = Y2 to provide a reference current by using the Y2 terminal. Note that if the core balance CT is located below the cable termination, the sheath ground must be routed through the CT. Otherwise, the zero-sequence current will be canceled by the sheath current and there will be no output from the CT during a fault.



EREF	Y1
REFRF1	Y2

Figure 5.57 Low-Impedance-Grounded Generator With a Core-Balance Reference CT

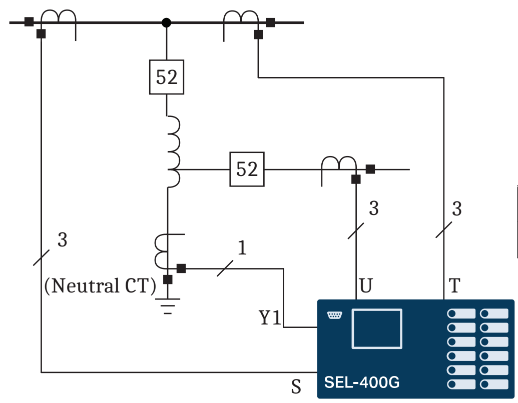
Figure 5.58 shows an ungrounded LV winding and a grounded-wye HV winding. Set EREF = Y2 to enable one REF element (this setting dictates that we connect the neutral CT to Terminal IY2). Terminal T electrically connects to the winding earmarked for REF protection. Therefore, set REFRF2 = T.



EREF	Y2
REFRF2	T

Figure 5.58 Single-Wye Winding Transformer REF

Figure 5.59 also shows an autotransformer, but in this application, the HV side has two CTs (breaker-and-a-half application). Set EREF = Y1 to enable one REF element (this setting dictates that we use IY1). In this case, Terminal S, Terminal T, and Terminal U connect electrically to the winding earmarked for REF protection. Therefore, set REFRF1 = S, T, U.



EREF	Y1
REFRF2	S, T, U

Figure 5.59 Autotransformer REF With Two-HV CTs

Setting Guidelines for Low-Impedance-Grounded Generators

The available ground fault current is a function the grounding resistor size and the fault location. Grounding resistors are often specified in terms of available current, for example 200 or 400 primary amperes. *Figure 5.60* shows the simulation results for a ground fault on a generator that is grounded through a 400 A resistor. The simulation ran for a two different MVA ratings. Note that the variation of the current with fault location is approximately linear when the fault is closer to the neutral. In this example, the fault current at 10 percent of the winding is approximately 10 percent of 400 A, or 40 A.

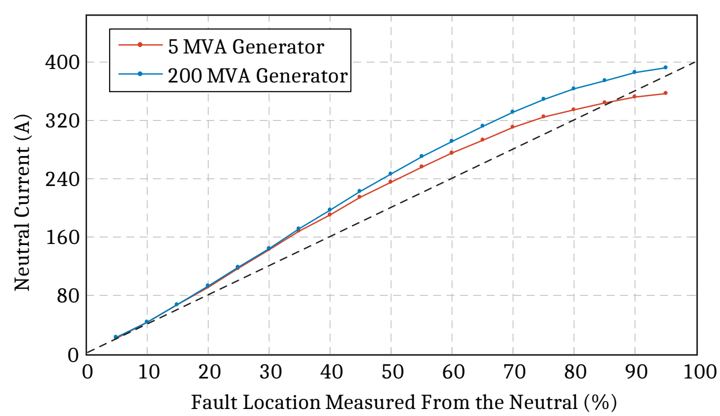


Figure 5.60 Ground Fault Simulation for a Low-Impedance-Grounded (400 A) Generator

The example of *Figure 5.61* shows two identical low-impedance-grounded generators connected to the same bus and with the same sized neutral grounding resistors. With an internal ground fault on G1 at an arbitrary location, the neutral currents, I1 and I2 have the same value. Therefore, coordination using simple overcurrent elements is problematic. In contrast, the REF scheme provides selectivity by checking the direction between the current at the neutral and at the terminals.

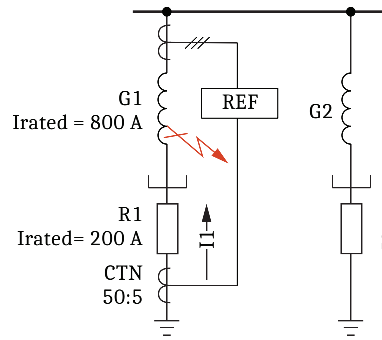


Figure 5.61 Low-Impedance-Grounded Generator Example

The REF element picks up when the generator neutral current exceeds the pickup setting. This setting is scaled to the nominal secondary neutral current. For the example shown in *Figure 5.61*, assume that R1 is sized to provide 200 A of fault current, the neutral CT (CT1N) has a ratio of 50:5, and a coverage of 90 percent of the winding is desired. The required pickup setting would be:

$$\text{Pickup} = 10\% \bullet 200 \bullet \frac{5}{50} \bullet \frac{1}{5} = 0.4$$

Performance for Steady-State CT Errors

The security provided by the REF element is very good because the operating signal is derived from the generator neutral current. The element cannot pickup unless there is a true ground fault. However, the directional check uses the generator terminal current, which is typically measured by a three-phase set of CTs that are sized for the rated current of the generator. The relay calculates 3I0 from these CTs, and CT errors will create a steady-state 3I0 error. If this error is significant in the relation to the fault current magnitude, then the element could pick up for an external ground fault. Setting the pickup greater than the worst-case 3I0 error ensures secure operation.

In the previous example, at full load, assume that the measured worst-case 3I0 at the generator terminals is 5 percent or 40 amperes primary. For secure operation, the pickup should be:

$$\text{Pickup} = 40 \bullet \frac{5}{50} \bullet \frac{1}{5} = 0.8$$

With a 200-ampere resistor, this translates to a coverage of 100% • (200 – 40) / 200 = 80% of the winding. You could still choose the 90 percent coverage setting. The element will not operate unless there is a ground fault but, in this case, a fault between 10–20 percent of G2 could cause both machines to trip.

One Hundred Percent Stator Ground Elements

Use this element to detect ground faults on the stator of unit-connected, high-impedance grounded machines. Application of a combination of the elements shown in *Figure 5.62* achieves 100 percent coverage of the stator winding.

Table 5.21 Stator Ground Element Setting

Setting	Prompt	Range	Default	Category
E64G	Enable 64G Protection	Combination of G1, G2, G3, OFF	G1, G3	Group

Use the E64G*n* setting to enable a combination of the elements shown. If the relay is used to protect a low impedance grounded machine, these elements are not effective and should be disabled.

The outputs from the various functions are combined in the 64G output logic. The output logic incorporates an acceleration path and integrating timer to achieve dependable operation for stator grounds while remaining secure for external events (see *64G Output Logic on page 5.72*).

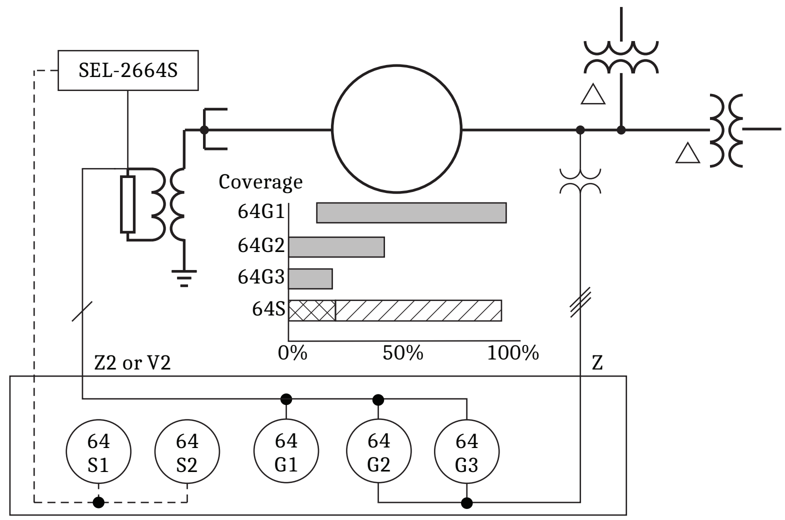


Figure 5.62 One Hundred Percent Stator Ground Element

Fundamental Neutral Overvoltage (64G1)

The 64G1 is an overvoltage element responding to the magnitude of the fundamental frequency component of the voltage measured at the generator neutral. Under normal operation, this voltage will be approximately zero. When a ground fault occurs in the winding of a high-impedance grounded generator, a fundamental frequency voltage appears at the generator neutral. The neutral voltage magnitude during the fault is proportional to the fault location within the winding measured from the generator neutral towards the terminals.

There are two 64G1 elements, each with its own pickup, delay and torque-control settings. *Figure 5.63* shows the 64G1 logic. The 64G1P*n* setting defines the pickup sensitivity of the element. Setting 64G1P*n* to OFF disables the level. The 64G1D*n* setting defines the element time delay. The 64G1TC*n* torque-control setting disables the element when its result is logical 0. This setting can normally be left at its default value of 1. The 64G1 and 64G1T Relay Word bits are combined with the other stator ground protection functions in the 64G output logic.

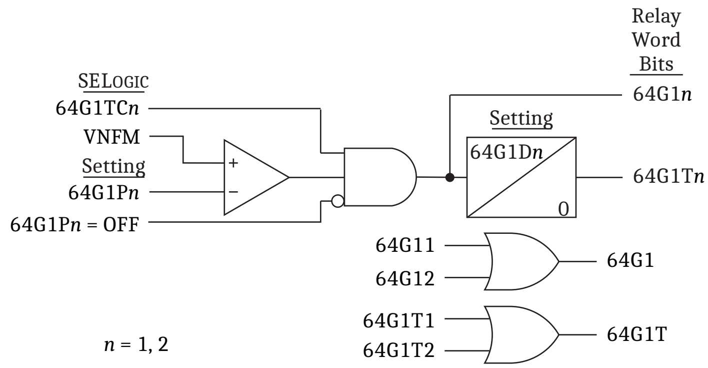


Figure 5.63 64G1 Element Logic

Setting Guidelines for the Fundamental Neutral Overvoltage Function

Table 5.22 Fundamental Neutral Overvoltage Settings

Setting	Prompt	Range	Default	Category
64G1P*n*[a]	Neutral O/V Level *n* Pickup	0.0–150.0 volts sec., OFF	OFF	Group
64G1D*n*[a]	Neutral O/V Level *n* Time Delay	0.00–400.00 seconds	1	Group
64G1TC*n*[a]	Neutral O/V Level *n* Torque Control (SV)	SELOGIC variable	1	Group

[a] n = 1, 2.

The example system in *Figure 5.64* illustrates setting calculations for the 64G1, 64G2, and 64G3.

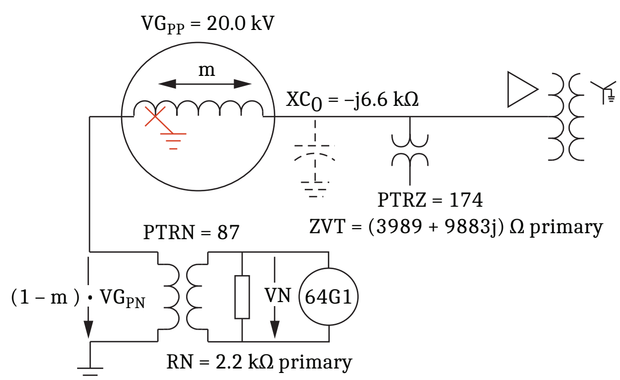


Figure 5.64 Example System for Setting of the 64G Element

We assume the goal to provide coverage of 95 percent of the winding ($m = 0.95$). The voltage measured by the 64G1 will be:

$$64G1P1 = \frac{(1-m) \bullet VG_{PP}}{PTRN} = \frac{(1-0.95) \bullet 20.0\ kV}{\sqrt{3} \bullet 87} = 6.7\ V$$

The setting for 64G1D1 should be long enough to secure the element for GSU HV faults and VT secondary ground faults. Note that the 64G output logic section provides dependable accelerated tripping for all of the 64G functions (see *64G Output Logic on page 5.72*).

Third-Harmonic Voltage Elements (64G2 and 64G3)

These elements use the third-harmonic voltage produced by the generator to detect ground faults near the generator neutral. The third-harmonic behaves like a zero-sequence component and produces third-harmonic voltage drops at the terminals and the neutral. If the generator terminal VT is connected as shown in *Figure 5.65* and PTCONZ = Y, the relay can calculate the third-harmonic voltage drop at the terminals.

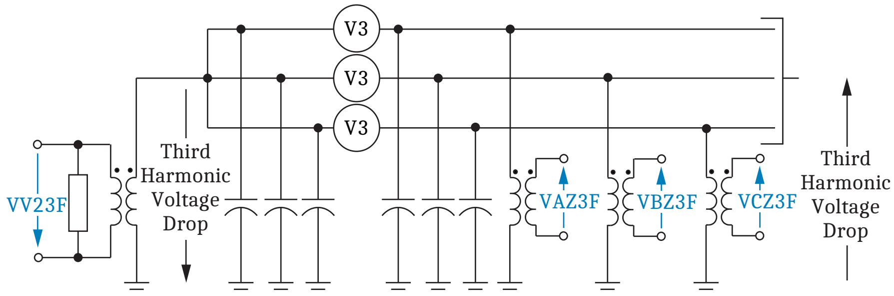


Figure 5.65 Third-Harmonic Voltage Distribution (PTCONZ = Y)

If the generator terminal VT is connected as shown in *Figure 5.66* and PTCONZ = D1, the relay can also directly measure the third-harmonic voltage drop at the terminals by using this connection.

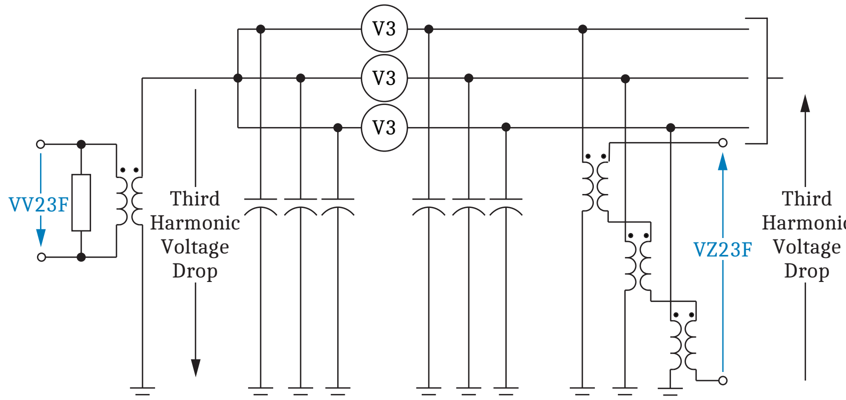


Figure 5.66 Third-Harmonic Voltage Distribution (PTCONZ = D1)

If the generator terminal PT is not connected as shown in *Figure 5.65* or *Figure 5.66*, the third-harmonic voltage drop at the terminals cannot be calculated or measured.

NOTE: In general, third-harmonic schemes that use the third-harmonic voltage drops at both the generator terminals and the neutral are more secure and easier to set.

The SEL-400G calculates the following third-harmonic quantities. VN3F is corrected for mismatch between the generator terminal and neutral VTs. The total third-harmonic produced by the machine (VG3) is a vector sum. Therefore, to measure VG3F, the generator neutral voltage measurement must be connected as shown in *Figure 5.65* and *Figure 5.66*.

$$\mathrm{VN3F} = \mathrm{VV23F}$$

$$\mathrm{3V0Z3F} = \mathrm{VAZ3F} + \mathrm{VBZ3F} + \mathrm{VCZ3F} \text{ for PTCONZ } = \mathrm{Y}$$

$$\mathrm{3V0Z3F} = \mathrm{VZ23F} \text{ for PTCONZ } = \mathrm{D1}$$

$$\mathrm{VG3F} = \frac{\mathrm{3V03ZF}}{3} \bullet \frac{\mathrm{PTRZ}}{\mathrm{PTRV2}} + \mathrm{VN3F}$$

$$PTR_{COMP} = \frac{PTRZ}{(3 \cdot PTRV2)}$$

NOTE: IF PTCONZ = D, VG3 is forced to zero. Similarly, if EGNPT = OFF, VN3 is forced to zero.

The SEL-400G carries out an angle check, as shown in *Figure 5.67*, to confirm the correct wiring.

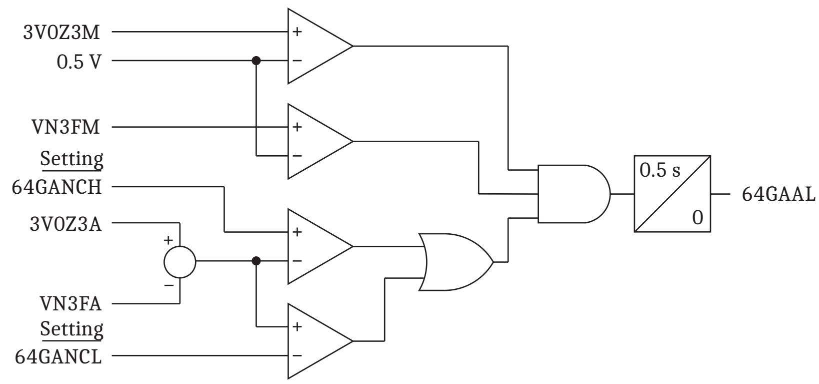


Figure 5.67 Third-Harmonic Angle Check

The default values of 64ANCL and 64ANCH are 45 and –135 degrees.

Typically, a generator produces varying amounts of third-harmonic voltage, depending on machine construction and loading. Note that the third-harmonic characteristics of generators have been observed to change over time. *Figure 5.68(A)* shows the typical variation in the third-harmonic voltage magnitude on a healthy machine. *Figure 5.68(B)* shows how the voltage distributions shifts because of a fault. A fault at the neutral reduces VN3FM to zero and increases 3V0Z3M. A fault at the terminals reduces 3V0Z3M to zero and increases VN3FM. There is a point near the center of the winding (o) in *Figure 5.68* where a fault produces no shift in the third-harmonic distribution.

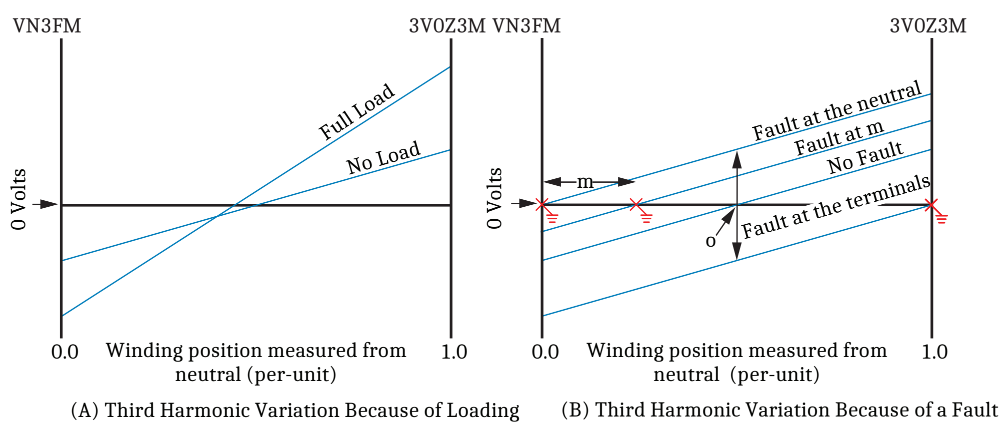


Figure 5.68 Typical Third-Harmonic Voltage Distribution in a Generator

Third-Harmonic Operating Principles

The SEL-400G provides two third-harmonic voltage elements; each using a different operating principle. Either scheme can provide protective coverage for the bottom portion of the winding. In general, the 64G2 provides greater coverage but requires a third-harmonic survey to ensure that the element is secure under all operating conditions. The 64G3 provides less coverage but does not require a survey. The following figure compares the resistive coverage of the 64G2 (differential mode) and the 64G3 for a typical application.

NOTE: In contrast with the SEL-300G and SEL-700G, the 64G2 element of the SEL-400G does not provide coverage at the generator terminals. This change improves security. When combined with the 64G1, 100 percent coverage is achieved.

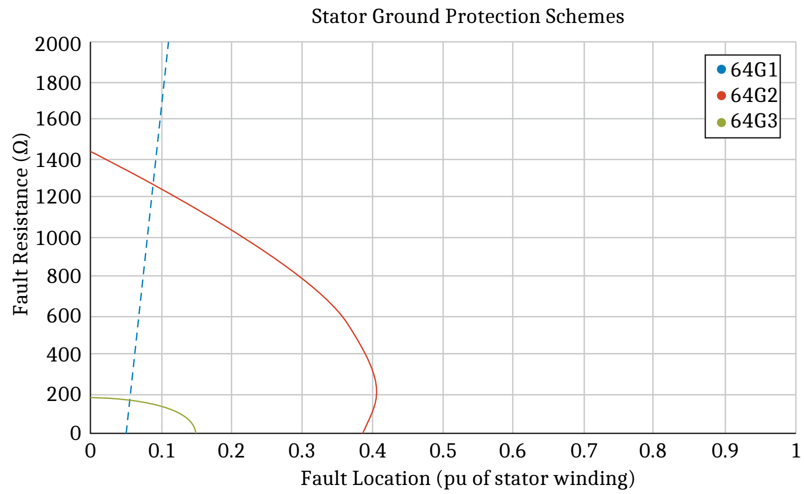


Figure 5.69 Typical Coverage Provided by the 64G1, 64G2 (Differential Mode), and 64G3 Elements

Third-Harmonic Alternative Settings

In some applications, the third-harmonic distribution may undergo significant changes during generator operation. For example, if the generator has a breaker on the low-voltage side of the GSU, the capacitance at the generator terminals can increase significantly when the breaker is closed. The SEL-400G provides two pickup and two ratio settings for the 64G2 element and two pickup settings for the 64G3 element. The element/function dynamically switches between these settings based on the 64GALT setting. This allows optimal settings to be applied.

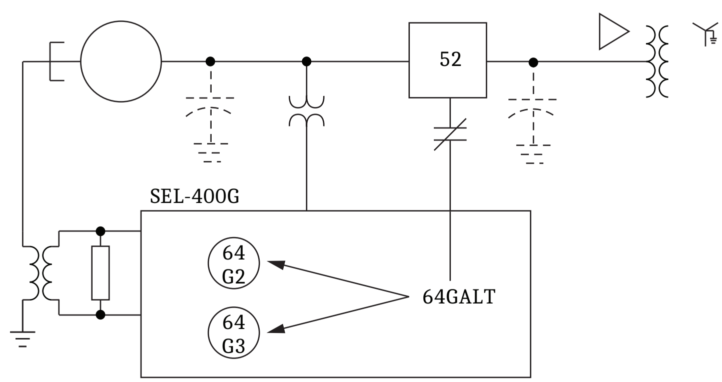


Figure 5.70 Using Breaker Position to Switch to Alternative Settings

Table 5.23 Third-Harmonic Alternative Switch Settings

Setting	Prompt	Range	Default	Category
64GALT	64G Alternate Setting	SELOGIC variable	NA	Group

64G2 Third-Harmonic Element

The 64G2 element can operate as a neutral third-harmonic differential when the SEL-400G is connected as shown in *Figure 5.65* or *Figure 5.66*. Note that PTCONZ must be set to Y or D1. If PTCONZ = D, then 64G2 switches to undervoltage mode.

64G2 Third-Harmonic Differential Mode

In differential mode, this element operates on the premise that VG3F changes during normal generator operation. The difference between the 3V0Z3F and VN3F magnitudes is defined by the shunt network impedances (see *Figure 5.65* and *Figure 5.66*) and therefore, this ratio does not change substantially. *Figure 5.71* shows the logic.

Referring to *Figure 5.71*, the value V3DIF is given as:

$$\mathrm{V3DIF} = \mathrm{PTR_{COMP}} \bullet \mathrm{3V0Z3M} \bullet \mathrm{64G2Rp} - \mathrm{VN3FM}$$

where *p* is 1 or 2 and refers to the normal and alternative settings

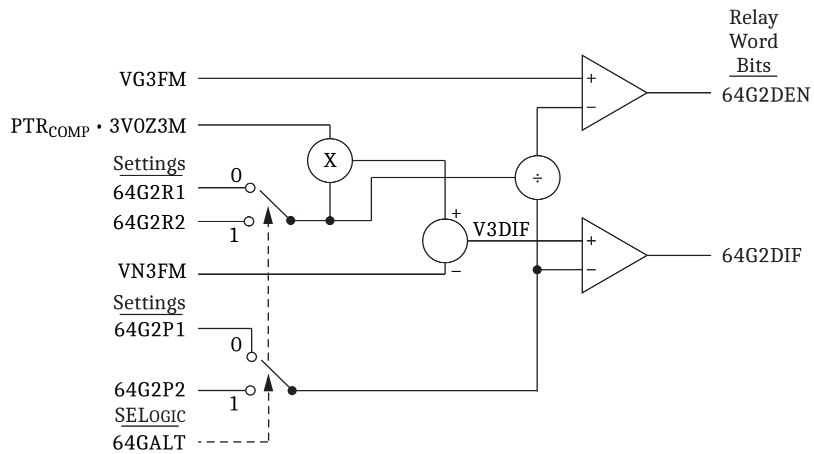


Figure 5.71 64G2 Third-Harmonic Voltage Differential Logic

The 64G2R*p* setting is calculated to minimize V3DIF over the operating range of the generator. The 64G2P*p* setting determines the sensitivity of the element. This setting should be set with margin greater than the largest value of V3DIF over the operating range of the generator after 64G2R*p* has been selected.

Setting Guidelines for the 64G2 Third-Harmonic Element (Differential Mode)

Table 5.24 64G2 Third-Harmonic Element Settings

Setting	Prompt	Range	Default	Category
64G2P*p*[a]	64G2 Voltage Pickup *p*	0.1–150	2	Group
64G2R*p*[a]	64G2 Ratio Correction *p*	0.10–10	1	Group
64G2D	64G2 Element Delay	0.000–400 s	1	Group
64G2PMN	64G2 Minimum Power	OFF, 1–2000 VA sec	OFF	Group
64G2PMX	64G2 Maximum Power	OFF, 1–2000 VA sec	OFF	Group
64G2TC	64G2 Element Torque Control	SELOGIC variable	1	Group

[a] p = 1, 2.

Because of the variations in the third harmonic, SEL recommends that you carry out a survey of VN3F and 3V0Z3F while the generator MW and MVAR output varies. Use the relay **METER** command to record the measured third-harmonic voltages, then calculate the settings. At a minimum, these measurements must be taken at no-load and full-load conditions. SEL recommends that measurements be taken at several intermediate loads as well to ensure that the data include the full range of variation of third-harmonic voltage.

For a detailed explanation of the procedure for setting the element by using the third-harmonic measurements at several load outputs, see the SEL application guide *Setting the 64G1 and 64G2 Elements in SEL Generator Protection Relays* (AG2005-08) on selinc.com.

64G2 Third-Harmonic Undervoltage Mode

The 64G2 can be applied as a neutral third-harmonic undervoltage element. The element automatically switches to undervoltage operation if PTCONZ = D.

When in undervoltage mode the 64G2P*p* setting defines the minimum magnitude of VN3F for pickup.

Undervoltage mode is blocked if the positive-sequence voltage is less than 0.8 of VNOM / √3. It can also be further supervised over a selectable window of forward real power, as shown in *Figure 5.73*.

The 64G2PMN and 64G2PMX settings define a window of forward power within which the 64G2 undervoltage element is blocked. If the 64GPMN setting is OFF, then blocking occurs when power is less than the 64GPMX setting. If the 64G2PMX setting is OFF, then blocking occurs when power is greater than the 64G2PMN setting. If both settings are OFF, then power supervision is disabled. The 64G2UEN Relay Word bit provides an indication that the element is available to operate if a ground fault occurs.

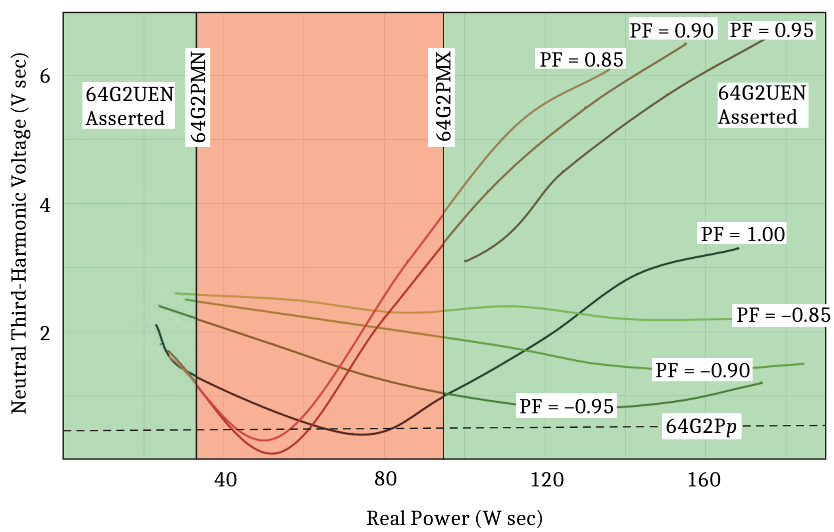


Figure 5.72 Example of 64G2 Undervoltage Setting From Survey Data

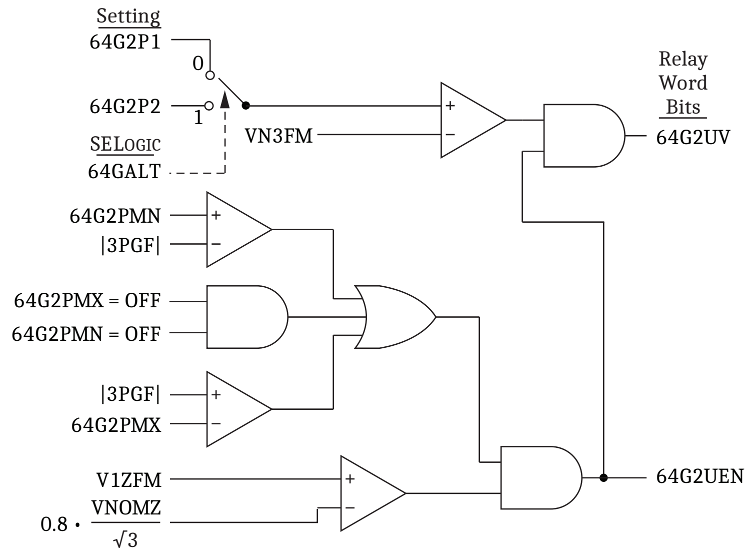


Figure 5.73 64G2 Third-Harmonic Undervoltage Logic

Setting Guidelines

It is critical to carry out a third-harmonic survey over the generator real and reactive power operating range to determine the optimal pickup setting. If the third-harmonic is reduced to a very low value over a range of generator loading, the 64G2PMX and 64G2PMN settings can be used to block operation over this range.

64G2 Output Logic

Figure 5.74 shows the output logic for the 64G2 element. Additional supervision can be applied using the torque-control input. The 64G2D has a default time delay of one second.

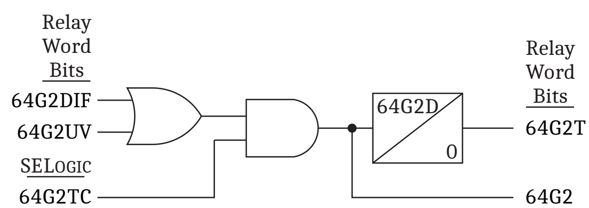


Figure 5.74 64G2 Output Logic

64G3 Third-Harmonic Element

Figure 5.75 is used to develop the principle of operation of this function. In this figure, *m* defines the location of the fault in per-unit, measured from the generator neutral. V3 is an arbitrary value of third harmonic produced by the machine at an instant in time.

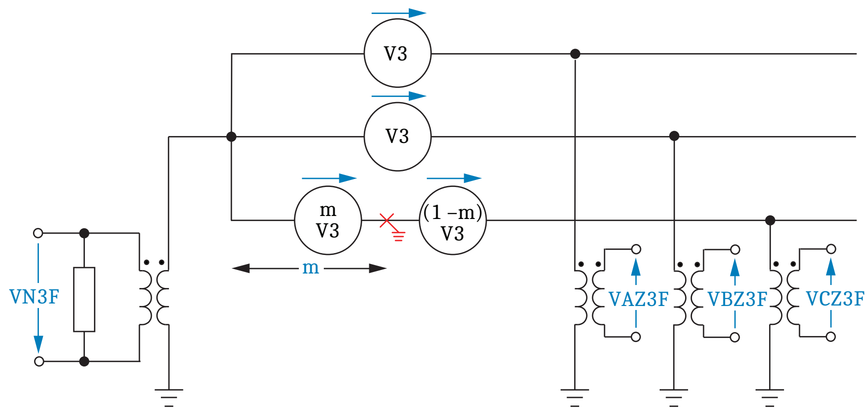


Figure 5.75 Third-Harmonic Components During a Ground Fault

For simplicity, we assume that all VT ratios are equal to one. For a fault at *m*:

$$VN3F = m \bullet V3$$

$$\begin{aligned} V0Z3F &= \frac{VAZ3F + VBZ3F + VCZ3F}{3} \\ &= \frac{(V3 - m \bullet V3) + (V3 - m \bullet V3) + (1 - m) \bullet V3}{3} \\ &= (1 - m) \bullet V3 \end{aligned}$$

$$VG3F = VN3F + V0Z3F = m \bullet V3 + (1 - m) \bullet V3 = V3$$

and

$$\frac{|VN3F|}{|VG3|} = \frac{m \bullet V3}{V3} = m$$

Accordingly, the ratio of |VN3F| / |VG3F| is used as the operating signal for this element.

Setting Guidelines for the 64G3 Third-Harmonic Element

Table 5.25 64G3 Third-Harmonic Element Settings

Setting	Prompt	Range	Default	Category
64G3R*p*[a]	64G3 Element Ratio *p*	0.01–1.00	0.15	Group
64G3D	64G3 Element Delay	0.00–400.00 s	1	Group
64G3P1	64G3 Element Pickup 1	0.10–150.00	2	Group
64G3TC	64G3 Element Torque Control	SELOGIC variable	1	Group

[a] p = 1, 2.

As shown in *Figure 5.76*, the 64G3 element operates when 64G3R*p* > VN3FM/VG3FM. During normal operation, this ratio is typically in the range of 0.4–0.85. For a fault near the generator neutral, the ratio will be equal to the location of the fault (measured from the neutral). A setting of 0.15 provides a reasonable overlap with the 64G1 element. A third-harmonic survey is usually not required for this element.

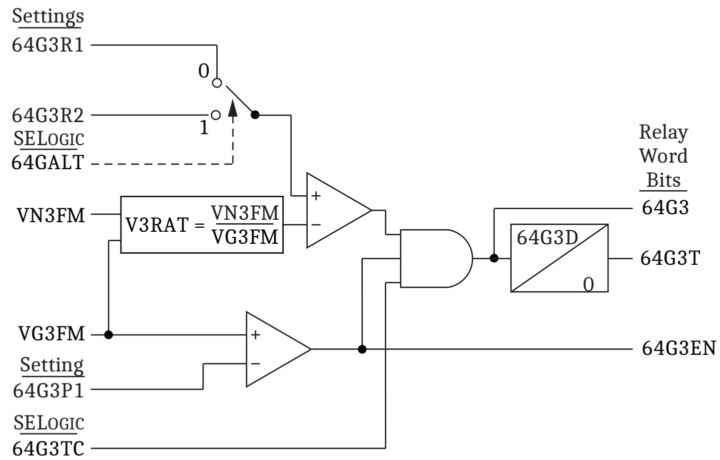


Figure 5.76 64G3 Third-Harmonic Ratio Logic

Multi-Machine Ground Fault Voltage Comparison

During a ground fault, the ratio of the fundamental neutral and fundamental terminal voltages provides a measure of the location of the fault within the winding. Similarly, the ratio of the neutral third-harmonic and the total third-harmonic voltages provides a similar location measurement. In applications with multiple high-impedance grounded machines sharing a common bus, the two ratios will agree for the faulted generator but will differ for the healthy generator. If the ground fault is on the bus, all ratios will agree and give an indication close to 1.

Equation 5.48 compares the fundamental and third-harmonic ratios to determine how closely they agree. The value of 64GMMS will be 1 when the ratios are in exact agreement. A selective tripping scheme can be implemented by comparing the values of 64GMMS among all of generators on a bus and tripping the unit with the highest value first. These values need to be exchanged among relays over a communications channel. Additional SELOGIC is required to implement the scheme logic. The value of 64GMMS is calculated when E64G has G2 or G3, and PTCONZ != D.

$$64GMMS = 1 - MIN\left(\left|\frac{VN3F}{VG3F} - \frac{VNF}{V1ZF \bullet \frac{PTRZ}{PTRV2}}\right|, 1\right)$$

Equation 5.48

64G Output Logic

A stator ground fault often begins as an intermittent fault. When the fault is intermittent, transients occur at every restrike. For an intermittent fault at the terminals, the fault energy caused by capacitive discharge can be much higher than that of a solid fault. Furthermore, the healthy phases are also exposed to recurring voltage transients. Therefore, it is important to clear faults as quickly as possible.

However, it is also possible for ground fault protection to pick up for external events under conditions such as the following:

- ➤ A ground fault on the high-voltage side of the GSU can result in an increase in the generator neutral voltage because of coupling through the capacitance between the HV and LV windings.
- ➤ Depending on the VT connections, a ground fault on the VT secondary wiring can also result in an increase in the generator neutral voltage until the fault is cleared by the VT fuses.

The SEL-400G 64G output logic incorporates two mechanisms to provide more effective tripping for ground faults.

Acceleration Path

The first mechanism is an acceleration path. Acceleration schemes discriminate between faults within the generator zone and those occurring elsewhere. Identification of the fault within the generator zone removes the need to time-coordinate. Custom schemes can be implemented in SELOGIC and assigned to the 64ATC SELOGIC control equation.

Integrating Timer

The second mechanism that provides improved performance for intermittent faults is an integrating timer. The timer operates as follows: when the input asserts, the timer accumulator increases linearly at a rate defined by the PU delay setting. If the input deasserts, the accumulated value is frozen. If the input reasserts, the timer accumulator increases once again. If the input is deasserted for a period longer than the dropout time, the timer output resets.

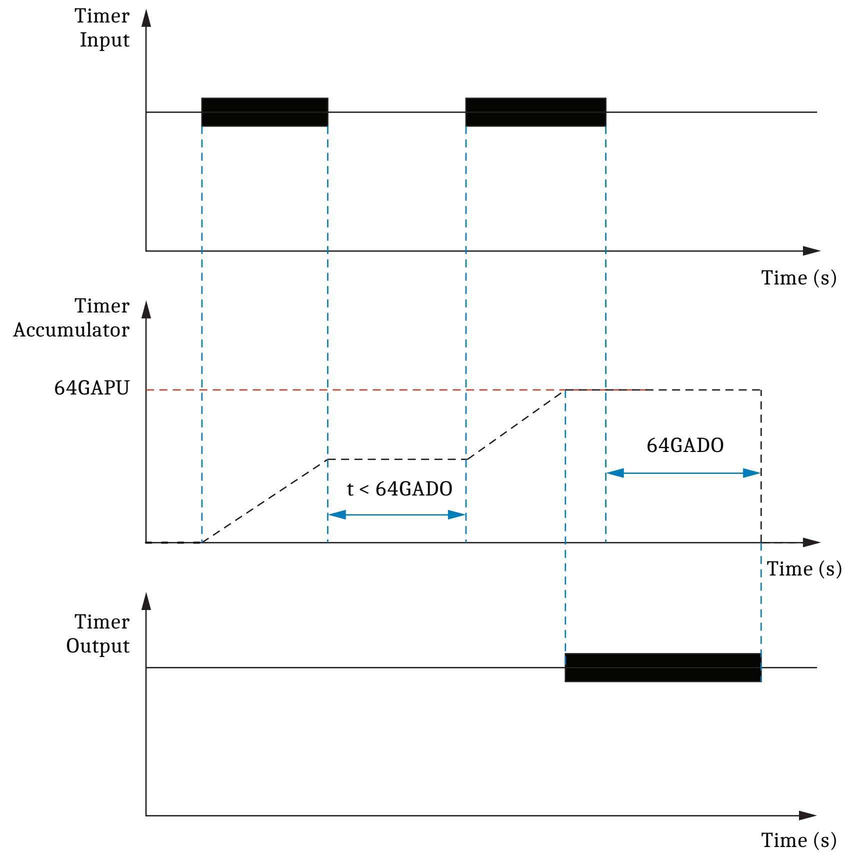


Figure 5.77 64G Integrating Timer

Figure 5.78 shows the output logic. The upper path is fed by the SELOGIC variable 64GTIN. It can be considered as the nonaccelerated or normal path for tripping. Elements assigned to this path operate via their own delay timers (64G1D, 64G2D, and 64G3D), regardless of the behavior of the acceleration logic or integrating timer.

The lower path is fed by the SELOGIC variable 64GAIN. This is the accelerated path. The default assignment is 64G1 OR 64G2 OR 64G3. The accelerated path is supervised by the 64GATC SELOGIC variable and drives the integrating timer. The integrating timer is intended to have a shorter pickup delay (64GD) as compared with the 64G1D, 64G2D, and 64G3D pickup delays.

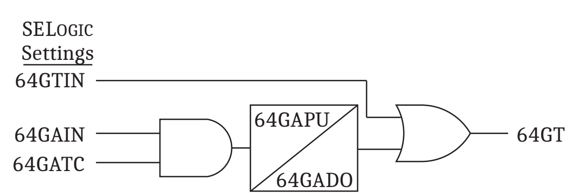


Figure 5.78 64G Output Logic

64G Output Logic Setting Guidelines

Table 5.26 64G Output Logic Settings

Setting	Prompt	Range	Default	Category
64GTIN	64G Normal Trip Input	SELOGIC variable	64G1T OR 64G2T OR 64G3T	Group
64GAIN	64G Accelerated Input	SELOGIC variable	64G1 OR 64G2 OR 64G3	Group
64GATC	64G Accelerated Torque Cont	SELOGIC variable	NA	Group
64GAPU	64G Accelerated PU Delay	0.000–400.000 seconds	0.20	Group
64GADO	64G Accelerated DO Delay	0.000–400.000 seconds	15	Group

The delayed output Relay Word bits of the individual ground fault functions are assigned to 64TIN by default. The pickup Relay Word bits of the individual ground fault functions are assigned to 64AIN by default.

The recommended setting for the 64GATC is:

64GATC := NOT 46Q11

This assignment checks that there are no GSU HV faults that the 64G elements could detect. It uses the pickup Relay Word bit of the generator unbalance element. To provide correct supervision, this element must be enabled. It will typically be set to pick up at 5–10 percent of the generators negative-sequence withstand. In this case, this Relay Word bit should assert dependably for any faults at the GSU HV terminals.

The 64GAPU can be set in the range of 0.08–0.20 seconds. The default setting is intended to be long enough to avoid tripping for a VT secondary fault. See *VT Secondary Ground Faults on page 5.75*.

The 64GADO setting determines the duration until the timer accumulator reset following deassertion of the input. They can be set in the range of 5–15 seconds.

VT Secondary Ground Faults

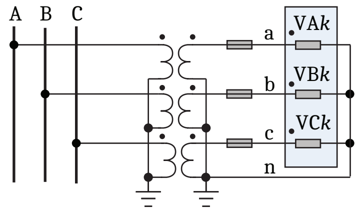
As mentioned earlier, generator ground fault schemes can respond to a ground on the secondary of the VT. There are several ways to deal with this issue.

Alternative VT Connections

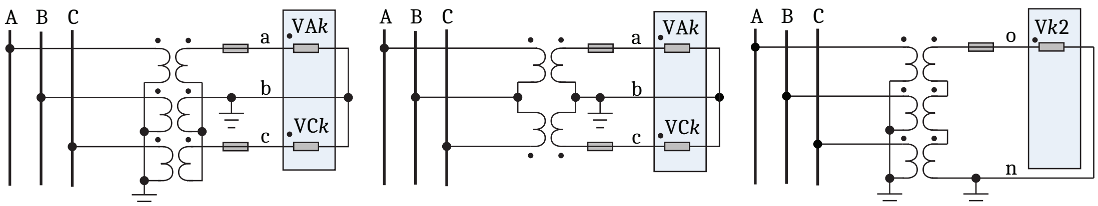
The generator terminal VT connection determines the protection functions that can be applied and the security risk to the 64G function. Connection A in *Figure 5.79* can provide phase-to-phase, phase-to-ground, positive-, negative-, zero-sequence, and third-harmonic voltages. However, Connection A also puts the 64G at risk for a VT secondary ground.

Connections B or C in *Figure 5.79* provide phase-to-phase, positive-, and negative-sequence voltages and do not put 64G at risk. These connections allow most generator protection functions to operate with the exception of the 64G2 (differential mode), 64G3, and zero-sequence overvoltage elements. However, if an open-corner delta-connected VT winding (Connection D) is available, the SEL-400G allows these functions to operate using this connection.

The use of Connection B, C, or D allows the 64GD timer setting to be reduced.



(A) 64G at risk for faults at a, b, and c



(B) 64G not at risk (C) 64G not at risk (D) 64G not at risk

Figure 5.79 Impact of VT Connections on 64G Security

VT Fuse Coordination

If Connection A of *Figure 5.79* is used then the 64G must be delayed to coordinate with the VT secondary fuses. The 59G element voltage pickup is converted to an equivalent minimum amperage pickup. The coordination process is illustrated using the example system of *Figure 5.64*.

The minimum VT secondary fault current for which the 64G1 responds is:

$$IFmin_{sec} = \frac{3 \bullet 64G1Pn \bullet PTRN}{|Z_0|} \bullet PTRZ$$

where PTRN = PTRV2 if EGNPT = V2 and PTRN = PTRZ2 if EGNPT = Z2.

And Z_0 is:

$$Z_0 = \frac{3 \bullet RN \bullet XC_0}{3 \bullet RN + XC_0}$$

If XC_0 is not known, $|Z_0|$ can be estimated as:

$$|Z_0| = \frac{3 \bullet RN}{\sqrt{2}}$$

Then, referring to the example system of *Figure 5.64*:

$$IFmin_{sec} = \frac{\sqrt{2} \bullet 6.7 \bullet 87 \bullet 174}{2200} = 65.2\ A$$

In *Figure 5.80*, the time-current current for a 15 A, KTK-R fuse is plotted. $IFmin_{sec}$ is superimposed on the plot. A 0.2-second pickup delay (64GD) results in a margin of approximately 80 ms or 5 cycles.

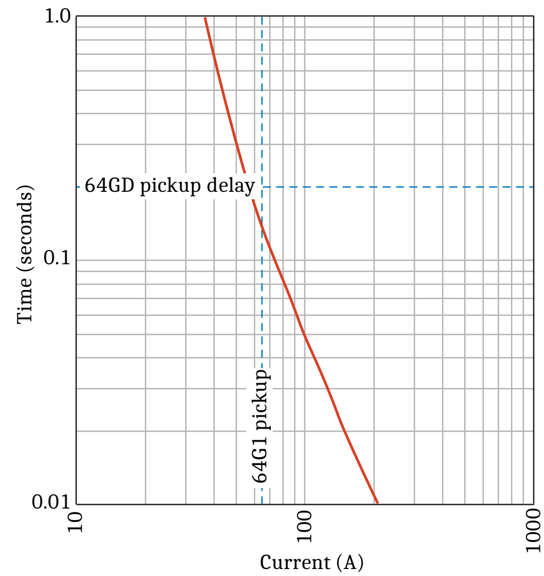


Figure 5.80 Coordination of the 64G1 With a 15 A KTK-R VT Secondary Fuse

Sequence Voltage Acceleration

A third way to address the issue of VT secondary grounds is based on sequence voltage checks. The sequence networks for a ground fault at the generator terminals and a VT secondary ground fault is shown in *Figure 5.81*.

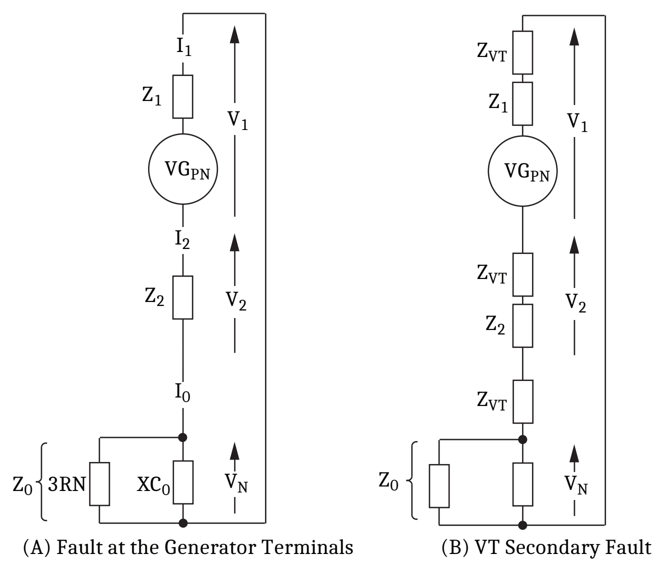


Figure 5.81 Ground Fault Sequence Networks

In *Figure 5.81(A)*, $Z_0 >> Z_2$, therefore V_2 is expected to be virtually zero for a stator fault. In *Figure 5.81(B)*, $Z_{VT} >> Z_2$. The ratio of V_2 / V_N can be written as:

$$\frac{V_2}{V_N} = \frac{I_2 \cdot Z_{VT}}{I_0 \cdot Z_0}$$

Because the currents in the three sequence networks are equal:

$$V_2 = \frac{Z_{VT}}{Z_0} \bullet V_N$$

We can substitute V_N with the pickup setting of the 64G1 reflected to the primary. Using the values from the example system of *Figure 5.64* and calculating the negative-sequence voltage for a VT secondary fault in secondary volts as:

$$3V2ZFM = 3 \bullet \left|\frac{ZVT}{Z_0}\right| \bullet \frac{PTRN \bullet 64G1P1}{PTRZ} = 3 \bullet \left|\frac{3989 + 9883j}{3300 - 3300j}\right| \bullet \frac{87}{174} \bullet 6.7\ V = 22\ V$$

where PTRN = PTRV2 if EGNPT = V2 and PTRN = PTRZ2 if EGNPT = V2.

A safety margin of 50 percent can be applied to this value. The acceleration torque-control equation now becomes:

64GATC := (NOT 46Q11) AND (3V2ZFM < 11)

For the case of two relays (referred to as Relay A and Relay B, each fed from a dedicated VT), if the fault is on the VT-A secondary, Relay B will not see a significant V2 and will accelerate. The same thing happens for a fault on VT-B. Acceleration must check that neither relay detects V2. This can be done by cross-wiring a low-V2 indication signal between the two relays. In the following equation, IN201 is used to monitor this indication, and the acceleration equation is then:

$$64ATC = (NOT\ 46Q11)\ AND\ (3V2ZFM < 11)\ AND\ IN201$$

Fuse coordination is not required in this approach. However, the previous calculations use the impedance of the VT (Z_{VT}). This value is not provided on the VT nameplate. If it is also not provided by the manufacturer, an estimate of Z_{VT} can be calculated from the VT nameplate data.

Directional Power Elements

You can enable as many as four independent three-phase power elements in the SEL-400G relay. Each enabled element can be set to detect real power or reactive power. When voltage inputs to the relay are taken from delta-connected PTs, the relay cannot account for unbalance in the voltages when calculating the power. Take this into consideration in applying the power elements.

The configuration options provide a wide variety of protection and control applications. Typical applications are:

- Reverse or low-forward power for generator anti-motoring protection
- Overpower and/or underpower protection/control
- VAR control for capacitor banks
- Detection of power export in DG applications

Figure 5.82 shows how the operating characteristic of a power element can be defined in the real-reactive power plane through the configuration of the 32O*n*, 32MOD*n*, and 32PP*n* settings.

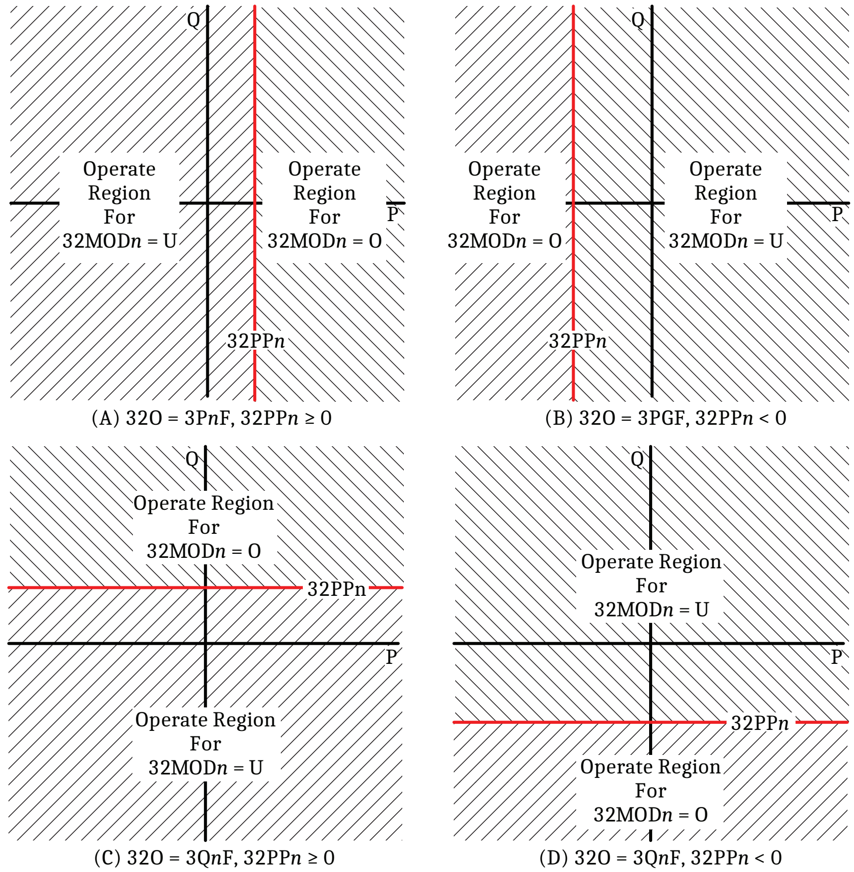


Figure 5.82 Directional Power Elements Operation in the Real/Reactive Power Plane

For example, to set an element as a conventional reverse power element, select a real-power operating signal, set 32PP*n* to be less than zero, and set 32MOD*n* = O. This results in the operating characteristic given in *Figure 5.82*. To set an element as a conventional low forward power element, select a real-power operating signal, set 32PP*n* to be greater than zero, and set 32MOD*n* = U. This results in the operating characteristic given in *Figure 5.82*.

In the SEL-400G, the calculated real and reactive power have the same sign as the power flowing in the primary system when the polarity marks of the VT and CTs are connected to the polarity marks on the relay. Note that a CT is often oriented with its polarity marks facing away from its associated generator, breaker, or transformer, as shown in *Figure 5.83*. In this example, real and reactive power are flowing out of the generator and into the GSU and AUX transformers, as indicated by the red and blue arrows. Because of the orientation of the CTs, the relay measures positive watts and VARs at the generator neutral and at the AUX transformer terminals, and negative watts and VARs flowing out of the breaker leading to the GSU.

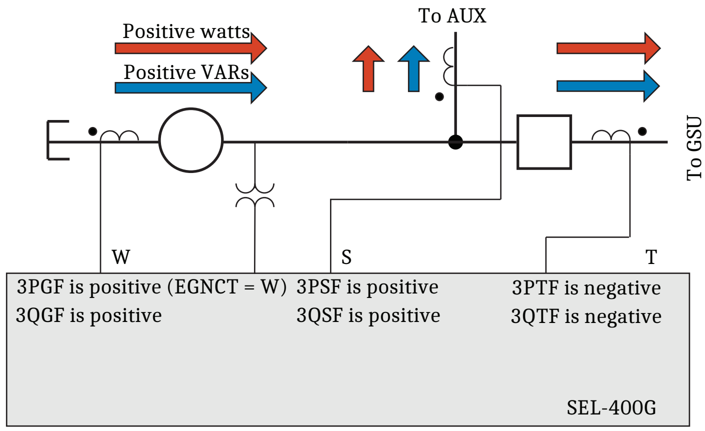


Figure 5.83 Example of Primary Power Flow and the Corresponding Relay Measurements

Figure 5.84 shows the element logic.

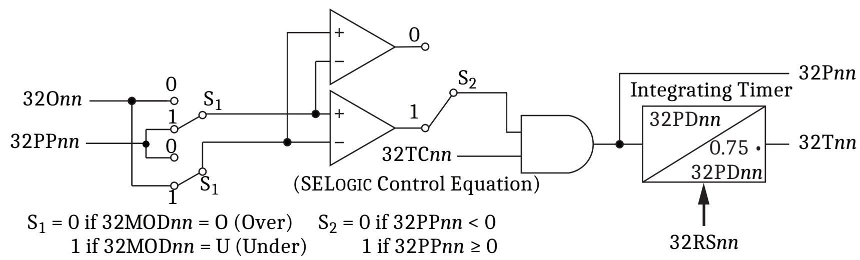


Figure 5.84 Directional Power Elements Logic

During a motoring event, the power element may dropout repeatedly because of the oscillation of the rotor. The directional power element incorporates an integrating timer to provide faster operation for these events. If enabled, the timer element does not reset immediately following a dropout. Instead, the timer is decremented at 1.33 times faster than its pickup rate. The timer can be forced to reset immediately by setting 32RS*nn* to Y.

Biased Operation

In some instances, a generator may motor while supplying significant reactive power to the system. Angle errors associated with the instrument transformers can cause a loss of dependability when motoring at a lower power factor.

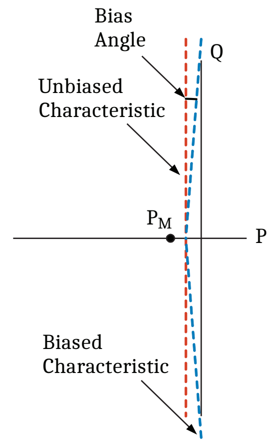


Figure 5.85 Dependability-Biased Characteristic

The bias angle has a default setting of 1 degrees.

Biased operation can only be enabled when the element is also configured to respond to real power.

Table 5.27 Directional Power Settings

Setting[a]	Prompt	Range	Default	Category
32O*nn*	Dir Power Element *nn* Operating Quantity	3P*m*F, 3Q*m*F[b]	3PGF	Group
32MOD*nn*	Dir Power Element *nn* Operating Mode	O, U	O	Group
32BIA*nn*	Dir Power Element *nn* Bias	SELOGIC	NA	Group
32ANG*nn*	Dir Power Element *nn*, Bias Angle	0.01 to 5	1	Group
32PP*nn*	Dir Power Element *nn* PU	–2000.00 to 2000 VA[c]	–10	Group
32PD*nn*	Dir Power Element *nn* Time Delay	0.000 to 400 s	2	Group
32RS*nn*	Dir Power Element *nn* Inst Reset	Y, N	Y	
32TC*nn*	Dir Power Element *nn* Torque Control	SELOGIC	1	Group

[a] nn = 01–04.
[b] m = S, T, U, Y, or G.
[c] The range shown is for a 5 A CT. Divide by 5 for 1 A rated CTs.

Generator Motoring Application

Generator motoring occurs when the prime mover input power to the generator is cut off while the generator is connected to the system. When this happens, the generator acts as a synchronous motor to drive the prime mover shaft. In steam-turbine prime mover applications, generator motoring can quickly damage the turbine by causing overheating. In applications of other prime movers, motoring can cause mechanical damage and/or unsafe operating conditions.

For this application, it is assumed that the real power measured by the relay is negative during motoring. Accordingly, the element is configured as a reverse power element, with 32PP*n* selected to be less than zero and 32MOD*n* selected as O.

For motoring protection of the generator, the pickup, 32PP*n* is usually set at 1/2 of the expected motoring power. This provides a margin in the case, for instance that a steam unit motors with the main valve not fully closed. The motoring power should be available from the generator manufacturer. It is a good idea to verify the pickup through a live trip test, if possible.

Table 5.28 Typical Motoring Power

Prime Mover	Power (pu)
Diesel	0.05–0.25
Gas Turbine	<0.50
Hydro	0.002–0.02
Steam	0.005–0.03

The dependability-biased characteristic is enabled using the 32BIA*n*. It is not required for the following applications:

- Motoring power is high (greater than 5 percent).
- Motoring power is low, but the generator will not motor with significant VARs (sequential trip or exciter is always in power factor regulation mode).
- Motoring power is low, but the angle errors are known to be less than 0.25 degrees (such as when the CTs and VTs haves a metering class specification or when instrument transformer accuracy has been measured and accounted for).

The 32BIA*n* setting is implemented as a SELOGIC control equation. Set it to 1 to enable biased operation. This implementation also permits dynamic application of biased operation.

There is a maximum permissible time that a generator can operate in a motoring mode without damage. The anti-motoring element time delay setting, 32PD*n* must be set less than this value. This value should be obtained from the generator manufacturer. It is also the case that the reverse power element can pick up for a stable power swing. The time delay setting must be set longer than this value which can be determined from a transient stability study.

Capability-Based Loss of Field

In addition to the impedance-based LOF, the SEL-400G includes a capability-based LOF element that defines characteristics that emulate the various capability curves associated with a synchronous generator. These characteristics are defined in the real and reactive power (PQ) plane. The relay implements the following zones:

- **Zone 1.** Operates quickly for severe LOF events.
- **Zone 2.** Operates for underexcitation events. Coordinates with the UEL and stator end-core heating limit (SECHL).
- **Zone 3.** Operates for a loss of steady-state stability. Coordinates with the SSSL.
- **Zone 4.** Alarms for abnormal loading. Coordinates with the GCC.

Each zone is designed to operate independently of the other zones. The impedance-based (40) element can be enabled simultaneously with any of the 40P zones. *Figure 5.86* shows the operating characteristics and the associated settings.

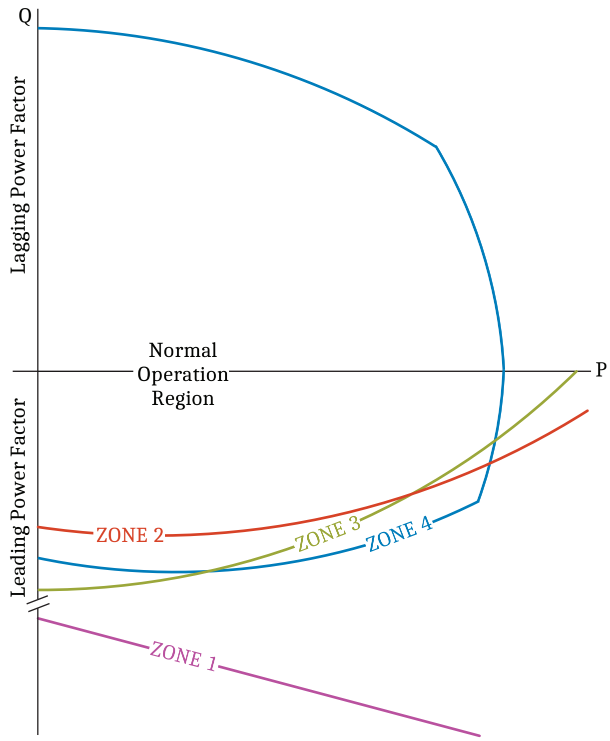


Figure 5.86 Capability-Based LOF (40P) Characteristics

40P Zone 1

A generator can lose synchronism if it suffers a complete loss of field, especially when it is operating near full load. A loss of field can occur for a variety of events, such as a short or open circuit. The machine can be damaged quickly because of the resulting overspeed and torque pulsations. The slip resulting from the overspeed can induce currents on the damper bars and rotor body and can damage the rotor because of excessive heating. A LOF event also poses a risk to the power system. The Zone 1 element is intended to provide high-speed protection. The characteristic is located farther from the GCC, which makes it more secure during stable power swings. This allows it to be set with a short delay with no additional supervision, which is important for dependability. This zone is analogous to the Zone 1 of the impedance-based LOF element. This characteristic is defined by a reactive offset setting (40P1P) and a slope setting (40P1DIR).

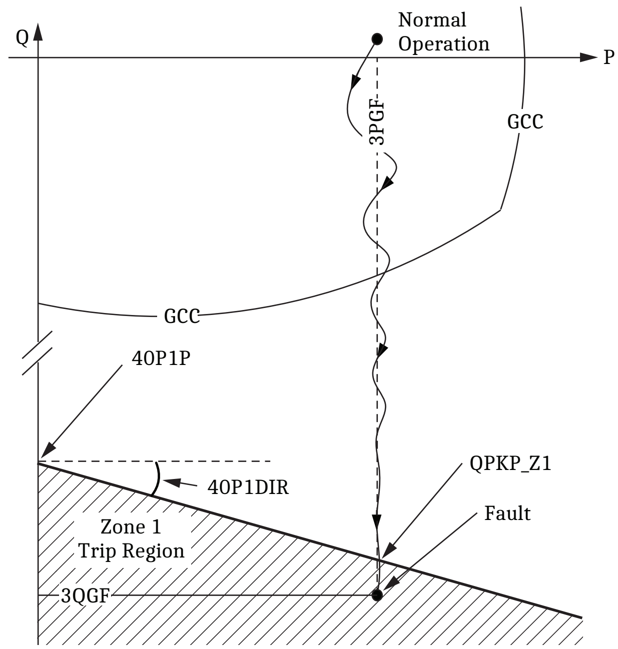


Figure 5.87 40P Zone 1 Characteristic and Associated Settings

Table 5.29 40P Zone 1 Settings

Setting	Prompt	Range[a]	Default	Category
E40PZ	40P Enable	Z1, Z2, Z3,Z4	Z1, Z2	Group
40P1P	40P Zone 1 pickup (VA, sec)	–2000.0 to –1	–100	Group
40P1DIR	40P Zone 1 characteristic angle (deg)	–30 to 30	–20	Group
40P1D	40P Zone 1 delay (seconds)	0.000 to 400	0.25	Group
40P1TC	40P Zone 1 torque control (SELOGIC Eqn)	SV	NOT LOPZ	Group

[a] The ranges and default settings shown are for a 5 A CT. Divide by 5 for 1 A rated CTs.

In general, the relay measures the generator real power, 3PGF, in secondary watts and applies it to a characteristic equation to calculate a reactive power pickup threshold, QPKP_Z1. It then checks if the generator reactive power 3QGF, in secondary VARs, is less than the pickup threshold, QPKP_Z1. For the 40P Z1 element the characteristic equation is:

$$\mathrm{QPKP\_Z1} = \left(\mathrm{40P1P} \bullet \left(\frac{\sqrt{3} \bullet \mathrm{V1ZFM}}{\mathrm{VNOMZ}}\right)^2 + |\mathrm{3PGF}| \bullet \tan(\mathrm{40P1DIR})\right)$$

Note that the voltage term makes this characteristic static in the impedance plane.

Figure 5.88 shows the logic for the 40P Zone 1. The following criteria should be considered for the 40P1D setting:

- Short enough to prevent damage for a loss of field at full power (refer to the guidance of the generator manufacturer).
- Short enough to allow the element to time out before the onset of pole slipping

If these criteria result in a delay of less the 0.25 seconds, then a check should be carried out to ensure that the element does not misoperate for stable power swings.

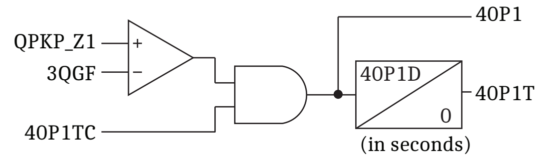


Figure 5.88 40P Zone 1 Logic

40P Zone 2

The Zone 2 element protects against sustained operation in the underexcited region of the PQ plane, below the GCC in *Figure 5.89*. Round-rotor generators can suffer damage because of end-iron heating when operating in this region. Underexcited operation can occur for several reasons, including high system voltage or problems with nearby generators. The role of the underexcitation limiter is to prevent operation in the underexcited region.

It is paramount that the 40P element does not operate for an event that can be corrected via the generator controls. The 40P Zone 2 element is designed to closely coordinate with the UEL. The element uses a curve-fitting algorithm to generate the characteristic equation. This is illustrated in *Figure 5.89*, where:

QPKP = function(3PGF)

Table 5.30 40P Zone 2 Settings

Setting	Prompt	Range	Default	Category
40P2SEG	40P Zone 2 shape	C, L	C	Group
40PUP5	40P Zone 2 real power at point 5 of the UEL (VA, sec)	1.00 to 2000	80	Group
40PUQ5	40P Zone 2 reactive power at point 5 of the UEL (VA, sec)	–2000.0 to 2000	–60	Group
40PUP6	40P Zone 2 real power at point 6 of the UEL (VA, sec)	1.00 to 2000	40	Group
40PUQ6	40P Zone 2 reactive power at point 6 of the UEL (VA, sec)	–2000.00 to 0	–80	Group
40PUQ7	40P Zone 2 reactive power of UEL at point 7 of the UEL (VA, sec)	–2000.00 to –1	–100	Group
40P2M	40P Zone 2 margin from UEL	1.05 to 1.25	1.2	Group
40P2D	40P Zone 2 pickup delay (seconds)	0.000–400	0.5	Group
40P2TC	40P Zone 2 torque control (SELOGIC equation)	SV	NOT LOPZ	Group
40PK	40P zone voltage coefficient	0–2	2	Group

Referring to *Figure 5.89*, the Zone 2 characteristic is defined by three coordinate-pairs (Points 5, 6, and 7) in the PQ plane. Using these settings, the relay fits either a curve or linear segments through the three points. The points are taken directly from a plot of the UEL. This allows the Zone 2 characteristic to closely match the shape of the UEL. The characteristic is then scaled by the Zone 2 margin setting (40P2M) to provide coordination with the UEL. The characteristic is bounded within the lower half of the PQ plane (3QGF < 0).

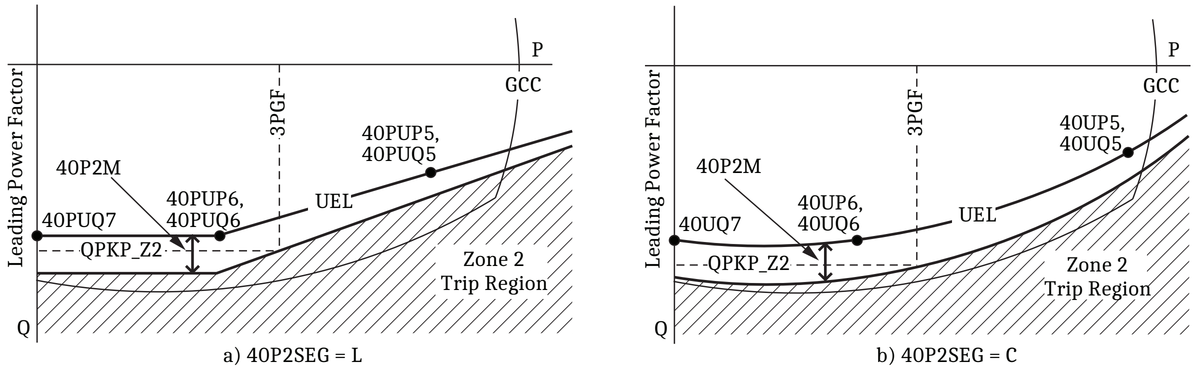


Figure 5.89 40P Zone 2 Characteristic and Associated Settings

The logic for the 40P Zone 2 is shown in *Figure 5.90*. The Zone 2 characteristic will often be large enough to cause the element to pick up for a stable power swing. The 40P2D setting should be set short enough to prevent generator damage for sustained operation outside the SECHL (refer to the guidance of the generator manufacturer). If this time is less than 0.25 seconds, then a study must be carried out to ensure that Zone 2 does not misoperate for a stable power swing.

The Zone 2 logic also implements an accelerated tripping path that is supervised by an undervoltage check. During a true underexcitation event, the terminal voltage will be reduced. If this path is used, and the 40PAD delay is less than 0.25 seconds, then the undervoltage pickup setting must be set less than the minimum voltage expected during a stable power swing.

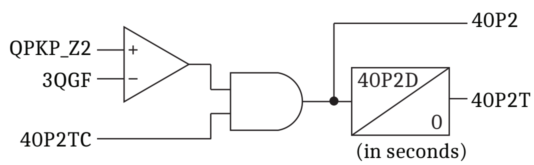


Figure 5.90 40P Zone 2 Logic

40P Zone 3

This zone is intended for detection of a loss of steady-state stability. Steady-state stability can occur when the automatic voltage regulator (AVR) is operated in manual mode. Manual operation is normally not permitted but some AVRs may transfer to manual for a PT fuse loss or loss-of-potential, for example. Often, in strong power systems, the SSSL will be situated outside the GCC, but for weak systems, the SSSL can intrude into the GCC. In this case, the generator could lose synchronism while still operating within the GCC. The 40P Zone 3 element is intended to detect this occurrence. *Figure 5.91* shows Zone 3 superimposed onto the GCC.

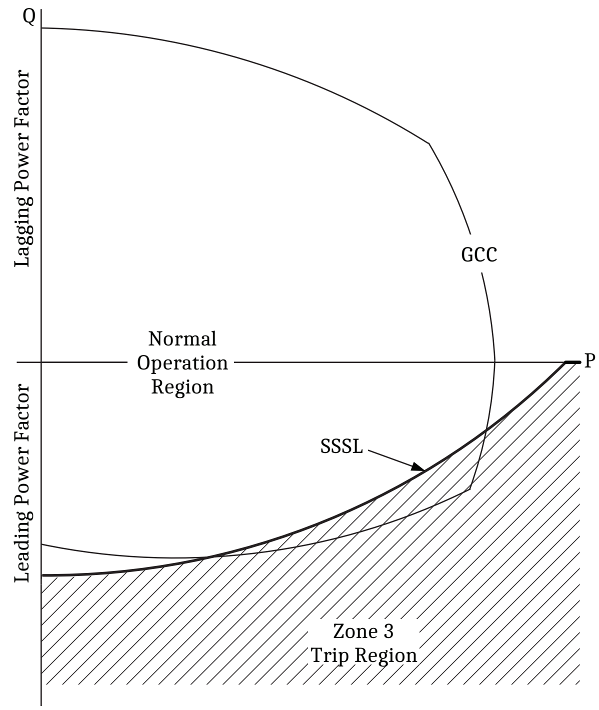


Figure 5.91 40P Zone 3 Characteristic

Table 5.31 40P Zone 3 Settings

Setting	Prompt	Range	Default	Category
40PUVP	40P U/V Element PU (V, sec)	OFF, 2.00–300.0	OFF	Group
40P3D	Zone 3 time delay (seconds)	0.000–400	10	Group
40P3TC	Zone 3 torque control (SELOGIC equation)	SV	NOT LOPZ	Group

The SSSL characteristic is implemented as a circle that is bounded within the lower half of the P-Q plane (3QGF < 0). Only the d-axis synchronous impedance (setting XDGEN) and the impedance of the weakest equivalent power system impedance (settings XESYS and XTXFR) are required to set this zone.

The characteristic equation of the SSSL in the PQ plane is given by *Equation 5.49*.

$$40\text{PSSL} = \text{re}\left(\left(3\text{PGF} + \text{j}3\text{QGF} - \frac{\text{jV1ZFM}^2}{\text{XESYS} + \text{XTXFR} \bullet \text{ZNOMGS}}\right) \bullet \left(\frac{-\text{jV1ZFM}^2}{\text{XDGEN} \bullet \text{ZNOMGS}} - 3\text{PGF} - \text{j}3\text{QGF}\right)\right)$$

Equation 5.49

where:

XESYS = the impedance of the power system in per-unit ohms

XDGEN = the direct-axis synchronous impedance of the generator in per-unit ohms

XTXFR = the transformer leakage reactance in per-unit

ZNOMGS = $(\text{KVGEN}^2 / \text{MVAGEN}) \bullet (\text{CTRG} / \text{PTRZ})$

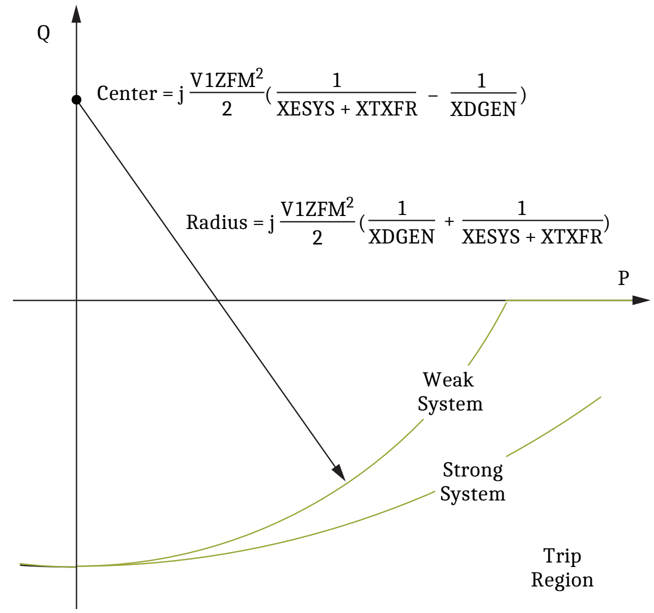


Figure 5.92 40P Zone 3 Examples for Strong and Weak Power Systems

Because Zone 3 replicates the SSSL, it is static in the impedance plane. Note that value of 40PSSL calculation changes sign from positive to negative at the onset of a loss of stability when the AVR is in Manual mode. If the AVR is in Automatic mode, the 40PSSL calculation could also transition from positive to negative during underexcited operation but without a loss of stability. However, in this case, the terminal voltage is expected to remain close to nominal.

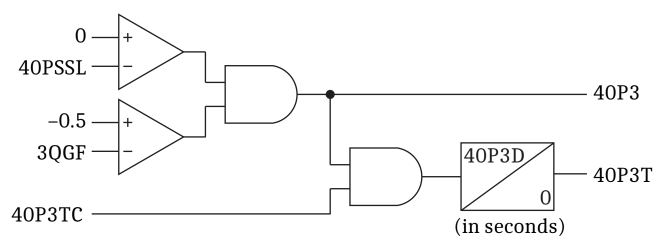


Figure 5.93 40P Zone 3 Logic

Application of the Zone 3 element is largely dependent on the specifics of the system:

- If studies show that the SSSL cannot intrude into the GCC (because the system is strong) or if the excitation system does not allow the possibility of manual AVR operation (because of design redundancies), Zone 3 can be disabled.
- Otherwise, if a loss of steady-state stability is possible and manual AVR operation is possible:
  - Zone 3 can be used to produce an alarm to indicate that, at the present level of real and reactive loading, a transfer to manual AVR operation will result in a loss of steady-state stability.
  - The AVR may provide an indication that it has transferred to manual. If available, this signal could be used to torque-control the element. In this case, the element could be used for tripping.
  - An actual loss of steady-state stability should be accompanied by reduced terminal voltage. Accordingly, an undervoltage element could be used to torque-control the element. In this case, the element could be used for tripping. A study is required to confirm the undervoltage pickup setting.

Accelerated Trip

The collapse of the terminal voltage or the field voltage provides an additional confirmation of an LOF event. Use *Figure 5.94* to provide accelerated tripping.

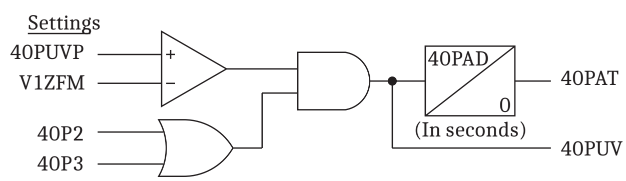


Figure 5.94 40P Acceleration Logic

Both the Zone 2 and Zone 3 are accelerated to trip if V1ZFM is less than the pickup setting along with a zone assertion.

40P Zone 4

This zone is intended to provide an alarm when the machine is operated outside the of the GCC. The logic includes a margin setting to allow the alarm to assert before reaching the boundary of the GCC.

The relay fits a curve for each segment using seven sets of PQ coordinates. The settings 40PQ1 and 40PQ7 define the upper and lower coordinates where the GCC intersects the Q axis (P = 0). The settings 40PP3 and 40PQ3 define the intersection between Segments 1 and 2. The settings 40PP5 and 40PQ5 define the intersection between Segments 2 and 3. The settings 40PP2, 40PQ2, 40PP4, 40PQ4, 40PP6, and 40PQ6 define the curvature of each of the three segments. The exact locations of the coordinates defined by these last settings are not critical but should be chosen at the approximate midpoints of each segment.

Table 5.32 40P Zone 4 Settings

Setting	Prompt	Range	Default	Category
40P4SEG	40P Zone 4 shape	C, L	C	Group
40PQ1	40P Zone 4 reactive power at point 1 of the GCC (VA, sec)	1.00 to 2000	100	Group
40PP2	40P Zone 4 real power at point 2 of the GCC (VA, sec)	1.00 to 2000	40	Group
40PQ2	40P Zone 4 reactive power at point 2 of the GCC (VA, sec)	1.00 to 2000	80	Group
40PP3	40P Zone 4 real power at point 3 of the GCC (VA, sec)	1.00 to 2000	80	Group
40PQ3	40P Zone 4 reactive power at point 3 of the GCC (VA, sec)	1.00 to 2000	60	Group
40PP4	40P Zone 4 real power at point 4 of the GCC (VA, sec)	1.00 to 2000	100	Group
40PQ4	40P Zone 4 reactive power at point 4 of the GCC (VA, sec)	–2000.0 to 2000	0	Group
40PP5	40P Zone 4 real power at point 5 of the GCC (VA, sec)	1.00 to 2000	80	Group
40PQ5	40P Zone 4 reactive power at point 5 of the GCC (VA, sec)	–2000.0 to 2000	–60	Group
40PP6	40P Zone 4 real power at point 6 of the GCC (VA, sec)	1.00 to 2000	40	Group
40PQ6	40P Zone 4 reactive power at point 6 of the GCC (VA, sec)	–2000 to 0	–80	Group
40PQ7	40P Zone 4 reactive power at point 7 of the GCC (VA, sec)	–2000 to –1	–100	Group
40PRU	40P Rated Power at Unity PF (VA, sec)	1.00 to 2000	100	Group
40P4M	40P Zone 4 margin	0.60 to 1	0.8	Group
40P4D	40P Zone 4 delay (seconds)	0.000 to 400	10	Group
40P4TC	40P Zone 4 torque control (SELOGIC Eqn)	SV	NOT LOPZ	Group

Use the 40PRU setting to specify the generator rated power at Unity Power Factor at maximum cooling. This setting is used in conjunction with the 40PRUD setting when the dynamic cooling feature is enabled. The analog value 40PPU will be scaled between the 40PRU and 40RUD settings based on the cooling level, 40DAM.

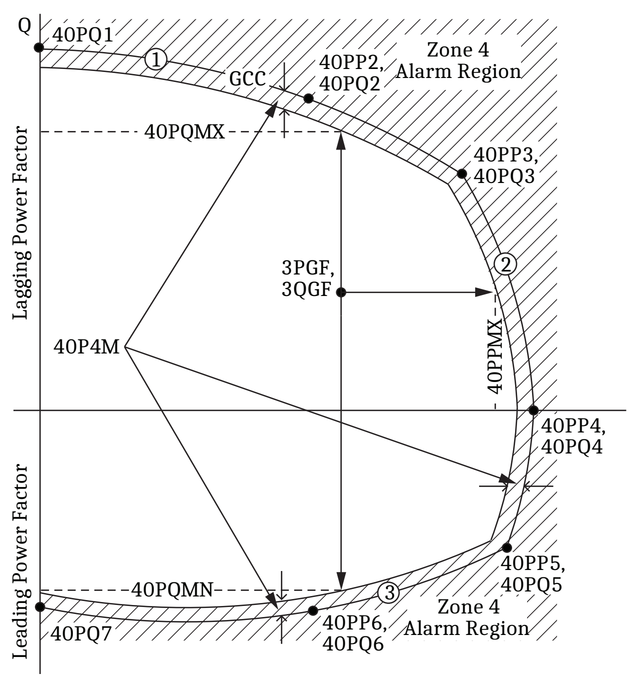


Figure 5.95 40P Zone 4 Characteristic and Associated Setting

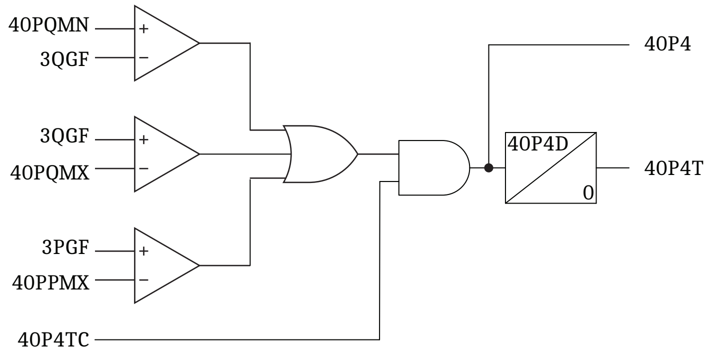


Figure 5.96 Capability Curve Alarm (Zone 4) Logic

Dynamic Functionality

In general, the real and reactive power that a generator can deliver varies directly with the ability to cool the machine. The GCC is essentially a representation of the safe thermal operating limits of the generator. In round-rotor generators the SECHL segment of the GCC can also vary with the terminal voltage. As a result, some modern generator control systems adapt the generator operating limits based on cooling capability and/or voltage magnitude.

In the SEL-400G, the Zone 2 and Zone 4 characteristics can be configured to adapt so that these zones maintain coordination with the UEL and GCC. *Figure 5.97* and *Figure 5.98* show the impact in protection coverage achieved by this dynamic behavior.

Table 5.33 40P Dynamic Function Common Settings

Setting	Prompt	Range	Default	Category
40PDAM	40P Dynamic Zone Analog Measurement	SELOGIC	RTS01TV	Group
40PDAQ	40P Dynamic Zone Analog Quality	SELOGIC	RTS01OK	Group
40PDAMX	40P Analog Meas Max Curve	–99999.000 to 99999	30	Group
40PDAMN	40P Analog Meas Min Curve	–99999.000 to 99999	50	Group
40PK	40P Zone Voltage Coefficient	0, 1, 2	2	Group

For cooling, a change of the zone characteristic is implemented through the introduction of a second set of settings which correspond to the minimum cooling capability. The relay also needs a measurement of the cooling level, (40PDAM). This, for example, could be a measurement of hydrogen pressure, ambient temperature, or other input that represents the present cooling level of the generator. The 40PDAM signal is wired to a transducer input. The signal is then scaled from 0 at minimum cooling to 1 at maximum cooling as follows:

$$40PX = \min\left(1, \max\left(0, \frac{40PDAM - 40PDAMN}{40PDAMX - 40PDAMN}\right)\right)$$

Equation 5.50

The relay then uses the 40PX value to linearly interpolate between the minimum and maximum characteristic. A quality indicator is provided for the cooling level measurement, 40PDAQ. If 40PDAQ = 0, the 40PX calculation is forced to 1, which shifts the zone characteristic to its maximum position.

For voltage, the zone characteristic is scaled using a terminal voltage measurement and exponent setting.

$$\left(\frac{\sqrt{3} \cdot \mathrm{V1ZFM}}{\mathrm{VNOMZ}}\right)^{40\mathrm{PK}}$$

Equation 5.51

The 40PK setting has a range of 0, 1, and 2 and a default setting of 2. The default setting results in a characteristic that is fixed in the impedance plane and is appropriate for hydro generators. A 40PK setting of 0 results in a characteristic that is fixed in the PQ plane.

Zone 2 Dynamics

The Zone 2 element can be configured to adapt its characteristic based on cooling. This functionality is enabled by setting E40P2D = Y. If the setting E40P2D = Y, then the SEL-400G provides additional settings for the location of the UEL during maximum cooling conditions.

Table 5.34 40P Dynamic Function Zone 2 Settings

Setting	Prompt	Range	Default	Category
E40P2D	Enable dynamic capability curve	Y, N	N	Group
40PUP5D	40P Zone 2 maximum real power at point 5 of the UEL (VA, sec)	1.00 to 2000	130	Group
40PUQ5D	40P Zone 2 maximum reactive power at point 6 of the UEL (VA, sec)	–2000.00 to 2000	–110	Group
40PUP6D	40P Zone 2 maximum real power at point 6 of the UEL (VA, sec)	1.00 to 2000	90	Group
40PUQ6D	40P Zone 2 maximum reactive power at point 6 of the UEL (VA, sec)	–2000.00 to 0	–130	Group
40PUQ7D	40P Zone 2 maximum reactive power of UEL at point 7 of the UEL (VA, sec)	–2000.00 to 2000	–100	Group

As shown in *Figure 5.97*, the relay calculates QPKP′ and QPKPD′. The relay uses the 40PX signal to interpolate between the minimum and maximum values as follows:

$$\mathrm{QPKP}' = \mathrm{QPKP} + (\mathrm{QPKPD} - \mathrm{QPKP}) \cdot 40\mathrm{PX}$$

Equation 5.52

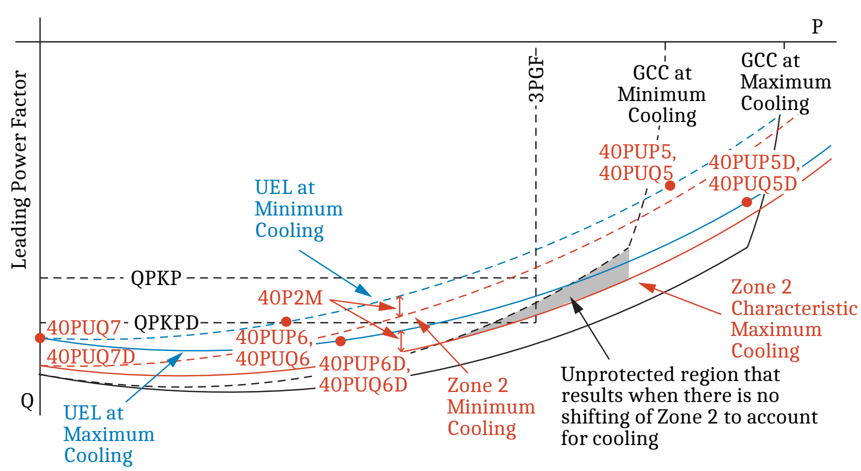


Figure 5.97 40P Zone 2 Dynamic Cooling Functionality

As mentioned, the GCC of round-rotor machines adapt with voltage and some UELs can also adapt to maintain coordination with the GCC. In these UELs, the characteristic is scaled using a voltage measurement and an exponent setting (40PK).

Accordingly, the 40P element includes a voltage exponent setting. This results in a Zone 2 pickup threshold of:

$$\text{QPKP\_Z2} = \text{QPKP}' \bullet \left(\frac{\sqrt{3} \bullet \text{V1ZFM}}{\text{VNOMZ}}\right)^{\text{40PK}}$$

Figure 5.98 shows Zone 2 applied to a round-rotor generator. Note that for an increase in terminal voltage, the reactive power that the generator can safely absorb is reduced, as denoted by the upward movement of the GCC. Also, if the UEL is configured for K = 2, the AVR reactive power limit increases for an increase in voltage as denoted by the downward movement of the UEL. The UEL is not coordinated with the GCC at this voltage and the machine is under-protected. Selecting K = 0 for the UEL makes it stationary in the P-Q plane. The Zone 2 element is also configured for 40PK = 0 in this example, making it stationary in the PQ plane and ensuring that it maintains coordination with the UEL.

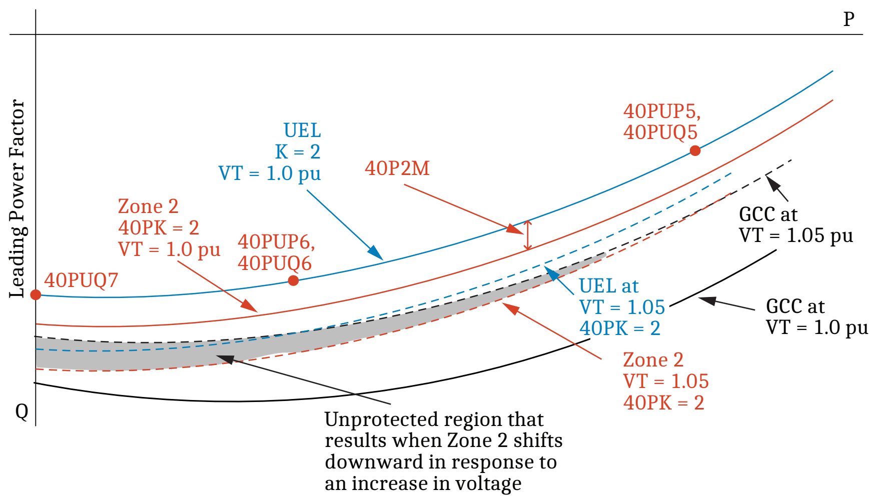


Figure 5.98 40P Zone 2 Dynamic Voltage Functionality

Zone 4 Dynamics

The Zone 4 element can dynamically expand and contract to follow the GCC that varies as a function of cooling level. If the setting E40P4D = Y, the SEL-400G provides additional settings for the GCC under changing cooling conditions.

Table 5.35 40P Dynamic Function Zone 4 Settings (Sheet 1 of 2)

Setting	Prompt	Range	Default	Category
E40P4D	Enable 40P Zone 4 dynamic capability curve	Y, N	N	Group
40PQ1D	40P Zone 4 maximum reactive power at point 1 of the GCC (VA, sec)	1.00 to 2000	150	Group
40PP2D	40P Zone 4 maximum real power at point 2 of the GCC (VA, sec)	1.00 to 2000	90	Group
40PQ2D	40P Zone 4 maximum reactive power at point 2 of the GCC (VA, sec)	1.00 to 2000	130	Group
40PP3D	40P Zone 4 maximum real power at point 3 of the GCC (VA, sec)	1.00 to 2000	130	Group
40PQ3D	40P Zone 4 maximum reactive power at point 3 of the GCC (VA, sec)	1.00 to 2000	110	Group
40PP4D	40P Zone 4 maximum real power at point 4 of the GCC (VA, sec)	1.00 to 2000	150	Group

Table 5.35 40P Dynamic Function Zone 4 Settings (Sheet 2 of 2)

Setting	Prompt	Range	Default	Category
40PQ4D	40P Zone 4 maximum reactive power at point 4 of the GCC (VA, sec)	–2000.00 to 2000	0	Group
40PP5D	40P Zone 4 maximum real power at point 5 of the GCC (VA, sec)	1.00 to 2000	130	Group
40PQ5D	40P Zone 4 maximum reactive power at point 5 of the GCC (VA, sec)	–2000.00 to 2000	–110	Group
40PP6D	40P Zone 4 maximum real power at point 6 of the GCC (VA, sec)	1.00 to 2000	90	Group
40PQ6D	40P Zone 4 maximum reactive power at point 6 of the GCC (VA, sec)	–2000.00 to 0	–130	Group
40PQ7D	40P Zone 4 maximum reactive power at point 7 of the GCC (VA, sec)	–2000.00 to –1.00	–100	Group
40PRUD	40P Rated Power at Unity PF (VA, sec)	1.00–2000	150	Group

Use the 40PRUD setting to specify the generator rated power at Unity Power Factor at minimum cooling. This setting is used in conjunction with the 40PRU setting when the dynamic cooling feature is enabled. The analog value 40PPU will be scaled between the 40PRU and 40RUD settings based on the cooling level, 40DAM.

The relay uses the 40PX signal to interpolate between the maximum and minimum values as follows:

$$\mathrm{QPKPMX'} = \mathrm{QPKPMX} + (\mathrm{QPKPMXD} - \mathrm{QPKPMX}) \bullet \mathrm{40PX}$$

$$\mathrm{QPKPMN'} = \mathrm{QPKPMN} + (\mathrm{QPKPMND} - \mathrm{QPKPMN}) \bullet \mathrm{40PX}$$

$$\mathrm{PPKP'} = \mathrm{PPKP} + (\mathrm{PPKPD} - \mathrm{PPKP}) \bullet \mathrm{40PX}$$

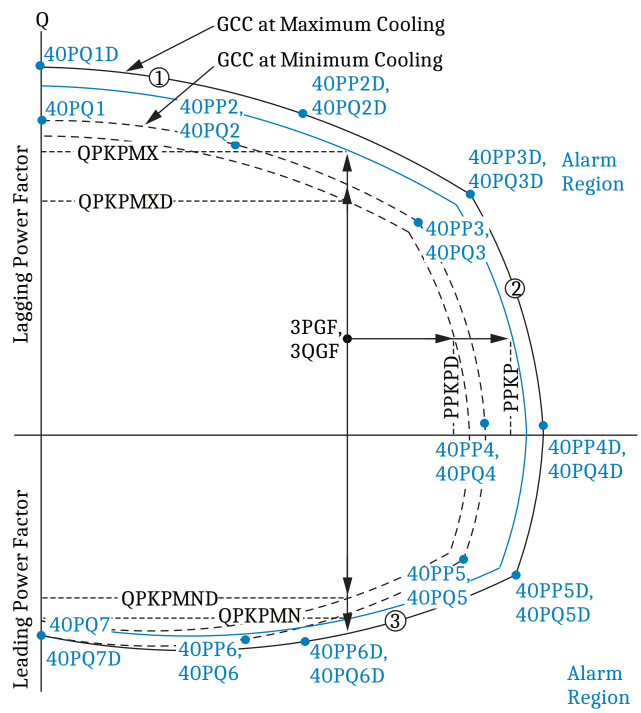


Figure 5.99 40P Zone 4 Dynamic Cooling Functionality

$$\mathrm{QPKPMX\_Z4} = \mathrm{QPKPMX'} \bullet \left(\frac{\sqrt{3} \bullet \mathrm{V1ZFM}}{\mathrm{VNOMZ}}\right)^{0}$$

$$\mathrm{QPKPMN\_Z4} = \mathrm{QPKPMN'} \bullet \left(\frac{\sqrt{3} \bullet \mathrm{V1ZFM}}{\mathrm{VNOMZ}}\right)^{\mathrm{40PK}}$$

$$PPKP\_Z4 = PPKP' \cdot \left(\frac{\sqrt{3} \cdot V1ZFM}{VNOMZ}\right)^2$$

Setting Guidelines

In the following example, the system of *Figure 5.100* is used to provide the steps for application of the 40P to a combustion gas turbine. In this application, the UEL does not shift to account for cooling and has a voltage coefficient, K of 0. It is assumed that an "AVR transferred to manual" signal is available for Zone 3 and that a measurement of inlet temperature is wired to the relay.

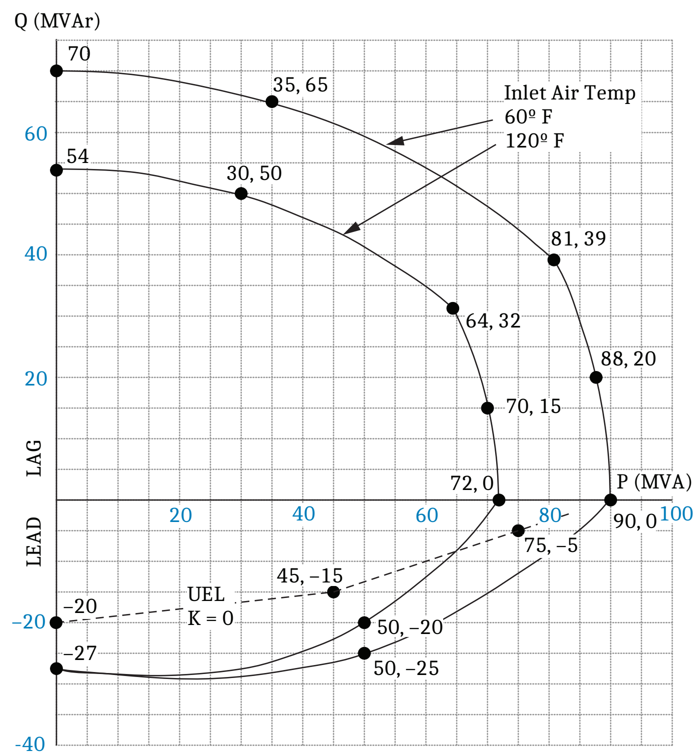


Figure 5.100 Example System

System Parameters	
Generator Rated MVA	90 MVA
Generator Rated Voltage	13.8 kV
PT Ratio (PTR)	120
CT Ratio (CTR)	800
Direct-Axis Synchronous Reactance (X_d)	2.08 p.u. at the generator base
System Reactance (X_S)[a]	0.36 p.u. at the generator base

[a] Includes the generator step up and the equivalent power system impedance.

We define a scaling factor to be used in the subsequent calculations:

$$SF = \frac{1\ MVA}{PTR \cdot CTR} = 10.42$$

Zone 1 Settings

For this application, set 40P1P as follows:

$$40P1P = -\frac{2 \bullet \text{Rated MVA}}{X_d(pu)} \bullet SF = -\frac{2 \bullet 90}{2.08} \bullet 10.42 = -901.4$$

The 40P1DIR default setting is –20 degrees. These settings result in a characteristic similar to that shown in *Figure 5.87*.

For this application, the delay and torque-control settings are left at their default values.

The following Zone 1 settings are applied to the relay:

- 40P1P = –901.4
- 40P1DIR = –20
- 40P1D = 0.25
- 40P1TC = NOT LOPZ

Zone 2 Settings

Select a linear characteristic for Zone 2.

From *Figure 5.101*, we obtain the coordinates for the UEL, which are then translated to relay settings using SF.

75 MW, –5 MVAR	40PUP5 = 75 • 10.42 = 781.3 40PUQ5 = –5 • 10.42 = –52.1
50 MW, –15 MVAR	40PUP6 = 50 • 10.42 = 521 40PUQ6 = –15 • 10.42 = –156.3
0 MW, –20 MVAR	40PUQ7 = –20 • 10.42 = –208.3

A margin setting of 120 percent is applied. This results in the following Zone 2 characteristic.

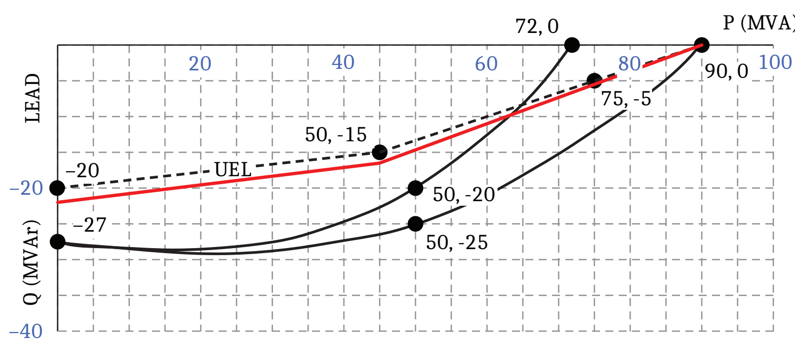


Figure 5.101 40P Zone 2 Characteristic With Example Settings

Accelerated tripping of Zone 2 is implemented if the positive-sequence voltage drops to 80 percent of nominal.

$$40PUVP = 0.8\frac{13800\ V}{\sqrt{3} \bullet 120} = 53.1\ V$$

For this application, the delay and torque-control settings are left at their default values.

The following Zone 2 settings are applied to the relay.

- ➤ 40P2SEG = L
- ➤ 40PUP5 = 781.3
- ➤ 40PUQ5 = –52.1
- ➤ 40PUP6 = 521
- ➤ 40PUQ6 = –156.3
- ➤ 40PUQ7 = –208.3
- ➤ 40PUVP = 53.1
- ➤ 40P2M = 1.2
- ➤ 40P2D = 60
- ➤ 40PAD = 0.25
- ➤ 40P2TC = NOT LOPZ

Zone 3 Settings

The Zone 3 characteristic is defined by the XDGEN, XESYS, and XTXFR settings, all of which are located in *Power System Data on page 6.7*. In this example, the following power system parameter settings are applied.

- ➤ MVAGEN = 90
- ➤ KVGEN = 13.8
- ➤ XDGEN = 2.08 pu
- ➤ XESYS = 0.31 pu
- ➤ XTXFR = 0.05 pu

For this example, the ratio of (XESYS + XTXFR) / XDGEN is 0.36 / 2.08 = 0.17. Because this value is greater than 0.1, it is likely that the SSSL can intrude into the GCC.

An actual SSSL should be accompanied by a significant undervoltage. A value in the range of 80 percent of nominal can be expected, which is the same as that of Zone 2.

Pole slipping occurs quickly, so a short delay in the range of 0.25 seconds is warranted.

In this application, an indication that the AVR is in MANUAL is available and this signal is wired to IN108.

The following Zone 3 settings are applied for the example system.

- ➤ 40PUVP = 53.1
- ➤ 40P3D = 0.25
- ➤ 40P3TC = NOT LOPZ AND IN108

Zone 4 Settings

From *Figure 5.100*, we obtain the coordinates for the GCC, which are then translated to relay settings using SF.

0 MW, 54 MVAR	40PQ1 = 54 • 10.42 = 562.68
30 MW, 50 MVAR	40PP2 = 30 • 10.42 = 312.6 40PQ2 = 50 • 10.42 = 521

64 MW, 32 MVAR	40PP3 = 64 • 10.42 = 666.9 40PQ3 = 32 • 10.42 = 333.4
70 MW, 15 MVAR	40PP4 = 70 • 10.42 = 729.4 40PQ4 = 15 • 10.42 = 156.3
72 MW, 0 MVAR	40PP5 = 72 • 10.42 = 750.2 40PQ5 = 0 • 10.42 = 0
50 MW, –20 MVAR	40PP6 = 50 • 10.42 = 521.0 40PQ6 = –20 • 10.42 = –208.3
0 MW, –27 MVAR	40PQ7 = –27 • 10.42 = –281.3

The delay and torque-control settings are left at the default values.

The following settings are applied for the example system.

- 40P4SEG = C
- 40PQ1 = 562.68
- 40PP2 = 312.6
- 40PQ2 = 521
- 40PP3 = 666.9
- 40PQ3 = 333.4
- 40PP4 = 729.4
- 40PQ4 = 156.3
- 40PP5 = 750.2
- 40PQ5 = 0
- 40PP6 = 521.0
- 40PQ6 = –208.4
- 40PQ7 = –281.3
- 40P4M = 0.95
- 40P4D = 60
- 40P4TC = NOT LOPZ

Dynamic Functionality

In this application, the UEL has a K of 0. Because a measurement of inlet temperature is wired to the relay, configure Zone 4 for dynamic cooling. According to *Figure 5.100*, the GCC is at its maximum for a temperature of 60 degrees and its minimum at 120 degrees. The following settings are applied to the relay:

- 40PDAMX = 60
- 40PDAMN = 120
- 40PK = 0

Because the UEL does not shift with cooling, this feature is disabled for Zone 2.

- E40P2D = N

Enable the dynamic capability curve for Zone 4. From *Figure 5.100*, we obtain the coordinates for the GCC, which are then translated to relay settings using SF.

0 MW, 70 MVAR	40PQ1D = 70 • 10.42 = 729.4
36 MW, 65 MVAR	40PP2D = 36 • 10.42 = 375.1 40PQ2D = 65 • 10.42 = 677.3

81 MW, 39 MVAR	40PP3D = 81 • 10.42 = 844 40PQ3D = 39 • 10.42 = 406.4
88 MW, 20 MVAR	40PP4D = 88 • 10.42 = 917 40PQ4D = 20 • 10.42 = 208.4
90 MW, 0 MVAR	40PP5D = 90 • 10.42 = 937.8 40PQ5D = 0 • 10.42 = 0
50 MW, –25 MVAR	40PP6D = 50 • 10.42 = 521.0 40PQ6D = –25 • 10.42 = –260.5
0 MW, –27 MVAR	40PQ7D = –27 • 10.42 = –281.3

The following settings are applied for the example system.

- E40P4D = Y
- 40PQ1D = 729.4
- 40PP2D = 375.1
- 40PQ2D = 677.3
- 40PP3D = 844
- 40PQ3D = 406.4
- 40PP4D = 917
- 40PQ4D = 208.4
- 40PP5D = 937.8
- 40PQ5D = 0
- 40PP6D = 521.0
- 40PQ6D = –260.5
- 40PQ7D = –281.3

Impedance-Based LOF Elements

A LOF event can occur because of an open or short circuit in the field circuit, an excitation failure, an operating error, or other events. The response of the generator to a LOF event is often impacted by generator pre-fault loading and by the characteristics of the power system at the time. The damage potential is varied. The generator may begin to slip poles, leading to large pulsating current/torque and damaging overspeed. Overheating of the rotor can also occur. An LOF event can also pose a risk to the power system.

The SEL-400G provides an impedance-based element composed of two zones. Zone 1 is intended to operate with little time delay in the event of a LOF under full load conditions. Zone 2 reaches farther and operates with a longer time delay. Zone 2 is intended to trip for LOF conditions that occur under light load conditions.

Because LOF affects all three phases, the condition is a balanced one. Accordingly, the SEL-400G applies a positive-sequence impedance measurement to the zone operating characteristics.

The Zone 1 and Zone 2 characteristics are implemented as offset mho circles. As shown in *Figure 5.102*, the SEL-400G supports LOF schemes where both zones are offset in the negative reactive direction or where Zone 2 has a positive reactive offset. In the latter case, the relay provides a directional element with a settable angle characteristic.

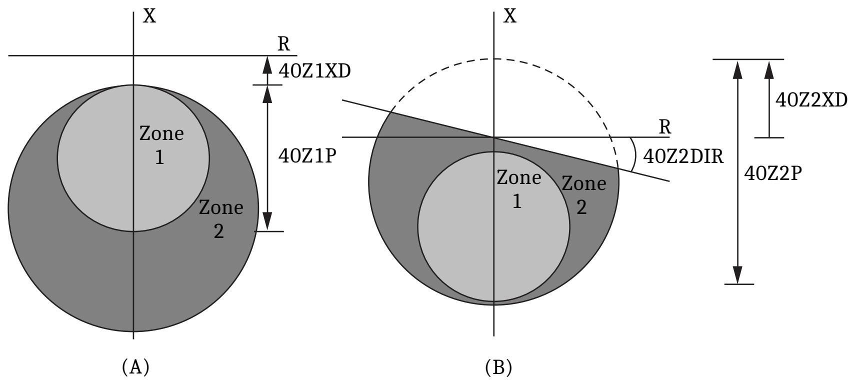


Figure 5.102 LOF Operating Characteristic Using (A) a Negative or (B) a Positive Zone 2 Offset

The Zone 2 element is used together with an undervoltage element to provide faster tripping when the system voltage is depressed during the LOF condition. The LOF elements are supervised by the 40Z1TC and 40Z2TC torque-control settings.

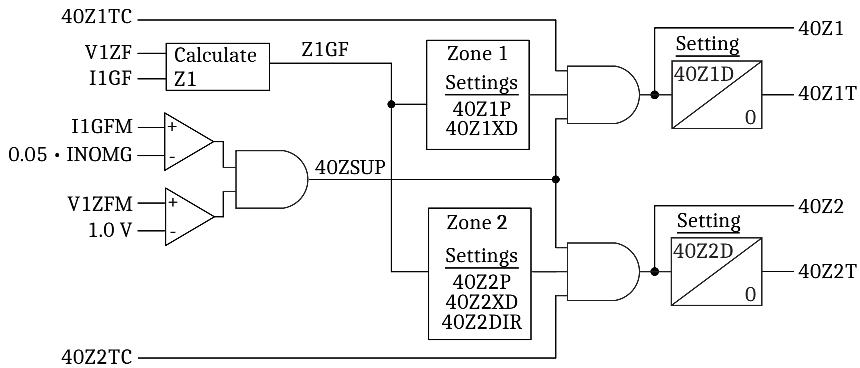


Figure 5.103 Impedance LOF Logic

Table 5.36 40Z Settings

Setting	Prompt	Range	Default	Category
40Z1P	40Z Zone 1 Diameter	OFF, 0.1 to 100 Ω[a]	13.4	Group
40Z1XD	40Z Zone 1 Offset	–50.0 to 0 Ω[a]	–2.5	Group
40Z1D	40Z Zone 1 Delay	0.00 to 400 s	0.25	Group
40Z1TC	40Z Zone 1 Torque Control	SELOGIC	NOT LOPZ	Group
40Z2P	40Z Zone 2 Diameter	OFF, 0.1 to 100 Ω[a]	13.4	Group
40Z2XD	40Z Zone 2 Offset	–50.0 to 50 Ω[a]	–2.5	Group
40Z2D	40Z Zone 2 Delay	0.00 to 400 s	0.50	Group
40Z2DIR	40Z Zone 2 Directional Angle	–20.0 to –5 deg	–10	Group
40Z2TC	40Z Zone 2 Torque Control	SELOGIC	NOT LOPZ	Group

[a] The ranges and default settings shown are for a 5 A CT. Multiply by 5 for 1 A rated CTs.

Set E40 to Z or Z, P to enable 40Z protection elements.

The Zone 1 element typically is applied as a tripping function. Zone 1 diameter and offset setting guidelines are described in *Settings Guidelines on page 5.101*. Set the Zone 1 offset equal to half the generator transient reactance, X'_d, in secondary ohms. Zone 1 LOF tripping is typically performed with short or no time delay. Use the 40Z1D setting to add any necessary delay.

The 40Z1 Relay Word bit asserts without time delay when the measured positive-sequence impedance falls within the Zone 1 mho circle defined by the offset and diameter settings.

The 40Z1T Relay Word bit asserts 40Z1D seconds after 40Z1 asserts.

The Zone 2 element typically is applied as a time-delayed tripping function. Zone 2 diameter and offset setting guidelines are described in *Settings Guidelines on page 5.101*.

Zone 2 LOF tripping typically is performed with a time delay of 0.5 to 0.6 seconds. Set 40Z2D equal to the necessary delay.

The 40Z2DIR setting is hidden when 40Z2XD < 0.

The 40Z2 Relay Word bit asserts without a time delay when the measured positive-sequence impedance falls within the Zone 2 mho circle defined by the offset and diameter settings, and less than the directional supervision line (if used). The 40Z2T Relay Word bit asserts 40Z2D seconds after 40Z2 asserts.

The LOF elements are disabled when the 40Z1TC and 40Z2TC SELOGIC control equation equals logical 0. The relay allows these elements to operate when the SELOGIC control equation equals logical 1. This element should be torque-controlled using NOT LOPZ to prevent an operation when the relay detects a loss-of-potential condition.

Settings Guidelines

Collect the following information to set LOF.

- Generator direct axis reactance, Xd, in per unit
- Generator transient reactance, X'd, in per unit
- Generator-rated line-to-line voltage, in secondary volts (VNOMZ)
- Generator-rated phase current, in secondary amperes (INOMG)
- When a positive Zone 2 offset is necessary, you also need the following:
  - Step-up transformer reactance XTXFR and system reactance XESYS in secondary ohms at the generator base
  - Generator-rated power factor

Two methods are available for LOF protection: negative offset Zone 2 and positive offset Zone 2. Recommendations for both setting methods are provided.

LOF Protection Using a Negative Offset Zone 2

NOTE: The following discussion includes the typical settings applied for the case that the Zone 2 has a negative offset. Carry out the required setting calculations for your particular application.

When setting Zone 2 with a negative offset, it is typical to set the Zone 1 diameter 40Z1P equal to 1.0 per unit impedance.

$$40Z1P = \frac{VNOMZ}{\sqrt{3} \cdot INOMG} \ \Omega \text{ sec}$$

NOTE: Typically, the Xd is greater than 1 per unit impedance. However, if Xd is less than or equal to 1 per unit impedance, set the 40Z1P shorter so that the worst-case stable power system swing does not enter the Zone 1 characteristic.

The Zone 1 offset, 40Z1XD is typically set to half the generator transient reactance, X'_d, in secondary ohms.

$$40Z1XD = \frac{-X'_d}{2}\ \Omega\ \text{sec}$$

Zone 1 LOF tripping is typically performed with little or no time delay.

40Z1D = 0 seconds

The Zone 2 diameter, 40Z2P, is typically set to equal to the machine direct axis reactance, Xd, in secondary ohms.

$$40Z2P = X_d\ \Omega\ \text{sec}$$

The Zone 2 offset, 40Z2XD, is typically set to the Zone 1 offset.

$$40Z2XD = \frac{-X'_d}{2}\ \Omega\ \text{sec}$$

Set the Zone 2 time delay, 40Z2D, long enough to avoid an incorrect operation during a worst-case stable power system swing condition, typically 0.5 to 0.6 seconds or according to the recommendations of the generator manufacturer.

40Z2D = 0.5 seconds

In this case, the 40Z2DIR setting is hidden.

The Relay Word bits 40Z1T and 40Z2T are configured to trip the field breaker and the generator breaker.

LOF Protection Using a Positive Offset Zone 2

NOTE: The following discussion includes the typical settings applied for the case that the Zone 2 has a negative offset. Carry out the required setting calculations for your particular application.

When setting Zone 2 with a positive offset, set the Zone 1 diameter:

$$40Z1P = 1.1 \bullet X_d + \frac{-X'_d}{2}\ \Omega\ \text{sec}$$

Set the Zone 1 offset equal to half the generator transient reactance, X'_d, in secondary ohms.

$$40Z1XD = \frac{-X'_d}{2}\ \Omega\ \text{sec}$$

Traditionally, the Zone 1 delay for this type of scheme is 0.25 seconds.

40Z1D = 0.25 seconds

Use the direct axis reactance and XS, the sum of the step-up transformer reactance XT and system reactance X_{SYS}, to set the Zone 2 diameter.

$$40Z2P = 1.1 \bullet X_d + X_T +$$

Use the total reactance of XS to set the Zone 2 offset.

$$40Z2XD = X_T + X_{SYS}\ \Omega\ \text{sec}$$

Traditionally, the Zone 2 delay for this type of scheme is approximately 60 seconds (it is advisable to conduct system studies to determine the best time delay when using the positive offset method).

40Z2D = 60.0 seconds

The relay applies a shorter delay if the Zone 2 element picks up at the same time that the relay detects an undervoltage condition. This logic is discussed in the following text. In this case, the 40Z2DIR setting is necessary. Set 40Z2DIR equal to –20 degrees or the arc cosine of the minimum rated power factor, whichever is smaller.

When applying LOF protection with a positive Zone 2 offset, you can use the time-delayed Zone 1 Relay Word bit, 40Z1T, and the long-time-delayed Zone 2 Relay Word bit, 40Z2T, directly in the generator breaker and field breaker tripping SELOGIC control equations.

Undervoltage Acceleration

The traditional application of this scheme provides accelerated (0.25 second) Zone 2 tripping in the event of an undervoltage condition occurring during the LOF. To achieve this accelerated tripping, it is necessary to use a positive-sequence undervoltage element, (27P1 in this example). Choose the Z terminal positive-sequence voltage for the operating signal.

27O1 := V1ZM

The undervoltage element is generally set to 80 percent of the nominal voltage for single-machine buses and 87 percent for multi-machine buses.

$$27P1P1 = \frac{0.8}{\sqrt{3}} \text{ VNOMZ sec}$$

Set the Level 1 delay to 0.25 seconds:

27P1D1 := 0.25

Use the 40Z2 Relay Word bit to torque-control the undervoltage element:

27TC1 := 40Z2

The Relay Word bit, 271P1T, should be used along with the Zone 1 and Zone 2 outputs, 40Z1T and 40Z2T trip the generator.

Current Unbalance Elements

Generator unbalance current causes induced harmonic heating of the rotor. IEEE ANSI Standard C50.12 and C50.13 define the ability of generators to withstand unbalance current in terms of negative-sequence current. The standard defines a continuous withstand capability as well as a short-time capability, expressed in terms of $I_2^2 \bullet t$.

The SEL-400G provides a negative-sequence definite-time overcurrent element suitable for unbalance alarm application and a negative-sequence, inverse time-overcurrent element for unbalance current tripping.

The negative-sequence current in the SEL-400G is calculated as:

$$I2GP = \frac{3I2GM}{3 \bullet INOMGS} \bullet 100$$

where:

INOMGS = the rated current of the generator

3I2GM = the instantaneous negative-sequence current magnitude through the generator neutral

Harmonic Heating

Harmonic components also cause rotor heating. Each harmonic induces a component that circulates clockwise or counter-clockwise depending on the harmonic order, *n*, as shown in *Figure 5.104*. The harmonic order has value equal to or greater than 1.

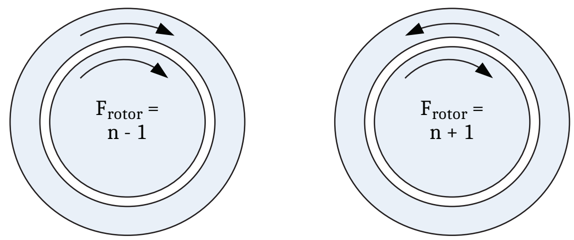


Figure 5.104 Frequency of the Induced Rotor Component Because of a Stator Harmonic

Rotor heating is a function of skin depth which is in turn dependent on the frequency of the induced component. Skin depth on the rotor face and in the damper bars decreases by $1/\sqrt{(F_{rotor})}$. Therefore, rotor resistance increases by $1/\sqrt{(F_{rotor})}$.

The SEL-400G calculates an equivalent negative-sequence current I2GPEQ, which includes harmonics as high as the 15th and accounts for skin depth. Refer to *Harmonic Meter on page 7.12* for additional information. The following equation shows the calculations. Harmonics are calculated every 5 seconds.

$$I2GPEQ = \left(\frac{100}{3 \bullet INOMGS}\right)\sqrt{(3I2GM)^2 + \sum_k\left(\sqrt{\frac{k+1}{2}}3I2GH_k{}^2 + \sqrt{\frac{k-1}{2}}3I1GH_k{}^2\right)}, k = 2 \ldots 15$$

Equation 5.53

where:

$3I2GH_k$ = is the negative-sequence component of the *k*th harmonic

$3I1GH_k$ = the positive-sequence component of the *k*th harmonic

The SEL-400G provides two elements. The operating quantity for each element can be selected either as I2GP or I2GPEQ.

Each element has two levels. Level 1 has a definite-time characteristic and is usually applied to alarm. The Level 1 logic is shown in *Figure 5.105*.

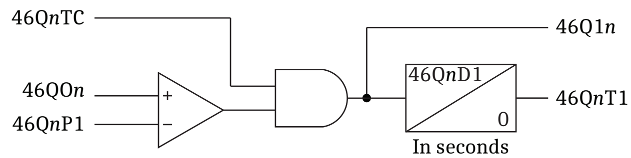


Figure 5.105 Current Unbalance Level 1 Logic for Element n (Definite Time)

Level 2 has an inverse-time characteristic and is typically applied to trip if the damage curve is reached (see *Figure 5.106*). Generally, negative-sequence overcurrent tripping is applied to the generator main breaker only. This permits rapid resynchronization after the system unbalance condition clears.

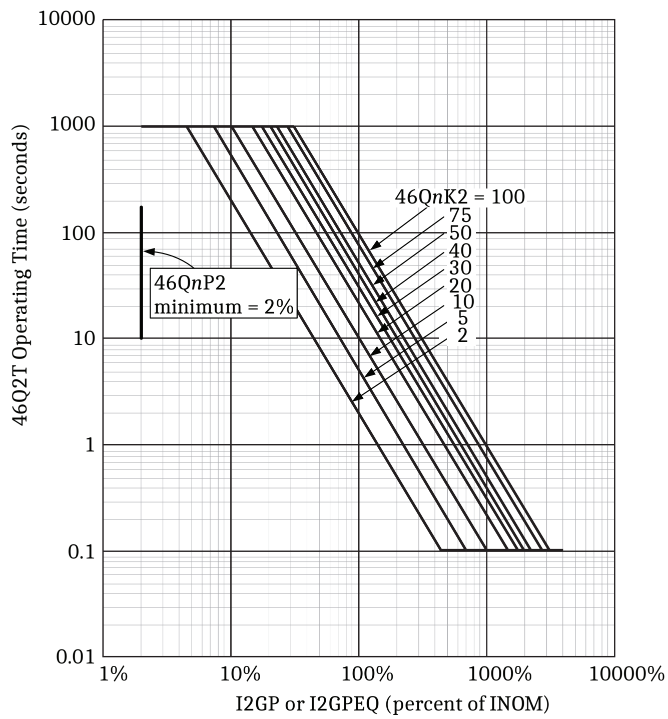


Figure 5.106 Current Unbalance Level 2 $I2^2t$ Operating Characteristic

$$t_{op} = \frac{46Q\textit{n}K2}{\left(\frac{I2}{INOMGS}\right)^2} \text{ seconds}$$

where:

I2 = I2GP or I2GPEQ

The 46Q*n*2 Relay Word bit asserts without time delay when the measured operating current 46QO*n* is greater than the element pickup 46Q*n*P2. The 46Q*n*T2 Relay Word bit asserts in a time defined by the time-overcurrent element operating characteristic of *Figure 5.107*. The negative-sequence time-overcurrent element resets after a fixed linear time of 240 seconds. If an element accumulates 50 percent of the 46Q*n*K2 setting, it resets in 120 s (50 / 100 x 240 s). The 46Q*n*R2 Relay Word bit asserts when the element is fully reset. The 46Q*n*R2 Relay Word bit can be used to prevent a resynchronization until the heating of the generator rotor has dissipated.

Figure 5.107 shows the logic for Level 2.

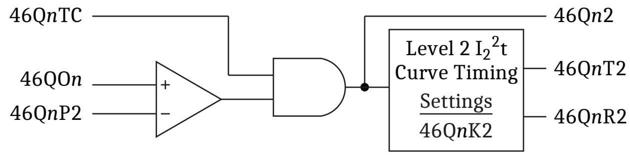


Figure 5.107 Current Unbalance Logic for Element n, Level 2

Table 5.37 Current Unbalance Setting

Setting	Prompt	Range	Default	Category
E46	Enable 46 Element	N, 1, 2	N	Group
46QO*n*	46 Element *n* Operate Quantity	I2GP, I2GPEQ	I2GP	Group
46Q*n*P1	46 Element *n* Level 1 PU (%)	OFF, 2.0–100	8.0	Group
46Q*n*D1	46 Element *n* Level 1 Delay (s)	0.000–1000 s	30	Group
46Q*n*P2	46 Element *n* Level 2 PU (%)	OFF, 2–100	8	Group
46Q*n*K2	46 Element *n* Level 2 Time Dial (s)	1–100	10	Group
46Q*n*TC	46 Element *n* Torque Control (SELOGIC Eqn)	SELOGIC	1	Group

The following information is typically necessary to calculate the negative-sequence overcurrent setting:

- P2: Generator continuous current unbalance withstand capability, percent of rated current
- K2: Generator negative-sequence current short-time withstand capability, seconds

Set E46 = 1 or 2 to enable the current unbalance elements. If current unbalance protection is not necessary, set E46 = N.

Level 1 is typically set to operate less than the continuous unbalance current capability, P2, This value is specified by the generator manufacturer and is typically in the range of 8.0–12.0 percent. Set the Level 1 pickup lower than the generator continuous current unbalance, P2.

Set the 46Q1D*n* time delay greater than the maximum time of normal unbalance current periods, including system phase-fault clearing time. This delay setting prevents unwanted unbalance current alarms.

Level 2 is typically set to operate greater than the Level 1 pickup and less than or equal to the continuous unbalance current capability, P2. Disable the level by setting 46Q2P*n* = OFF. Set the Level 2 pickup equal to the generator continuous current unbalance, P2.

The Level 2 time dial is set according to the negative-sequence capability rating, K2, defined by the generator manufacturer. Set the Level 2 time dial equal to the generator short-time withstand capability, K2.

You can define conditions that prevent negative-sequence overcurrent element operation in the 46QTC*n* torque-control setting. Normally, the negative-sequence overcurrent elements should be enabled all of the time.

Volt/Hertz Elements

Generators and transformers have a magnetic core. To minimize iron usage, the core is typically designed to produce a magnetic flux that is close to the limit of linear operation when the equipment is operated at rated voltage and frequency. Overexcitation refers to an event that causes the core to saturate. As a result, stray flux can link to nonlaminated components, causing overheating. Such an event can be caused by overvoltage, underfrequency, or a combination of the two conditions. The SEL-400G detects overexcitation by calculating the ratio of normalized voltage to normalized frequency (V/Hz). This ratio is proportional to the level of flux in the core.

The SEL-400G has two elements, each with a selectable operating signal and torque control. In addition, each element has two levels. In the following description, *n* refers to the element and can have a value 1 or 2.

The operating signal is selectable for each element using the 24O*n* setting. The available signals are shown in *Table 5.38*. Note that the availability of the VPMAXVF, VV1FM, VV2FM, and VV3FM signals depends on the PTCONV setting. See *Configuration of Current Inputs on page 5.9* for details.

Equation 5.54 shows the operating signal for each element.

$$24\text{RPUn} = \left(\frac{24\text{On}}{\text{VNOMn}}\right) \bullet \left(\frac{\text{NFREQ}}{\text{FREQn}}\right) \bullet 100$$

Equation 5.54

NOTE: Choosing a nominal voltage setting equal to the rated voltage of the protected equipment makes it easier to coordinate the V/Hz element with the manufacturer's overexcitation damage curve.

Note that VNOM*n* (where *n* = 1, 2) in *Equation 5.54* corresponds to the nominal voltage setting for the selected operating signal, as shown in *Table 5.38*. For example, if 24O*n* = VPMAXZF, then VNOM*n* = VNOMZ.

The value, FREQ*n*, is automatically chosen to be the frequency that is used to track the selected operating signal as shown in the following table. NFREQ is the nominal frequency (50 or 60 Hz).

Table 5.38 Volts per Hertz Operating Signal and Associated Frequency

24On	VNOM	FREQn
VPMAXZF	VNOMZ	Always FREQPG
VPMAXVF[a]	VNOMV	Determined by the ESYSPT and FTSRCV settings
VV1FM[b]	VNOMV1	Determined by the ESYSPT and FTSRCV1 settings
VV2FM[c]	VNOMV2	Determined by the ESYSPT and FTSRCV2 settings
VV3FM[b]	VNOMV3	Determined by the ESYSPT and FTSRCV2 settings

[a] Available when PTCONV = Y, D, or D1.
[b] Available when PTCONV = 1PH.
[c] Available when PTCONV = 1PH or D.

See *Frequency Tracking on page 5.12* for more details.

Level 1 implements a definite-time characteristic using a conditional timer. This level may be applied to provide an alarm prior to tripping (via Level 2). The element picks up when the operating signal exceeds the pickup setting and the torque-control input is asserted. The timer resets instantaneously. Once picked up, the element operates after the timer expires.

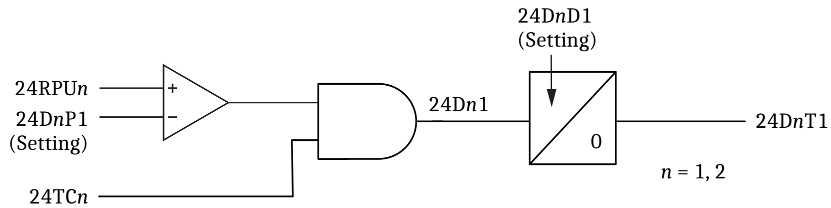


Figure 5.108 Volts per Hertz Element n, Level 1 Logic

Level 2 can be configured either with a definite-time characteristic or a user-defined curve characteristic using the 24CCS*n* setting. This level is disabled if 24CCS*n* is set to OFF. The Level 2 definite-time logic is enabled by setting 24CSS*n* = DD. Two pickup thresholds and two delays are implemented as illustrated in *Figure 5.109*. If 24CSS*n* = U1 or U2, then Level 2 uses the corresponding user curve. *Figure 5.109* shows the Level 2 characteristic.

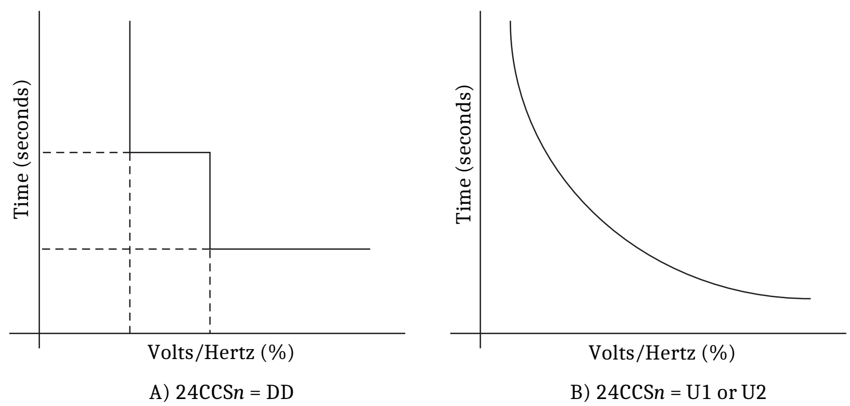


Figure 5.109 Volts per Hertz Element n, Level 2 Characteristic

The Level 2 definite-time logic is implemented using a stair counter that provides a memory of previous pickup events. The counter starts to increment once the operating signal exceeds the pickup setting and the torque-control input is asserted. Although the counter increments in discrete steps, it is calibrated to reach its operating limit at the same time as would the Level 1 conditional timer with the same setting. *Figure 5.110* shows the logic.

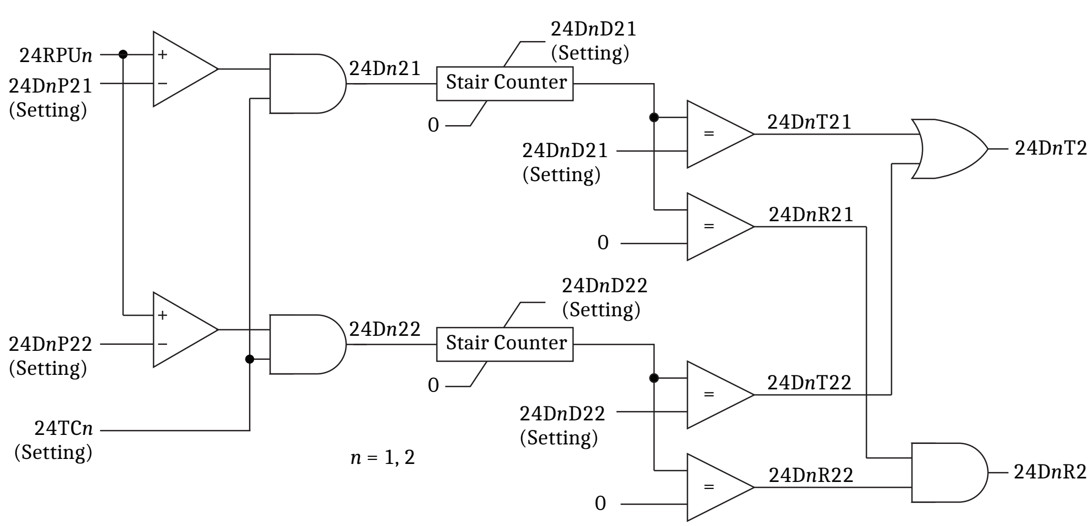


Figure 5.110 Volts per Hertz Element n, Level 2 Definite-Time Logic

The Level 2 user-defined curve logic is enabled by setting 24CSS*n* = U1 or U2. Each user-defined curve consists of as many as 20 points to form the characteristics suitable for most applications. Each element has two output Relay Word bits. When the element times out, Relay Word bits 24U1T (Element 1) and 24U2T (Element 2) assert. When the elements reset, Relay Word bits 24U1R (Element 1) and 24U2R (Element 2) assert. *Figure 5.111* shows the logic.

The element begins timing when the operating signal, 24RPU*n*, is greater than the first point on the user curve (24U*n*1011 for Curve 1 and 24U*n*2011 for Curve 2). Note that when using the serial terminal, curve points are entered (**SET**) and displayed (**SHO**) as a pair of settings separated by a comma. In this case, 24U*n*1011 is the first entry of the setting 24U*n*101.

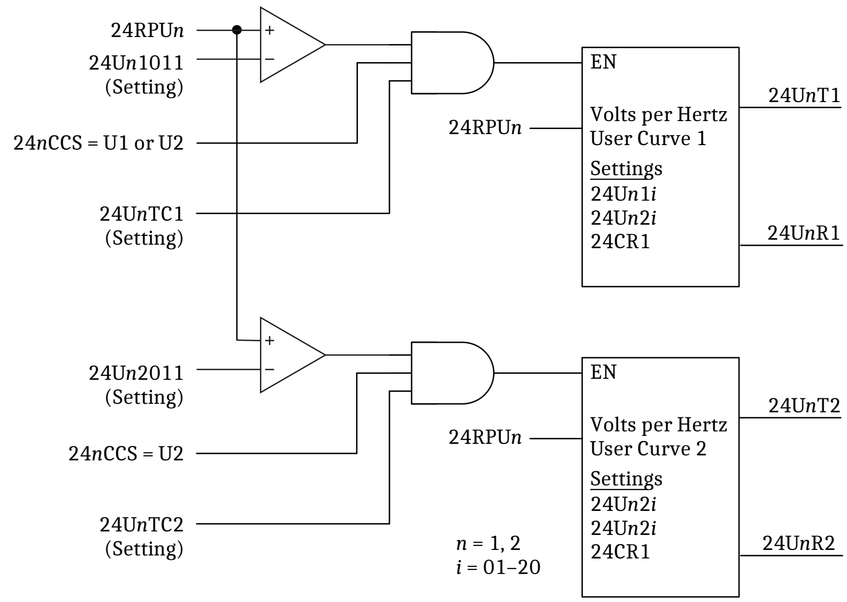


Figure 5.111 Volts per Hz, Element n Level 2, User-Defined Curve Logic

Setting Guidelines

24On (Operating Quantity)

Table 5.39 24On Setting

Setting	Prompt	Range	Default	Category
24O*n*[a]	24 Element *n* Operating Quantity	VPMAXZF, VPMAXVF[b], VV1FM[c], VV2FM[d], VV3FM[c]	VPMAXZF	Group

[a] n = 1, 2.
[b] Available when PTCONV = Y, D, or D1.
[c] Available when PTCONV = 1PH.
[d] Available when PTCONV = 1PH or D.

Select the operating signal corresponding to the voltage input at the location of the protected equipment. VPMAXZF and VPMAXVF are the maximums of the AB, BC, and CA voltages for the respective Z and V inputs.

24TCn (Torque Control)

Table 5.40 24TCn Setting

Setting	Prompt	Range	Default	Category
24TC*n*[a]	24 Element *n* Torque Control	SELOGIC	1	Group

[a] n = 1, 2.

Use the torque-control setting to specify the conditions for which the definite-time V/Hz element. must be active. This setting is used both the Level 1 logic and the Level 2 Definite-Time logic. The default setting is 1.

Composite Curve, (24CCSn)

Table 5.41 24CCSn Setting

Setting	Prompt	Range	Default	Category
24CCS*n*[a]	24 Element *n* Level 2 Comp. Curve	OFF, DD, U1, U2	OFF	Group

[a] n = 1, 2.

Use this setting to select either the definite-time characteristic, user-defined Curve 1 (24CCS*n* = U1) or both user-defined Curves 1 and 2 (24CCS*n* = U2).

Level 1

Table 5.42 Level 1 Settings

Setting	Prompt	Range	Default	Category
24D*n*P1[a]	24 Element *n* Level 1 Pickup	100% to 200%	110	Group
24D*n*D1[a]	24 Element *n* Level 1 Time Delay	0.04 to 6000 s	10	Group

[a] n = 1, 2.

Level 1 Pickup (24DnP1)

Set the Level 1 pickup using the 24D1P1 setting. If the nominal voltage setting of the operating signal is set equal to the rated voltage of the equipment, then the pickup setting is equivalent to the rated equipment capability (expressed as a percentage).

Level 1 Time Delay (24DnD1)

Set the delay (in seconds) for which the timer must run before the 24D1D1 setting asserts the output.

Level 2, Definite Time

Table 5.43 Level 2 Settings (Sheet 1 of 2)

Setting	Prompt	Range	Default	Category
24D*n*P21[a]	24 Element *n* Level 2 Pickup 1	100% to 200%	105	Group
24D*n*D21[a]	24 Element *n* Level 2 Time Delay 1	0.04 to 6000 s	10	Group
24D*n*P22[a]	24 Element *n* Level 2 Pickup 2	101% to 200%	110	Group

Table 5.43 Level 2 Settings (Sheet 2 of 2)

Setting	Prompt	Range	Default	Category
24D*n*D22[a]	24 Element *n* Level 2 Time Delay 2	0.04 to 6000 s	5	Group
24CCS*n*[a]	24 Element *n* Level 2 Comp. Curve	OFF, DD, U1, U2	OFF	Group

[a] n = 1, 2.

Level 2 Pickup 1 and Pickup 2 (24DnP21 and 24DnP22)

These settings are available when Level 2 is configured as a definite-time element 24CCS*n* = DD. You can use the pickup settings to implement a two-step characteristic, as shown in *Figure 5.112*.

Level 2 Time Delay 1 and Time Delay 2 (24DnD21 and 24DnD22)

These settings are available when Level 2 is configured as a definite-time element 24CCS*n* = DD. You can use the delay settings to implement a two-step characteristic, as shown in *Figure 5.112*.

NOTE: The 24DnD22 timer setting must be less than the 24DnD21 timer setting.

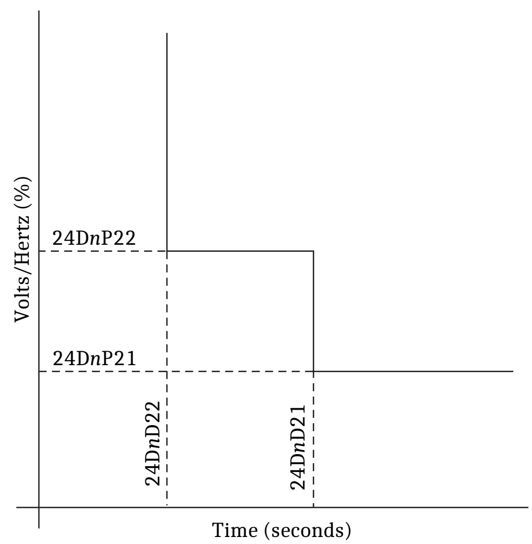


Figure 5.112 Two-Step Characteristic

Level 2, User-Defined Curve

Table 5.44 Level 2 User-Defined Curve Settings

Setting	Prompt	Range	Default	Category
24U*n*NP1[a]	24 Element *n* No. of Point on User 1 Curve (3–20)	3 to 20	10	Group
24U*n*1*i*[a, b]	24 Ele. *n* Cur. 1, Pnt. *i* (100-200%, 0.040–6000 s)	100% to 200%, 0.04 to 6000 s	112, 6000	Group
24U*n*CR1[a]	24 Element *n* Curve 1 Reset Time (0.010–400 s)	0.01 to 400 s	0.01	Group
24U*n*TC1[a]	24 Element *n* Curve 1 Torque Control (SELOGIC Eqn)	SELOGIC control equation	1	Group
24*n*UNP2[a]	24 Element *n* No. of Point on User 2 Curve (3–20)	3 to 20	10	Group
24U*n*2*i*2[a, b]	24 Ele. *n* Cur. 2, Pnt. (100–200%, 0.040–6000 s)	100% to 200%, 0.04 to 6000 s	112, 6000	Group
24U*n*CR2[a]	24 Element *n* Curve 2 Reset Time (0.010–400 s)	0.01 to 400 s	0.01	Group
24U*n*TC2[a]	24 Element *n* Curve 2 Torque Control (SELOGIC Eqn)	SELOGIC control equation	1	Group

[a] n = 1, 2.
[b] i = 01–20.

Number of Data Points on User-Defined Curves 1 and 2 (24UnNP1 and 24UnNP2)

NOTE: Manufacturers data are often provided on a semi-log plot to show time over a wide range. The relay uses linear interpolation to calculate values between datapoints. Check coordination between the V/Hz element and the manufacturers curve, using both a linear and a semi-log plot to confirm adequate margin.

Enter the number of points for the curve. Because the relay calculates the time after linear interpolation of the V/Hz values, enter as many points as possible for accurate element operate time.

Data Points for User Curves 1 and 2 (24Un1i and 24Un2i)

Enter the data point here to form the user-defined curve. Data points are entered in order of increasing V/Hz value. When entering the curve settings using the terminal interface, the data point format is <volts per hertz>(comma)<time> (e.g., 115,30). The units are volts per hertz in percent and time in seconds.

NOTE: User-defined curve data points must be entered in order of increasing V/Hz values.

The V/Hz value of the first entry defines the minimum pickup of the element. The time value of the last entry defines the minimum operating time of the element.

For example, assume that you obtain the V/Hz characteristic in *Figure 5.113* from a transformer manufacturer and pick three points from the curve.

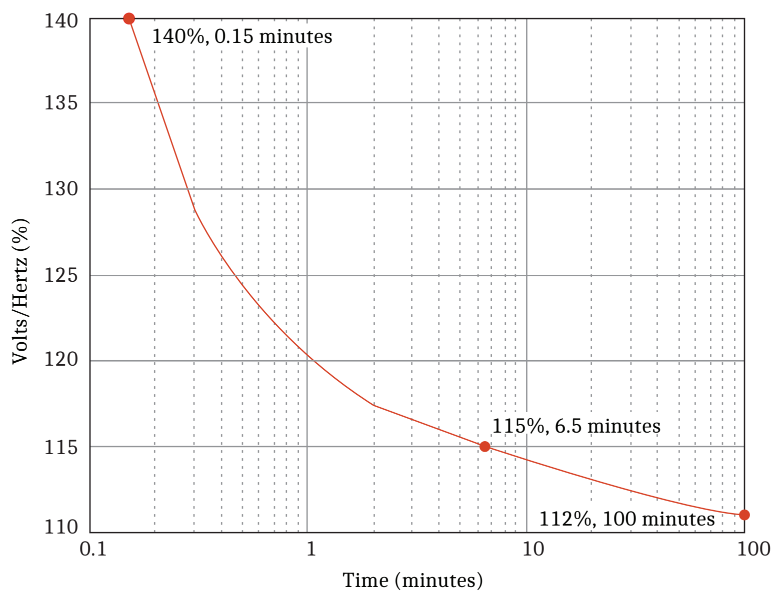


Figure 5.113 Manufacturer V/Hz Curve

Figure 5.114 shows an example of a programmed curve from entry of only the three points shown in the previous figure. Clearly, this programmed curve is much different from the original curve, and the transformer is under-protected.

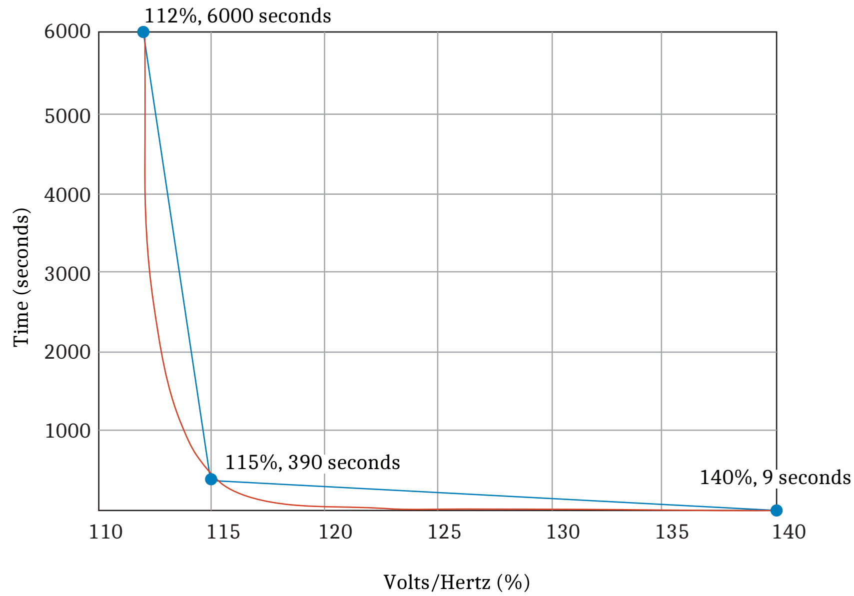


Figure 5.114 Three-Point Curve

Figure 5.115 shows a programmed curve, obtained after entry of 10 points, superimposed onto the manufacturer's curve. With more points, the programmed curve more closely follows the manufacturer's curve.

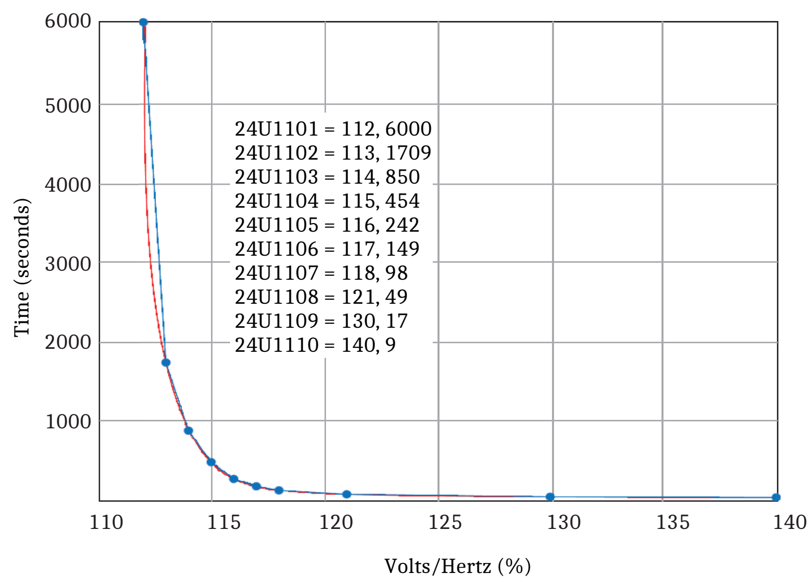


Figure 5.115 Ten-Point Curve

User-Defined Curves 1 and 2 Reset Time (24UnCR1 and 24UnCR2)

Specify the curve reset time with this setting. This setting is only an absolute value if the element has timed out. If there is interruption of the curve timing, then the reset time is proportional to the elapsed time. For example, assume Curve 1 is used and an overexcitation condition occurs on the system and the Curve 1 starts timing. At the 60 percent mark, the system overexcitation condition disappears and Curve 1 stops timing. Because the timing interruption was at the 60 percent mark, the reset time is also 60 percent of the 24U*n*CR1 setting.

User-Defined Curves 1 and 2 Torque Control (24UnTC1 and 24UnTC2)

Use the torque-control setting to specify conditions under which the user-defined curve must be active. The default setting is 1. Note that each curve has a dedicated torque-control equation, as shown in *Table 5.47*.

Split-Phase Protection

Although split-phase protection can detect many types of stator faults, it is typically applied for detection of turn-to-turn faults. The current flowing in a shorted-turn can be significant usually six to eight times of rated current and damage can occur quickly.

The stator windings of large synchronous generators are generally constructed either from multi-turn coils or Roebel bars (single-turn coils). The latter method is more common for generators larger than 50 MVA.

The stator is often constructed from multiple parallel branches per phase. This allows the winding to accommodate the rated current without the need for large stator slots. Hydro generators, because of their lower speed of rotation, often have many parallel branches.

If the turn voltage is relatively large and the number of parallel branches is relatively low, as in the case for a large turbo generator, voltage-based protection may detect a single shorted turn. These functions include the fundamental neutral overvoltage element (64G1) and the negative-sequence directional element (32Q). Turbo generators usually are not equipped with split-phase CTs.

Consider the example in *Figure 5.116*. The winding has four parallel branches and is constructed from multi-turn coils. Assume that a single turn is shorted, as shown in *Figure 5.116*.

Nominal power:	65 MVA
Nominal voltage:	13.8 kV
Nominal current:	2719 A
Base Impedance:	2.93 Ω
Leakage reactance:	0.15 pu
Number of parallel branches:	4
Number of coils:	33
Turns per coil:	4

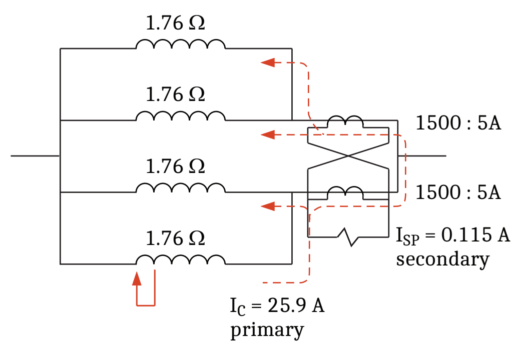


Figure 5.116 Equivalent Circuit for a Single-Turn Fault in a Machine

The voltage across a single turn is:

$$V_{TURN} = \frac{13800}{\sqrt{3} \bullet 4 \bullet 33} = 60.4\ V$$

Equation 5.55

Because there are four parallel branches, the branch impedance is approximated four times the leakage reactance:

$$Z_B = 4 \bullet 2.93\ \Omega \bullet 0.15 = 1.76\ \Omega$$

Equation 5.56

The circulating current is:

$$I_C = \frac{60.4}{(1.76 - 0.013) + \frac{1.76}{3}} = 25.8\ A$$

Equation 5.57

The split-phase current is:

$$I_{SP} = 2 \bullet \frac{5}{1500} \bullet \frac{25.8 \bullet 1.76}{1.76 + \frac{1.76}{2}} = 0.115\ A$$

Equation 5.58

Note that the split-phase current can be quite low.

The pickup setting of the split-phase protection must be set greater than the steady-state value. In the past, a margin of 150 percent has been applied. The existence of circulating currents in the winding makes it more difficult to determine optimal settings. To address this issue, conduct periodic field measurements of the currents and compare with those of the existing split-phase settings. If the magnitude of the circulating currents found from the measurements has increased significantly over time, revise the relay settings accordingly. Measurement of the highest split-phase current is usually found at the maximum operating voltage and current but can also occur for an unloaded machine under high voltage.

The split-phase current should be recorded over a reasonably long period, such as 18 months, followed by spot checks taken approximately every 6 months in the succeeding years. SEL recommends placing the 6-month checks at the points when the established split-phase current reaches its minimum and maximum over its repetitive cycle.

Figure 5.117 shows an example of the variation in split-phase current for a generator over an 18 month period.

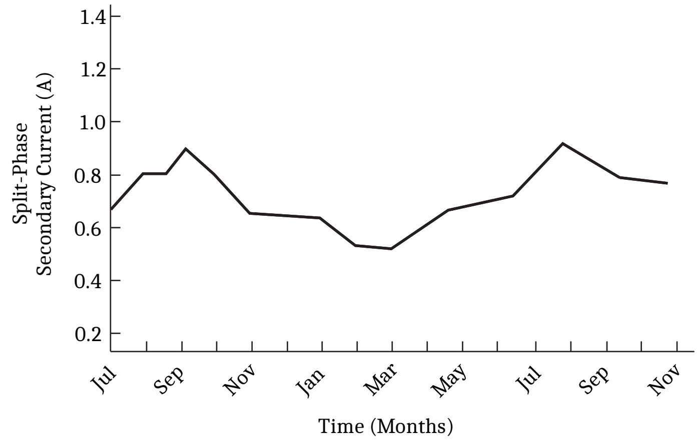


Figure 5.117 Split-Phase Current Variation Over Time

In some generators, the split-phase current may exhibit a significant transient response during an external fault. Time coordination may be necessary in such cases to avoid a misoperation.

The SEL-400G provides two split-phase functions. The 60P function can be applied to a three-phase split-phase CT, and the 60N function can be applied to an inter-neutral CT, as shown in *Figure 5.118*. Because the inter-neutral CT does not respond to load, it can have a much lower ratio and provide greater sensitivity. On the other hand, the 60P function provides an indication of the faulted phase. The 60P function provides a unique pickup setting for each phase.

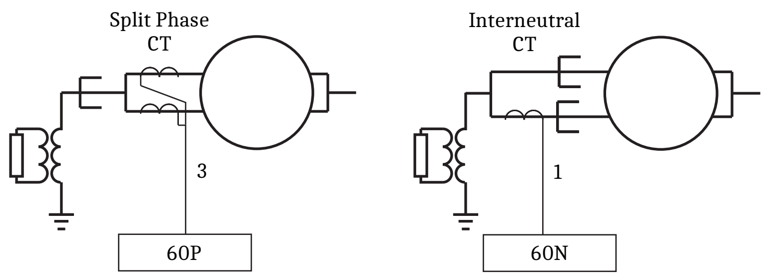


Figure 5.118 Split-Phase Protection Functions

Each function is enabled by selecting an operating signal through use of the E60P and E60N settings, as shown in *Figure 5.119*. Select **N** to disable the function.

NOTE: The EADVS setting must be set to Y before the split-phase E60P and/or E60N can be enabled.

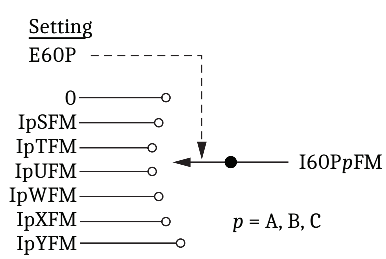


Figure 5.119 60P and 60N Operating Signal Selection

Each function consists of two levels: a high-set level and an adaptive low-set level.

The 60P and 60N high-set levels are shown in *Figure 5.120*. If the split-phase current is greater than the pickup setting and the torque control is asserted, the level will trip after Timer t1 expires. Both levels include a secure tripping path that introduces an additional Timer t2. This timer is factory-set at 0.5 seconds.

Transition to the secure tripping path is controlled by the 60P*p*HSS and 60NHSS SELOGIC variables. The default setting for the 60P*p*HSS setting is CON*p*1. The default setting for the 60NHSS setting is CON1. These bits will assert during external faults.

NOTE: It is possible that a severe event, such as the short of a significant portion of a branch, will also assert the CON1 Relay Word bits. For this reason, SEL recommends that the split-phase functions be applied in conjunction with the 64G1 and 67Q functions.

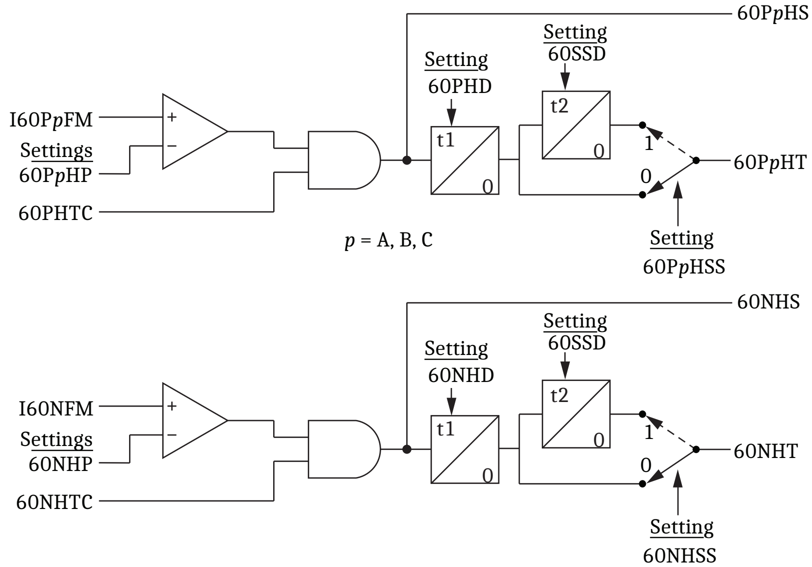


Figure 5.120 60P and 60N High Set Levels

The adaptive low-set levels are intended for use when there is a split-phase current under normal operation that compromises the effectiveness of the high-set function. This can occur in machines that produce a low split-phase current for a single-turn fault. Consider using the adaptive low-set levels when the normal variation in the split-phase current is significant and the expected current for a shorted turn is low. The adaptive low-set level should be used in conjunction with the high-set level.

NOTE: SEL recommends the use of the low-set function initially in a monitoring mode (not tripping). The output of the low-pass filter should be monitored to confirm that it is closely tracking the split-phase current and that there are no spurious assertions of the function.

The adaptive offset logic provides better sensitivity by tracking the value of the offset and subtracting this value from the operating signal. A low-pass filter is used to track the offset.

If a level is picked up, the output of its filter is frozen to prevent the level from adapting to the fault.

The logic also incorporates reset inputs, 60PLR and 60NLR, to force the output of a filter equal to the input. This may be required to account for a fast change in the split-phase current that could occur, for instance, when the machine is connected or disconnected from the power system. Assertion of the reset input takes precedence over the freeze input.

The logic is shown in *Figure 5.121*. Operation is the same as that of the high-set levels except for the addition of the low-pass filter logic.

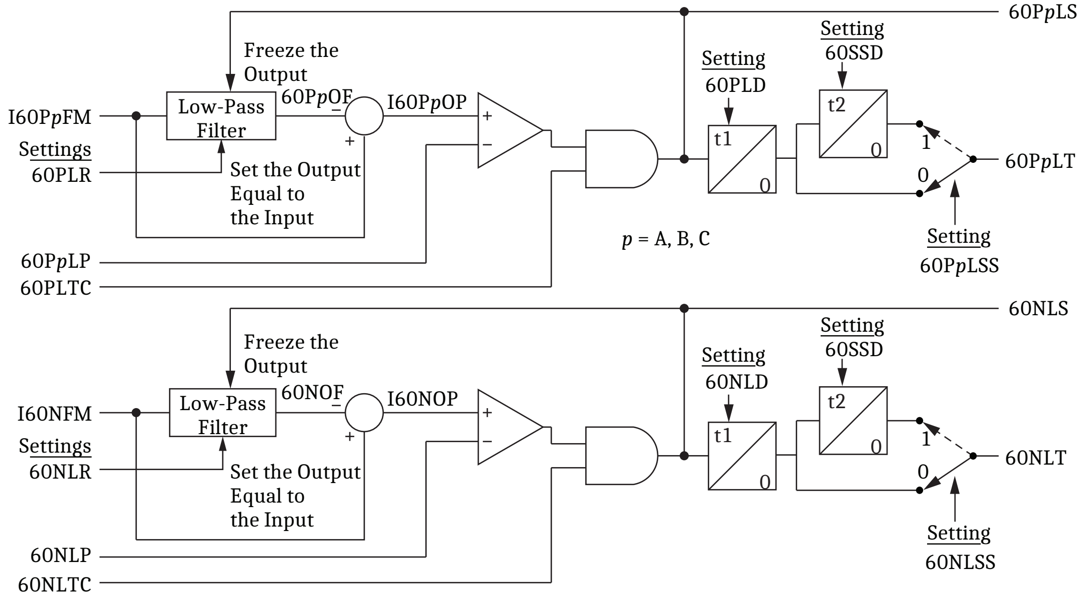


Figure 5.121 60P and 60N Low Set Levels

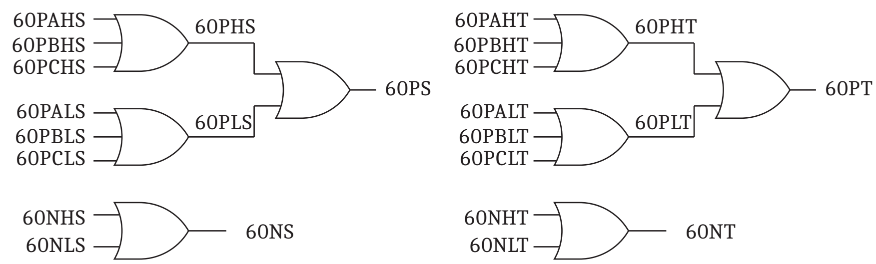


Figure 5.122 Output Logic

Setting Guidelines

Table 5.45 Split-Phase Settings (Sheet 1 of 2)

Setting	Prompt	Range	Default	Category
E60P	Enable 60P Split-Phase Element	N, S, T, U, W, X, Y[a, b]	N	Group
60P*p*HP	60P High Set Lvl Ph [p] Pickup (A,sec)	OFF, 0.10–100	OFF	Group
60PHD	60P High Set Lvl Delay (s)	0.000–400	0.005	Group
60P*p*HSS	60P High Set Lvl Ph [p] Switch to Sec	SV	CON*p*1	Group
60PHTC	60P High Set Lvl Torque Control	SV	1	Group
60P*p*LP	60P Low Set Lvl Ph [p] Pickup (A,sec)	OFF, 0.10–100	OFF	Group
60PLD	60P Low Set Lvl Delay (s)	0.000–400	0.005	Group
60PLR	60P Low Set Lvl Reset (SELOGIC Eqn)	SV	NA	Group
60PLT	60P Low Set Lvl Time Constant (s)	1–2400	100	Group
60P*p*LSS	60P Low Set Lvl Ph [p] Switch to Sec	SV	CON*p*1	Group
60PLTC	60P Low Set Lvl Torque Control	SV	1	Group
E60N	Enable 60N Split-Phase Element	N, Y1, Y2, Y3	N	Group
60NHP	60N High Set Lvl Pickup (A,sec)	OFF, 0.10–100	OFF	Group
60NHD	60N High Set Lvl Delay (s)	0.000–400	0.005	Group

Table 5.45 Split-Phase Settings (Sheet 2 of 2)

Setting	Prompt	Range	Default	Category
60NHSS	60N High Set Lvl Switch to Secure	SV	CON1	Group
60NHTC	60N High Set Lvl Torque Control	SV	1	Group
60NLP	60N Low Set Lvl Pickup (A,sec)	OFF, 0.10–100	OFF	Group
60NLD	60N Low Set Lvl Delay (s)	0.000–400	0.005	Group
60NLR	60N Low Set Lvl Reset	SV	NA	Group
60NLT	60N Low Set Lvl Time Constant (s)	1–2400	100	Group
60NLSS	60N Low Set Lvl Switch to Secure	SV	CON1	Group
60NLTC	60N Low Set Lvl Torque Control	SV	1	Group

[a] W is unavailable if EGNCT contains W.
X is unavailable if EGNCT contains X.

[b] m is unavailable if ESYSCT contains m, where m = S, T, U, or Y.

E60P, E60N (Enable Split-Phase Element)

This setting enables the function and specifies the current terminal connected to the split-phase or inter-neutral CT.

60PpHP, 60NHP (High-Set Level Pickup)

The pickup setting should be lower than the current expected for a single shorted turn and higher than the maximum current during normal operation. If both criteria cannot be met, consider enabling the adaptive low-set level as well. In this case, the high-set level acts as a backup to the low-set level.

Generators that have undergone temporary repairs can have normal split-phase currents that differ significantly among the three phases. For this reason, a pickup setting is provided for each phase.

60PHD, 60NHD, 60PLD, 60NLD (Delay)

The delay setting should be set long enough to last through transient variations in split-phase current. The duration of a transient may be significant depending on the generator. Consider a delay in the range of 100 ms. Note that the level includes a secure path, which adds an additional tripping delay. This value is factory-set at 500 ms.

60PpHSS, 60NHSS, 60PpLSS, 60NLSS (Switch to Secure Trip Path)

These settings control switching to the secure tripping path. The 60P level has a default values of CON*p*1 and the 60N has a default of CON1. These Relay Word bits are associated with the Zone 1 differential element. This element must be enabled for these Relay Word bits to be active. The CON*p*1 bits will assert when an external fault associated with Phase *p* is detected. The CON1 Relay Word bit will assert if an external fault is detected for any of the three phases.

60PHTC, 60NHTC, 60PLTC, 60NLTC (Torque Control)

The torque-control setting can be typically left at the default setting of 1. Some generators may experience an increase in split-phase current when the generator terminal voltage is high. The torque-control setting can be used to inhibit operation in such circumstances.

60PpLP, 60NLP (Low Set Pickup)

Use this setting to enable the low set element when the normal variation in the split-phase current exceeds the current expected for a single shorted turn. The low set element should be used in conjunction with the high set element.

Generators that have undergone temporary repairs can have normal split-phase currents that differ significantly among the three phases. For this reason, a pickup setting is provided for each phase.

60PLR, 60NLR (Low Set Level Reset)

Use this setting to force the output of the low-pass filter to equal the input. This may be required to account for a fast change in the split-phase current that could occur, for instance, when the machine is connected or disconnected from the power system. It may be necessary to extend the reset signal by using a dropout timer in SELOGIC.

60PLT, 60NLT (Low Set Level Time Constant)

This setting determines how quickly the low-pass filter follows the variation in split-phase current. This setting may be tuned during the initial monitoring period. For example, spurious pickups may require a shorter setting. If a turn fault occurs, the current is expected to change quickly. Once picked up, the output of the filter is frozen. Therefore, there is no significant risk associated with a short time constant.

System Backup Protection

The SEL-400G provides three functions for system backup protection: a phase distance element, a voltage-restrained, time-overcurrent element, and a voltage-controlled, time-overcurrent element. One of these elements is typically selected for backup protection in the event of an uncleared fault on the system side of the step-up transformer. The EBUP setting controls which of these elements is enabled. Multiple elements may be selected.

Table 5.46 System Backup GSU Compensation Angle Settings

Setting	Prompt	Range	Default	Category
EBUP	Enable System Backup Protection	OFF or combo of 51C, 51V, 21P	21P	Group
GSUCA	GSU Compensation Angle	0, –30, 30	30	Group

The relay applies the following compensation to the voltages and currents to maintain the correct reach through the GSU. The compensated voltages and currents are used by the 21P and 51V functions.

$$\begin{bmatrix} \text{VABZFC} \\ \text{VBCZFC} \\ \text{VCAZFC} \end{bmatrix} = [\text{tv}] \bullet \begin{bmatrix} \text{VABZF} \\ \text{VBCZF} \\ \text{VCAZF} \end{bmatrix}$$

Equation 5.59

$$\begin{bmatrix} IABGFC \\ IBCGFC \\ ICAGFC \end{bmatrix} = [tc] \bullet \begin{bmatrix} IAGF \\ IBGF \\ ICGF \end{bmatrix}$$

Equation 5.60

Where V*pp*ZFC is the voltage at the generator terminals, I*p*GF is the current at the generator neutral, and tv and tc are defined in *Table 5.47*.

NOTE: Backup protection for faults on the low-voltage side of the GSU is not effective for GSU settings values of +30 or −30. Set GSUCA to **0** if backup protection for faults on the low-voltage side of the GSU is required.

Table 5.47 System Backup Compensation Matrices

GSUCA	tv	tc
0	$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$\begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix}$
+30	$\frac{1}{\sqrt{3}} \bullet \begin{bmatrix} 1 & 0 & -1 \\ -1 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix}$	$\sqrt{3} \bullet \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$
–30	$\frac{1}{\sqrt{3}} \bullet \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix}$	$\sqrt{3} \bullet \begin{bmatrix} 0 & -1 & 0 \\ 0 & 0 & -1 \\ -1 & 0 & 0 \end{bmatrix}$

When the backup element is set to respond to phase faults on the high side of a delta-wye transformer and the system phase-to-neutral voltage phase angle leads the generator phase-to-neutral voltage phase angle by 30 degrees, set GSUCA = –30°. When the system phase-to-neutral voltage phase angle lags the generator phase-to-neutral voltage phase angle by 30 degrees, set GSUCA = +30°.

Phase Distance Element

The SEL-400G provides a two-zone distance element designed for backup distance protection for system phase-to-phase and three-phase faults. Each zone is equipped with independently settable forward reach, resistive blinder reach, and definite-time delay settings. This element is enabled when EBUP includes 21P.

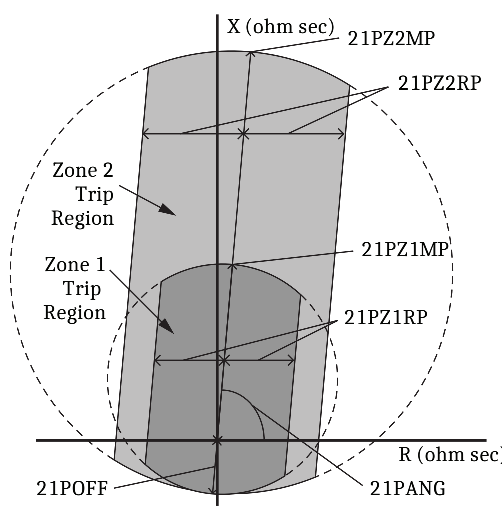


Figure 5.123 Backup Distance Element

The reach in the forward direction along the angle 21PANG is calculated as:

$$\text{MppF} = \frac{\text{VppZFCM}^2 + \text{21POFF} \bullet \text{Re}(\text{VppZFC*} \bullet \text{IppGFC} \bullet e^{\text{j21PANG}})}{\text{MppDF}}$$

Equation 5.61

The reach in the direction of the resistive axis is calculated as:

$$\text{RppF} = \frac{\text{Im}(\text{VppZFC} \bullet (\text{IppGFC} \bullet e^{\text{j21PANG}})^*)}{\text{Im}(\text{IppGFC} \bullet (\text{IppGFC} \bullet e^{\text{j21PANG}})^*)}$$

Equation 5.62

$$\text{MppDF} = \text{Re}(e^{\text{j21ANG}} \bullet \text{IppGFC} \bullet \text{VppZFC*}) + \text{21POFF} \bullet \text{IppGFCM}^2$$

Equation 5.63

where:

V*pp*ZFC = the compensated voltages. See *Equation 5.59*.

I*pp*GFC = the compensated currents. See *Equation 5.60*.

pp = AB, BC, and CA

Figure 5.124 uses the reach calculations. The logic for the AB loop is shown. The other two loops are similar.

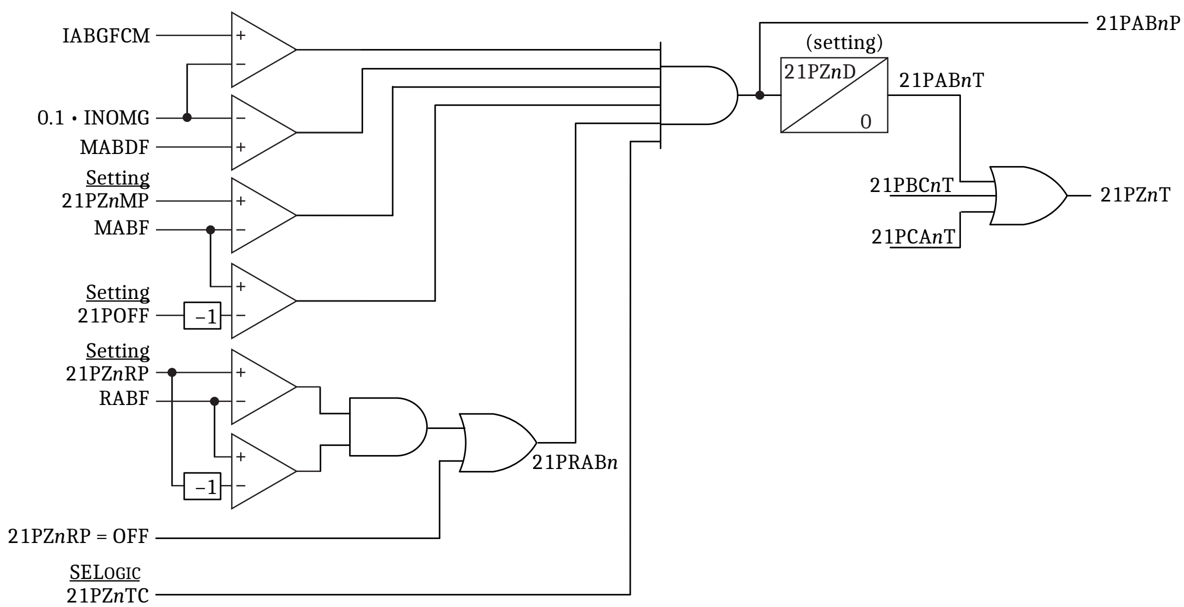


Figure 5.124 Backup Distance, Zone n Logic (AB Loop Shown)

Table 5.48 Backup Distance Settings (Sheet 1 of 2)

Setting	Prompt	Range	Default	Category
21PZ*n*MP	21P Zone *n* Reactive Reach	OFF, 0.1–100 Ω secondary[a]	8	Group
21PZ*n*RP	21P Zone *n* Resistive Reach	OFF, 0.1–100 Ω secondary[a]	8	Group
21PZ*n*D	21P Zone *n* Delay	0.00–400 seconds	10	Group
21PZ*n*TC	21P Zone *n* Torque Control	SELOGIC	NOT LOPZ AND NOT ZLOAD	Group

Table 5.48 Backup Distance Settings (Sheet 2 of 2)

Setting	Prompt	Range	Default	Category
21PANG	21P Zone Characteristic Angle	45–90 degrees	88	Group
21POFF	21P Zone Offset Impedance	0.0–10 Ω secondary[a]	0	Group

[a] The ranges shown are for a 5 A CT. Multiply by 5 for 1 A rated CTs.

The characteristic angle setting, 21PANG, is common to both zones and should be set according to the angle of the transformer and the angle of the power system covered by the longest reaching zone.

The 21POFF setting is common to both zones and corresponds to the element reach in the reverse direction.

NOTE: Select an offset impedance, 21POFF, equal to 10 percent of the shortest reach setting to ensure for dependable operation for zero-ohm faults at the isolated phase bus.

Reach settings are in secondary ohms and delay settings are in seconds. In a typical application, you might set the Zone 1 pickup, 21PZ1MP, to reach into the GSU transformer and, with shorter time delay for 21PZ1D, protect the phase-to-phase and three-phase faults external to the generator differential zone to as far as the transformer delta winding. You can then set the Zone 2 element pickup, 21PZ2MP, to reach through the step-up transformer into the system and use a longer time delay for 2P1Z2D.

NOTE: This element is not intended to be used for applications that require instantaneous operation and control of transient overreach. When applied with no time delay, allow for a transient overreach of as much as 30 percent.

Alternatively, you can set the Zone 1 element to provide backup protection for faults on the high-side bus with a coordinating time delay and set the Zone 2 element with a long reach and a long time delay for breaker failure backup protection.

Each zone includes the torque-control equation 21PZ*n*TC. This equation should include NOT LOPZ to disable the distance elements for a loss of potential. In addition, you can supervise the zone from the load-encroachment function to provide three-phase element security under maximum generator loading conditions by including NOT LOPZ AND NOT ZLOAD in the torque-control equation (see *Load-Encroachment Logic on page 5.127*).

Voltage-Controlled, Inverse Time-Overcurrent Element

The voltage-controlled, inverse time-overcurrent element, 51C, can be configured to use voltage to account for the decrement of the generator fault current that occurs as the generator impedance transitions from the sub-transient, to the transient and finally to the synchronous value. At its final value, the generator fault current may be less than the generator rated current. The 51C will not operate until there is an undervoltage at the terminals of the generator. This condition enables an inverse time-overcurrent element, which can have a low pickup setting. This element is enabled when EBUP includes 51C.

The 51C overcurrent element includes a settable pickup, curve shape, and time-dial. Ten curve shapes are available. Curves U1–U5 emulate the popular North American induction disk relays. Curves C1–C5 emulate popular European analog time-overcurrent relays. Operating characteristics of the available curves are shown in *Figure 5.213–Figure 5.215*.

When you set 51CRS = Y to enable electromechanical reset emulation, the relay provides a slow reset that is dependent on the amount of current measured, similar to an induction disk relay reset. When you select N, the relay fully resets the time-overcurrent element one cycle after current drops below the pickup setting, similar to analog and many microprocessor-based time-overcurrent relays. Select Y or N to match the operating characteristic of other time-overcurrent protection protecting the system near this generator.

The element is also equipped with a torque-control setting. When the equation result is logical 1, the element can operate. When the result is logical 0, the element cannot operate. Use other protection elements, logic conditions, or control inputs to supervise these elements if necessary.

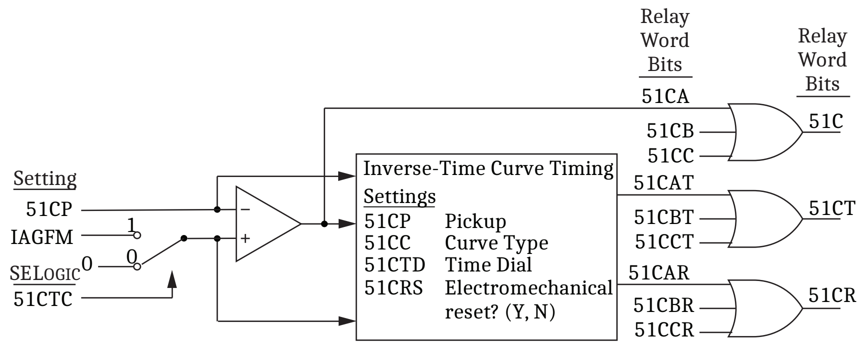


Figure 5.125 51C Controlled, Overcurrent Element (A Loop Shown)

Table 5.49 Voltage-Controlled Time-Overcurrent Settings

Setting	Prompt	Range	Default	Category
51CP	51C Inv. Time O/C Pickup	OFF, 0.25–16 A	2[a]	Group
51CC	51C Inv. Time O/C Curve	U1–U5, C1–C5	U1	Group
51CTD	51C Inv. Time O/C Time Dial	0.50–15[b]	0.5	Group
51CRS	51C Inv. Time O/C E/M Reset	Y, N	N	Group
51CTC	51C Inv. Time O/C Torque Control	SELOGIC	NOT LOPZ	Group

[a] Ranges and default settings shown are for 5 A CT. Divide by 5 for 1 A rated CTs.
[b] Setting range shown is for U.S. curves. Range is 0.05–1.00 for the IEC curves.

Undervoltage Supervision

Use an undervoltage element to achieve voltage-controlled tripping. In this example, we configure the 27P1 element to respond to the Z terminal, minimum phase-to-phase voltage. Choose the 27P1 operating signal as:

27O1 = VPMIN*k*F

The undervoltage element is generally set to 80 percent of the nominal voltage for single-machine buses and 87 percent for multi-machine buses.

$$27P1P1 = 0.8 \bullet \text{VGEN V sec}$$

where VGEN is the rated generator voltage in secondary volts.

Use the pickup Relay Word bit to torque-control the 51C. In this case, the curve setting 27P1C1 and the delay setting 27P1D1 are not important and can be left at their default values.

To prevent misoperation if a potential transformer fuse blows, the element is torque-controlled by the NOT LOPZ Relay Word bit.

27TC = NOT LOPZ

Assign the undervoltage pickup to torque-control the 51C:

51CTC = 271P1

With the previous settings, the 51C element is enabled whenever the generator voltage is less than 80 percent of generator nominal voltage, as long as there is no simultaneous loss-of-potential condition. You can choose to use a different undervoltage element pickup setting.

Set the 51CP pickup setting less than the generator fault duty, IP, which you can calculate by using the generator steady-state reactance, X_d (you can use transient reactance X'_d if the generator excitation system supports higher fault voltage and current). This value may safely be below maximum load, because the element is only enabled during low-voltage fault conditions. Divide the generator fault duty by the phase current transformer ratio, CTRG, to find the element pickup current in secondary amperes.

$$51CP \leq \frac{IP}{CTRG}$$

where CTRG is the CT ratio of the input assigned to EGNCT (W or X).

Select a curve shape and time-dial that allow this element to coordinate with the system primary protection. For example:

51CC = U2

51CTD = 3.00

Operating characteristics of the available curves are shown in *Figure 5.213–Figure 5.215*.

Apply electromechanical reset emulation if the system phase overcurrent relays are induction disk relays; otherwise, electromechanical reset emulation is not necessary.

51CRS = N

Voltage-Restrained Phase Time-Overcurrent Element

The operation of the voltage-restrained phase time-overcurrent element, 51V, is different from 51C in that the element pickup setting is reduced automatically as the generator phase-to-phase voltage decreases during a fault. When the generator voltage is 100 percent of the VNOMZ setting, the 51V overcurrent element operates based on 100 percent of its pickup setting, 51VP. As the generator phase-to-phase voltage drops, the relay decreases the element pickup by a like amount, down to 12.5 percent of nominal phase-to-phase voltage. For voltages below 12.5 percent, the relay uses a pickup that is 12.5 percent of the 51VP setting. This element is enabled when EBUP includes 51V.

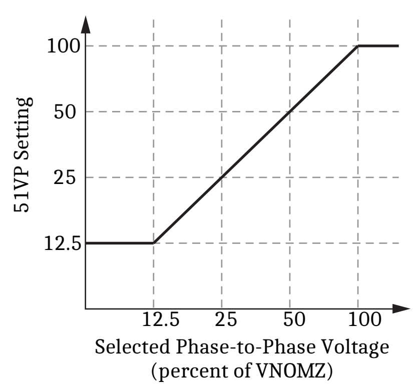
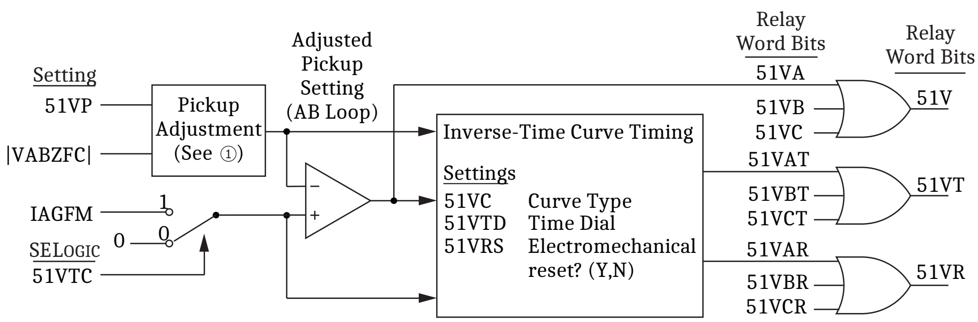


Figure 5.126 51VP Setting Reduction

The overcurrent elements include a settable pickup, curve shape, and time-dial. Ten curve shapes are available. Curves U1–U5 emulate the popular North American induction disk relays. Curves C1–C5 emulate popular European analog time-overcurrent relays. Operating characteristics of the available curves are shown in *Figure 5.213* through *Figure 5.215*.

When you set 51VRS := Y to enable electromechanical reset emulation, the relay provides a slow reset that is dependent on the amount of current measured, similar to an induction disk relay reset. When you select N, the relay fully resets the time-overcurrent element one cycle after current drops below the pickup setting, similar to analog and many microprocessor-based time-overcurrent relays. Select Y or N to match the operating characteristic of other time-overcurrent protection protecting the system near this generator.

Each of the elements is also equipped with a torque-control setting. When the equation result is logical 1, the element can operate. When the result is logical 0, the element cannot operate. Use other protection elements, logic conditions, or control inputs to supervise these elements if necessary.



① Figure 5.126.

Figure 5.127 Voltage-Restrained, Phase Overcurrent Element (AB Loop Shown)

Table 5.50 Voltage-Restrained Time-Overcurrent Settings

Setting	Prompt	Range	Default	Category
51VP	Voltage Restrained Overcurrent Pickup	2.00–16 A	2[a]	Group
51VC	Voltage Restrained Overcurrent Curve	U1–U5, C–C5	U1	Group
51VTD	Voltage Restrained Overcurrent Time Dial	0.50–15[b]	0.5	Group
51VRS	Voltage Restrained Overcurrent Reset	Y, N	N	Group
51VTC	Voltage Restrained Overcurrent Torque Control	SELOGIC	NOT LOPZ	Group

[a] Ranges and default settings shown are for 5 A CT. Divide by 5 for 1 A rated CTs.
[b] Setting Range shown is for U.S. curves. Range is 0.05–1.00 for the IEC curves.

Set the 51VP pickup setting greater than the maximum generator phase current expected at rated generator voltage. Divide this current by the phase current transformer ratio, CTRG, to find the element pickup current in secondary amperes.

$$51VP > \frac{\text{Max Load Current}}{\text{CTRG}}$$

where CTRG is the CT ratio of the input assigned to EGNCT (W or X).

Select a curve shape and time-dial that allow this element to coordinate with the system primary protection.

51VC = U2

51VTD = 3.00

Operating characteristics of the available curves are shown in *Figure 5.213* through *Figure 5.215*.

Apply electromechanical reset emulation if the system phase overcurrent relays are induction disk relays; otherwise, electromechanical reset emulation is not necessary.

51VRS = N

Because this element reduces its pickup setting automatically as generator voltage decreases, the element should not be permitted to operate if there is a blown potential transformer fuse condition. To prevent misoperation if a potential transformer fuse blows, the element is torque-controlled by the NOT LOPZ Relay Word bit.

51VTC = NOT LOPZ

With the previous settings, the 51V element is enabled as long as there is no loss-of-potential condition.

Load-Encroachment Logic

The load-encroachment function can be used to supervise the backup phase distance protection (21P) elements or the phase overcurrent (50P) elements. This allows the 21P and 50P to be set independent of the load. Two independent positive-sequence impedance characteristics monitor the positive-sequence load impedance (Z1GFM) for both export and import load. *Figure 5.128* illustrates the load-encroachment settings and corresponding characteristics in the positive-sequence impedance plane.

Relay Word bit ZLOUT indicates that load is flowing out with respect to the relay (an export or generating condition) and the apparent impedance lies within the shaded region.

Relay Word bit ZLIN indicates that load is flowing in with respect to the relay (an import or motoring condition) and the apparent impedance lies within the shaded region.

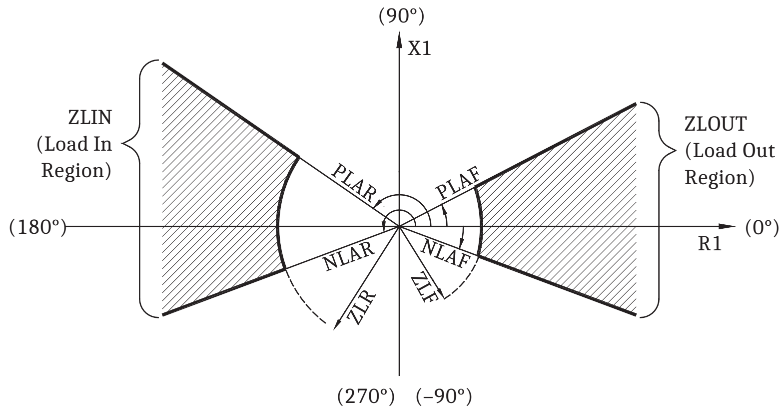


Figure 5.128 Load Encroachment Characteristics

Figure 5.129 illustrates the load-encroachment logic. The logic operates only if the positive-sequence generator current (I1GFM) is greater than the positive-sequence threshold (10 percent of the nominal relay current).

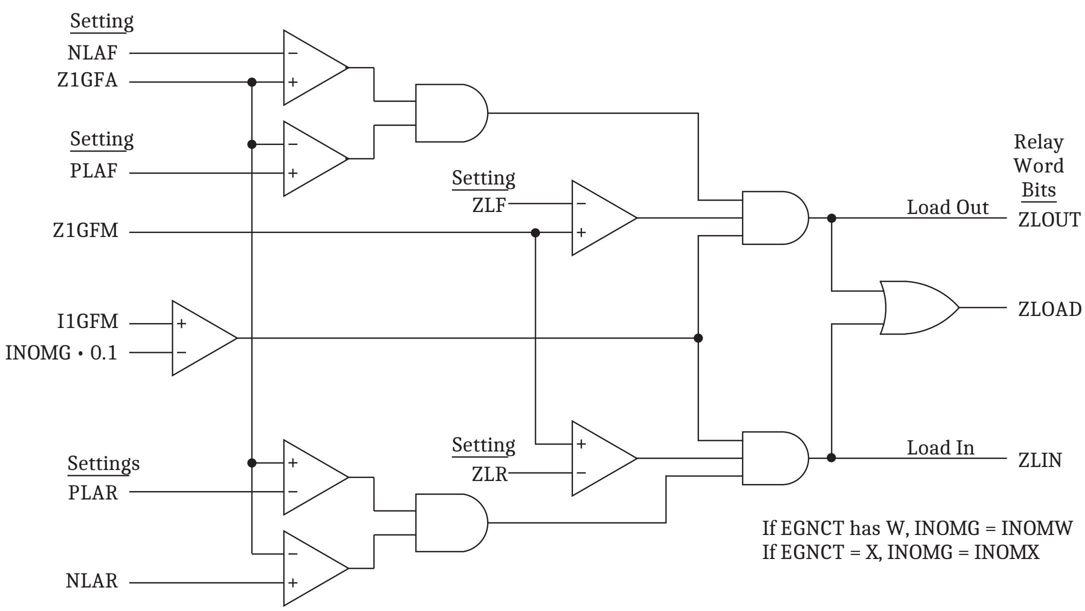


Figure 5.129 Load Encroachment Logic

Setting Guidelines

The load-in region of the load encroachment characteristic is not required for generators that are not operated as pump storage units, because no pump storage unit will import sufficient current to meet the minimum current requirements that will enable the load encroachment logic.

Table 5.51 Load Encroachment Settings (Sheet 1 of 2)

Setting	Prompt	Range	Default	Category
ELOAD	Enable Load Encroachment	Y, N	N	Group
ZLF	Forward Load Impedance	0.05–64.00 Ω secondary[a]	9.22	Group
ZLR	Reverse Load Impedance	0.05–64.00 Ω secondary[a]	9.22	Group
PLAF	Forward Load Positive Angle	–90.0 to 90 degrees	30	Group

Table 5.51 Load Encroachment Settings (Sheet 2 of 2)

Setting	Prompt	Range	Default	Category
NLAF	Forward Load Negative Angle	–90.0 to 90 degrees	–30	Group
PLAR	Reverse Load Positive Angle	90.0 to 270 degrees	150	Group
NLAR	Reverse Load Negative Angle	90.0 to 270 degrees	210	Group

[a] The ranges shown are for a 5 A CT. Multiply by 5 for a 1 A rated CT.

Forward/Reverse Load Impedance (ZLF, ZLR)

Set ZLF and ZLR in secondary ohms based on the apparent impedance when the generator is operating at its maximum expected load and minimum expected voltage.

Forward/Reverse, Positive/Negative Angle (PLAF, NLAF, PLAR, NLAR)

Set PLAF, NLAF, PLAR, and NLAR based on expected worst-case lagging and leading power factor.

Thermal Model

The thermal model is a general-purpose model of a single-body, thermal mass. It can be used in a variety of applications. The SEL-400G implements three independent thermal elements that conform to the IEC 60255-149 standard.

The element computes the accumulated thermal level, THRL, of the protected equipment (generator, transformer, etc.). The thermal level is the ratio of the computed temperature divided by the temperature at the equipment maximum permissible current. THRL is expressed as a percentage.

The current used by the thermal model is called the equipment current (IEQ) and is defined as:

$$\mathrm{IEQ} = \frac{\mathrm{THRO}}{\mathrm{INOM}}$$

where THRO is a user-selectable operating current in secondary amperes. For instance, THRO could be the current through the generator, GSU, or excitation transformer. INOM is the nominal current rating of the input associated with THRO operating current (1 A or 5 A).

Electrical insulation is usually rated according to the maximum allowable temperature of the winding when the ambient temperature is 40°C. This maximum allowable temperature is expressed as TMAX in the thermal element.

A correction factor, KCONS is implemented to account for the possibility that the current magnitude at TMAX differs from the rated current. It is calculated as:

$$\mathrm{KCONS} = \frac{\text{Current at T = TMAX}}{\text{Rated Current}}$$

where TMAX is a user-selectable maximum operating temperature of the equipment.

For example, if the equipment reaches maximum allowable temperature at 100 percent of rated current then KCONS would be set to 1.0. If maximum temperature is reached at 110 percent of rated current, then KCONS would be set to 1.1.

As mentioned, TMAX is defined for an ambient temperature of 40°C. At lower ambient temperatures the equipment is expected to shed heat more readily. The relay accounts for the actual value of the ambient temperature using the ambient temperature factor, FAMB. FAMB has a value of 1 when the ambient temperature is 40°C. It is computed by the relay as follows:

$$\mathrm{FAMB} = \frac{\mathrm{TMAX} - 40°\mathrm{C}}{\mathrm{TMAX} - \mathrm{MAMBT}}$$

Equation 5.64

where MAMBT is the ambient temperature measurement from a user-selectable temperature probe.

For example, if TMAX = 130°C and TAMB = 25°C, then FAMB = (130 – 40) / (130 – 25) = 0.857. This means that, for the same level of heating, the resulting equipment temperature at 25°C will be 85.7 percent of the value expected at 40°C.

H_t is defined as the level of heating at time = t. Note that heating is assumed to be a function of I^2R, where R is constant. In the relay, it is computed as:

$$H_t = \left(\frac{\mathrm{IEQ}_t}{\mathrm{KCONS} \cdot \mathrm{IBAS}}\right)^2 \cdot \mathrm{FAMB}$$

where IBAS the rated current of the equipment expressed in per unit of nominal secondary amperes. It is calculated as:

$$\mathrm{IBAS} = \frac{\text{Rated Current in Primary Amperes}}{\mathrm{CTR} \cdot \mathrm{INOM}}$$

The model implements separate user-selectable heating and cooling time constants, TCONH and TCONC. The model switches from cooling to heating when the equipment current exceeds a minimum value IEQPU. The accumulated thermal level during the heating and cooling is computed using *Equation 5.65* and *Equation 5.66*:

If IEQ ≥ IEQPU:

$$\mathrm{THRL}_t = \mathrm{THRL}_{t-1} \cdot \frac{\mathrm{TCONH}}{\mathrm{TCONH} + \Delta t} + H_t \cdot \frac{\Delta t}{\mathrm{TCONH} + \Delta t}$$

Equation 5.65

If IEQ < IEQPU:

$$\mathrm{THRL}_t = \mathrm{THRL}_{t-1} \cdot \frac{\mathrm{TCONC}}{\mathrm{TCONC} + \Delta t}$$

Equation 5.66

where Δt is the processing interval for the element (20 ms).

Rotating machinery can exhibit a significantly longer cooling time constant when at standstill. In this case, it is appropriate to select an IEQPU equal to the no-load current, for example, 0.05. As a result, when IEQ is less than 0.05, the machine is assumed to be at standstill and the TCONC time constant is applied.

Selecting an IEQPU of zero means that the cooling time constant is never applied, which would be appropriate for a transformer.

The thermal element in the SEL-400G also incorporates a state switch, THLSW*n*, which is driven by a SELOGIC variable. When asserted this dynamically switches KCONS*n*, TCONH*n*, and TCONL*n* between two preconfigured values. For example, this logic can be used to adapt the thermal model according to the functional state of the cooling system (OK or faulty).

In the following example, the heating and cooling time constants are TCONH = 1 minute and TCONC = 5 minutes. The example uses the previously calculated FAMB of 0.857. The current makes the following four transitions (in per unit):

- ➤ Step from zero to 1.08, (equal to 1/√0.857), TCONH is applied
- ➤ Step from 1.08 to 0.05 (equal to IEQPU), TCONH is applied
- ➤ Step from 0.05 to 1.08, TCONH is applied
- ➤ Step from 1.08 to zero, TCONC is applied

At each step, the relay calculates instantaneous heating, H_t. This value is applied to *Equation 5.65* and *Equation 5.66* to produce the plot of *Figure 5.130*.

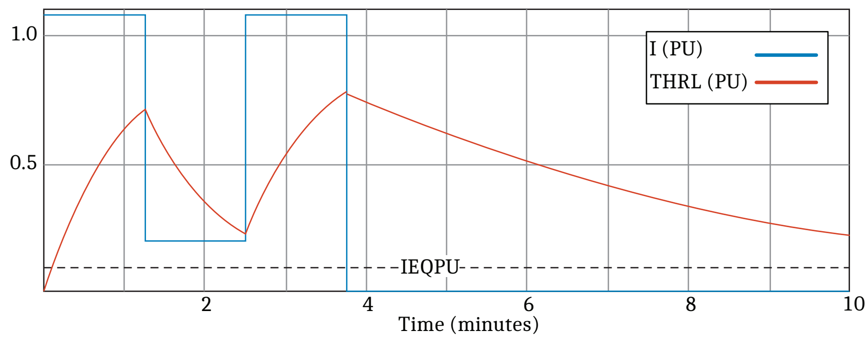


Figure 5.130 Current and Accumulated Thermal Level (THRL) Versus Time For TCONH = 1, TCONC = 5, IEQPU = 0.1, KCONS = 1, and FAMB = 0.857

Thermal Element Logic

Figure 5.131 shows the thermal alarming and tripping logic for each of the three thermal elements (*n* = 1, 2, and 3). The element asserts the trip output, THRLT*n*, when THRL*n* exceeds the trip setting THLT*n*. Note that THLT is expressed in percent. A reset ratio setting, THLTR*n* governs the reset of THRLT*n*. Similar logic is implemented for the alarm output, THRLA*n*.

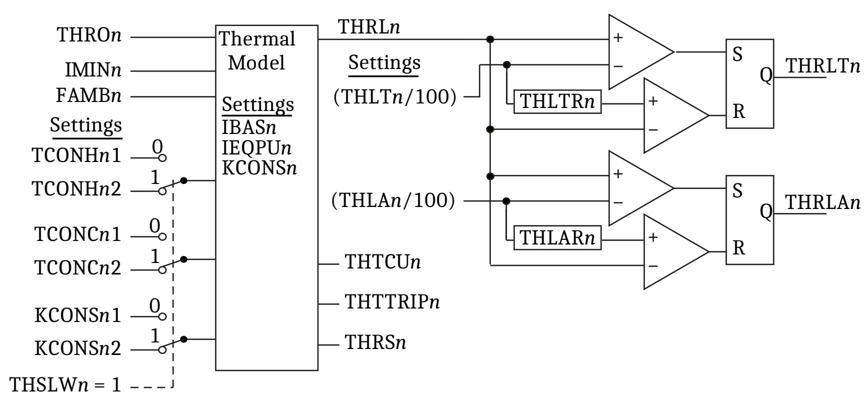


Figure 5.131 Thermal Element Logic

The relay calculates how much of the thermal capacity (in percent) of the equipment is currently being used, as shown in *Equation 5.67*.

$$\mathrm{THTCUn} = 100 \bullet \left(\frac{\mathrm{THRLn}}{\mathrm{THLTn}/100}\right)$$

Equation 5.67

If the thermal level, H*n*, is greater than the thermal level trip limit, THRL*n*, and THRLT*n* has not yet asserted, the relay calculates the remaining time before the thermal element trips, as shown in *Equation 5.68*.

$$\mathrm{THTRIPn} = \mathrm{TCONHn} \bullet \ln\left(\frac{\mathrm{Hn} - \mathrm{THRLn}}{\mathrm{Hn} - \left(\frac{\mathrm{THLTn}}{100}\right)}\right)$$

Equation 5.68

Following an assertion of THRLT*n*, and IEQ*n* < IEQPU*n*, the relay computes remaining time required for the thermal level, THRL*n*, to return to zero, as shown in *Equation 5.69*.

$$\mathrm{THRSn} = \mathrm{TCONCn} \bullet \ln\left(\frac{\mathrm{THRLn}}{\mathrm{THLRTn} \bullet \left(\frac{\mathrm{THRLn}}{100}\right)}\right)$$

Equation 5.69

The thermal level (THRL*n*) thermal element remaining time before trip (THTRIP*n*) and thermal element capacity used (THTCU*n*) are all available as analog quantities. Additionally, the thermal level alarming Relay Word bit, THRLA*n*, as well as the thermal level tripping Relay Word bit, THRLT*n*, are available. These values are also available in the thermal event report, which is accessed using the **THE** command.

Ambient Temperature Measurement

If the SEL-400G is equipped and configured to measure ambient temperature, the thermal element uses this value. Otherwise, the algorithm defaults to a user-configurable value, DAMB*n*, for ambient temperature. The TAMB*n* setting is used to select the measurement probe. The signal from this probe is routed to MAMB*n*. If the relay is configured to measure ambient temperature and the measurement is faulty, the measurement defaults either to the default value or to the last good measurement according to the AMBRTF*n* setting. The logic is shown in *Figure 5.132*.

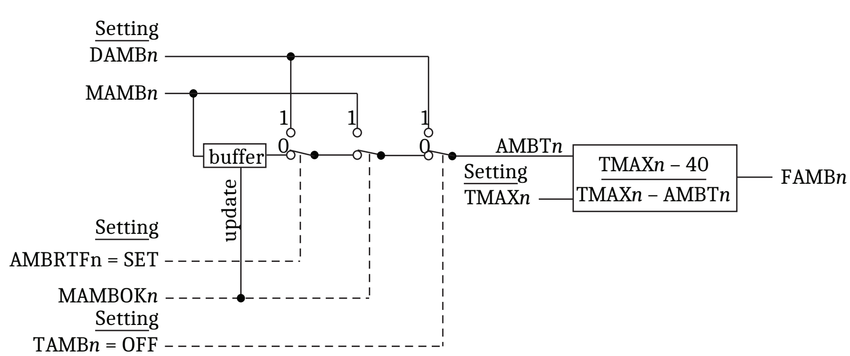


Figure 5.132 Ambient Compensation Logic

Table 5.52 Thermal Element Settings

Setting	Prompt	Range	Default	Category
ETHRIEC	Enable IEC Thermal Element	N, 1–3	N	Monitor
THRO*n*[a]	Thermal Model *n* Operating Quantity	I1GM, I1GMB, I*pm*RMS, IMAX*m*R	THRO1 = I1GMB THRO2 = IMAXSR THRO3 = IMAXSR	Monitor
IBAS*n*[a]	Basic Current Value *n*	0.1–3	1.1	Monitor
IEQPU*n*[a]	Equivalent Heating Current Threshold *n*	0.05–1	0.05	Monitor
KCONS*n*[a]	Basic Current Correction Factor *n*	0.5–1.5	1	Monitor
THSLW*n*[a]	Thermal element *n* state switch	SV	NA	Monitor
TCONH*nq*[a, b]	Heating Thermal Time Constant *n*	1–500 min	60	Monitor
TCONC*nq*[a, b]	Cooling Thermal Time Constant *n*	1–500 min	60	Monitor
THLA*n*[a]	Thermal Level Alarm Limit *n*	1.0%–100%	50%	Monitor
THLT*n*[a]	Thermal Level Trip Limit *n*	1.0%–150%	80%	Monitor
THLAR*n*[a]	Thermal element *n* Alarm Reset Ratio	0.5–1.5	0.98	Monitor
THLTR*n*[a]	Thermal element *n* Trip Reset Ratio	0.5–1.5	0.98	Monitor
DAMB*n*[a]	Default Ambient Temperature *n*	–50 to 100°C	25°C	Monitor
TAMB*n*[a]	Ambient Temp. Meas. Probe *n*	NA, RTS01–24, RTC01–24	NA	Monitor
AMBRTF*n*[a]	Default Temp if Amb Temp RTD Fails *n*	BUFF, SET	SET	Monitor
TMAX*n*[a]	Maximum Temperature of the Equipment *n*	80–300°C	155°C	Monitor

[a] n = 1, 2, 3.
[b] q = 1, 2.

Enable IEC Thermal Element (ETHRIEC)

Use this setting to enable 1, 2, or 3 independent thermal elements as needed.

Thermal Model n Operating Quantity (THROn)

Use this setting to select the operating signal for the element.

You can choose I1GMB in generator applications when it is desired to account for both negative and positive-sequence current. I1GMB is calculated as follows:

$$\mathrm{I1GMB} = \sqrt{\mathrm{I1GM}^2 + \left(\frac{3\mathrm{I2GM}}{3}\right)^2}$$

Use an individual phase rms current or the IMAX*m*R current for THRO*n* to account for harmonic heating in equipment such as a transformer. IMAX*m*R is the maximum rms current seen among the three-phase currents for Terminal *m*.

Basic Current Value n (IBASn)

Enter the rated current for the monitored equipment in per unit.

Equivalent Heating Current Pickup (IEQPUn)

This setting is used by the relay to switch between the hot and cold time constant thermal equations. Rotating machinery may exhibit a larger cooling time constant when at standstill. In this case, selecting an IEQPU*n* equal to the no-load current, for example 0.05, is appropriate. Selecting an IEQPU*n* of zero means that the cooling time constant is never applied, which may be appropriate for a transformer.

Basic Current Correction Factor (KCONSn)

This should be set to the ratio of the current at maximum allowable temperature to the rated current. For example, if the equipment reaches maximum allowable temperature at 100 percent of rated current, then KCONS*n* would be set to 1.0. If maximum temperature is reached at 110 percent of rated current, then KCONS*n* would be set to 1.1.

Heating Thermal Time Constant (TCONHnq)

This setting defines the thermal time constant (in minutes) of the equipment when the equipment is energized, that is when the current is above the IEQPU*n* value.

Cooling Thermal Time Constant (TCONCnq)

This setting defines the thermal time constant (in minutes) of the equipment when the equipment is de-energized, that is when the current is below the IEQPU*n* value. If this value is the same as the heating thermal time constant, TCONH*n*, then enter the same value.

Thermal Level Alarm Limit (THLAn)

This setting specifies the per-unit thermal level when the relay asserts the thermal alarm Relay Word bit.

Thermal Level Trip Limit (THLTn)

This setting specifies the per-unit thermal level when the relay asserts the thermal trip Relay Word bit.

Default Ambient Temperature n (DAMBn)

Use this setting to specify an ambient temperature in the case that a temperature probe is not available. This value is also used as a default value if a probe is used but the measurement is faulty.

Ambient Temperature Measurement Probe n (TAMBn)

Use this setting to specify the probe to be used for ambient temperature measurement.

Default Temperature if Ambient Temperature RTD Fails n (AMBRTFn)

In applications using a temperature probe, this setting determines which value is used for ambient temperature if the measurement is faulty. If set to BUFF, then the last good measurement is used. If set to SET, then DAMB*n* is used.

Maximum Temperature of the Equipment (TMAXn)

This setting specifies the maximum operating temperature of the protected equipment. This setting is used to calculate FAMB*n* (see *Equation 5.64*).

THE Command

Use the **THE** command to display the IEC thermal model element reports of the equipment monitored by the relay. The report includes ambient temperature, operating quantity selected, level of equivalent heating, the percentage of thermal capacity used, thermal element status (NORMAL, ALARM, or TRIP), time to trip if picked up, and time to reset if in trip status. When used with P parameter, **THE** enables you to preload the thermal values for enabled elements. The inputs are to be given in percentages and the format is *xx.xx* with a resolution of 0.01 percent. The maximum input that you can give is 99.99 percent. **THE R** or **C** can be used to clear the thermal data for enabled elements, when used with parameter *n* (*n* = 1–3). **THE *n* R** or **C** clears the thermal data for that particular element *n*. *Figure 5.133* shows the THE command report with all three elements enabled.

```
=>THE <Enter>

Relay 1                                    Date: 12/19/2019  Time: 11:57:29.675
Station A                                  Serial Number: 1181300591


IEC Thermal Elements Data
                                   Element 1   Element 2   Element 3
Ambient Temperature (deg. C)           50.00       32.00       34.00
Thermal Operating Quantity            IASRMS      IMAXGR       I1GMB
Max. Equivalent Thermal Level (pu)      0.97        0.00        0.00
Thermal State                              1           2           1
Thermal Level Value                    75.22        0.00        0.00
Thermal Capacity Used (%)             100.29        0.00        0.00
Thermal Element Status                  TRIP      NORMAL      NORMAL
Time to Trip (s)                        0.00     $$$.$$      $$$.$$
Time to Reset (s)                     124.77        0.00        0.00
```

Figure 5.133 THE Report

RTD Element

Use the RTD element to alarm and trip from RTD monitored values. A total of 12 RTD elements are provided. Any of the SEL-2600 or remote analog monitored values can be mapped to the element using the 46RO*n* setting. The RTD status Relay Word bit is also mapped to the logic by using the same setting. Two pickup settings are provided to set levels for alarming and tripping. The logic is shown in *Figure 5.134*.

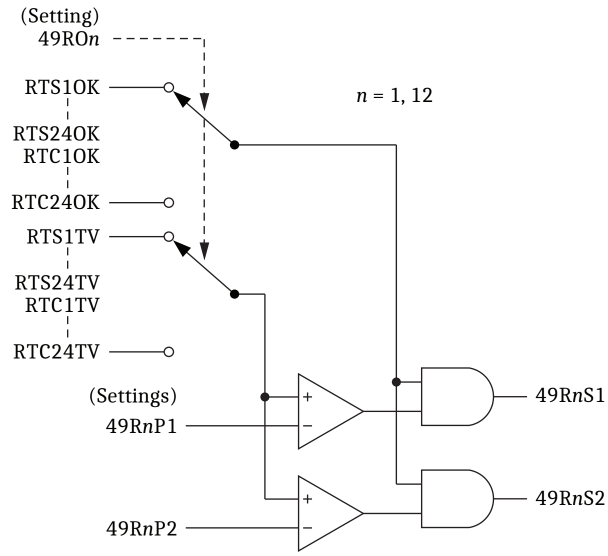


Figure 5.134 RTD Element Logic

RTD Voting

The SEL-400G provides RTD voting by all RTDs at a particular location. As many as four locations can be configured. Voting is enabled using the 49RLV*m* setting. Any of the 12 RTD elements can be assigned to a location by using the 49RL*m* setting. The output 49RLV*m*P asserts when two or more RTD elements assert. The logic is shown in *Figure 5.135*.

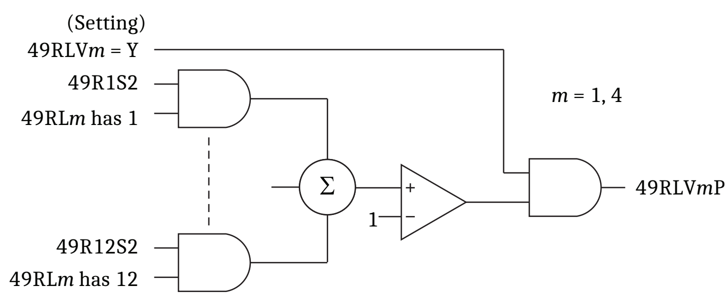


Figure 5.135 RTD Voting Logic

Out-of-Step Element

The SEL-400G includes an out-of-step element to detect out-of-step conditions between two electrical sources. Two interconnected systems can experience an out-of-step condition for several reasons. For example, loss of excitation can cause a generator to lose synchronism with the rest of the system. Similarly, delayed tripping of a generator breaker to isolate a fault can cause the generator to go out of step with the rest of the system.

Detecting and isolating an out-of-step condition as early as possible is imperative because the resulting high peak currents, winding stresses, and high shaft torques can be very damaging to the generator and the associated GSU transformer.

The SEL-400G implements two out-of-step tripping schemes: single blinder and double blinder, as shown in *Figure 5.136* and *Figure 5.138*. Users can select whichever scheme suits their application, or they can disable out-of-step protection.

The element uses the positive-sequence impedance as an operating signal which is calculated as:

$$\mathrm{Z1GF} = \frac{\mathrm{V1ZF}}{\mathrm{I1GF}}$$

Equation 5.70

The operating equation of the 78 mho characteristic (78Z1 in *Figure 5.137* and *Figure 5.139*) is:

$$\mathrm{78Z1} = \mathrm{Re}((\mathrm{Z1GF} + \mathrm{j} \bullet \mathrm{78FWD}) \bullet (\overline{\mathrm{j} \bullet \mathrm{78REV} - \mathrm{Z1GF}})) > 0$$

Equation 5.71

If the magnitude of I1GF is less than 0.05 • CTNOM, 78Z1 is forced to zero.

Single-Blinder Scheme

The single-blinder scheme consists of a mho element, 78Z1; right and left resistance blinders, 78R1 and 78R2; and associated logic. *Figure 5.136* shows the characteristic for the single-blinder scheme.

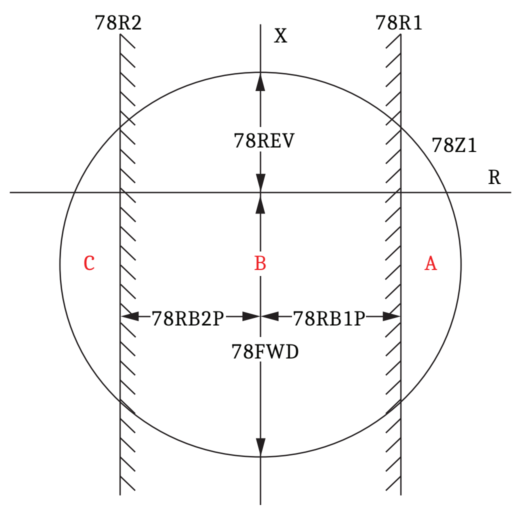


Figure 5.136 Out-of-Step Characteristics

Figure 5.137 shows the logic for the single-blinder scheme.

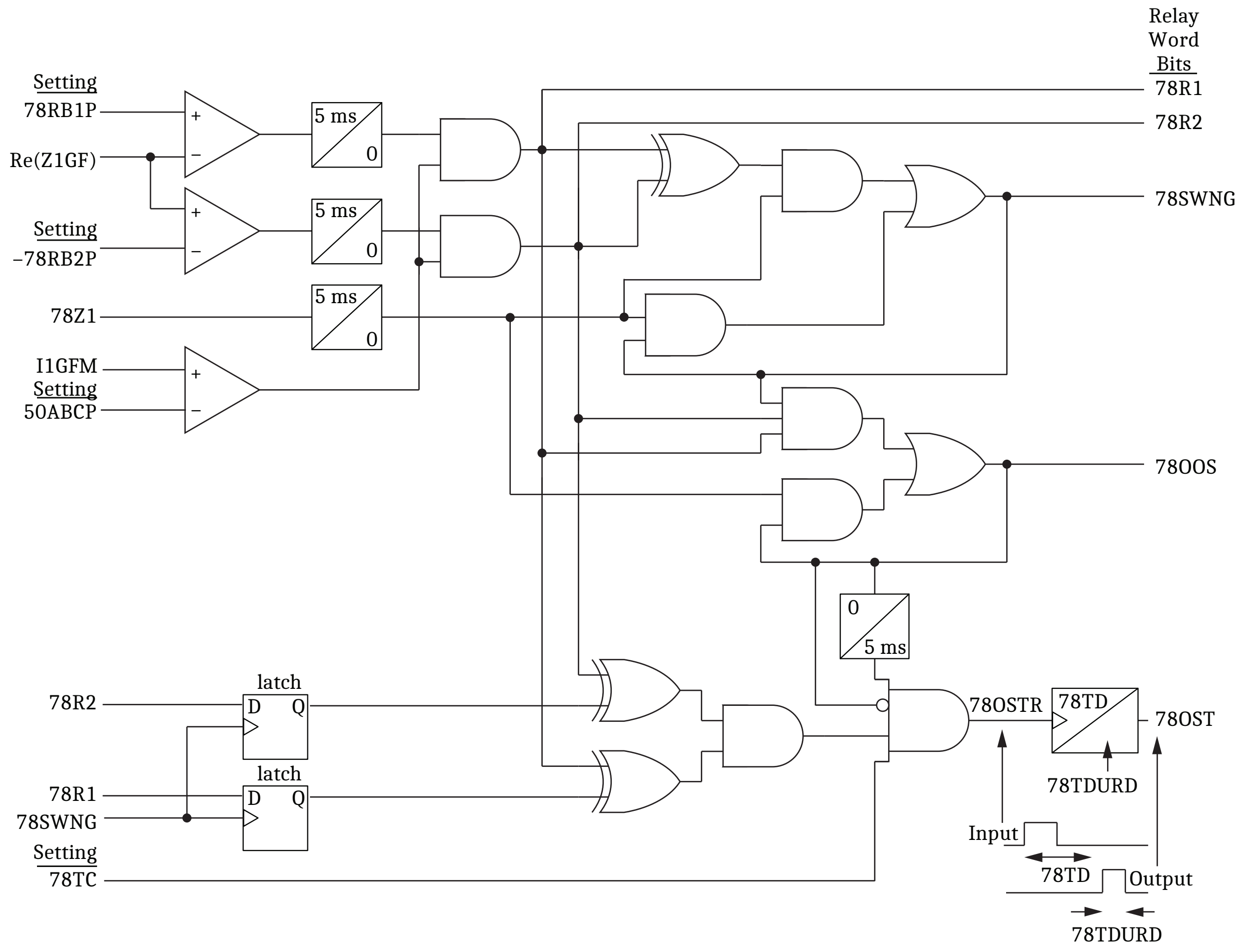


Figure 5.137 Single-Blinder Logic

The scheme declares a swing, 78SWNG, when the positive-sequence impedance moves from the load region into Area A (only 78Z1 and 78R2 are asserted) for 5 ms.

The scheme declares an out-of-step, 78OOS, when the impedance trajectory subsequently advances to Area B between the two blinders (the mho element 78Z1 and both blinders asserted) for 5 ms.

At the time the impedance trajectory exits the mho circle via Area C, the rising-edge triggered timer with 78TD pickup delay and 78TDURD dropout delay starts timing. Relay Word bit 78OST remains picked up for 78TDURD seconds after the pickup delay time 78TD expires.

The previous description applies to trajectories traveling from right to left. The Relay Word bits assert in the same way for trajectories traveling from left to right.

During short-circuit faults, the impedance locus moves from the load region (outside of 78Z1) into Area B almost instantaneously. For these events, the scheme timers are not able to expire and the scheme outputs do not assert.

The states of 78R1 and 78R2 are latched on the rising edge of 78SWNG to determine if the swing has entered the mho circle from the right or the left. For an out-of-step trip, 78OST, to occur, the swing must exit the mho circle on the opposite side of the impedance plane from where it entered. The latched states of 78R1 and 78R2 are retained until the next time 78SWNG asserts, which is the next time a power system swing occurs. This feature reduces the possibility of an OOS trip for a stable power swing.

Double-Blinder Scheme

The double-blinder scheme consists of mho element 78Z1, two blinder pairs: outer resistance blinder 78R1 and inner resistance blinder 78R2, and associated logic. *Figure 5.138* shows the characteristic for the double-blinder scheme.

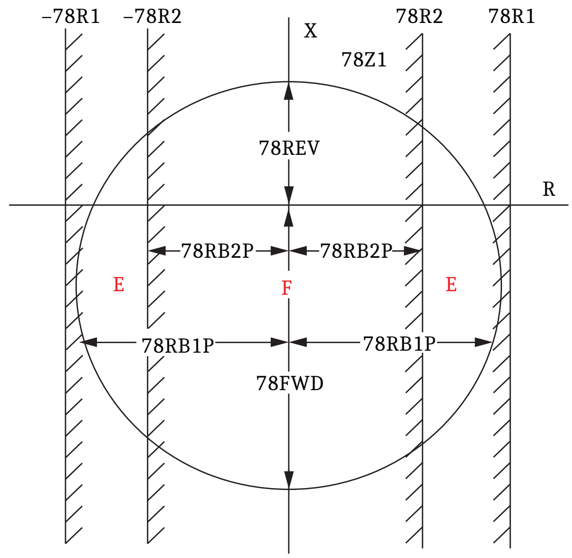


Figure 5.138 Double-Blinder Scheme Characteristic

Figure 5.139 shows the double-blinder logic.

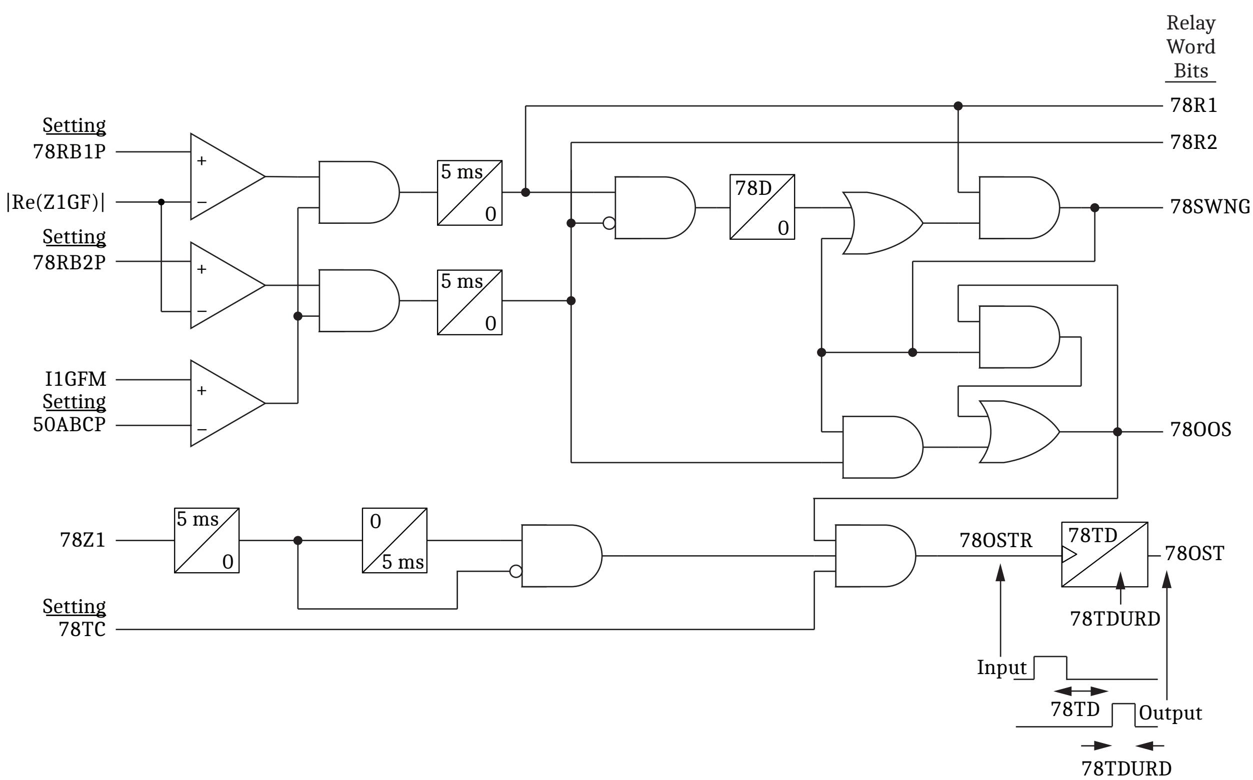


Figure 5.139 Double-Blinder Logic

Relay Word bit 78SWNG picks up when the impedance locus enters Area E and remains for more than 78D seconds.

NOTE: The double-blinder scheme does not include logic to check the direction in which the impedance locus exits the mho circle. The impedance locus must not cross the inner blinder during a stable power swing. Correct selection of the inner blinder reach setting is therefore critical.

Relay Word bit 78OOS picks up when positive-sequence impedance locus subsequently enters Area F (both blinders picked up) after 5 ms.

The logic issues an out-of-step trip, 78OST, when the impedance enters and then exits the mho circle while 78OOS is picked up.

The double-blinder scheme distinguishes between short-circuit faults and out-of-step conditions by checking the length of time that the impedance trajectory stays in Area E. During short-circuit faults, the impedance moves through Area E almost instantaneously so that the 78D timer does not expire.

Pole Slip Counter

The SEL-400G includes two pole slip counters. The logic uses either of the OOS schemes in conjunction with a reactive blinder element. This blinder is defined by the 78XP setting and divides the impedance plane into a system zone and a generator zone.

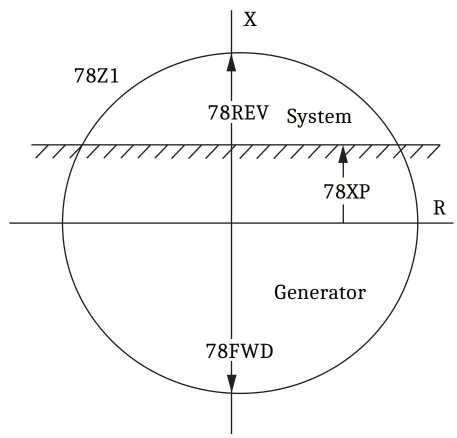


Figure 5.140 Slip Counter Zone

In *Figure 5.141*, the upper counter accumulates the total number of pole slips. The middle counter accumulates the number of slips passing through the system zone, 78SCN. The lower counter accumulates the number of slips that pass through the generator zone, 78GCN. Individual thresholds can be applied to each count. The counters are reset if the impedance locus remains outside the mho characteristic for longer than the 78SCD delay setting.

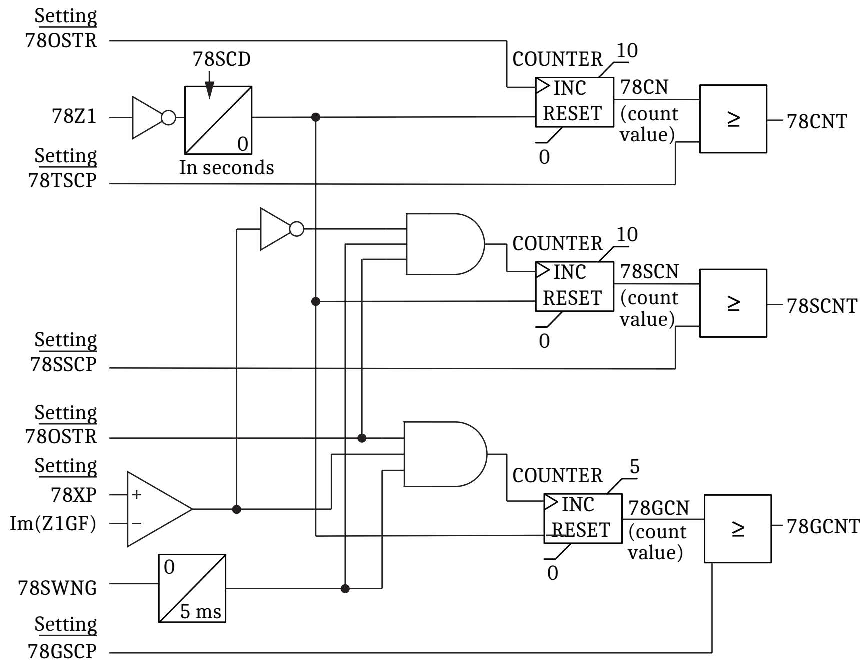


Figure 5.141 Pole Slip Counter Logic

Settings Guidelines

Table 5.53 Out-of-Step Settings

Setting	Prompt	Range	Default	Category
E78	Enable Out-of-Step Element	N, 1B, 2B	1B	Group
78FWD	78 Forward Mho Reach	0.05–100.00[a] Ω secondary	8	Group
78REV	78 Reverse Mho Reach	0.05–100.00[a] Ω secondary	8	Group
78RB1P	78 Right (Outer) BL Reach	0.05–100[a] Ω secondary	8	Group
78RB2P	78 Left (Inner) BL Reach	0.05–100[a] Ω secondary	7	Group
50ABCP	78 Pos.-Seq Current Supervision	1.00–100[b] A secondary	1	Group
78D	78 Out-of-Step Delay	0.00–1 s	0.05	Group
78TD	78 Out-of-Step Trip Delay	0.00–1 s	0	Group
78TDUR	78 Out-of-Step Trip Duration	0.00–5 s	0	Group
78TC	78 Out-of-Step Torque Cont	SELOGIC	NOT LOPZ	Group
78XP	78 Slip Counter Zone Reach	OFF, 0.05–100 Ω	OFF	Group
78GSCP	78 Generator Slip Counter Pickup	1–5	2	Group
78SSCP	78 System Slip Counter Pickup	OFF, 1–10	OFF	Group
78TSCP	78 Total Slip Counter Pickup	OFF, 1–10	OFF	Group
78SCD	78 Slip Counter Reset Delay	0.000–1 s	0.05	Group

[a] Ranges are for a 5 A CT. Multiply by 5 for a 1 A CT.
[b] Range is for a 5A CT. Divide by 5 for a 1A CT.

Note that the 78 element must not trip the generator for a recoverable power swing. The best way to confirm that the element is properly configured is to carry out a transient stability study.

78 Forward and Reverse Mho Reach (78FWD and 78REV)

Select these settings to ensure that the impedance locus for an unstable swing always passes through the mho characteristic. Also, the impedance locus should not be inside the mho characteristic at the maximum possible generator load. Typically, set the forward reach, 78FWD, at 2–3 times the generator transient reactance, X'_d, in secondary ohms, and set the reverse reach, 78REV, at 1.5–2.0 times the transformer reactance, XT, in secondary ohms.

78 Right (Outer) BL Reach (78RB1P) and 78 Left (Inner) BL Reach (78RB2P)

Single-Blinder Scheme

For the single-blinder scheme, 78RB1P is right blinder and 78RB2P is the left blinder. These are typically set so that the separation angles are approximately 120 degrees, as shown in *Figure 5.142*. Separation angles of 120 degrees or greater between the two sources usually results in loss of synchronism. The right blinder should not be asserted at the maximum expected generator load.

Double-Blinder Scheme

For the double-blinder scheme, 78R1 is outer blinder and 78R2 is the inner blinder. The inner reach must be set such that the impedance locus does not cross the inner blinder for a stable (recoverable) swing. The outer blinder reach should be set such that all of the following are true:

- Outer blinder is not asserted at the maximum expected load
- Outer blinder sits outside the mho circle to satisfy the relay logic
- Outer blinder separates from the inner blinder far enough to allow proper setting of the 78D timer

78 Out-of-Step Delay (78D)

This setting is used only by the double-blinder scheme. It is set to ensure that it expires while the impedance locus is passing between the outer and inner blinders at the fastest expected slip frequency for an unstable swing. To ensure that the relay times the out-of-step slip frequency accurately, the outer and inner blinders must be separated appropriately. For example, assume that the highest out-of-step frequency encountered is 5 slip cycles per second, which translates to 30 degrees per cycle (60 Hz). Set the blinders with a 70-degree separation. This separation translates to a positive-sequence impedance travel time of 2.3 cycles between the two blinders, which should provide adequate timing accuracy. Set the 78D timer at 0.035 seconds, which ensures that 78D picks up for swings traveling at 30 degrees per cycle or less.

78 Torque Control (78TC)

The torque-control SELOGIC control equation, 78TC, has a default setting of one. If this value is left at 1, the out-of-step element is not controlled by any other conditions external to the element. However, users can block the operation of the element for certain conditions, such as the presence of excessive negative-sequence currents, by setting 78TC to NOT 46Q1.

78 Positive-Sequence Current Supervision (50ABCP)

This setting defines a minimum current for operation of the element. Normally, a setting of 1 A for a 5 A relay is adequate for most applications. However, a higher setting can be applied based on minimum expected swing currents.

78 Trip Delay (78TD)

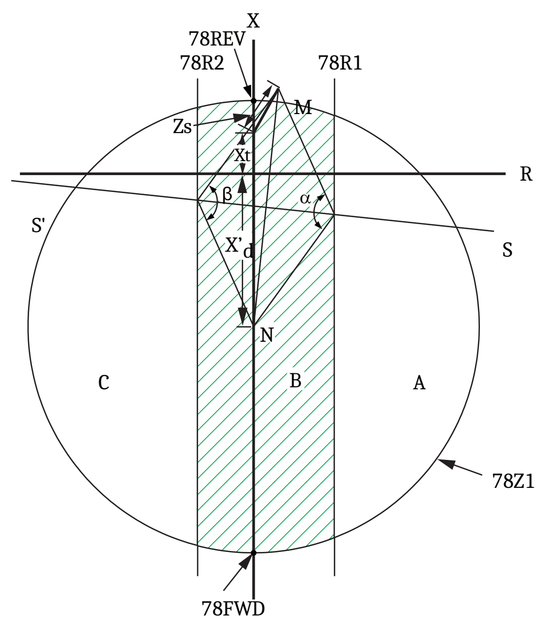
Use this setting to delay tripping of the element after exiting the mho characteristic to ensure that the breaker duty cycle is not exceeded.

78 Trip Duration (78TDUR)

This setting defines the minimum time that the 78OST asserts. This can be set longer than the opening time of the breaker, but shorter than the breaker failure time with some margin, for example 50 ms. The default setting for the 78TDUR is 0 because 78OST is configured to trip the generator breaker with default trip logic (which includes an identical timer). Change the settings (trip logic and/or 78DURD) if your application requires a different action.

78 Pole Slip Counter (78XP, 78TSCP, 78SSCP, and 78GSCP)

These setting are used to implement tripping after a number of pole slips have occurred. This may be beneficial especially in the case of pole slips that pass through the system. SEL recommends that you contact the generator manufacturer before configuring the relay to allow multiple pole slips prior to tripping.



78FWD:	Forward Reach
78REV	Reverse Reach
X'_d:	Generator Transient Reactance
Xt:	Transformer Reactance
Zs:	System Impedance
M-N:	Total Impedance between Generator and System
S-S':	Perpendicular Bisector of M-N
α, β:	Angle of separation between generator and system

Figure 5.142 Typical Single-Blinder Settings

Inadvertent Energization

Inadvertent energization occurs when the generator main circuit breaker or auxiliary transformer circuit breaker is incorrectly closed to energize the generator when it is out of service. When this occurs, the generator behaves like an induction motor, drawing as much as four to six times the rated stator current from the system. These high stator currents induce high currents in the rotor, which can quickly damage the rotor. The objective of inadvertent energization protection is to quickly detect that the generator has been re-energized after being removed from service.

A voltage-supervised overcurrent scheme can be implemented in the SEL-400G using the undervoltage check that is integrated into the inadvertent energization scheme logic. Other supervisions, for example field breaker open (52Fb), can be implemented using the torque-control input (INADTC).

The overcurrent detector has a dual role; it provides an arming input when it is dropped out and, once armed, it picks up to indicate that an inadvertent energization event has occurred.

The scheme will be armed (INADA*m* asserted) after de-energization of the generator. Arming the assertion requires that the voltage is below the pickup setting (INADVP*m*), the current is below the pickup setting (INADIP*m*), and the torque control (INADTC*m*) is asserted. Arming is delayed by the INADAD*m* setting. Once armed, if the current exceeds the INADIP*m* setting, the output INADT*m* asserts after the INADD*m* timer expires. If any of the arming conditions (undervoltage, undercurrent, or torque control) deasserts, the scheme disarms. Disarming is delayed by the INADDD*m* setting.

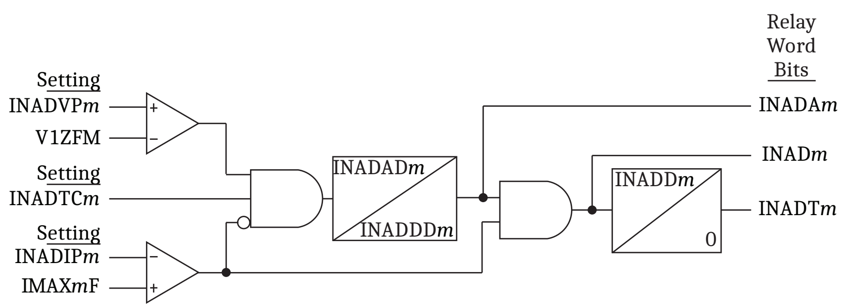


Figure 5.143 INAD Scheme Logic

Note that because this protection scheme is disabled when the generator voltage returns to near normal, this scheme does not provide protection for a breaker flashover that occurs just prior to synchronizing. The SEL-400G includes dedicated logic for breaker flashover.

Setting Guidelines

Table 5.54 Inadvertent Energization Settings (Sheet 1 of 2)

Setting	Prompt	Range	Default	Category
INADIP*m*[a]	Inad. Ener. O/C PU –BKR *m* A, sec	0.25–10[b]	1	Group
INADVP*m*[a]	Inad. Ener. U/V PU –BKR *m* V, sec	1.00–300	10	Group
INADTC*m*[a]	Inad. Ener. TC –BKR *m*	SELOGIC variable	NOT LOPZ	Group
INADAD*m*[a]	Inad. Ener. Arm. Dly. –BKR *m* s	0.0000–100 s	2	Group

Table 5.54 Inadvertent Energization Settings (Sheet 2 of 2)

Setting	Prompt	Range	Default	Category
INADDD*m*[a]	Inad. Ener. Disarm. Dly. –BKR *m* s	0.0000–100 s	1	Group
INADD*m*[a]	Inad. Ener. PU Delay –BKR *m* s	0.0000–10 s	0.25	Group

[a] m = S, T, U, and Y.

[b] This range is for a 5 A CT. Divide by 5 for a 1 A CT.

Inadvertent Energization Overcurrent Pickup –BKR m, (INADIPm)

The overcurrent pickup must be set to operate for the lowest current expected for an inadvertent energization event. If the generator is connected to a weak system or re-energized through the auxiliary bus, the current can be as low as 1–2 times nominal current. A sensitive setting in the range of 0.25 A secondary is recommended. Note that, in the SEL-400G, the inadvertent energization element monitors the breaker current and an inadvertent energization element is provided for each breaker. This allows a low pickup setting to be used in static starting and pumped-storage applications.

Inadvertent Energization Undervoltage Pickup –BKR m, (INADVPm)

Set the undervoltage pickup to a low value to ensure that the generator voltage is zero prior to arming.

Inadvertent Energization Torque Control –BKR m, (INADTCm)

The torque-control setting (INADTC) has a default setting of NOT LOPZ. Use this input to provide additional security for your application. Some examples of INADTC settings include:

- NOT LOP
- Breaker open indication
- Field breaker open indication

Note that if the three-pole open (3PO) Relay Word bit is used to supervise inadvertent energization, the 52A setting of the breaker monitor logic must be assigned to a normally open breaker status contact and EPO must be enabled for the breaker.

Inadvertent Energization Arming Delay –BKR m, (INADADm)

The arming delay setting (INADAD*m*) ensures that the element will not pickup spuriously when the generator is taken offline. The default setting is 2 seconds.

Inadvertent Energization Disarming Delay –BKR m, (INADDDm)

The disarming delay (INADDD*m*) provides a window to allow the scheme to operate for the occurrence of an actual inadvertent energization event. It must be shorter than the time required to parallel the generator to the system following application of the field. A setting of 1 second is usually adequate

Inadvertent Energization Pickup Delay –BKR m, (INADDm)

The INADPU*m* defines the pickup time of the element. It must be set shorter than then INADDD*m* setting; otherwise, the scheme disarms before it can operate for an inadvertent energization event.

Field Ground Protection

The SEL-400G can receive a rotor field winding insulation resistance measurement from an SEL-2664 Field Ground Module directly by using SEL Fast Message protocol or via the SEL-2664S by using the IEC 61850 protocol. See *Section 2: Installation* for details on connecting and configuring these devices. See the *SEL-2664 Field Ground Module Instruction Manual* for application details related to the module.

The Field Ground Scheme logic is shown in *Figure 5.144*. Two levels are provided. One level can be set with a relatively high pickup for alarming. The second level can be set with a lower pickup for tripping.

The technology used in SEL-2664 does not discriminate between one point of insulation breakdown and multiple points of insulation breakdown. A single point of insulation breakdown will not cause any harm to the generator. Multiple points of insulation breakdown could lead to very serious generator damages because the distribution of magnetic flux in the rotor will be substantially altered. When an additional device, such as a generator vibration detector for example, is used for the detection of multiple points of insulation breakdown, a field ground indication without vibration detection can be used for the alarm level and the assertion of the vibration detector can supervise the tripping level. When an additional device is not used, SEL recommends that you alarm and trip from a field ground indication.

When the SEL-400G is communicating with the SEL-2664 by using SEL Fast Message, the resistance measurement is automatically mapped to the analog quantity 64FIR by using the 64FIRM Group setting to select the corresponding port. Set the field insulation quality setting 64FIQ to **NOT 64FFLT** to secure the element against data and communications errors. 64FFLT asserts for either a reported SEL-2664 status failure or a loss of communication, as indicated by Relay Word bits 64FDF and 64FCF, respectively.

NOTE: Averaging is applied to the resistance measurement in the SEL-2664S. This adds an additional delay to the response time of the field ground scheme logic. If the SEL-2664 is injecting at 1 Hz, the additional delay is less than 1 second. If the SEL-2664 is injecting at 0.25 Hz, the additional delay is less than 5 seconds. You should account for this in the setting delay (64FnD)

When the SEL-400G is communicating with the SEL-2664 by using GOOSE protocol, the resistance measurement appears in the SEL-400G as a remote analog, which is then assigned to 64FIR by using the 64FIRM setting. Likewise, the associated communications quality bit is assigned to the 64FIQ setting.

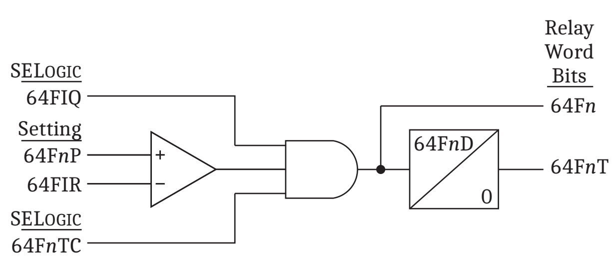


Figure 5.144 Field Ground Scheme Logic, Level n

Setting Guidelines

Table 5.55 Field Ground Settings

Setting	Prompt	Range	Default	Category
64FIRM	64F Field Insulation Resistance Mapping	PORT*m*[a], RA001–RA256	PORT1	Group
64FIQ	64F Field Insulation Quality (SELOGIC Eqn)	SV	NOT 64FFLT	Group
64F*n*P[b]	64F Level *n* Pickup (OFF, 0.5–200 kOhms)	OFF, 0.5–200.0	OFF	Group
64F*n*D[b]	64F Level *n* Delay (0.000–400 s)	0.000–400.000	60	Group
64F*n*TC[b]	64F Level *n* Torque Cont (SELOGIC Eqn)	SV	1	Group

[a] m = 1–3.
[b] n = 1, 2.

64F Field Insulation Resistance Mapping (64FIRM)

If the SEL-400G is using SEL Fast Message protocol for communications with the SEL-2664, enter the serial port used to establish the connection. If the SEL-400G is using GOOSE protocol for communications with the SEL-2664 via the SEL-2664S, enter the remote analog that is mapped to the field insulation resistance.

64F Field Insulation Quality (SELOGIC Control Equation) (64FIQ)

If the SEL-400G is using SEL Fast Message protocol, enter **NOT 64FFLT**, the failure detection bit. If the SEL-400G is using GOOSE protocol, enter the quality bit for the remote analog that is mapped to the field ground element. The element is blocked if the quality bit is not asserted.

64F Level n Pickup (OFF, 0.5–200 kΩ) (64FnP)

NOTE: If there is no insulation deterioration, there is no leakage path between the field winding to ground; the insulation resistance value can be upwards of 20 MΩ. Because of sensitivity limitations, the accuracy of the SEL-2664 is specified for the range of 0.5 to 200 kilohms. Consequently, the pickup setting is limited to the same range.

Enter the desired pickup of the element in kilohms. You can use the analog signal profiling function to track the variation of the insulation resistance over time to determine an optimal setting.

64F Level n Delay (0.000–400 s) (64FnD)

Enter the desired delay in seconds. The SEL-2664 uses the square-wave injection principle. Depending on the injection frequency, the resistance measurement is updated twice a second or once every two seconds. See the *SEL-2664 Field Ground Module Instruction Manual* for more details.

64F Level n Torque Control (SELOGIC Control Equation) (64FnTC)

This setting has a default value of 1. If tripping is supervised by a high-vibration indication, then this indication can be assigned in this setting.

Synchronism-Check Element

The synchronism-check element prevents a circuit breaker from closing if the voltage across the open circuit breaker is not matched in phase, magnitude, or frequency.

You can use synchronism-check elements to supervise circuit breaker closing. The element outputs are Relay Word bits 25A*n*, 25C*n*, and 25WC*n* (*n* = S, T, U, or Y).

Voltage Selection

Figure 5.145 shows the generator voltage selection logic. VPFM and VPFA are the magnitude and angle of a selected generator phase-to-phase or phase-to-neutral voltage.

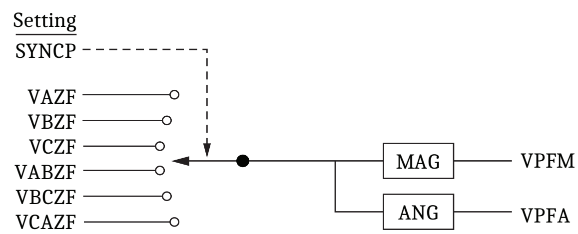


Figure 5.145 Generator Voltage Selection

Figure 5.146 shows the system voltage selection logic. NVS*n*FM and NVS*n*FA are the magnitude and angle, respectively, of a selected system phase-to-phase, phase-to-neutral, or single-phase voltage. The scaling factor, KS*n* is a complex value equal to KS*n*M ∠KS*n*A. The settings KS*n*M and KS*n*A are typically used to account for VT ratio mismatch and magnitude and angle errors.

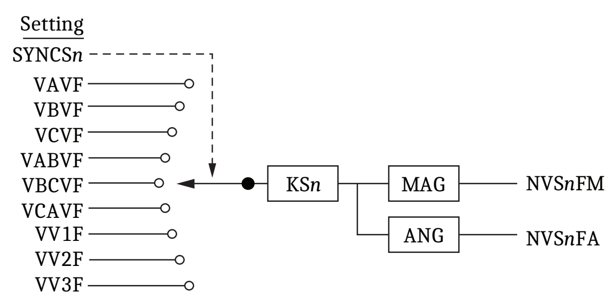


Figure 5.146 System Voltage Selection

Voltage Magnitude Checks

The synchronism-check element includes checks on the magnitudes of the generator and system voltages.

In *Figure 5.147*, the logic asserts the 59VP*n* Relay Word bit if the generator voltage is available and within set limits required for synchronization. A similar check asserts the 59VS*n* Relay Word bit if the system voltage is available and within limits.

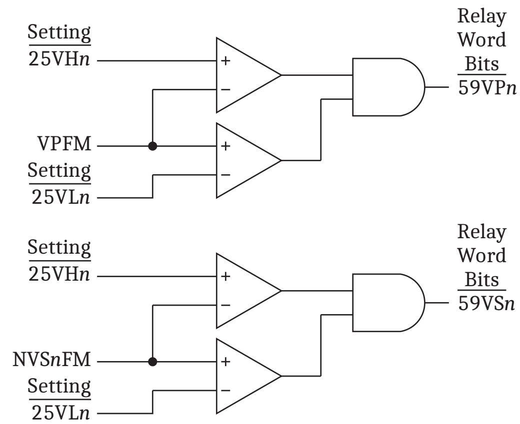


Figure 5.147 Generator and System Voltage Magnitude Checks

Voltage Difference Check

In generator applications, it is common practice to check that the percentage difference between the generator and system voltages is within limits. This is implemented using the 25VDIF*n* setting, which defines a voltage acceptance window for the element. If the 25VDIF*n* setting is selected to OFF, then the voltage difference check is bypassed and the associated Relay Word bits are permanently deasserted.

Logic is also included to shrink the voltage acceptance window when it is required to synchronize only when the generator voltage is higher than the system voltage. This is controlled by the 25GVHI*n* setting.

The voltage difference check is carried out when the system voltage is available, as indicated by the assertion of the 59VS*n* Relay Word bit.

The percentage difference in the voltage magnitudes, DIFV*n*, is calculated as:

$$\mathrm{DIFVn} = \left(\frac{\mathrm{VPnFM}}{\mathrm{NVSnFM}} - 1\right) \bullet 100\%$$

In *Figure 5.148*, the logic asserts 25VDIF*n* if the voltage difference is less than the 25VDIF*n* setting. If not, the logic declares whether the generator voltage is high or low.

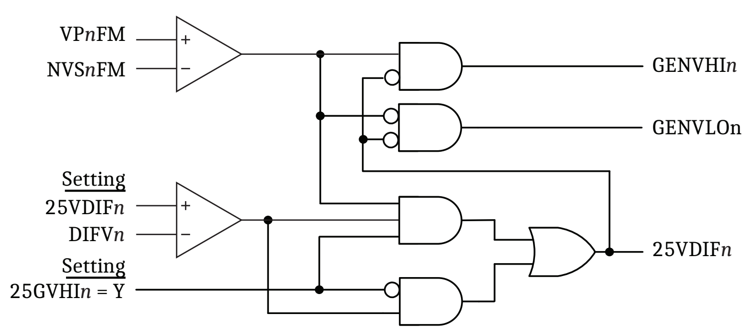


Figure 5.148 Voltage Difference Check

Figure 5.149 shows how the Relay Word bits in *Figure 5.148* assert according to the 25VDIF*n* and 25GVHI*n* settings. Note that when 25GVHI = Y, the 25VDIF*n* Relay Word bit only asserts when the generator voltage is greater than the system voltage.

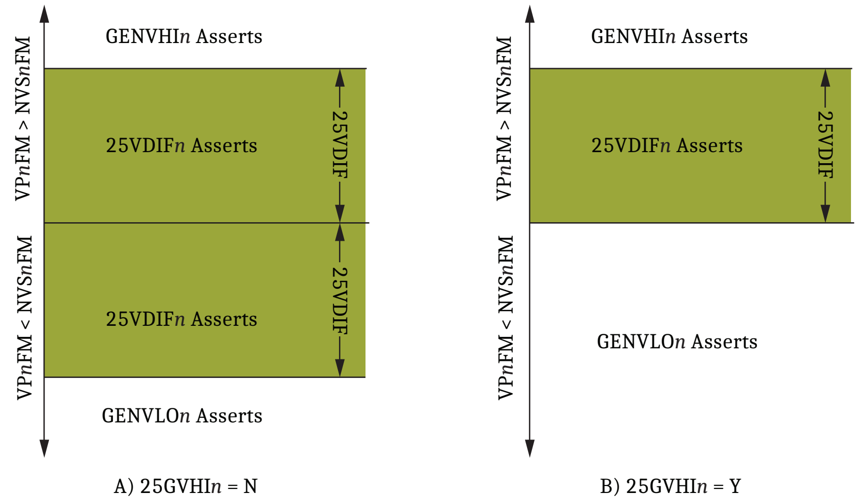


Figure 5.149 Voltage Acceptance Window

Figure 5.150 shows the combined voltage check logic. Note that checks on the generator and system voltage magnitudes are always carried out but these can be set to assert over a very wide voltage range (20 to 200 volts).

Note also that if the 25VDIF setting is selected to OFF, then the voltage difference check is bypassed.

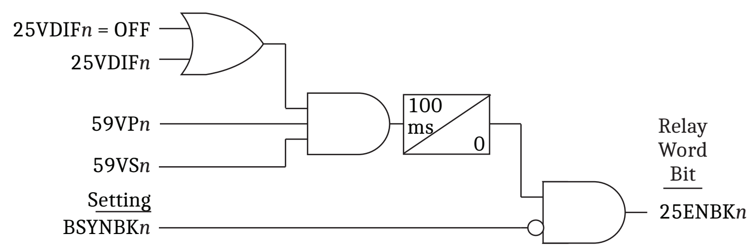


Figure 5.150 Combined Voltage Check Logic

25ENBK*n* is also supervised by the SELOGIC variable, BSYNBK*n*. BSYNBK*n* is used to define conditions to block the assertion of the synchronism-check element. See the settings guidelines for more information.

Angle and Slip Frequency Calculation

When 59VP*n* and 59VS*n* are both asserted, slip and angle difference calculations are carried out as shown in *Figure 5.151*.

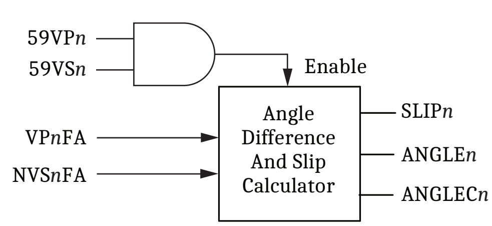


Figure 5.151 Angle Difference and Slip Calculation

ANGLE*n* is calculated as the difference between the generator voltage angle and the system voltage angle as follows:

ANGLE*n* = VP*n*FA – NVS*n*FA

Note that the system voltage is the reference for the angle calculation. Angle difference is corrected to be between ±180°.

In *Figure 5.151*, slip is calculated as the rate-of-change of ANGLE*n*. Additional filtering is applied to produce the slip signal. Note that when the generator frequency is higher than the system frequency, the slip is positive.

Slip Check

It is a common practice to check that the slip is within set limits. This is implemented using the slip frequency setting, 25SFBK*n*, which defines a slip acceptance window for the element. If the 25SFBK*n* setting is selected to OFF, then the slip check is bypassed as described in *Uncompensated and Compensated Angle Checks on page 5.152*.

Logic is also included to shrink the slip acceptance window when it is required to synchronize only when the generator frequency is higher than the system frequency (positive slip). This is controlled by the 25GFHI*n* setting.

Figure 5.152 shows the slip-check logic. This logic runs when 59VP*n* and 59VS*n* both assert. Otherwise, the associated Relay Word bits are deasserted.

The logic indicates whether the generator is fast or slow with respect to the system or when the generator and system are virtually stationary with respect to one another as indicated by the Zero Slip Relay Word bit, SFZBK*n*.

If SFZBK*n* is not asserted and the absolute value of slip is less than 25SFBK*n*, then SFBK*n*, the slip within limits Relay Word bit, asserts.

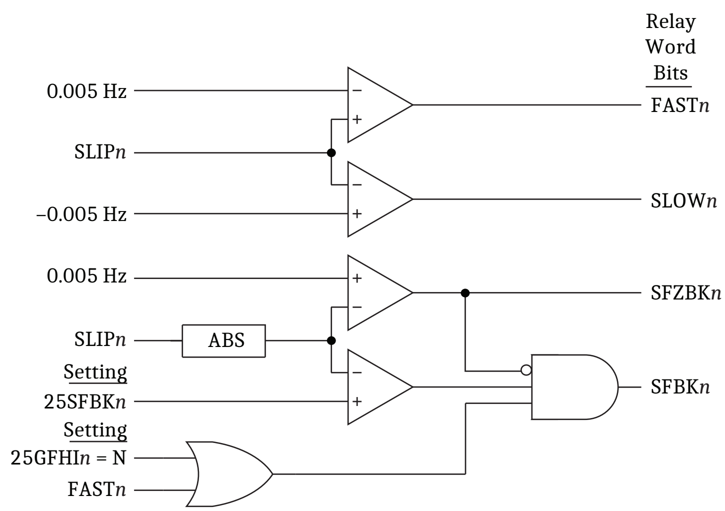


Figure 5.152 Zero-Slip and Slip-Within-Limits Checks

Figure 5.153 shows how the Relay Word bits in *Figure 5.152* assert according to the 25SFBK*n* and 25GFHI*n* settings.

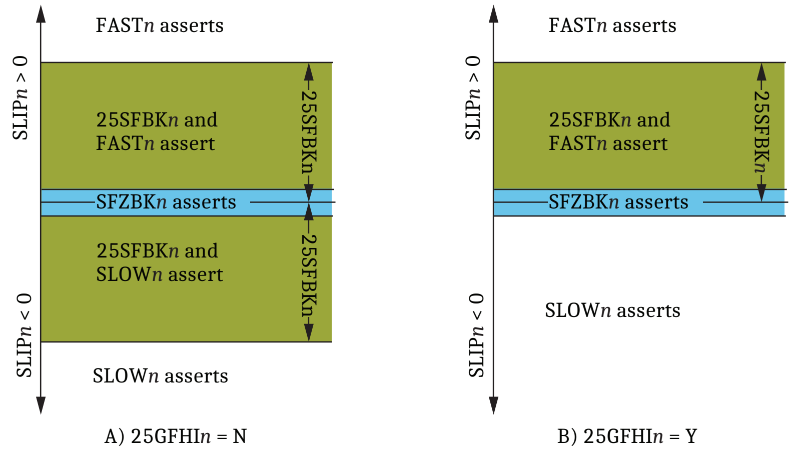


Figure 5.153 Slip Acceptance Window

Uncompensated and Compensated Angle Checks

The synchronism-check element includes compensated and uncompensated angle checks. Both checks are enabled by 25ENBK*n*.

The behavior of both angle checks is governed by the 25SFBK*n* setting. If 25SFBK*n* is set to OFF, then the compensated check is permanently disabled and uncompensated logic provides a basic synchronism check with no checking of slip. In this case, the uncompensated logic could be used to provide basic supervision for an external autosynchronizer, for example.

If 25SFBK*n* is not set to OFF, then the compensated angle check is active when there is slip and uncompensated angle check is active when there is no slip. In some applications, the generator connects to the system via more than two breakers (for example, a generator connected to a ring bus). In these applications, the generator is synchronized via the first breaker using the compensated logic. When closing the second breaker, there will be no slip but there may be a significant standing angle across the breaker. The uncompensated synchronism-check logic can be used to supervise closing of the second breaker. This is often referred to as a parallel close.

Table 5.56 summarizes the prior discussion.

Table 5.56 Uncompensated and Compensated Angle Checks

Angle Checks	25SFBKn := OFF	25SFBKn := 0.005–0.5
Uncompensated	Enabled	Enabled when there is no slip
Compensated	Disabled	Enabled when there is slip

Figure 5.154 shows the uncompensated synchronism-check logic for Breaker *n*. Note that the generator and system must not be slipping, (SFZBK asserted). Note also that the zero-slip requirement can be bypassed if 25SFBK*n* is set to OFF.

The uncompensated angle must remain in the uncompensated angle acceptance window long enough to satisfy the 25AD*n* timer.

This logic runs only if 25ENBK*n* is asserted. Otherwise, the associated Relay Word bits are deasserted.

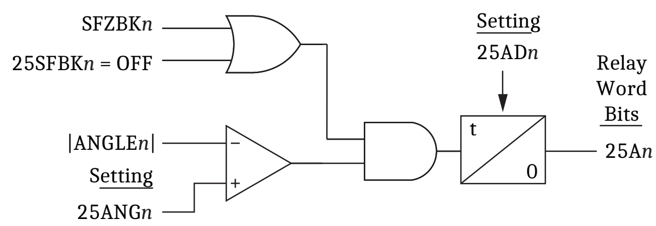


Figure 5.154 Uncompensated Synchronism-Check Logic

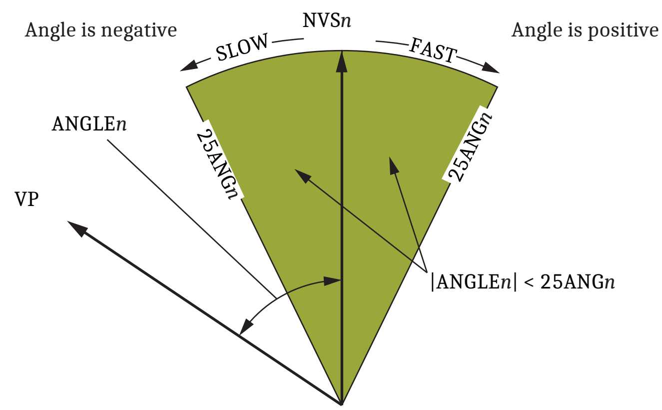


Figure 5.155 Uncompensated Angle Acceptance Window

The compensated angle difference, ANGLEC*n*, accounts for the breaker closing time, TCLSBK*n*, in seconds and is calculated as follows:

ANGLEC*n* = ANGLE + SLIP • TCLSBK*n* • 360

We can define a compensated phasor, V'P as:

V'P = |VP|∠ANGLEC*n*

Figure 5.156 shows the phase relationships. The compensated phasor therefore enters the angle acceptance window in advance of the uncompensated phasor. This allows the logic to send an early close command to the breaker. This ensures that the circuit breaker primary contacts make at zero degrees; thereby minimizing the stress on the generator.

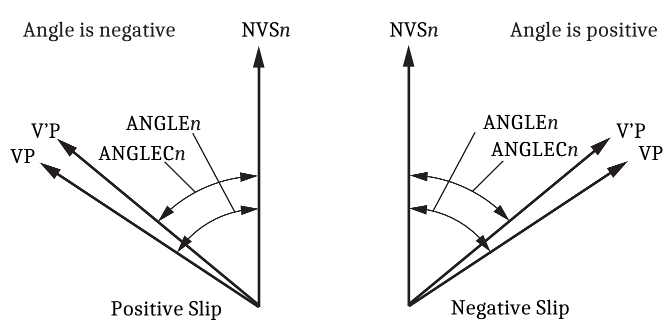


Figure 5.156 Compensated and Uncompensated Phasor Relationships

Figure 5.157 shows the compensated synchronism-check logic for Breaker *n*. The slip must be within the slip acceptance window. The logic creates angle acceptance windows on either side of zero degrees depending on whether the FAST*n* or SLOW*n* Relay Word bits are asserted, as shown in *Figure 5.158*.

This logic runs only if 25ENBK*n* asserts. Otherwise, the associated Relay Word bits are deasserted.

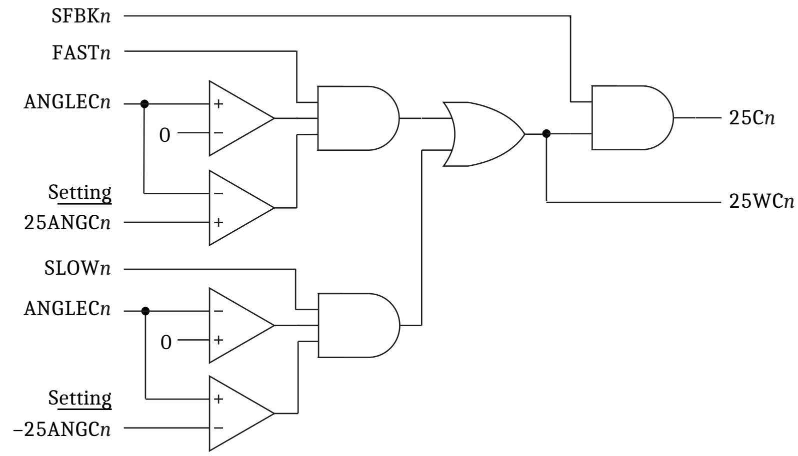


Figure 5.157 Compensated Synchronism-Check Logic

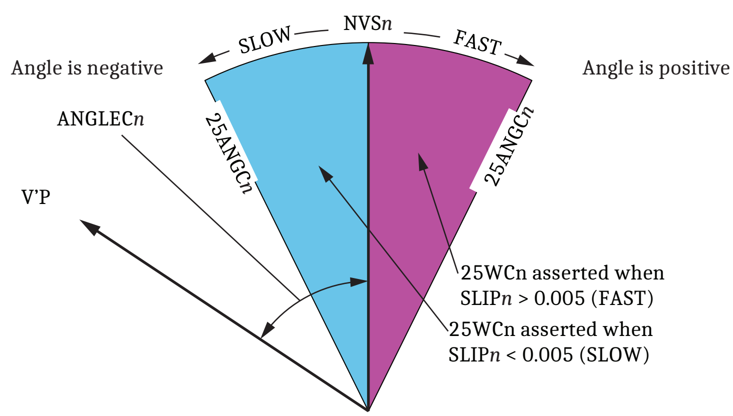


Figure 5.158 Compensated Angle Acceptance Window

Synchronism-Check-Based Breaker Closed Indication

The logic shown in *Figure 5.159* can be used in the breaker failure scheme as an indication that the breaker has not opened. See *Breaker Failure Elements on page 5.175*. The premise for this logic is that when the breaker opens either the voltage difference, slip, or angle difference will move out of its associated window, causing the 25BFSP Relay Word bit to deassert.

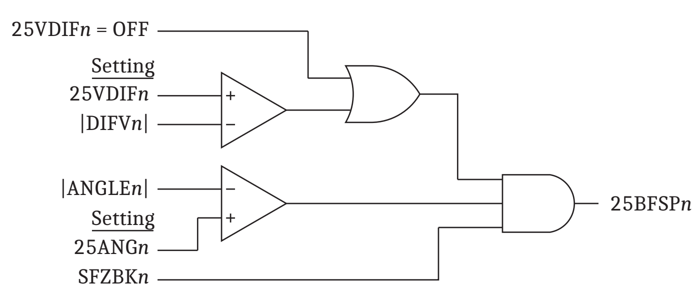


Figure 5.159 Breaker Closed Indication for Breaker Failure

Close Fail Alarm

The logic shown in *Figure 5.160* detects an event where the breaker took an excessive amount of time to close. Such an operation can be damaging both for the breaker and the generator.

This logic runs only if 25ENBK*n* is asserted and CFANG*n* is not set to OFF. Otherwise, the associated Relay Word bit is deasserted.

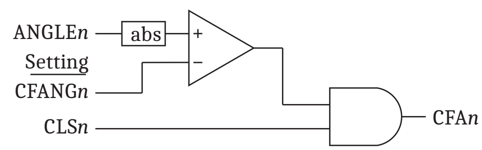


Figure 5.160 Close Fail Angle Alarm

Setting Guidelines

Table 5.57 Synchronism-Check Element Settings

Setting	Prompt	Range	Default	Category
SYNCP	Synch (25) Reference	VAZ, VBZ, VCZ, VABZ, VBCZ, VCAZ	VABZ	Group
SYNCS*n*[a]	Synch Source *n*	VAV,VBV,VCV,VABV,VBCV,VCAV,VV1, VV2, VV3	VV1	Group
KS*n*M[a]	Synch Source *n* Ratio Factor	0.10–3.00	1	Group
KS*n*A[a]	Synch Source *n* Angle Shift	–179.99 to 180	0	Group
25VL*n*[a]	Voltage Window Low Thresh –BK*n*	20.0–200	55	Group
25VH*n*[a]	Voltage Window High Thresh –BK*n*	20.0–200	70	Group
25VDIF*n*[a]	Max. Voltage Difference –BK*n*	OFF, 1.0–15	5	Group
25GVHI*n*[a]	Generator Voltage High Required –BK*n*	Y, N	Y	Group
25SFBK*n*[a]	Maximum Slip Frequency –BK*n*	OFF, 0.005–0.5	0.067	Group
25ANG*n*[a]	Max. Angle Diff. Uncompensated –BK*n*	0.1–80	5	Group
25AD*n*[a]	Uncompensated Angle Delay –BK*n*	0.000–0.6000	0.16	Group
25ANGC*n*[a]	Max. Angle Diff. Compensated –BK*n*	0.1–80	5	Group
TCLSBK*n*[a]	Breaker *n* Close Time	0.010–0.6	0.085	Group
25GFHI*n*[a]	Generator Frequency High Required –BK*n*	Y, N	Y	Group
BSYNBK*n*[a]	Block Synchronism Check –BK*n*	SV	NA	Group
CFANG*n*[a]	Close Failure Angle –BK*n*	OFF, 3.0–120	7	Group

[a] n = S, T, U, or Y.

Synchronism Check (25) Reference (SYNCP)

Select the phase-to-ground or phase-to-phase reference (generator) voltage. If the generator VT is not wye connected, then phase-to-ground voltages will not be available.

Synchronism Source n (SYNCSn)

Select the system voltage to be compared with the generator voltage. This may be a phase-to-ground, phase-to-phase, or single-phase voltage depending on the configuration of the V voltage input. This voltage will normally be in phase with the generator voltage when the breaker is closed.

Synchronism Source n Ratio Factor and Angle Shift (KSnM and KSnA)

Use these settings to account for VT mismatch or VT accuracy errors. These values may be determined during commissioning.

Voltage Window Low and High Threshold (25VLn and 25VHn)

Select the lowest and highest magnitudes in secondary volts for which a synchronized close is permitted.

Maximum Voltage Difference –BKn (25VDIFn)

Select the maximum voltage magnitude difference in percent for which a close is permitted. For instance, the ANSI C50.13 Standard for cylindrical rotor generators over 10 MVA states that generators shall be designed to withstand a 5 percent difference without inspection or repair. Consult with the generator manufacturer for the specific value.

Generator Voltage High Required –BKn (25GVHIn)

Select **Y** if the generator voltage is required to be higher than the system voltage at the instant of closing. This causes the generator to export reactive power and can avoid a dip in voltage after breaker closing.

Generator Frequency High Required –BKn (25GFHIn)

Select **Y** if the generator frequency is required to be higher than the system frequency at the instant of closing. This causes the generator to export real power and can avoid a reverse-power event after breaker closing.

Maximum Slip Frequency –BKn (25SFBKn)

Select the maximum frequency difference in Hz for which a close is permitted. For instance, the ANSI C50.13 standard specifies a maximum difference of ±0.067 Hz. Consult with the generator manufacturer for the specific value.

Max. Angle Difference Uncompensated –BKn (25ANGn)

Enter the maximum angle in degrees for which a close operation is permitted using the uncompensated synchronism-check logic. For instance, the ANSI C50.13 standard specifies a maximum angle of ±10°. The lower the setting, the lower the potential for stress placed on the generator. Consult with the generator manufacturer for the specific value.

Uncompensated Angle Delay –BKn (25ADn)

This setting defines a minimum time wherein the uncompensated angle must remain in the uncompensated angle acceptance window.

Max. Angle Difference Compensated –BKn (25ANGCn)

As illustrated in *Figure 5.157*, the compensated synchronism-check logic accounts for slip and breaker closing time to issue a close command such that the breaker primary contacts make at zero degrees. The close window is extended to account for breaker timing errors. Enter the maximum angle in degrees for which a close operation is permitted. For instance, the ANSI C50.13 standard specifies a maximum angle of ±10°. The lower the setting, the lower the potential for stress placed on the generator. Consult with the generator manufacturer for the specific value.

Breaker n Close Time (TCLSBKn)

Enter the closing time of the breaker in seconds. This is the time from energization of the close coil to making of the primary contacts. This value can be determined from a breaker timing test. The relay uses this value along with the measured slip frequency to determine the compensated angle difference, ANGLEC*n*, as shown in *Figure 5.158*.

Block Synchronism Check –BKn (BSYNBKn)

Define any conditions for which a breaker synchronism check is not permitted. For example, the LOP logic asserts for certain VT wiring errors even though the individual phase-to-phase or phase-to-neutral voltages are normal. Other considerations include a circuit breaker trouble indication. A breaker closed indication has been used previously to deassert the synchronism-check Relay Word bits after the breaker is closed. Do not assign a breaker-closed indication to the BSYNSK*n* input if the 25BFSP*n* logic is also used.

Close Failure Angle –BKn (CFANGn)

A slow close operation results in a significant transient current through the breaker and exposes the generator to a significant transient torque. Check with the manufacturer when selecting an appropriate value for this setting.

Refer to *Synchronism-Check Meter on page 7.16* for command information.

Voltage Selection Examples

Example 1

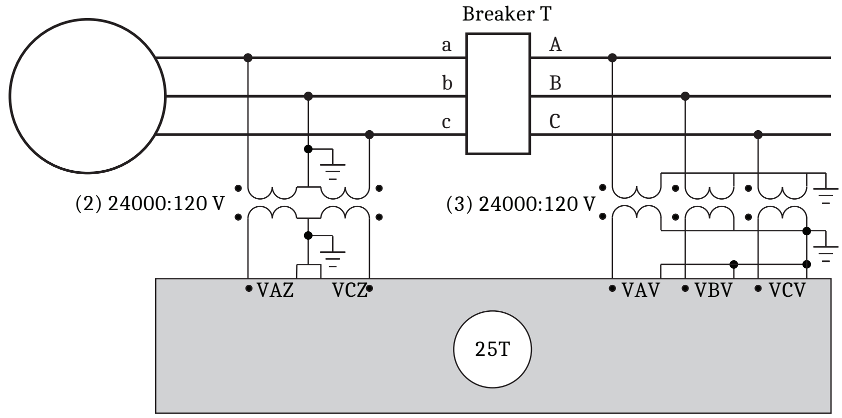


Figure 5.161 Synchronizing Voltage Selection Example 1

The V and Z voltage are configured as follows:

PTCONV = Y

PTCONZ = D

ESYSPT = V to configure the relay to track the frequency of the V voltage input

Use the T synchronism-check element.

Because the generator VT is delta connected, phase-to-ground voltages are not available. Therefore, a phase-to-phase voltage is chosen for the SYNCP setting. (VBCZ or VCAZ would also be appropriate).

SYNCP = VABZ

While in theory, any system phasor could be selected and matched to the generator phasor, SEL recommends that you select the same phasor on both sides of the breaker.

SYNCST = VABV

The sync source ratio factor will be:

KSTM = PTRZ / PTRV = 120 / 120 = 1.00

The sync source angle shift will be:

KSTA = 0.00

These settings may be adjusted to account for any small errors in PT accuracy.

Example 2

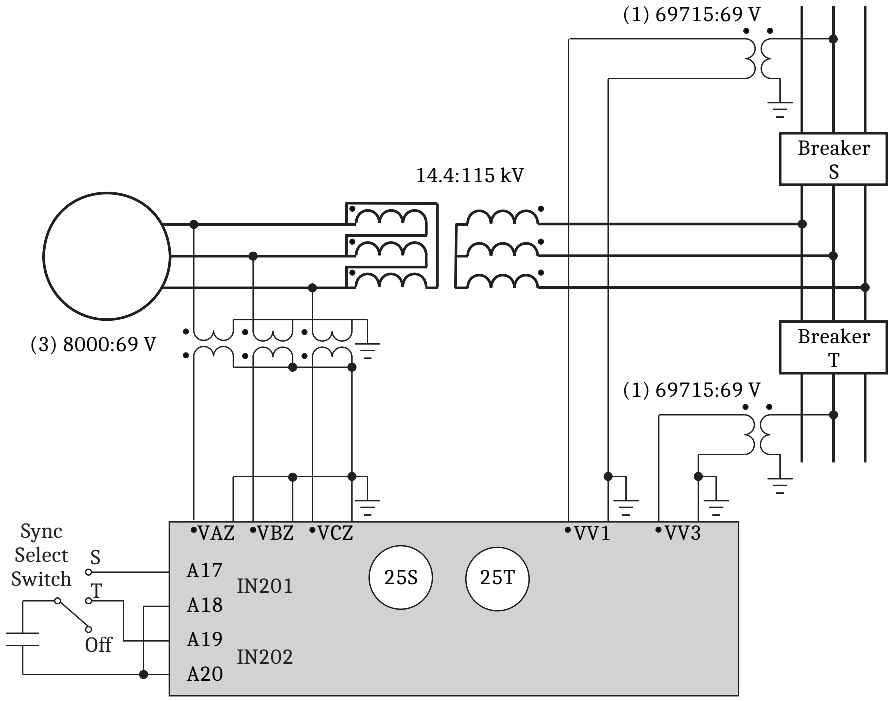


Figure 5.162 Synchronizing Voltage Selection Example 2

The V and Z voltage are configured as follows:

PTCONV = 1PH

PTCONZ = Y

ESYSPT = V1, V3 to configure the relay to track the frequency of either the VV1 or VV3 voltage input

The relay forces the frequency tracking to S (system) on these inputs.

Use the S and T synchronism-check elements:

SYNCSS = VV1

SYNCST = VV3

In *Figure 5.162*, a selector switch is used to enable synchronism check either of the S or the T breakers. The switch contacts are wired to IN201 and IN202. These are assigned to select the VV1 or VV2 input for frequency tracking.

FTSSV1 = IN201

FTSSV3 = IN202

The generator PT is wye-connected so all phase-to-phase and phase-to-ground phasors are available. However, because of the GSU connection, the matching phasor is VBCZ.

SYNCP = VBCZ

Because a phase-to-neutral voltage is compared to a phase-to-phase voltage, the Synch Source Ratio Factor will be:

KSSM = KSTM = 120 / 63.492 = 1.89

Because VBCZ is in phase with VBV, the sync source angle shift will be:

KSSA = KSTA = 0.0

Autosynchronizer

The autosynchronizer (25A) sends raise and lower commands to the governor to reduce the frequency difference (slip) between the generator and system to within an acceptable level. It also sends raise and lower commands to the AVR to reduce the voltage difference between the generator and system to within an acceptable level. Once voltage and frequency are matched, it sends additional raise (dead scope) pulses to the governor to bring the phase angle difference between the generator and system to zero.

A complete scheme is implemented in the SEL-400G using a combination of hard-coded logic and default SELOGIC for the auxiliary logic.

As is the case with the synchronism-check function, there are four instances of the logic (S, T, U, and Y) plus additional common logic. However, only a maximum of three breakers are configurable for autosynchronizing. Also note that the autosynchronizer is meant to synchronize a single generator using one or more breakers, therefore synchronizing can only be active for one breaker at a time.

Enabling the Autosynchronizer

Several signals and settings from the synchronism-check element are used in the autosynchronizer. The percentage voltage difference signal, DIFV*n*, is used for voltage control. Similarly, the slip signal SLIP*n* is used for frequency control. Therefore, before enabling the autosynchronizer, the corresponding synchronism-check element must also be enabled.

Pulse Control Types

The 25A implements several types of pulse control.

Table 5.58 Types of Pulse Control

OFF	Pulse control is disabled
Proportional Width (PW)	The pulse width (W in *Figure 5.163*) is proportional to the error signal (slip or voltage difference) and the pulse period is fixed.
Fixed (FD)	Both the pulse width and pulse frequency are fixed. This control mode may be more suitable for control using certain distributed control systems.
Proportional Frequency (PF)	The pulse width is fixed and the pulse frequency (F in *Figure 5.163*) is proportional to the error signal. Proportional pulse frequency (PPF) may be more suitable in control systems that require a definite minimum pulse width.

Pulse control is enabled using the 25AVMOD and 25AFMOD settings. Because voltage control uses the DIFV*n* signal (where *n* = S, T, U, Y), voltage pulse control cannot be enabled if 25VDIF*n* is set to OFF. Similarly, frequency control uses the SLIP*n* signal, frequency pulse control cannot be enabled if 25SFBK*n* is set to OFF.

The pulse control type for voltage and frequency control can be different.

Figure 5.163 illustrates the three control types.

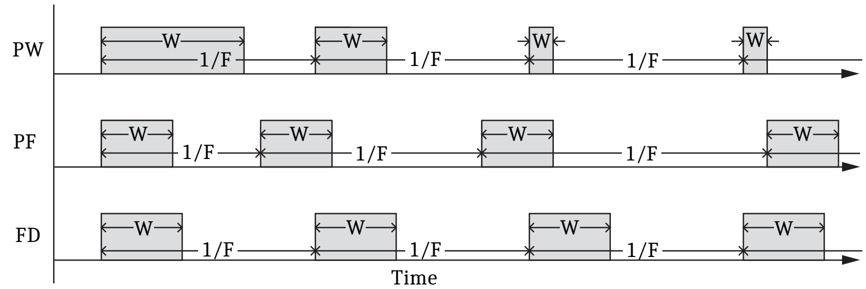


Figure 5.163 Pulse Control Types

Biased Operation

The 25A supports biased operation. Biased frequency control means that the autosynchronizer controls the generator frequency to be greater than the system frequency and the synchronism-check element only allows the breaker to close when the generator frequency is greater than the system frequency. Biased voltage control means that the autosynchronizer controls the generator voltage to be greater than the system voltage and the synchronism-check element only allows the breaker to close when the generator voltage is greater than the system voltage.

The autosynchronizer uses the 25GVHI*n* setting to enable biased voltage control and the 25GFHI*n* setting to enable biased frequency control. This maintains coordination between the autosynchronizer and the synchronism-check elements, ensuring that the autosynchronizer continues to issue control pulses as long as the controlled value (frequency or voltage) remains outside the corresponding synchronism-check acceptance window.

Biased operation can be applied independently to voltage and frequency control.

Refer to *Figure 5.149* and *Figure 5.153* to see the synchronism-check voltage and frequency acceptance windows. Refer to *Figure 5.169* and *Figure 5.170* to see the autosynchronizer operating characteristic.

Start/Cancel Logic

Referring *Figure 5.164*, synchronizing is started for Breaker *n* by asserting the 25AST*n* Relay Word bit. The scheme seals-in until synchronizing is canceled via the 25A*n*CN SELOGIC variable or when the 25ACD timer expires. Note that, when a synchronization operation is active for a particular breaker (as indicated by the 25A*n*ACT Relay Word bit), synchronizing cannot be started for another breaker.

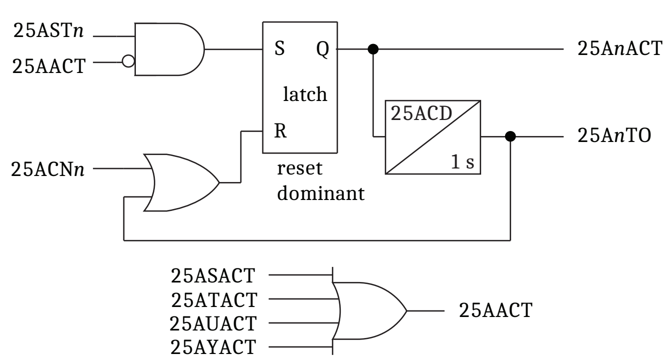


Figure 5.164 Start/Cancel Logic

Voltage Control Logic

Referring to *Figure 5.165*, voltage control is enabled when the 25A*n*ACT Relay Word bit asserts.

The pulse calculations enable the control pulse timer logic, determine the pickup and dropout delays of the timers, and determine if a raise or lower pulse should be issued.

The pulse calculations are active between pulses and frozen during a pulse assertion.

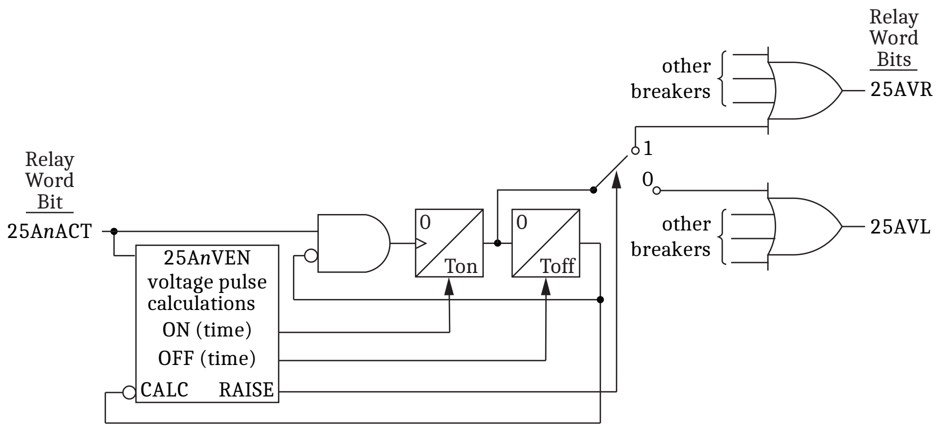


Figure 5.165 Breaker n Voltage Control Logic

Frequency Control Logic

Referring to *Figure 5.166*, frequency control is enabled when the 25A*n*ACT Relay Word bit asserts.

The pulse calculations enable the control pulse timer logic, determine the pickup and dropout delays of the timers, and determine if a raise or lower pulse should be issued.

The pulse calculations are active between pulses and frozen during a pulse assertion.

Dead scope and frequency pulses are mutually exclusive. Dead scope pulses bring the generator and system into synchronism in the case that the frequency becomes matched at an angle greater than the angle setting of the synchronism-check element. This feature is only active for unbiased operation (25GFHI*n* = N) and when the slip is very close to zero. The dead scope pulse control mode is FD.

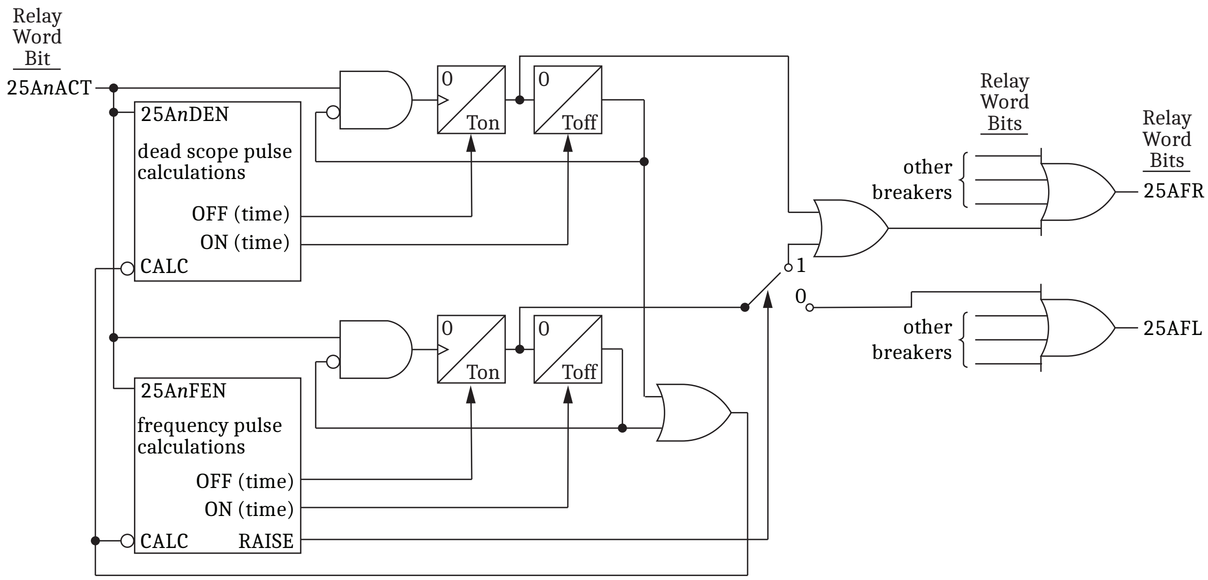


Figure 5.166 Breaker n Frequency Control Logic

Counters that accumulate the number of control pulses for a close operation are implemented as shown in *Figure 5.167*.

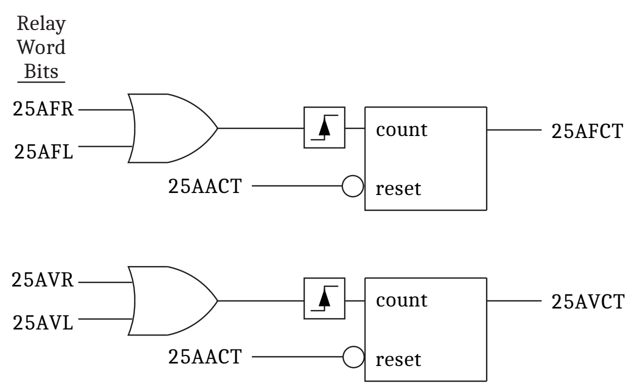


Figure 5.167 Pulse Counter Logic

The autosynchronizer also provides a phase-reversal check. This logic can be used if there are three-phase voltages available on both sides of the circuit breaker wired to the Z and V voltage inputs and PTCONV = Y, D, or D1. It can be used to supervise the synchronism-check element using the BSYNBK*n* SELOGIC variable.

Referring to *Figure 5.168*, the logic checks that both the generator and system voltages have correct phase rotation. The Z and V voltages must have at last 5 volts of positive-sequence voltage and the ratio of negative- to positive-sequence voltage must be less than 5 percent.

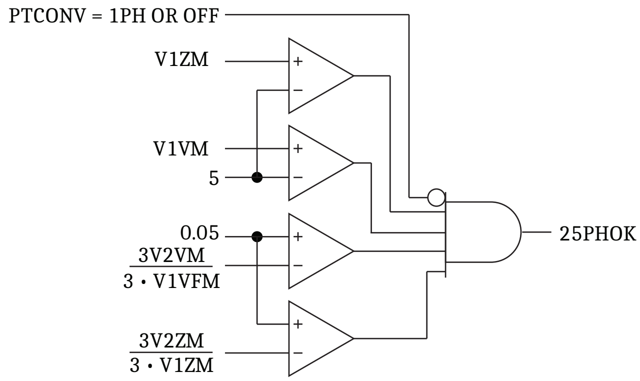


Figure 5.168 Phase Check Logic

Control Pulse Calculations

The general equations for Proportional Width, Proportional Frequency, and Fixed control are:

Proportional Width and Proportional Frequency:

$$Y(X) = (X > MINP) \bullet Slope \bullet (\min(X, MAX) - OFS) + (X < MINN) \bullet Slope \bullet (\max(X, -MAX) - OFS)$$

Equation 5.72

Fixed:

$$Y(X) = Duration \bullet ((X > MINP) - (X < MINN))$$

Equation 5.73

where:

X =	either slip (frequency control) or voltage difference (voltage control)
Slope =	the value of 25AFSLP (frequency control) or 25AVSLP (voltage control)
MINP, MINN, OFS, and MAX	are derived from the Slope and Win parameters
min and max =	the minimum and maximum functions
Y =	the pulse width for PPW and the pulse frequency for PPF.

The sign of Y determines if the pulse is a raise (negative) or a lower (positive). Note that for biased operation, raise pulses can still be generated while X is positive. Win takes the value of SLIP*n* (frequency control) or 25VDIF*n* (voltage control).

For unbiased operation:

- MINP = 0.8 • Win
- MINN = –0.8 • Win
- OFS = Win/2
- MAX = 4 • Win

For biased operation:

- MINP = 0.8 • Win
- MINN = 0.2 • Win
- OFS = 0
- MAX = 4 • Win

The correction deadband includes a 20 percent margin inside the slip allowed band to reduce the possibility of the generator frequency remaining right at the edge of the slip allowed band. *Figure 5.169* shows a plot of (1) for a slope setting of 0.5 and a Win of 0.067.

Frequency control is unbiased when 25GFHI*n* = N. This is the case when the associated synchronism-check element is configured to allow a close when the generator frequency is higher OR lower than the system frequency. Frequency control is biased when 25GFHI*n* = Y. This is the case when the associated synchronism-check element is configured to allow a close only when the generator frequency is higher than the system frequency.

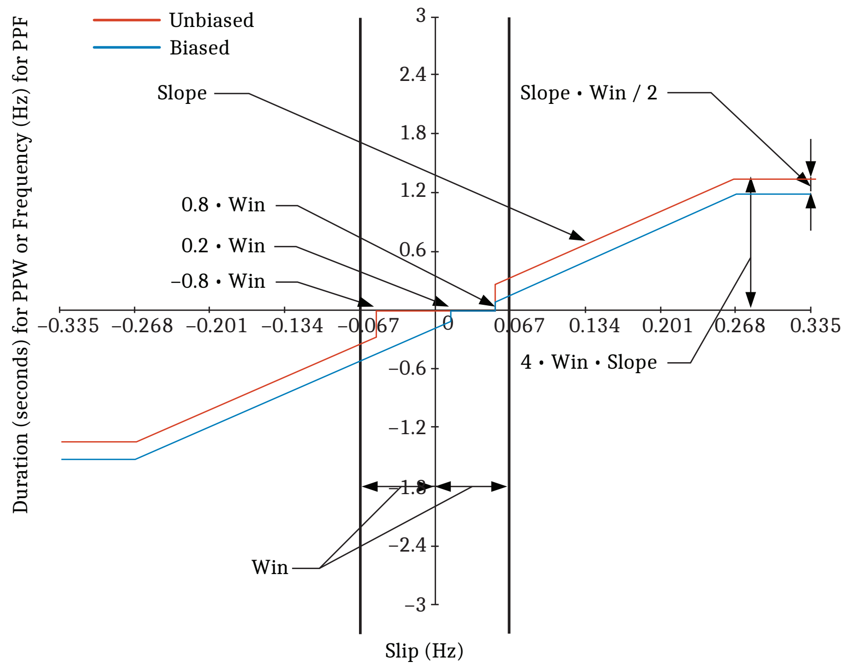


Figure 5.169 Frequency Control Characteristic for Slope = 5 and Win = 0.067

Voltage control is unbiased when 25GVHI*n* = N. This is the case when the associated synchronism-check element is configured to allow a close when the generator voltage is higher OR lower than the system voltage. Voltage control is biased when 25GVHI*n* = Y. This is the case when the associated synchronism-check element is configured to allow a close only when the generator voltage is higher than the system frequency.

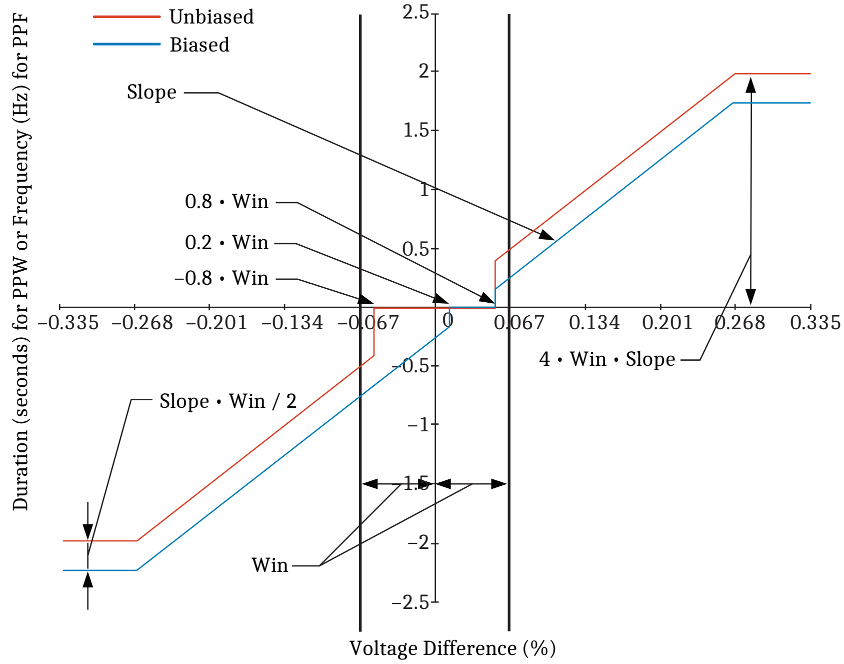


Figure 5.170 Voltage Control Characteristic for Slope = 1 and Win = 5

Synchronizing Event Capture

Use the SEL-400G event report to capture synchronizing events. The event report can capture waveforms as long as 12 seconds in length and can capture the instantaneous voltage waveforms, as well as voltage magnitudes, angles, frequency and Relay Word bits. The disturbance report can capture waveforms as long as 300 seconds and can capture voltage magnitudes, angles, frequency, and Relay Word bits.

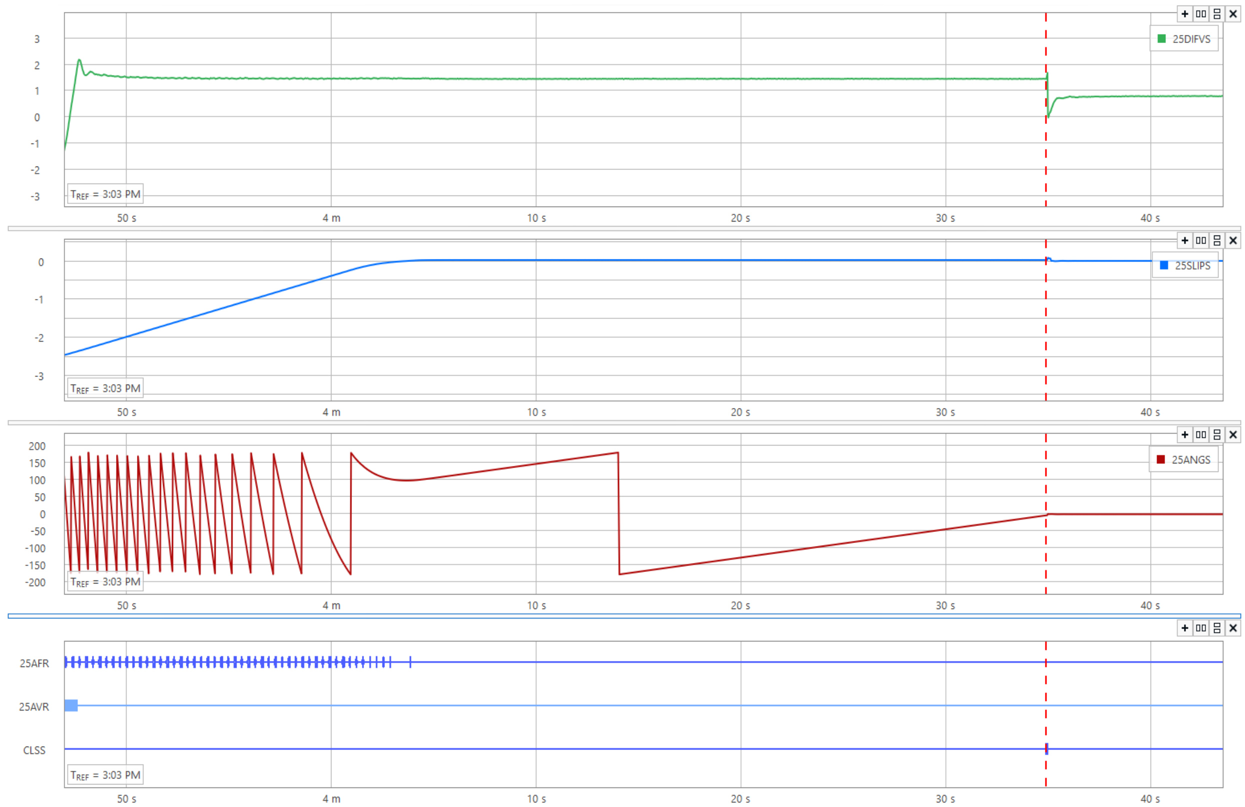


Figure 5.171 Close Test

Setting Guidelines

Table 5.59 Autosynchronizer Settings

Setting	Prompt	Range	Default	Category
25AST*n*[a]	Start Auto-Sync. Check –BK*n*	SELOGIC	NA	Group
25ACN*n*[a]	Cancel Auto-Sync. Check –BK*n*	SELOGIC	BSYNBK*n* OR 52CL*n*	Group
25ACD	25A Control Expiration Delay	0.000–400 s	30	Group
25AVMOD	25A Voltage Control Pulse Mode	OFF, PW, FD, PF	OFF	Group
25AVSLP	25A Voltage Control Slope (V/s)	0.01–100	1	Group
25AVPER	25A Voltage Control Pulse Period (0.000–60 s)	0.000–60	10	Group
25AVDUR	25A Voltage Control Pulse Duration (0.000–60 s)	0.000–60	2	Group
25AFMOD	25A Frequency Control Pulse Mode (OFF, PW, FD, PF)	OFF, PW, FD, PF	OFF	Group
25AFSLP	25A Frequency Control Slope (Hz/s)	0.01–100	1	Group
25AFPER	25A Frequency Control Pulse Period (0.000–60 s)	0.000–60	10	Group
25AFDUR	25A Frequency Control Pulse Duration (0.000–60 s)	0.000–60	2	Group

[a] n = S, T, U, Y.

Start Auto-Sync. Check -BKn (25ASTn)

Select an input to initiate a synchronization. This may be a pushbutton or a digital control system (DCS) signal. This signal will typically be ANDed with additional inputs that are required to supervise breaker closing.

Cancel Auto-Sync. Check -BKn (25ACNn)

Select an input to cancel a synchronization. This can be a pushbutton or a DCS signal. A cancel should also be issued when the associated synchronism-check function is blocked. This can be implemented by ORing the cancel input with BSYNBK*n*.

Autosynchronizer Time-out Delay (25ACD)

The 25ACD setting determines the duration for which the autosynchronizer remains active. Set this timer longer than the expected time for a successful autosynchronization operation. This value varies depending on the characteristics of the specific generator and control system.

Voltage and Frequency Control Pulse Modes (25AVMOD, 25AFMOD)

The settings 25AVMOD and 25AFMOD enable pulse control and determine whether proportional width, proportional frequency, or fixed pulse control is used. These settings also control which settings are used to define the control pulse characteristics, as illustrated in *Table 5.60*.

Table 5.60 Autosynchronizer Active Settings for Each Pulse Control Mode

Mode/Setting	PW	FD	PF
25AFDUR, 25AVDUR	Not used	Used	Used
25AFPER, 25AVPER	Used	Used	Not used
25AFSLP, 25AVSLP	Used	Not used	Used

Control Pulse Characteristics (25AFDUR, 25AVDUR, 25AFPER, 25AVPER, 25AFSLP, 25AVSLP)

The following commissioning guidelines describe a method for the settings using a step response test. In *Figure 5.172*, a raise-frequency control pulse is sent to the governor of a machine. The response is captured. The gain of the system is:

$$K = \frac{\Delta Y}{\Delta X} = \frac{0.5\ \text{Hz}}{0.5\ \text{s}} = 1$$

The system time constant, T is the time required to reach 63.2 percent of the steady-state which, in this example, is 4 seconds.

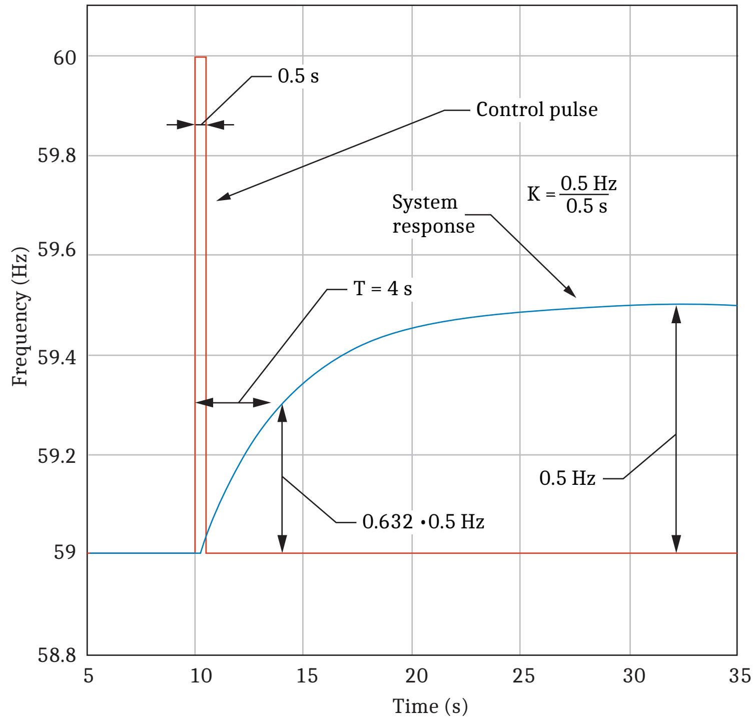


Figure 5.172 Step Response Test

The following guidelines provide settings that allow matching in a relatively short time without hunting. Note that these guidelines do not consider the details of the control system, so it is important to complete a synchronization test to check overall system operation and to fine-tune the response.

In *Table 5.61*, K and T are determined from *Figure 5.172* and Win is the voltage difference window for voltage control or slip window for speed control.

Table 5.61 Autosynchonizer Pulse Control Setting Guidelines

Mode/Setting	PPW	PPF
25AFDUR, 25AVDUR	NA	Win/(2 • K) (sec)
25AFPER, 25AVPER	T/2 (sec)	NA
25AFSLP, 25AVSLP	1/(6 • K) (sec/Hz)	2/(3 • T • Win) (Hz/Hz)

External Wiring

Figure 5.173 shows the associated wiring for Breaker S.

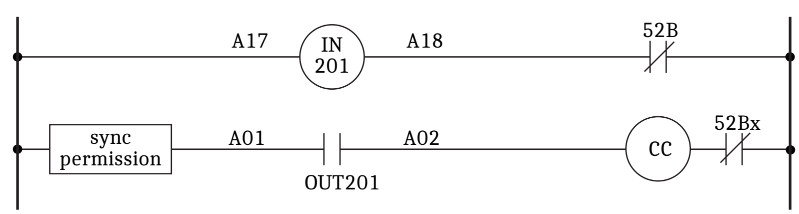


Figure 5.173 Breaker S External Circuit Wiring Example

Loss-of-Potential Element

The LOP element detects a loss of voltage potential to the relay. The logic is designed to distinguish between a valid LOP and other events such as a fault or a normal shutdown of the generator. In this section, the index *k* refers to the voltage input terminal (V or Z). The index *m* refers to the current terminal (S, T, U, Y, G) identified in the setting LOPIS*k*.

The LOP element can be used in the large majority of applications with its default settings. However, the element includes features that allow it to be modified for challenging applications. These include a torque-control SELOGIC control equation and configurable output logic.

Voltage-Current Scheme

The voltage-current scheme uses the voltage and current to detect an LOP condition.

Figure 5.174 implements a current-based disturbance detector. The logic measures the change in positive-sequence and negative-sequence current. Current disturbance (LOPDI*k*) is declared when over a period of 20 ms, the positive-sequence current was and remains higher than the minimum threshold (5 percent of nominal current), there has been a change in positive-sequence current magnitude that is greater than 2 percent of nominal current, and a positive-sequence current angle change greater than 5 degrees has occurred. Further, the logic also declares current disturbance detection if, over a period of 20 ms, the negative-sequence current magnitude has changed more than 2 percent of nominal current.

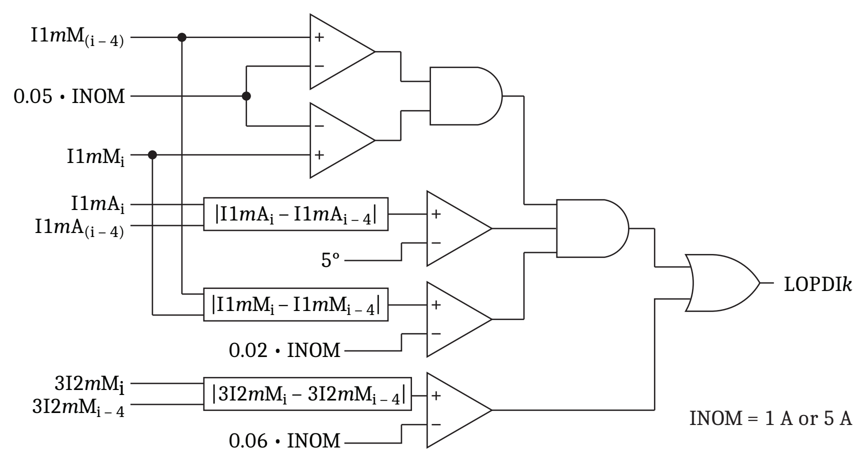


Figure 5.174 Current Disturbance Detector

The logic of *Figure 5.175* checks for an incremental drop in the positive-sequence voltage magnitude. The LOPVR*k* setting determines this increment. It has a default value of 0.90. Using this value, the upper comparator checks that the voltage has dropped by 10 percent over a period of 20 ms. A voltage change because of a valid LOP will be practically instantaneous. On the other hand, the voltage drop during a normal generator shut down will be much more gradual. The lower comparator checks that the initial voltage was greater than 1 V.

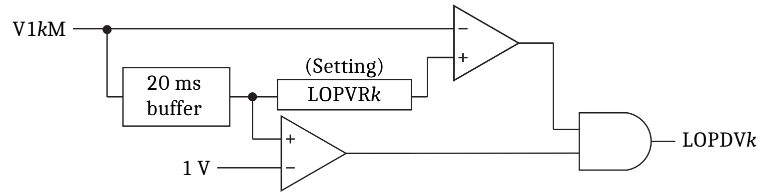


Figure 5.175 Positive-Sequence Voltage Change Detector

Figure 5.176 shows the incremental voltage-current logic. If the positive-sequence voltage change detector asserts without a coincident current disturbance, the LOPI*k* Relay Word bit asserts and seals in. Any subsequent current disturbance would break the seal-in. Therefore, once LOP is declared, the current disturbance path is blocked. A check is made that the positive-sequence voltage is healthy and there is relatively little negative-sequence voltage. This check asserts LOPRS*k* which acts to break the seal-in.

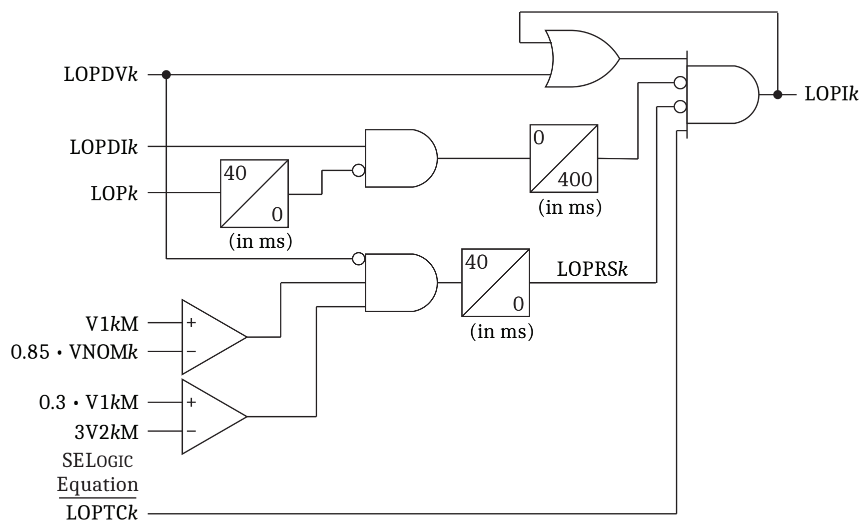


Figure 5.176 Incremental Voltage-Current Detection Logic

The incremental voltage-current logic cannot detect the case where the generator is energized with no voltages connected to the relay. This can happen if fuses are removed during a shutdown and are not replaced. The three-phase undervoltage logic, shown in *Figure 5.177*, can be used to detect this condition.

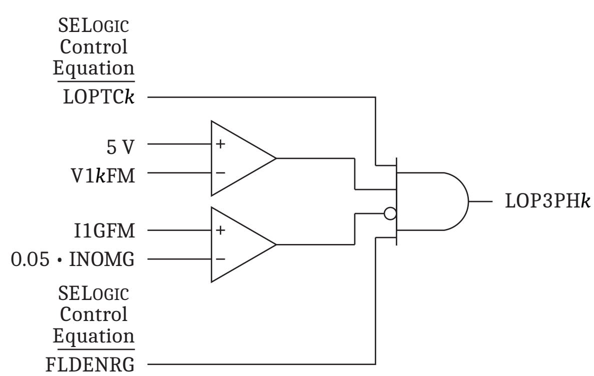


Figure 5.177 Three-Phase Undervoltage Logic

The three-phase undervoltage logic is intended to operate when the generator field is known to be energized (via the FLDENRG setting) but virtually no voltage is measured at the terminals. One option for setting FLDENRG is to use an indication that the field breaker is closed (52Fa). This signal must be wired to the relay. A second option is to use the magnitude of the third-harmonic voltage measured at the generator neutral as shown in *Figure 5.178*. EGNPT must be configured to monitor the generator neutral voltage. Check the third-harmonic voltage level while the generator is energized and offline to determine the value for comparison. Asserting the FLDENRG signal may need to be delayed using a SELOGIC timer to avoid a spurious LOP assertion when the field is applied. This depends on the method used to derive the signal. For example, a 52aF contact likely asserts before the stator voltage exceeds the 5 V threshold in *Figure 5.177*.

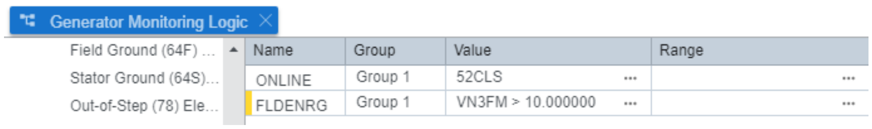


Figure 5.178 Using Third-Harmonic Neutral Voltage to Indicate That the Field Is Energized

The negative-sequence logic, shown in *Figure 5.179*, checks for a significant negative-sequence voltage (greater than 15 percent of V1) without a coincident negative-sequence current. The logic also checks that there is virtually no generator neutral voltage. The check (in the dashed box) is bypassed if there is no neutral voltage measurement (EGNPT = OFF) or for the V element when ESYSPT = V.

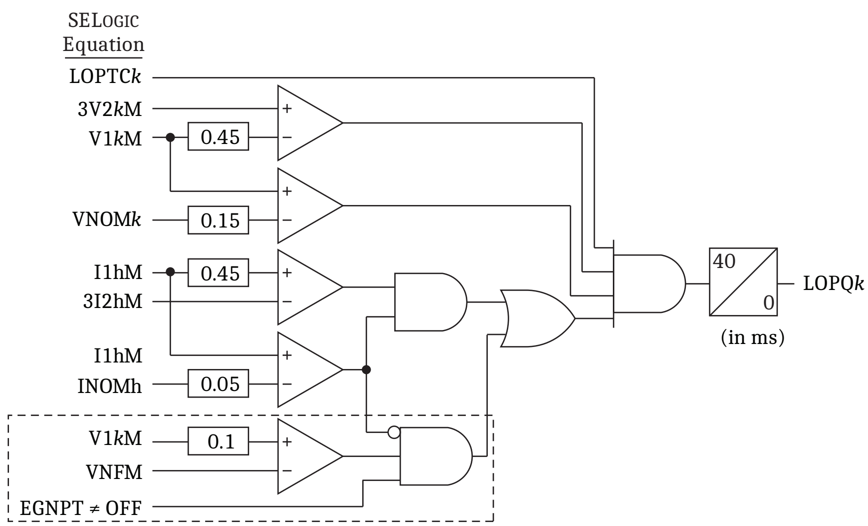


Figure 5.179 Negative-Sequence Logic

The SEL-400G also provides a voltage balance LOP scheme, as shown in *Figure 5.180*. This scheme checks for a small difference between the V and Z positive-sequence voltages to detect an LOP. This scheme can operate over a wide voltage range, making it more suitable for a generator that is started with its field applied (for example a combustion gas turbine). On the other hand, this scheme requires that the V and Z inputs be wired to two different VTs at the generator terminals or to two different windings on the same VT. If this scheme is used, the V input cannot be configured as 1PH.

A loss of potential is expected to result in a reduction in positive-sequence voltage on the faulty VT. The logic uses this principle to declare which VT has a problem.

The 60LVR setting accounts for small ratio errors between the two VTs. The 60LVP setting determines the sensitivity of the element. The function is disabled when the pickup is set to off.

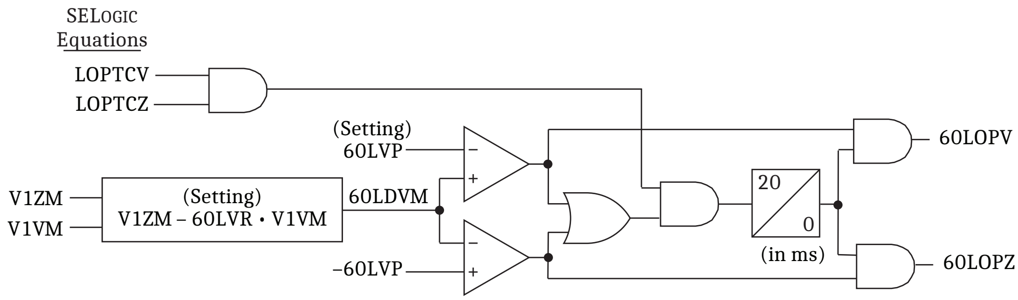


Figure 5.180 Voltage-Balance Logic

Configurable Output Logic

Assertion of the SET input (LOPS*k*) immediately asserts the output. If the SET time delay (LOPSD*k*) expires, the output is latched. Assertion of the RESET input (LOPS*k*) until the reset timer (LOPR*k*) resets the latch and deasserts the output. *Figure 5.181* shows the output logic.

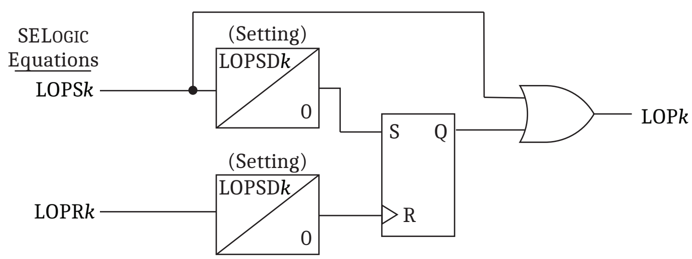


Figure 5.181 Voltage-Current LOP Settings

Setting Guidelines

Table 5.62 Loss-of-Potential Settings

Setting	Prompt	Range	Default	Category
ELOP	Enable Loss of Potential	OFF or combo of V, Z	Z	Group
LOPIS*k*[a]	LOP *k* Current Source	S, T, U, Y, G	G	Group
LOPTC*k*[a]	LOP *k* Torque Control (SELOGIC Eqn)	SV	1	Group
LOPVR*k*[a]	LOP *k* Incremental Voltage Ratio	OFF, 0.50–0.98	0.9	Group
LOPS*k*[a]	LOP *k* Set	SV	(LOPIk OR LOPQ*k* OR 60LOP*k* OR LOP3PH*k*) AND (NOT LOPR*k*)	Group
LOPSD*k*[a]	LOP *k* Set Delay	0.000–1	0.3	Group
LOPR*k*[a]	LOP *k* Reset	SV	LOPRS*k*	Group
LOPRD*k*[a]	LOP *k* Reset Delay (0.000–1 s)	0.000–1	0.5	Group

[a] k = V, Z.

Enable Loss of Potential

LOP should be enabled for a voltage terminal if the input is used for protection and the protection function is at risk of misoperation for a loss of potential. Examples of an at-risk protection function is voltage restrained overcurrent.

LOP Current Source

The LOPIS*k* setting determines which current will be used by the scheme. This current must be physically associated with the monitored voltage. In other words, a disturbance that produces a change in the monitored voltage should also produce a change in the selected current. In most instances, the default setting (generator current) can be used.

LOP Torque Control

The default setting of 1 is adequate in the large majority of applications. This input can be used to block LOP in special circumstances such as during dynamic braking. Another example is the case of a VT on the system-side of a generator breaker as shown in *Figure 5.182*. In this example, both LOP elements are configured to use the voltage-current scheme. LOPV asserts for a fault when Breaker U is open. To prevent this, the element can be torque-controlled using breaker-closed status.

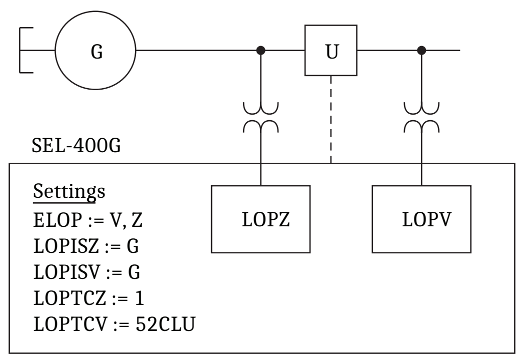


Figure 5.182 VT on the System-Side of Generator Breaker

LOP Incremental Voltage Ratio

This setting defines the sensitivity of the incremental voltage-current detection logic. A higher setting results in a more sensitive setting. However, an overly sensitive setting could result in spurious LOP assertions. A setting of OFF disables the incremental logic.

LOP Set

This setting defines the conditions which assert the LOP output. The default assignment ORs the output Relay Word bits for the incremental voltage-current logic, the negative-sequence logic and the voltage-balance logic. The SELOGIC control equation allows conditions to be added or removed. For example, the auxiliary contact from a mini-circuit breaker.

LOP Set Delay

This setting defines how long an LOP must be asserted before it is latched.

LOP Reset

This setting defines the conditions which reset the LOP output after latching. The default assignment uses the LOPRS*k* setting, which checks that there is a significant positive-sequence voltage and relatively little negative-sequence voltage. A reset signal could also be derived from a pushbutton.

LOP Reset Delay

This setting defines how long the reset signal must be asserted before the output latch is reset. For example, if the latch is reset from a pushbutton, this value should be set to zero.

Open-Phase Detection Logic

Subsidence current results from energy trapped in a CT magnetizing branch after a circuit breaker opens to clear a fault or interrupt load. This current exponentially decays and delays the resetting of instantaneous overcurrent elements used for breaker failure protection. Breaker failure protection requires fast open-phase detection to ensure fast resetting of instantaneous overcurrent elements. *Figure 5.183* shows open-phase logic that asserts SEL-400G open-phase detection elements OPH*pm* (*p* = A, B, C; *m* = S, T, U, Y) in less than one cycle, even during subsidence current conditions.

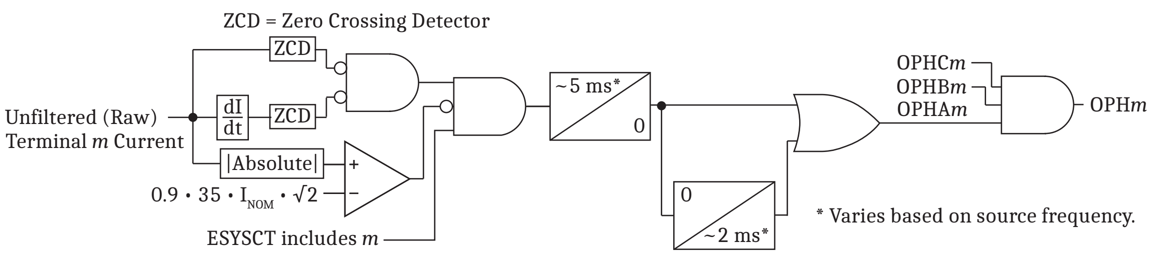


Figure 5.183 A-Phase Open-Phase Detection Logic

The relay declares an open phase when the logic does not detect a zero crossing or current value within a fraction of a power system cycle since the previous measurement. OPH*m*, the output of the logic, asserts when all three phases of a particular winding assert.

Breaker Failure Elements

The SEL-400G contains four standard breaker failure elements, one for each of the S, T, U, and Y current terminals. Use the EBFL Group setting to enable the appropriate terminals necessary for your particular application. *Figure 5.184* and *Figure 5.186* show the breaker failure logic. In *Figure 5.184*, three comparators test the three-phase currents against the 50FPU*n* settings and one comparator tests the neutral current against the INFPU*n* setting. SELOGIC setting ENINBF*n* allows the neutral breaker failure function to be conditional if system unbalance conditions could cause inadvertent initiation of the neutral element, such as what might occur in single-pole tripping systems. When any phase current exceeds the 50FPU*n* setting or the neutral current exceeds the INFPU*n* setting, the appropriate Relay Word bit asserts (IA*n*BF, IB*n*BF, IC*n*BF, and/or IN*n*BF). Each phase current comparator is supervised by the associated open-phase detectors OPHp*n* (*p* = A, B, C; *n* = S, T, U, Y). The neutral current comparator is supervised by the all three poles open detector (OPH*n*).

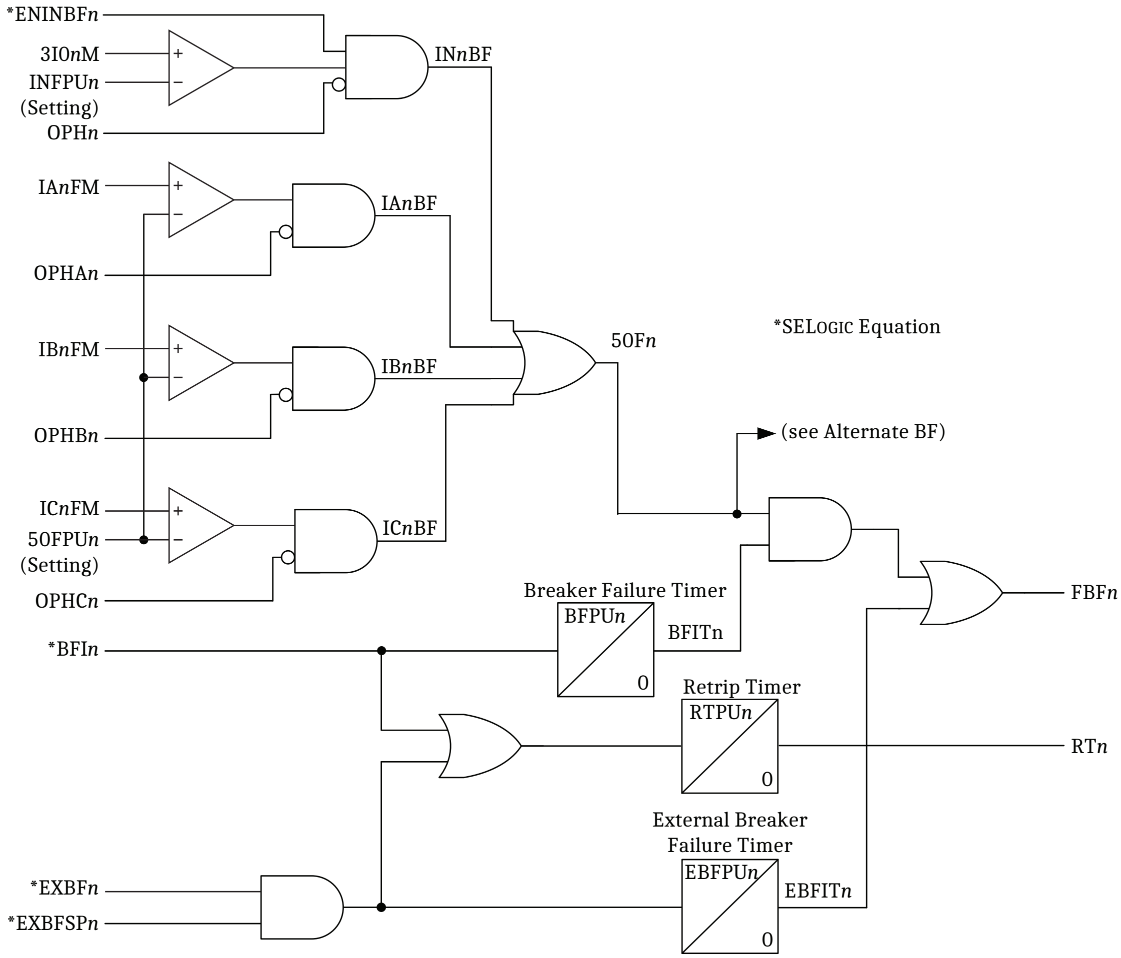
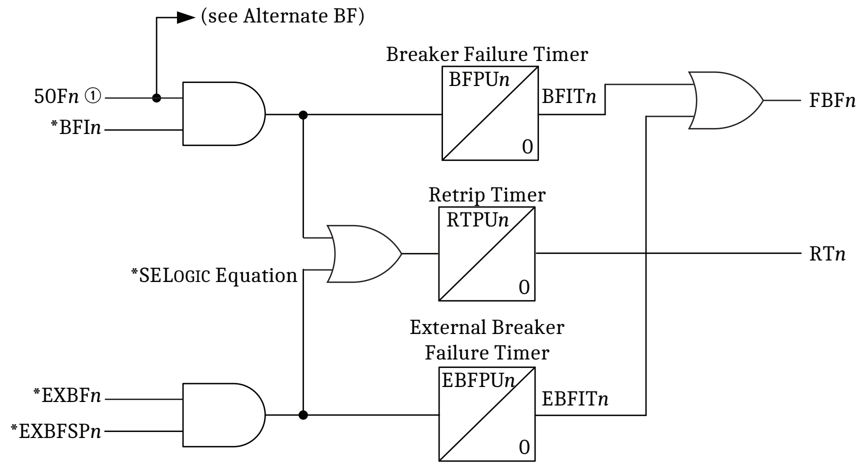


Figure 5.184 Breaker Failure Logic for Breaker n When BF_SCHM = Y

Input BFI*n* is a SELOGIC control equation that provides the breaker failure initiate signal. When BFI*n* asserts, both the breaker failure timer and the re-trip timer start timing. When the re-trip timer expires, RT*n* asserts, and when the breaker failure timer expires, BFIT*n* asserts. If 50F*n* is asserted when BFIT*n* asserts, the breaker failure output, FBF*n*, asserts. Note that BFI*n* must be present for the entire duration of the breaker failure timer setting. If BFI*n* is not present constantly, the timers reset when BFI*n* falls away (see alternate initiate logic in *Figure 5.186*).



① From Figure 5.184.

Figure 5.185 Breaker Failure Logic for Breaker n when BF_SCHM = Y1

The logic shown in *Figure 5.185* is enabled when the breaker failure scheme setting is set to Y1 (BF_SCHM = Y1). The logic enabled with option Y1 is similar to that shown in *Figure 5.184*, but the current check (50F*n*) is now part of the breaker failure initiate timer (BFPU*n*) and retrip time delay (RTPU*n*).

The logic includes a path for the case when breaker failure initiates from a protection function that can operate for events with little or no associated current (when there is no current supervision), such as for a generator sequential trip or for a Buchholz relay operation on an unloaded transformer. Because a Buchholz assertion can be present even after the breakers are open, to increase security a non/low-current supervision, EXBFSP*n* is provided.

This path is controlled via the ANDed output of the EXBF*n* and EXBFSP*n* control equations. The logic is the same for both BF_SCHM = Y and BF_SCHM = Y1. Configuration of this path is described in *Generator Breaker Failure and Breaker Current Considerations on page 5.177*.

Generator Breaker Failure and Breaker Current Considerations

An incorrect breaker-failure operation can have serious consequences. In a generator protection application, such an event can lead to the loss of adjacent generators and/or transmission lines. Therefore, it is useful to analyze the breaker failure logic in terms of security and dependability.

Current Detector Supervision

An incorrect breaker failure operation can occur if the breaker opens but still appears closed. In the past, current detectors were known to remain picked up in the presence of subsidence currents and protection engineers needed to account for this possibility. In the SEL-400G, the open-phase detectors provide sub-cycle resetting of the current detectors, even when subsidence current is present. This makes current detection the most secure indication that the breaker is still closed.

The SEL-400G is equipped with overcurrent detectors on each phase and an additional current detector that responds to the zero-sequence (3I0) component of the breaker current.

Dependable operation for an actual breaker failure requires that the pickup of the current detectors be set less than the minimum expected current through the breaker for a fault seen by any of the protection elements assigned to BFI*n* (or ATBFI*n* if this logic is used).

A secondary consideration is to set the current detectors so that they are not permanently picked up under normal operation. For the phase current detectors, this would entail setting the pickup greater than the maximum expected load current and for the unbalanced current detector to set the pickup greater than the maximum expected zero-sequence current.

There are a variety of generator abnormal conditions for which the relay provides protection but that do not result in significant breaker current during the event. For instance, a ground fault on a high-impedance-grounded machine produces virtually no increase in the breaker current. Another example is sequential tripping, which is often employed as part of a normal generator shutdown. During a sequential trip, the prime mover is tripped first and the opening of the generator breaker is delayed until a reverse power condition is confirmed. The current drawn by the machine prior to breaker opening can be very low. If the breaker fails to open, the unit can suffer damage while motoring. In transformer applications, the Buchholz can operate when the transformer is unloaded.

Sometimes there is insufficient current for current detectors in a generator breaker failure application. Furthermore some initiating signals such as the Buchholz relay can be present even after the breakers are open. Therefore, these schemes require an additional indication that the breaker is still closed.

The SEL-400G provides a non-current-supervised initiate path via the EXBF*n* input. Protection functions that do not produce significant fault current should be assigned to this input. This path is supervised by the EXBFSP*n* control equation. The logic is the same for both BF_SCHM = Y and BF_SCHM = Y1. The SEL-400G provides two methods to provide this supervision. Configuration of this path is described in *Breaker-Closed Supervision on page 5.178*.

Breaker-Closed Supervision

A breaker-closed auxiliary contact is often used to supervise the EXBF*n* path. If each pole of the breaker has its own operating mechanism, a breaker-closed indication from each pole should be paralleled to provide reliable indication in the case of a single stuck pole.

A breaker auxiliary contact is not completely reliable. One of the more common failures is an open connection in the control wiring between the contact and the relay. In this case, the relay receives a permanent indication that the breaker is open. A subsequent protection operation will not lead to an incorrect breaker failure operation, but the scheme will also not operate for an actual stuck breaker.

The following equations show individual protection functions supervised by the breaker-closed indication to form the non-current-supervised initiate for Breaker S. In this example, the protection functions that do not produce significant fault current are V/Hz, reverse power, frequency, and stator ground. This list may differ depending on the application.

EXBFIS := 24D1T1 OR 32T01 OR 81D1T OR 64GT

EXBFSPS := 52CLS

Because it is possible that there can be a failure of the breaker indication, the relay includes breaker status logic (see *Circuit Breaker Monitor on page 7.18*). This logic is the source of the 52CL*n* Relay Word bit shown here. The logic also provides an alarm for an incorrect breaker status using breaker-closed (52a) and breaker-opened (52b) contacts as well as a current-based open-phase indication. The alarm output 52AL*n* asserts if the 52a and 52b disagree. It also operates if they do agree but disagree with the open-phase indication. Monitoring the 52AL*n* alarm and promptly addressing the cause of problem can reduce the possibility of a loss of availability of the breaker failure function.

Synchronism-Check Supervision

A breaker failure may involve a failure of the mechanism to move the contacts apart sufficiently to interrupt the current, while the mechanism that drives the auxiliary contacts moves normally. In this case, the breaker failure to open would go undetected by the breaker failure scheme, leaving the generator vulnerable to motoring. Conversely, if the mechanism fails to open the breaker auxiliary contact correctly, a false breaker-closed can be indicated, resulting in an unnecessary backup trip even though the main contacts have successfully interrupted the current.

In applications where a synchronism-check element has been applied to the generator breaker, the 25BFSP*n* Relay Word bit is provided as an alternative to the breaker-closed auxiliary contact (see *Synchronism-Check-Based Breaker Closed Indication on page 5.154*). The premise for this logic is that when the breaker opens, the generator and system will not remain in exact synchronism. The voltage magnitude difference, or slip or the angle difference, moves out of its respective acceptance window and the 25BFSP*n* Relay Word bit deasserts. On the other hand, if the breaker remains closed, the 25BFSP*n* Relay Word bit remains asserted. The following equations show this signal supervising the V/Hz, reverse power, frequency, and stator ground functions to form the non-current-supervised initiate for Breaker S.

EXBFIS := 24D1T1 OR 32T01 OR 81D1T OR 64GT

EXBFSPS := 25BFSPS

The logic shown in *Figure 5.185* is enabled when the breaker failure scheme setting is set to Y1 (BF_SCHM = Y1). The logic enabled with option Y1 is similar to that shown in Figure 5.172, but the current check (50F*n*) is now part of the breaker failure initiate timer (BFPU*n*) and retrip time delay (RTPU*n*).

For a detailed discussion of this topic, see the technical paper *New Voltage-Based Breaker Failure Scheme for Generators*, by Michael Thompson and Dale Finney, at selinc.com.

Alternate Breaker Failure Initiate Logic

Figure 5.186 shows an alternate breaker failure initiate logic. This logic is applied when the protection philosophy dictates that both current and breaker-failure initiate signals may not be coincident. Referring to *Figure 5.186*, the alternate breaker failure logic creates a time window following the reset of a breaker failure initiate (ATBFI*n*). If the current detector asserts during this time window, the breaker failure operation will still occur.

To use the alternate initiate logic, connect the breaker failure initiate signal to ATBFI*n* (instead of to BFI*n* in *Figure 5.184*). Then connect the output of the alternate initiate logic (ABFIT*n*) to BFI*n* (*Figure 5.184*).

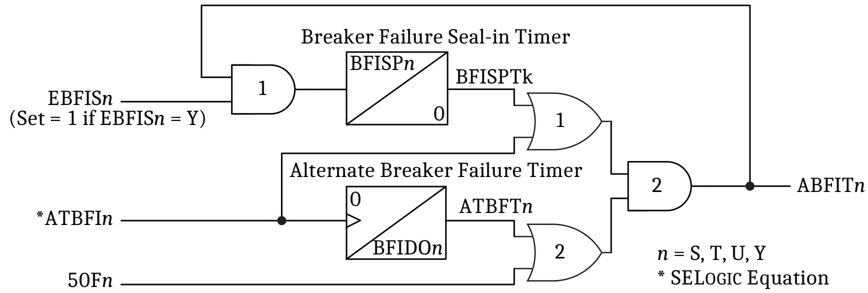


Figure 5.186 Alternate Breaker Failure Logic for Terminal k

The timers in this logic accommodate possible intermittent behavior of either the breaker failure initiate signal or the current detector signal, as described in the following sections.

1. Substitution of the current detector signal using the BFIDO*n* timer

   Use this option in dual-breaker applications when current is not immediately present. This can happen in a dual-breaker application, as shown in *Figure 5.187*. In this scenario, Breaker T has failed but most of the fault current is initially flowing through Breaker S. Once Breaker S opens, the fault current is redistributed through Breaker T. The dropout timer (BFIDO*n*) is used to prevent a delayed breaker failure operation under this scenario (because of insufficient current through Breaker T). Set the dropout time longer than the expected operate time of Breaker S. On the rising edge of ATBFI*n*, the lower input of AND Gate 2 is asserted for the duration of BFIDO*k*. After time-out, the current detector takes over this roll.

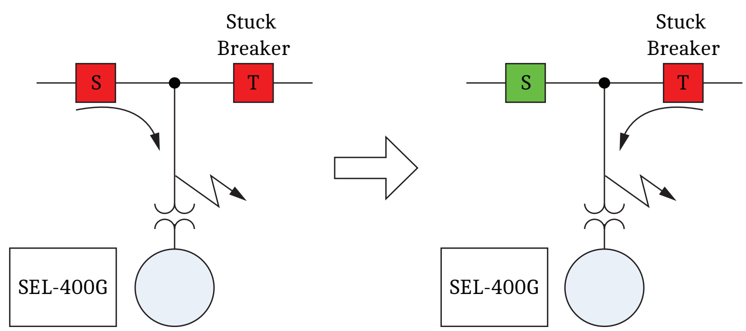


Figure 5.187 Current Redistribution in a Dual-Breaker Configuration

2. Seal-in of the breaker-failure initiation signal

   Use this option when it is possible for the breaker-failure-initiate signal to reset prior to time-out of the breaker failure timer (BFPU*n*). The logic requires that both the breaker-failure initiate and current detector signals are initially present for period longer than the breaker failure seal-in (BFISP*n*) time delay. Once this timer expires, the scheme seals-in until the current detector resets. To use this option, set EBFIS*n* to Y. It is important to set BFISP*n* long enough to avoid seal-in from any possible spurious protection assertion.

Breaker Failure Setting Guidelines

Table 5.63 Breaker Failure Settings

Setting	Prompt	Range	Default	Category
EBFL	Enable Breaker Fail Prot.	OFF or combo of S, T, U, Y	OFF	Group
BF_SCHM	Breaker Failure Scheme,	Y, Y1	Y	Group
BFI*n*[a]	Breaker Fail Initiate—BKR *n*	SELOGIC control equation	NA	Group
EXBF*n*[a]	Enable External Breaker Fail – BKR *n*	SELOGIC control equation	NA	Group
EXBFSP*n*[a]	External Bkr Fail Superv – BKR *n*	SELOGIC control equation	NA	Group
EBFPU*n*[a]	Ext. Brkr Fail Init PU Delay *n*	0.0000 to 100 s	0.1	Group
50FPU*n*[a]	Fault Current Pickup—BKR *n*	0.50 to 50 s	10	Group
BFPU*n*[a]	Brkr Fail Init Pickup Delay BKR *n*	0.0000 to 100 s	0.1	Group
RTPU*n*[a]	Retrip Delay—BKR *n*	0.0000 to 100 s	0.05	Group
ENINBF*n*[a]	Enable Neutral Breaker Failure—BKR *n*	SELOGIC control equation	NA	Group
INFPU*n*[a]	Neutral Current Pickup—BKR *n*	0.50 to 50 s	0.5	Group

[a] n = S, T, U, Y.

EBFL (Enable Breaker Fail)

Set EBFL to enable breaker failure protection for the specific terminals in your application. Breaker failure can only be enabled for breakers included in the ESYSCT setting.

BF_SCHM

This setting determines whether the current check occurs before or after the Breaker Failure Timer expires. Refer to *Figure 5.184* and *Figure 5.185* and the associated text.

BFIn (Breaker Fail Initiate)

Use the BFI*n* setting (SELOGIC control equation) to specify conditions under which the breaker failure initiate input must be active. These will be protection functions associated with faults that produce a significant current through the breaker. These Relay Word bits must be ORed.

50FPUn (Fault Current Pickup)

The setting 50FPU*n* is the current pickup setting in amperes secondary for the breaker failure overcurrent element of each enabled terminal. The setting must be set less than the minimum current expected through the breaker for a fault seen by any of the protection elements assigned to BFI*n*.

BFPUn (Breaker Failure Initiation Pickup Delay)

For each enabled terminal, select a time in seconds that you want the breaker failure timer to wait before asserting a breaker failure trip. This needs to be long enough to allow the breaker to open and the current detectors to reset but short enough to isolate a failed breaker before the power system becomes unstable. Not that the current detectors can reset in less than a cycle even in the presence of a subsidence component.

RTPUn (Retrip Delay)

Select a time in seconds that you want the retrip timer to wait before asserting. This delay can normally be set to zero.

EXBFn (Enable External Breaker Fail)

Use the EXBF*nk* setting (SELOGIC control equation) to specify conditions under which the breaker failure initiate input must be active. These will be protection functions associated with faults that do not produce a significant current through the breaker, such as V/Hz for a generator or a Buchholz relay indication on an unloaded transformer. These Relay Word bits must be ORed.

EXBFSPn (External Breaker Failure Supervision –BKR n)

Select a signal that indicates that the breaker is still closed. This is typically either the 52CL*n* or 25BFSP*n* Relay Word bit.

EBFPUn (External Breaker Failure Initiation Pickup)

Select a time in seconds that you want the external breaker failure element to wait before asserting. This must be long enough to allow the breaker to open and the supervising signal (breaker position or sync-check) to indicate that the breaker is open. Note that because there is no significant fault current associated with this path, power system stability is less of a concern. Consequently, this delay can safely be set longer than the BFPU*n* delay.

ENINBFn (Enable Neutral Breaker Fail)

Use the ENINBF*n* setting (SELOGIC control equation) to specify conditions under which the neutral breaker input must be active. There is a setting for each of the enabled terminals. If you set ENINBF*n* = 1, the input is asserted permanently.

INFPUn (Neutral Current Pickup)

INFPU*n* is the current pickup setting in secondary amperes for the neutral breaker failure overcurrent element of each enabled terminal. The setting must be set below the minimum current expected through the breaker for a fault seen by any of the protection elements assigned to BFI*n* or (ATBFI*n* when using the alternate breaker failure initiate logic.

Alternate Breaker Failure Initiate Setting Guidelines

Table 5.64 Alternate Breaker Failure Settings (Sheet 1 of 2)

Setting	Prompt	Range	Default	Category
ATBFI*n*	Alt Breaker Fail Initiate—BKR *n*	SELOGIC control equation	NA	Group
EBFIS*n*	Breaker Fail Initiate Seal-In—BKR *n*	Y, N	N	Group

Table 5.64 Alternate Breaker Failure Settings (Sheet 2 of 2)

Setting	Prompt	Range	Default	Category
BFISP*n*	Brkr Fail Init Seal-In Delay—BKR*n*	0.0000 to 20 s	0.05	Group
BFIDO*n*	Brkr Fail Init Dropout Delay—BKR*n*	0.0000 to 20 s	0.025	Group

Use the alternate breaker failure initiate logic in situations where breaker failure protection philosophy requires a simultaneous assertion of the breaker failure initiate and current detector signals. When using this logic, be sure to set BFI*n* (*Figure 5.184*) to ABFIT*n*.

ATBFIn (Alternate Breaker Fail Initiate)

Use the ATBFI*n* setting (SELOGIC control equation) to specify conditions under which the breaker failure initiate input must be active. These will be protection functions associated with faults that produce a significant current through the breaker. These Relay Word bits must be ORed.

EBFISn (Breaker Fail Initiate Seal-In)

Use the seal-in logic when it is possible for the breaker failure initiate signal (ATBFI*n*) to reset before a breaker failure operation can occur. Enable the breaker failure seal-in timer circuit by setting EBFIS*n* = Y (see *Breaker Failure Setting Guidelines on page 5.181*).

BFISPn (Breaker Fail Initiate Seal-In Delay)

Select a time in seconds that you want the breaker failure seal-in timer to wait before asserting (see *Breaker Failure Setting Guidelines on page 5.181*). This setting should be long enough to avoid seal-in for a spurious assertion of ATFBFI*n*.

BFIDOn (Alternate Breaker Failure Timer)

Select a time in seconds that you want the alternate breaker failure timer to wait before asserting (see *Alternate Breaker Failure Initiate Setting Guidelines on page 5.182*). Use this timer to avoid a delayed breaker failure operation in cases where the current detector may not assert immediately.

Breaker Flashover Elements

A breaker flashover can occur just prior to closing of a breaker or just after opening of a breaker. During this period, the voltage across the open contacts can be in the range of two per-unit. The SEL-400G provides a breaker flashover element for each breaker.

Two schemes are provided, as shown in *Figure 5.188*. Either scheme can be selected using the EFOBF*n* setting. If the breaker is located on the high-voltage side of the GSU, both schemes can detect a flashover of one or two phases or a flashover involving ground.

If EFOBF*n* = G, the scheme consists of a zero-sequence current detector supervised by breaker-open indication 52B_*n* (see *Figure 5.80*). This scheme is highly tolerant of incorrect breaker status, but cannot detect a three-phase flashover.

If EFOBF*n* = P, the scheme employs current detectors for each phase. This scheme can detect a three-phase flashover, but could be at greater risk of misoperation because of an incorrect breaker status, because the phase current detectors are likely to be continuously picked up when the breaker is closed. Therefore, the logic opens a 5-cycle (at 60 Hz) window on the appearance of current. If the breaker status indicates open during this period, the logic declares breaker flashover. During a normal breaker closing, these conditions may be briefly satisfied, therefore the logic must be supervised by a breaker close command indication via BLKFO*n*. This signal is extended for a period longer than the time expected for breaker closing.

If the breaker is located on the low-voltage side of the GSU, a single-phase flashover or a flashover involving ground will be detected by ground fault protection schemes. These events will be cleared via breaker failure if the ground fault protection initiates breaker failure by using the low current (EXBF) initiate path, as shown in *Figure 5.184*, or by ground fault protection (3V0) associated with the IPB.

A breaker flashover is a breaker failure and should therefore trip the same power system elements as required by the breaker failure scheme.

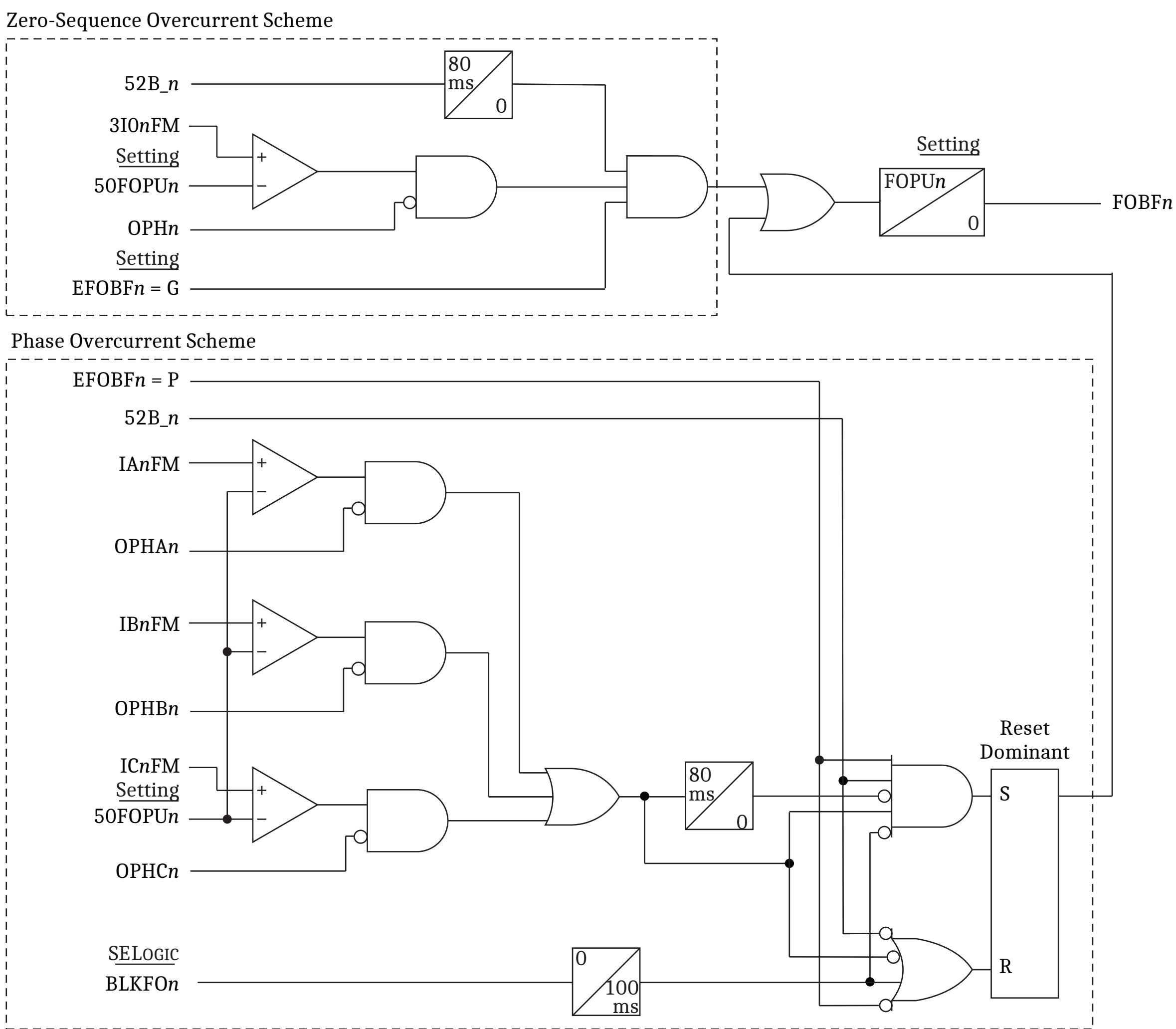


Figure 5.188 Breaker Flashover Logic

Setting Guidelines

Table 5.65 Breaker Flashover Elements Settings

Setting	Prompt	Range	Default	Category
EFOBF*n*	Enable Flash Over –BKR *n*	P, G	P	Group
50FOPU*n*	Flash Over Current PU –BKR *n*	0.50–50 A, sec	10	Group
FOPU*n*	Flash Over Init PU Delay –BKR *n*	0.0000–100 s	0.1	Group
BLKFO*n*	Block Flash Over –BKR *n*	SV	NA	Group

EFOBFn (Enable Flash Over –BKR n)

Use this setting to enable either scheme. The per-phase scheme provides more comprehensive protection but also requires an additional blocking input.

50FOPUn (Flash Over Current PU –BKR n)

Set the pickup low enough to detect a flashover condition. The expected current is expected to have a high maximum value but varies as the machine moves in and out of synchronism with the system. For the zero-sequence scheme, this value should also be greater than the maximum expected zero-sequence current during normal operation.

FOPUn (Flash Over Init PU Delay –BKR n)

Set the delay longer than the normal breaker closing time plus margin.

BLKFOn (Block Flash Over –BKR n)

Choose a signal that indicates that a command has been issued to close the breaker.

Over- and Underfrequency Elements

Use the relay frequency elements for such abnormal frequency protection as underfrequency load shedding.

Figure 5.189 shows the logic for the six levels of over- and underfrequency elements in the relay.

The frequency input to each element is given by the selection setting, 81O*n* (*n* = 1–6), which can be set to either generator (FREQPG) or system (FREQPS) frequency.

Each frequency element can operate as an overfrequency or as an underfrequency element, depending on its pickup setting. If the element pickup setting (81D*n*P, *n* = 1–6) is less than the nominal system frequency setting, NFREQ, the element operates as an underfrequency element, picking up if measured frequency is less than the set point. If the pickup setting is greater than NFREQ, the element operates as an overfrequency element, picking up if measured frequency is greater than the set point. Each element can be enabled or disabled individually using the torque-control setting (81D*n*TC), which can be set to a SELOGIC control equation.

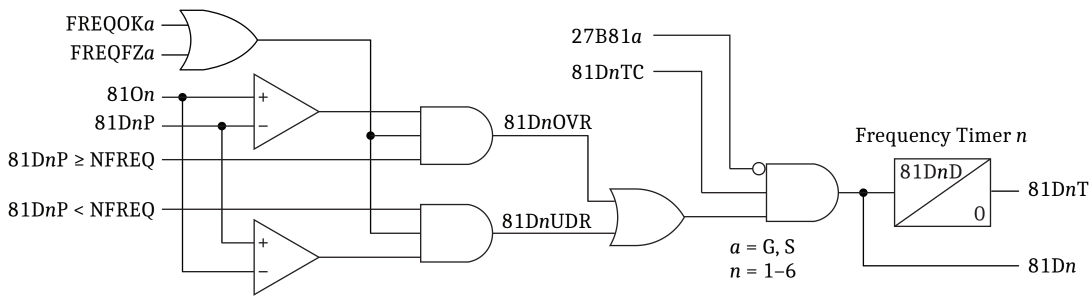


Figure 5.189 Frequency Element Logic

Note that Relay Word bit 27B81*a* controls all frequency elements associated with the same frequency tracking source, i.e., 27B81G controls the frequency elements that are associated with FREQPG and 27B81S controls the frequency elements that are associated with FREQPS. This undervoltage supervision control prevents erroneous frequency element operations during system faults.

Over- and Underfrequency Element Settings

Table 5.66 Over- and Underfrequency Element Settings

Setting	Prompt	Range	Default	Category
E81	Enable Frequency Elements	N, 1–6	2	Group
81UVSP	81 Element U/V Supervision	OFF, 20.00–200	85	Group
81O*n*[a]	81 O/U Element *n* Operating Quantity	FREQPG, FREQPS	FREQPG	Group
81D*n*P[a]	81 O/U Element *n* Pickup	5.01–119.99	61	Group
81D*n*D[a]	81 O/U Element *n* Time Delay	0.050–400.000	2	Group
81D*n*TC[a]	81 O/U Element *n* Torque Control	SELOGIC control equation	1	Group

[a] n = 1–6.

E81 (Enable 81 Elements)

Set E81 to enable as many as six over- and underfrequency elements. When E81 = N, the relay disables the frequency elements and hides corresponding settings; you do not need to enter these hidden settings.

81UVSP (81 Element Undervoltage Supervision)

This setting applies to all six frequency elements. If the instantaneous value of the tracking voltage associated with Element *n* falls lower than the 81UVSP setting, all frequency elements associated with the tracking source are disabled.

81On (Level n Operating Quantity)

Select the frequency source that is used as the operating quantity for Element *n*. This can be set to FREQPG (for generator frequency) or FREQPS (for system frequency).

81DnTC (Level n Torque Control)

Set 81D*n*TC to a SELOGIC conditional statement that will disable Element *n* when false.

81DnP (Level n Pickup)

Set the value at which you want the frequency element for each of six levels to assert. For a value of 81D*n*P less than the nominal system frequency NFREQ (50 or 60 Hz), the element operates as an underfrequency element. For a value greater than NFREQ, the element operates as an overfrequency element. Note that *n* can be one of six levels, 1–6.

81DnD (Level n Time Delay)

Select a time in seconds that you want frequency elements to wait before asserting.

Accumulated Frequency Element

In steam and combustion turbine applications, system operation at other than the design speed can excite mechanical vibrations in the turbine. This vibration can cause cumulative metal fatigue in turbine blades that can lead to premature and catastrophic turbine failure. To detect and protect against such an occurrence, the SEL-400G relay records the total time of operation of the generator at off-nominal frequencies in as many as eight frequency bands. This function satisfies the requirements of IEEE C37.106-2003, *Guide for Abnormal Frequency Protection for Power Generating Plants*.

If the frequency is within a time accumulator band, the relay asserts an alarm bit and starts the 81AD timer. If the frequency remains within the band for greater than 81AD seconds, the relay begins to accumulate time for that band (81AB*n*S, *n* = 1–8). If the total time of operation within a band exceeds the limit setting for that particular band (81A*n*D), the relay asserts a Relay Word bit (81AB*n*T), which you can use for alarm and/or trip as necessary.

The SEL-400G gives the user an option to set the band pickup limits individually, or as a conventional continuous set of bands (i.e., lower setting of one band becomes the upper setting of the next band). This selection is made using the E81ABD setting.

Each band can be used in either of two ways depending on the 81A*n*D setting:

> **81A*n*D = OFF:** The band does not assert an output but the accumulator is active and can be monitored. It can accumulate to a maximum of 10000 days ($8.64 \bullet 10^8$ seconds), at which point it is clamped until reset.
>
> **81A*n*D NOT = OFF:** The band asserts an output when the accumulator reaches the delay setting. The element can be set in the range of 0.5–6000 seconds.

Figure 5.190 shows the logic for eight levels of 81A accumulated frequency bands. The accumulator values are nonvolatile and are retained through relay power-off cycles. You can use the relay serial port **81A** command to view, reset or preload the accumulator values.

All frequency accumulated band elements are disabled if any one of the following conditions are true:

- ➤ No accumulated frequency element is selected (E81A = N)
- ➤ The frequency is out of permissible limits (5–120 Hz)
- ➤ Rate-of-change of frequency more than 30 Hz/s

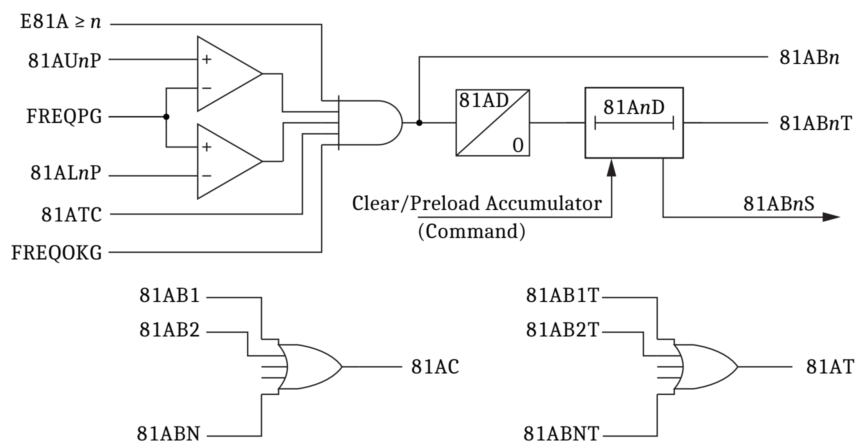


Figure 5.190 Accumulated Frequency Element Logic

Setting Guidelines

Table 5.67 Accumulated Frequency Element Settings

Setting	Prompt	Range	Default	Category
E81A	Enable Accumulated Freq Elements	N, 1 to 8	N	Group
E81ABD	81A Enable Conventional Frequency Band	Y, N	N	Group
81AD	81AC Element PU Time delay	0.000–400	0.2	Group
81ATC	81AC Element Torque Control	SELOGIC control equation	1	Group
81AU*n*P[a]	81AC Ele. Band *n* Upper Limit PU	5.01–119.99[b]	59.5	Group
81AL*n*P[a]	81AC Ele. Band *n* Lower Limit PU	5.01–119.99[c]	58.8	Group
81A*n*D[a]	81AC Ele. Band *n* Time Limit PU	OFF, 0.5–6000[d]	3000	Group

[a] n = 1–8.
[b] Default value is for Band 1; 58.8, 58.0, 57.5, 57, 56.5, 56, 55 are the default values for Bands 2–8 when enabled.
[c] Default value is for Band 1; 58.0, 57.5, 57, 56.5, 56, 55, 40 are the default values for Bands 2–8 when enabled.
[d] Default value is for Band 1; 540.0, 100.0, 14.0, 2.5, 1.0, 0.5, 0.5 are the default values for Bands 2–8 when enabled.

E81A (Enable 81A Elements)

Set E81A to enable as many as eight accumulated frequency band elements. When E81A = N, the relay disables the accumulated frequency elements and hides corresponding settings; you do not need to enter these hidden settings.

E81ABD (Enable Conventional Frequency Band)

Set E81ABD to set the enabled bands in a seamless manner. When E81ABD = N, the relay enables the user to set the upper limit and lower limit for all the accumulated frequency band. When E81ABD = Y, the lower limit of Band 1 becomes the upper limit of Band 2 and so on until the last enabled band; the upper limit settings are hidden for all bands except for the first band.

81AD (Pickup Time Delay)

Set a time (in seconds) that you want the accumulated frequency elements to wait for starting the accumulation. This setting is common for all enabled bands.

81ATC (Accumulated Frequency Torque Control)

Use the torque-control setting to specify conditions under which the accumulated frequency elements must be active. There is only one setting for all the enabled accumulated frequency bands. With the default setting 1, all bands are active unless changed.

81AUnP (Accumulated Frequency Band n Upper Limit)

Select the value (in Hz) that you want to be the upper limit of pickup for the accumulated frequency Band *n* for each of the enabled bands as high as 8 bands. These values are hidden and forced to 81AL(*n* – 1)P except for first band when E81ABD = Y.

81AUnP (Accumulated Frequency Band n Lower Limit)

Select the value (in Hz) that you want to be the lower limit of pickup for the accumulated frequency Band *n* for each of the enabled bands as high as 8 bands.

81AnD (Accumulated Frequency Band n Time Delay)

When the frequency is within the upper limit and lower limit for an accumulated frequency element Band *n*, the accumulator starts accumulating time. Set the delay (in seconds) for which the timer must run before the 81A*n*D setting asserts the output.

Accumulated Frequency Elements Settings Calculation

Consult the turbine manufacturer abnormal operation frequency protection information before calculating the setting. Turbine manufacturers can provide documentation showing the turbine operating time limitations during abnormal frequency. This documentation should show continuous operation at nominal frequency, an area of restricted operation, and an area of prohibited operation. Define the accumulator frequency bands and assign times to those bands that prevent the generator from operating in the restricted area. *Figure 5.191* shows an example with settings shown. You can also monitor how much time the turbine operated in the continuous operating range by setting 81A*n*D to OFF (Band 1 in *Figure 5.191*).

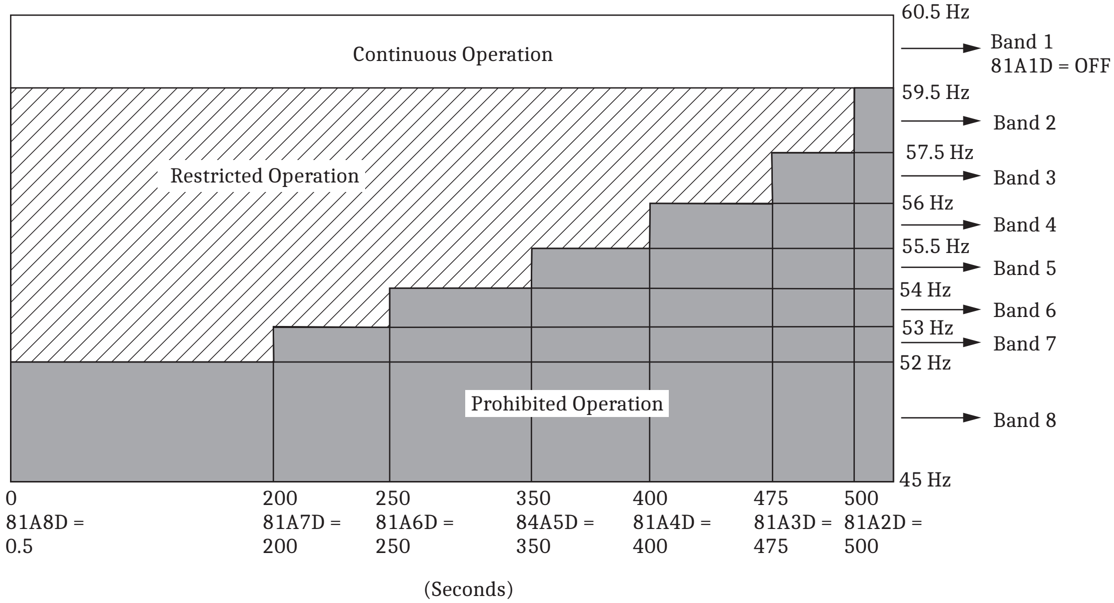


Figure 5.191 Example Turbine Operating Limitations During Abnormal Frequency With 81A Settings

81A Command

Use the **81A** command to display the accumulated frequency element reports of the equipment monitored by the relay. When used with the P parameter, **81A** enables you to preload the values for accumulated bands. The format a particular band input should be dddd:hh:mm:ss.s with a resolution of 0.5 seconds. The maximum input that you can give is 0000:01:39:59.5 when 81A*n*D != OFF (*n* = 1–8), 9999:23:59:59.5 otherwise. **81A R** or **C** can be used to clear the accumulated time data for all accumulated frequency bands, and when used with parameter *n* (**81A *n* R** or **C**) clears the accumulated data for that particular Band *n*. *Figure 5.192* shows the 81A command report with all eight bands enabled.

```
=>>81A <Enter>

Relay 1                                    Date: 02/28/2020  Time: 12:45:35.986
Station A                                  Serial Number: 1234

Frequency Band Accumulated Time Data
#                                           Acc. Time         Percentage
                                          (dddd:hh:mm:ss.s)       (%)
Frequency Band 1 from   60.50 to 59.50     0014:16:12:18.5   81A1D = OFF
Frequency Band 2 from   59.50 to 57.50     0000:00:00:13.5     2.70 of 500.0
Frequency Band 3 from   57.50 to 56.00     0000:00:00:05.5     1.16 of 475.0
Frequency Band 4 from   56.00 to 55.50     0000:00:00:03.5     0.88 of 400.0
Frequency Band 5 from   55.50 to 54.00     0000:00:00:01.0     0.29 of 350.0
Frequency Band 6 from   54.00 to 53.00     0000:00:00:03.5     1.40 of 250.0
Frequency Band 7 from   53.00 to 52.00     0000:00:00:01.5     0.75 of 200.0
Frequency Band 8 from   52.00 to 45.00     0000:00:00:00.0     0.00 of 0.5
```

Figure 5.192 81A Command Report

Over- and Under-Rate-of-Change-of-Frequency Element

Use the relay rate-of-change-of-frequency (ROCOF) elements to speed up control actions such as load shedding, islanding, and other cases that cause abnormal frequency conditions.

Figure 5.193 shows the logic for the ROCOF elements.

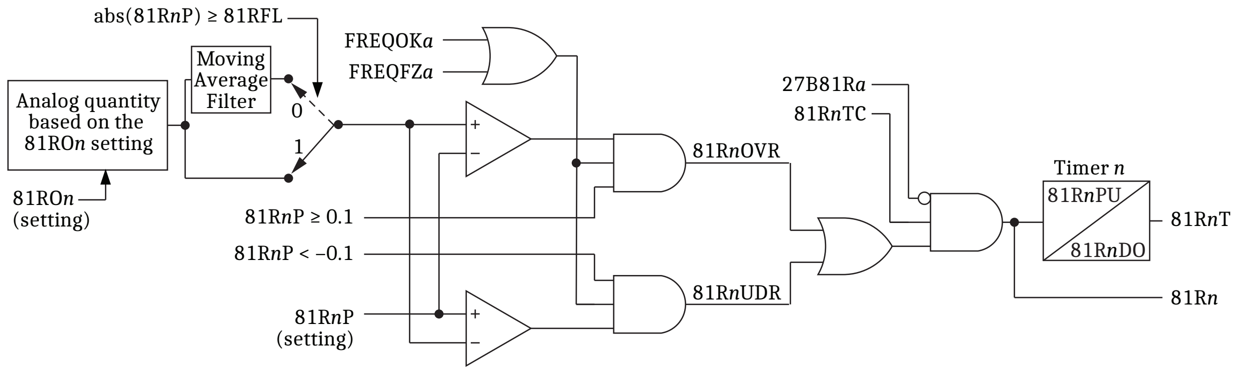


Figure 5.193 ROCOF Element Logic

The relay supports six elements, each of which can be used independently. The operating quantity for each of these elements is selectable using the operating quantity setting (81RO*n*, *n* = 1–6). This can be set to either generator or system by choosing DFREQPG or DFREQPS.

Each frequency element can operate as an over-ROCOF or as an under-ROCOF element, depending on its pickup setting. If the element pickup setting (81R*n*P, *n* = 1–6) is less than –0.1 Hz/s, the element operates as an under-ROCOF element, picking up if measured rate-of-change of frequency is less than the set point. If the pickup setting is greater than 0.1 Hz/s, the element operates as an over-ROCOF element, picking up if measured rate-of-change of frequency is greater than the set point.

The selected operating quantity, given by the 81RO*n* setting, will be used as the input to Element *n* if the pickup setting (81R*n*P) is greater than the 81RFL setting value, which is 0.5 Hz/s by default. If Element *n* pickup setting is lower than the 81RFL setting, the rate-of-change-of-frequency quantity will be passed through a four-point moving average filter, and the output is used as the operating quantity. This filter is used to remove noise at low values of the operating quantity. 81RFL is a Calibration Level setting.

Each element can be individually controlled using the associated torque-control setting (81R*n*TC), which can be set to a SELOGIC conditional statement. Element *n* is disabled if the 81R*n*TC setting is evaluated to be false.

The quantity 27B81R*a* controls all frequency elements associated with the same frequency tracking source, i.e., 27B81RG controls the frequency elements that are associated with DFREQPG and 27B81RS controls the frequency elements that are associated with DFREQPS.

Each element has an associated output timer whose pickup time and dropout time can be selected using the settings 81R*n*PU and 81R*n*DO, respectively.

Over- and Under-ROCOF Element Settings

E81R (Enable 81R Elements)

Set E81R to enable as many as six over- and under-ROCOF elements. When E81R = N, the relay disables the ROCOF elements and hides corresponding settings; you do not need to enter these hidden settings.

81RUVSP (81R Element Undervoltage Supervision)

This setting applies to all six ROCOF elements. If the instantaneous value of the tracking voltage quantity falls lower than the 81UVSP setting, all ROCOF elements associated with the tracking source are disabled.

81ROn (Level n Operating Quantity)

Select the ROCOF source that is used as the operating quantity for Element *n*. This can be set to DFREQPG (for generator) or DFREQPS (for system).

81RnTC (Level n Torque Control)

Set 81R*n*TC to a SELOGIC conditional statement that will disable Element *n* when false.

81RnP (Level n Pickup)

Set the value at which you want the ROCOF element for each of six levels to assert. For a value of 81R*n*P less than –0.1 Hz/s, the element operates as an under-ROCOF element. For a value greater than 0.1 Hz/s, the element operates as an over-ROCOF element. Note that *n* can be one of six levels, 1–6.

81RnPU (Level n Pickup Time Delay)

Select a time in seconds that you want ROCOF elements to wait before asserting.

81RnDO (Level n Dropout Time Delay)

Select a time in seconds that you want ROCOF elements to wait before deasserting.

Injection-Based Stator Ground Protection

The SEL-400G can receive a stator winding insulation resistance measurement from an SEL-2664S Stator Ground Protection Relay using the IEC 61850 protocol. See *SEL-2664 and SEL-2664S Application on page 2.19* for details on connecting and configuring remote devices. See the *SEL-2664S Stator Ground Protection Relay Instruction Manual* for application details related to the relay.

The SEL-2664S uses an injection-based principle to monitor the stator winding for ground faults, while the generator is both online and offline. During online operation, the 64S elements must be combined with the 64G1 element to provide 100 percent coverage of the stator winding. The 64S element provides complete stator coverage when the unit is offline.

Injecting a subharmonic signal onto the stator requires the SEL-2664S to be connected to the stator winding either through the neutral grounding transformer (NGT) when the neutral grounding resistor (NGR) is located on the NGT secondary (*Figure 5.194*) or through a voltage transformer of sufficient thermal rating if the NGR is connected between ground and the generator neutral point (*Figure 5.195*). For complete guidance on SEL-2664S application design and settings considerations, see the *SEL-2664S Stator Ground Protection Relay Instruction Manual*.

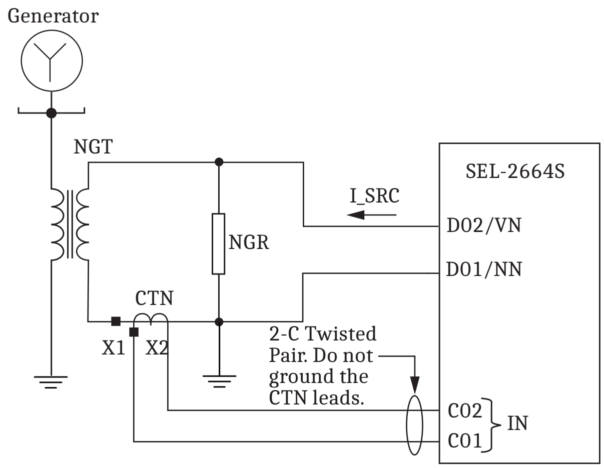


Figure 5.194 AC Connections With NGR on the Secondary Side of the Neutral Grounding Transformer

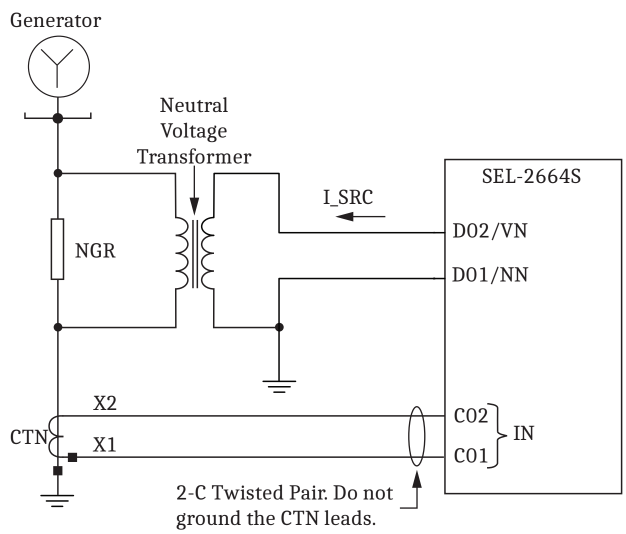


Figure 5.195 AC Connections With NGR Between the Generator Neutral Point and Ground

A multisine signal, consisting of two or four subharmonic frequencies, generated by the SEL-2664S processor is injected onto the stator winding. The relay performs a Discrete Fourier Transform (DFT) to extract the injected frequencies from measured current and voltage signals. Combining the results of these measurements with circuit parameters learned during relay calibration, the relay provides continuous measurement of NGR resistance, stator insulation resistance, and stator insulation capacitance. An NGR monitor is also provided. As mentioned previously, the SEL-2664S can share these analog quantities with the SEL-400G by using the IEC 61850 protocol.

The Stator Ground Scheme logic is shown in *Figure 5.196*. Two levels are provided.

The resistance measurement appears in the SEL-400G as a remote analog, which is then assigned to 64SIR using the 64SIRM setting. Likewise, the associated communications quality bit is assigned to the 64SIQ setting. The capacitance measurement can also be mapped to 64SIC by using the 64SICM setting. This value is not used in the scheme logic but may be assigned to the analog profiling function.

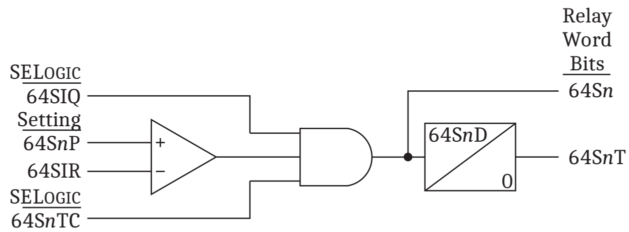


Figure 5.196 Stator Ground Scheme Logic, Level n

Setting Guidelines

Table 5.68 Injection-Based Stator Ground Protection Settings

Setting	Prompt	Range	Default	Category
64SIRM	64S Stator Insu Resi Mapping	RA001–RA256	RA002	Group
64SICM	64S Stator Insu Capa Mapping	RA001–RA256	RA003	Group
64SIQ	64S Stator Insu Quality (SELOGIC Eqn)	SV	NA	Group
64S*n*P[a]	64S Level *n* Pickup (kOhms)	OFF, 0.1–10	OFF	Group
64S*n*D[a]	64S Level *n* Delay (0.000–400 s)	0.000–400	60	Group
64S*n*TC[a]	64S Level *n* Torque Cont (SELOGIC Eqn)	SV	1	Group

[a] n = 1, 2.

64S Stator Insulation Resistance Mapping (64SIRM)

Enter the remote analog address, which is configured as the insulation resistance measurement.

64S Stator Insulation Capacitance Mapping (64SICM)

Enter the remote analog address, which is configured as the insulation capacitance measurement.

64S Stator Insulation Quality (SELOGIC Control Equation) (64SIQ)

Enter the quality bit for the remote analog that is mapped as the insulation resistance measurement. The element is blocked if the quality bit is not asserted.

64S Level n Pickup (OFF, 0.5–10 kilohms) (64SnP)

Enter the desired pickup of the element in kilohms. You can use the analog signal profiling function to track the variation of the insulation resistance over time to determine an optimal setting.

64S Level n Delay (0.000–400 s) (64SnD)

Enter the desired delay in seconds. See the *SEL-2664S Stator Ground Relay Instruction Manual* for more details.

64S Level n Torque Control (SELOGIC Control Equation) (64SnTC)

This setting has a default value of 1.

Over- and Undervoltage Elements

The SEL-400G offers as many as six undervoltage and six overvoltage elements. Each of these 12 elements has two levels, for a total of 24 under- and overvoltage elements. Each level can be configured either with a definite-time or an inverse-time characteristic.

Table 5.69 Operating Quantities

Parameter	Quantities
Phase, Phase-to-Phase, and Single-Phase	V*pk*FM[a, b], V*ppk*FM[b, c], VNMIN*k*F[b, d], VNMAX*k*F[b, e], VPMIN*k*F[b, d], VPMAX*k*F[b, e], VV*a*FM[f], VZ2FM
Sequence	V1*k*M[b], 3V2*k*M[b, e], 3V0*k*M[b, e]

[a] p = A, B, C.
[b] k = V, Z.
[c] pp = AB, BC, CA.
[d] Not available for overvoltage elements.
[e] Not available for undervoltage elements.
[f] a = 1, 2, 3.

Inverse-Time Characteristics

The over- and undervoltage inverse-time characteristic equations are:

$$t_{pkp} = \frac{59\mathrm{P}n\mathrm{D}x}{\dfrac{59n\mathrm{OP}}{59\mathrm{P}n\mathrm{P}x} - 1}$$

Overvoltage **Equation 5.74**

$$t_{pkp} = \frac{27\mathrm{P}n\mathrm{Dx}}{1 - \dfrac{27n\mathrm{OP}}{27\mathrm{P}n\mathrm{P}x}}$$

Undervoltage **Equation 5.75**

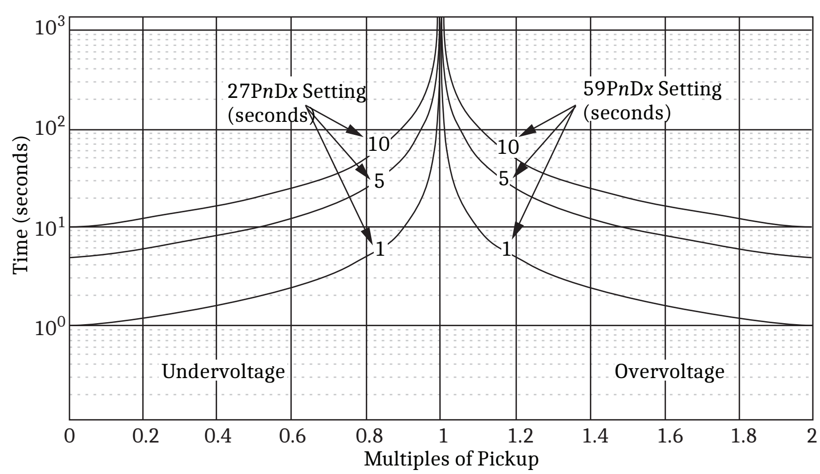


Figure 5.197 Over-/Undervoltage Inverse-Time Characteristic

The dropout is instantaneous.

Figure 5.198–Figure 5.201 show the logic diagrams for the over- and undervoltage elements.

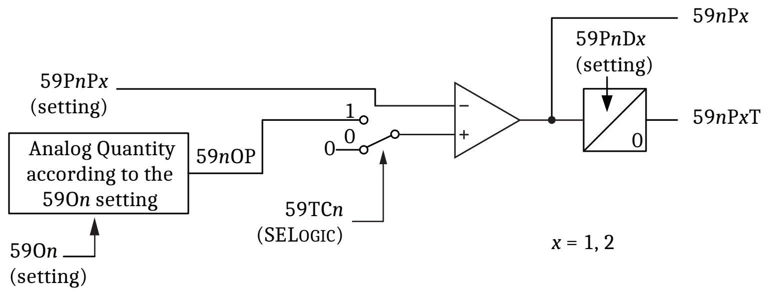


Figure 5.198 Element n, Level x, Definite-Time Overvoltage (59PnCx = D)

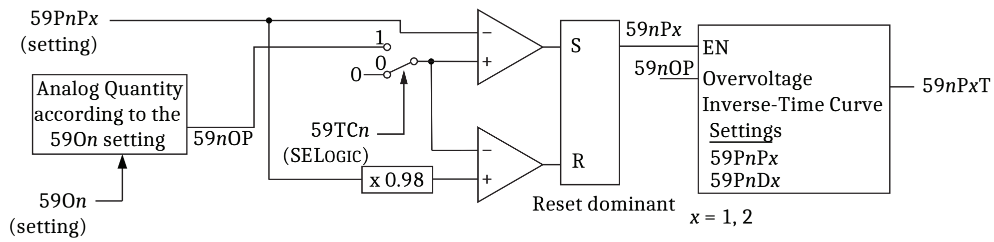


Figure 5.199 Element n, Level x, Inverse-Time Overvoltage (59PnCx = I)

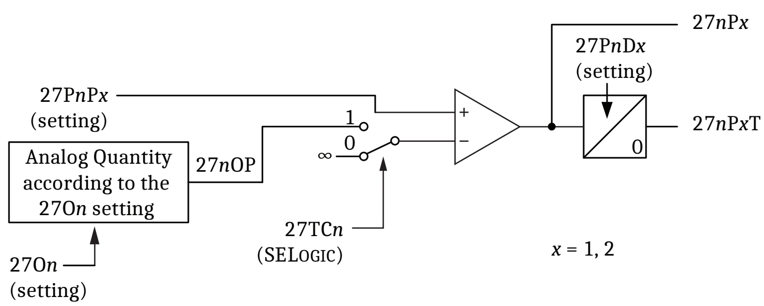


Figure 5.200 Element n, Level x, Definite-Time Undervoltage (27PnCx = D)

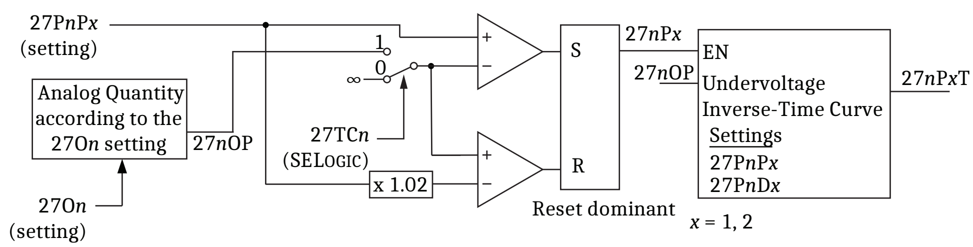


Figure 5.201 Element n, Level x, Inverse-Time Undervoltage (27PnCx = I)

Setting Guidelines

Table 5.70 Over- and Undervoltage Settings (Sheet 1 of 2)

Setting	Prompt	Range	Default	Category
59O*n*[a]	O/V Element *n* Operating Quantity	V*pk*FM[b, c], VNMAX*k*F[c], V*ppk*FM[c, d], VV*a*FM[e], VZ2FM, VPMAX*k*F[c], V1*k*M[c], 3V2*k*M[c], 3V0*k*M[c]	VPMAXZF	Group
59P*n*P*x*[a, f]	O/V Element *n* Level *x* PU (V, sec)	OFF, 2.00–300[g]	OFF	Group
59P*n*C*x*[a, f]	O/V Element *n* Level *x* Curve	D, I	D	Group
59P*n*D*x*[a, f]	O/V Element *n* Level *x* Delay (s)	0.000–400	10	
59TC*n*[a]	O/V Element *n* Torque Control	SV	1	

Table 5.70 Over- and Undervoltage Settings (Sheet 2 of 2)

Setting	Prompt	Range	Default	Category
27O*n*[a]	U/V Element *n* Operating Quantity	V*pk*FM[b, c], VNMIN*k*F[c], V*ppk*FM[c, d], VPMIN*k*F[c], V1*k*M[c], VV*a*FM[e], VZ2FM	VNMINZF	Group
27P*n*P*x*[a, f]	U/V Element *n* Level *x* PU (V,sec)	OFF, 2.00–300[g]	OFF	Group
27P*n*C*x*[a, f]	U/V Element *n* Level *x* Curve	D, I	D	Group
27P*n*D*x*[a, f]	U/V Element *n* Level *x* Delay (s)	0.000–400	10	
27TC*n*[a]	U/V Element *n* Torque Control	SV (SELOGIC variables)	1	

[a] n = 1–6.
[b] p = A, B, C.
[c] k = V, Z.
[d] pp = AB, BC, CA.
[e] a = 1, 2, 3.
[f] x = 1, 2.
[g] The range for VppkFM, VPMAXkF is 4.00–520.

59On (Overvoltage Element Operating Quantity)

Select the operating quantity you want from *Table 5.69*. Both levels use the same operating quantity.

59PnP1 (Overvoltage Level 1 Pickup)

Set pickup values for the voltage values above which you want the Level 1 overvoltage elements to assert.

59PnD1 (Overvoltage Level 1 Time Delay)

When the system voltage rises above the overvoltage setting value, the overvoltage timer starts timing. Set the delay (in seconds) that the timer must run before the 59P*n*D1 setting asserts the output.

59PnP2 (Overvoltage Level 2 Pickup)

Set pickup values for the voltage values above which you want the Level 2 overvoltage elements to assert.

59PnD1 (Overvoltage Level 2 Time Delay)

When the system voltage rises above the overrvoltage setting value, the overvoltage timer starts timing. Set the delay (in seconds) that the timer must run before the 59P*n*D2 setting asserts the output.

59TCn (Overvoltage Torque Control)

Use the torque-control setting to specify conditions under which the overvoltage elements must be active. There is only one setting for both Level 1 and Level 2 elements. With the default setting equal to 1, both levels are active permanently.

27On (Undervoltage Element Operating Quantity)

Select the operating quantity you want for the element from *Table 5.69*. Both levels use the same quantity.

27PnP1 (Undervoltage Level 1 Pickup)

Set pickup values for the voltage values below which you want the Level 1 undervoltage elements to assert.

27PnD1 (Undervoltage Level 1 Time Delay)

When the system voltage falls below the undervoltage setting value, the undervoltage timer starts timing. Set the delay (in seconds) that the timer must run before the 27P*n*D1 setting asserts the output.

27PnP2 (Undervoltage Level 2 Pickup)

Set pickup values for the voltage values below which you want the Level 2 undervoltage elements to assert.

27PnD1 (Undervoltage Level 2 Time Delay)

When the system voltage falls below the undervoltage setting value, the undervoltage timer starts timing. Set the delay (in seconds) that the timer must run before the 27P*n*D2 setting asserts the output.

27TCn (Undervoltage Torque Control)

Use the torque-control setting to specify conditions under which the undervoltage elements must be active. There is only one setting for both Level 1 and Level 2 elements. With the default setting equal to 1, both levels are active permanently.

27On (Undervoltage Element Operating Quantity)

Select the operating quantity you want for each voltage terminal from *Table 5.69*.

27PnP1 (Undervoltage Level 1 Pickup)

Set pickup values for the voltage values below which you want the Level 1 undervoltage elements to assert.

27PnD1 (Undervoltage Level 1 Time Delay)

When the system voltage falls below the undervoltage setting value, the undervoltage timer starts timing. Set the delay (in seconds) that the timer must run before the 27P*n*D1 setting asserts the output.

27PnP2 (Undervoltage Level 2 Pickup)

Set pickup values for the voltage values below which you want the Level 2 undervoltage elements to assert.

27PnD1 (Undervoltage Level 2 Time Delay)

When the system voltage falls below the undervoltage setting value, the undervoltage timer starts timing. Set the delay (in seconds) that the timer must run before the 27P*n*D1 setting asserts the output.

27TCn (Undervoltage Torque Control)

Use the torque-control setting to specify conditions under which the undervoltage elements must be active. There is only one setting for both Level 1 and Level 2 elements. With the default setting equal to 1, both levels are active permanently.

Overcurrent Elements

The SEL-400G provides three levels of instantaneous overcurrent elements (50) for phase, negative-sequence, and zero-sequence currents for each of the four terminals (S, T, U, Y) and 10 configurable time-overcurrent (51) elements. These overcurrent elements are nondirectional, but you can make any of the 50 or 51 elements directional with a choice of phase and sequence directional elements (see *Directional Elements on page 5.213*).

Phase Instantaneous Overcurrent Elements

Figure 5.202 shows the logic for the phase instantaneous overcurrent element. At the top of the logic are four settings that enable the overcurrent element. All four settings must evaluate to a logical 1 to enable the overcurrent element. To enable the Level 1 instantaneous overcurrent element for Terminal S, apply the following settings: ESYSCT = S, … , E50 = S, … , E50S = P, and 50SP1P = 4 (any setting within the range other than OFF).

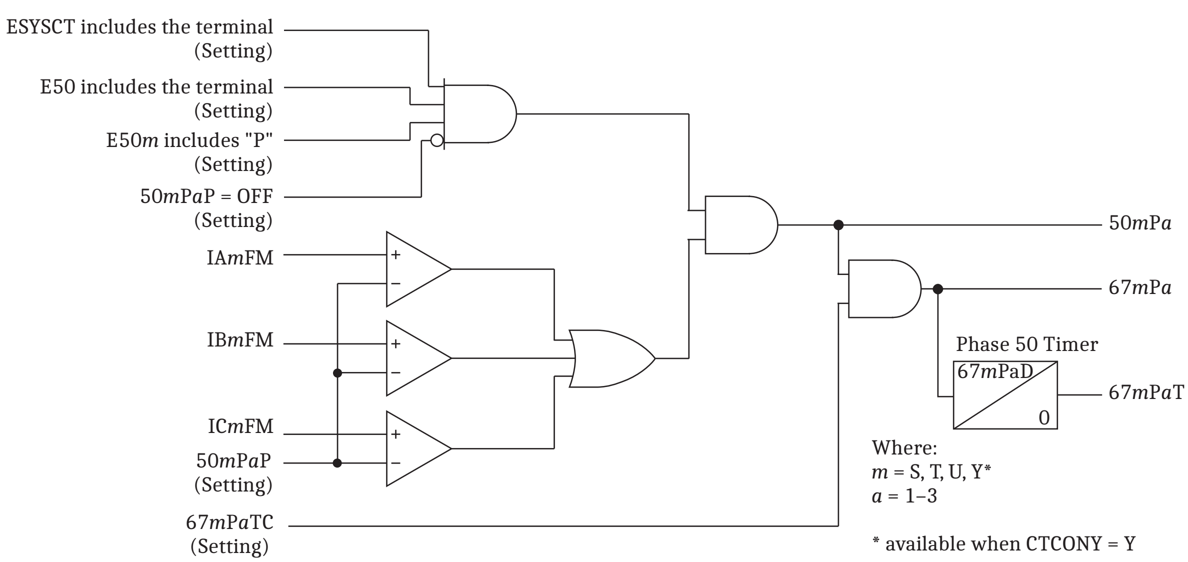


Figure 5.202 Phase Instantaneous Overcurrent Element

Setting 50SP1P also provides the reference value against which three comparators test the three phase currents (IA*m*FM, IB*m*FM, IC*m*FM). If the element is enabled, and any phase current exceeds the 50SP1P setting value, then Relay Word bit 50SP1 asserts.

Use the torque-control setting 67*m*P*a*TC to combine the 50 element with other functions such as the directional element, or to add a time delay. For a time delay (Terminal S, Level 1), set 67SP1TC = 1 (or any other appropriate condition such as the directional element or a breaker auxiliary contact status) and set 67SP1D to the desired time delay. If the element is enabled and any phase current exceeds the 50SP1P setting value, then Relay Word bits 50SP1 and 67SP1 assert instantaneously and Relay Word bit 67SP1T asserts when the Phase 50 timer times out.

Negative-Sequence Instantaneous Overcurrent Elements

Figure 5.203 shows the logic for the negative-sequence instantaneous overcurrent element. This element operates similarly to the phase instantaneous overcurrent element, except that the element uses negative-sequence values instead of phase values.

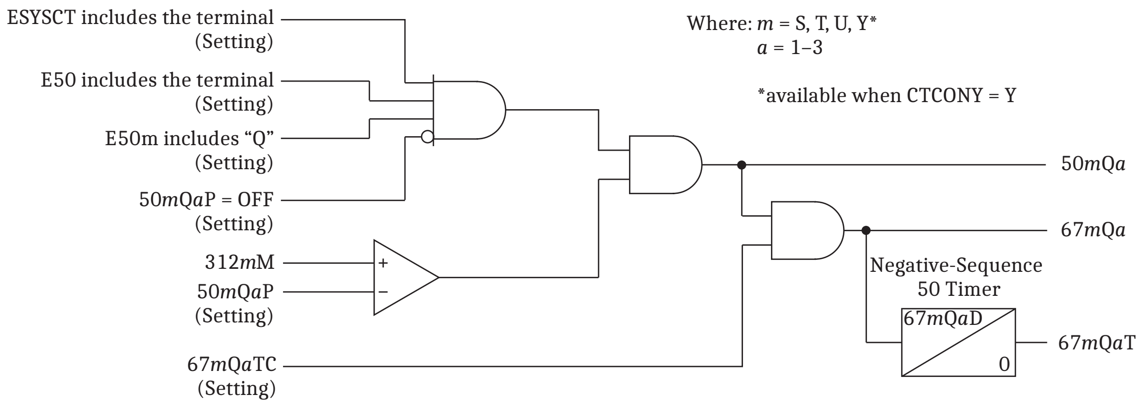


Figure 5.203 Negative-Sequence Instantaneous Overcurrent Element

Zero-Sequence Instantaneous Overcurrent Elements

Figure 5.204 shows the logic for the zero-sequence instantaneous overcurrent element. This element operates similarly to the phase instantaneous overcurrent element, except that the element uses zero-sequence values instead of phase values.

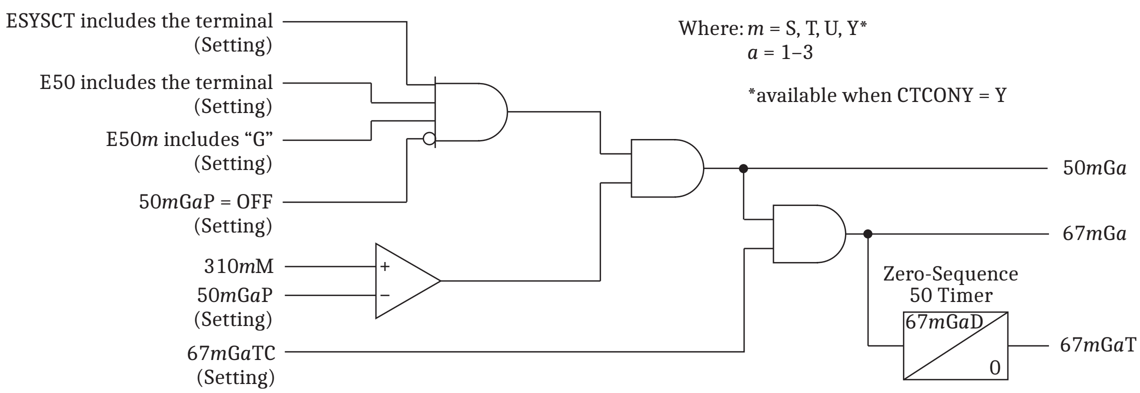


Figure 5.204 Zero-Sequence Instantaneous Overcurrent Element

Setting Descriptions

E50 (Definite-Time Overcurrent and Directional Element Enable)

Setting E50 is a composite setting that identifies the following three protection options for each terminal:

- Terminals that require only definite-time overcurrent elements
- Terminals that require only directional elements
- Terminals that require both definite-time overcurrent elements and directional elements

For example, at a particular substation you want the following protection:

- Terminal S: negative-sequence definite-time overcurrent only
- Terminal T: only directional control (directional elements for time-overcurrent [51] protection)
- Terminal U: both definite-time overcurrent protection (Level 1) and directional control
- Terminal Y: not used

Figure 5.205 shows the flow diagram for setting the three protection options (gray blocks are not used).

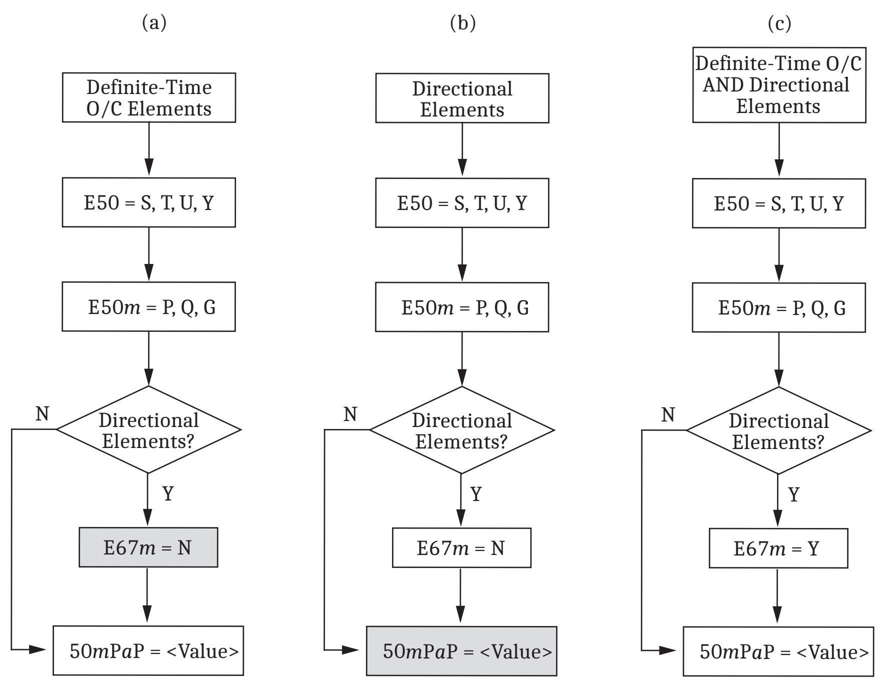
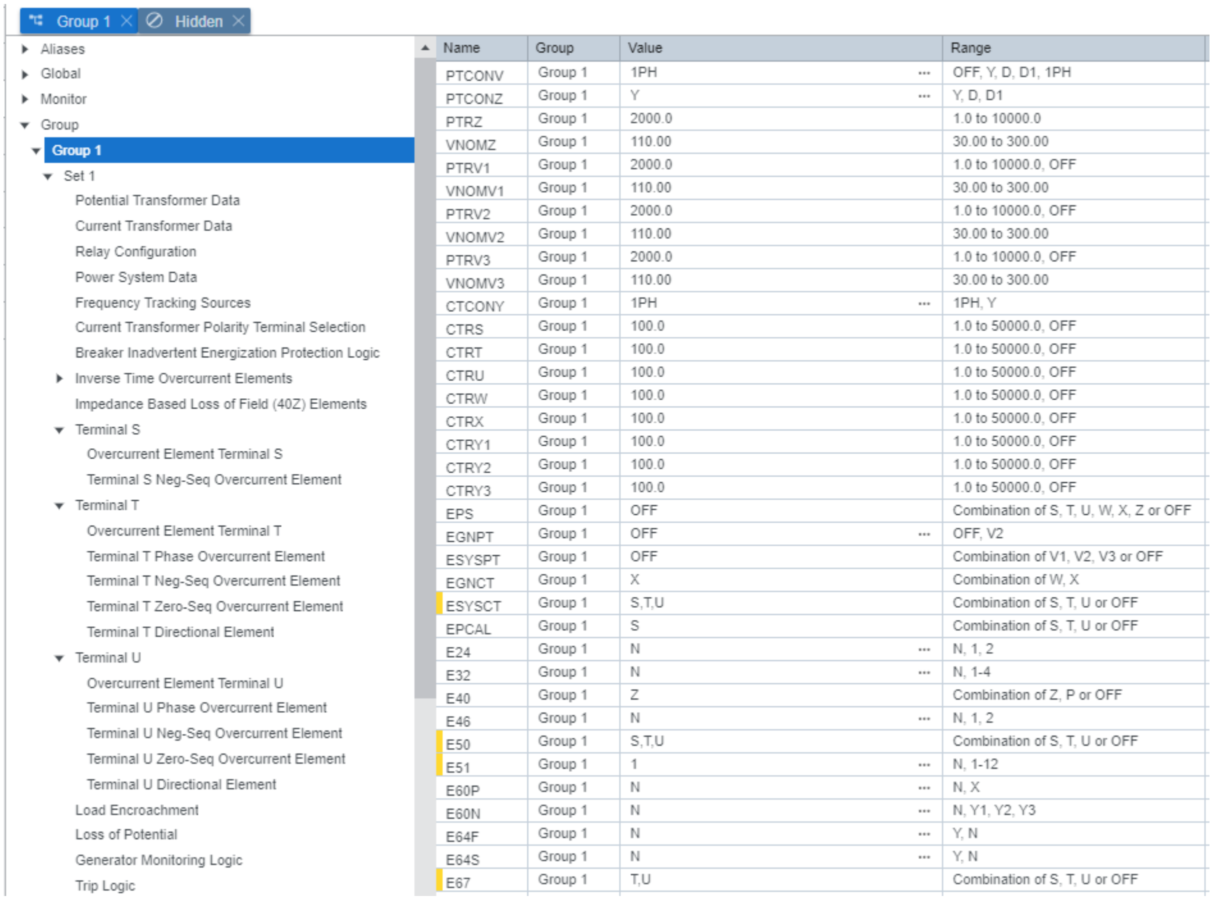


Figure 5.205 Three Settings Possibilities

In general, regardless of the function you want (overcurrent or directional), always enter the E50 and E50*m* settings. In this example, include Terminals S, T, and U in the Group setting ESYSCT to enable these terminals for processing, as shown in *Figure 5.206*. Directional elements are polarized using the same voltage used for frequency tracking. By default, this will be the Z voltage terminal. See *Directional Elements on page 5.213* for more details.

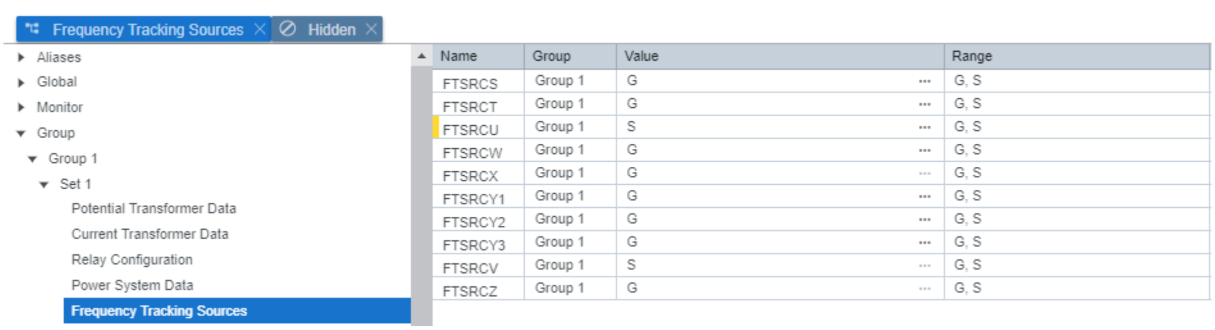


Name	Group	Value	Range
PTCONV	Group 1	1PH	OFF, Y, D, D1, 1PH
PTCONZ	Group 1	Y	Y, D, D1
PTRZ	Group 1	2000.0	1.0 to 10000.0
VNOMZ	Group 1	110.00	30.00 to 300.00
PTRV1	Group 1	2000.0	1.0 to 10000.0, OFF
VNOMV1	Group 1	110.00	30.00 to 300.00
PTRV2	Group 1	2000.0	1.0 to 10000.0, OFF
VNOMV2	Group 1	110.00	30.00 to 300.00
PTRV3	Group 1	2000.0	1.0 to 10000.0, OFF
VNOMV3	Group 1	110.00	30.00 to 300.00
CTCONY	Group 1	1PH	1PH, Y
CTRS	Group 1	100.0	1.0 to 50000.0, OFF
CTRT	Group 1	100.0	1.0 to 50000.0, OFF
CTRU	Group 1	100.0	1.0 to 50000.0, OFF
CTRW	Group 1	100.0	1.0 to 50000.0, OFF
CTRX	Group 1	100.0	1.0 to 50000.0, OFF
CTRY1	Group 1	100.0	1.0 to 50000.0, OFF
CTRY2	Group 1	100.0	1.0 to 50000.0, OFF
CTRY3	Group 1	100.0	1.0 to 50000.0, OFF
EPS	Group 1	OFF	Combination of S, T, U, W, X, Z or OFF
EGNPT	Group 1	OFF	OFF, V2
ESYSPT	Group 1	OFF	Combination of V1, V2, V3 or OFF
EGNCT	Group 1	X	Combination of W, X
ESYSCT	Group 1	S,T,U	Combination of S, T, U or OFF
EPCAL	Group 1	S	Combination of S, T, U or OFF
E24	Group 1	N	N, 1, 2
E32	Group 1	N	N, 1-4
E40	Group 1	Z	Combination of Z, P or OFF
E46	Group 1	N	N, 1, 2
E50	Group 1	S,T,U	Combination of S, T, U or OFF
E51	Group 1	1	N, 1-12
E60P	Group 1	N	N, X
E60N	Group 1	N	N, Y1, Y2, Y3
E64F	Group 1	N	Y, N
E64S	Group 1	N	Y, N
E67	Group 1	T,U	Combination of S, T, U or OFF

Figure 5.206 ESYSCT Setting, Overcurrent, and Directional Enables

After enabling the CTs for processing, enter Terminals S, T, and U in the Group setting E50 (see *Figure 5.206*). *Figure 5.206* also shows the selection of the 51 element that must have directional control. The 51 elements are not terminal specific, so setting the terminal CT/51 elements correlation occurs later.

In this example, Terminal S and Terminal T will be frequency-tracked using the generator frequency and Terminal U will be frequency-tracked using the system frequency. Because Terminal T and Terminal U have directional control enabled, the T directional elements are polarized using the Z voltage and the U directional elements are polarized using the V voltage.



Name	Group	Value	Range
FTSRCS	Group 1	G	G, S
FTSRCT	Group 1	G	G, S
FTSRCU	Group 1	S	G, S
FTSRCW	Group 1	G	G, S
FTSRCX	Group 1	G	G, S
FTSRCY1	Group 1	G	G, S
FTSRCY2	Group 1	G	G, S
FTSRCY3	Group 1	G	G, S
FTSRCV	Group 1	S	G, S
FTSRCZ	Group 1	G	G, S

Figure 5.207 Frequency Tracking Configuration

Use the E50*m* setting to specify the type of overcurrent elements you want to use, both for overcurrent elements and for directional elements. Because Terminal S requires negative-sequence definite-time overcurrent only, set E50S = Q.

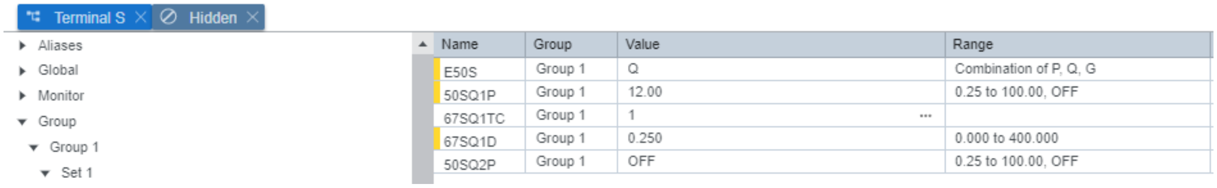


Figure 5.208 Overcurrent Settings

Figure 5.208 shows the negative-sequence definite-time overcurrent settings. The setting 50SQ1P is the Level 1 negative-sequence overcurrent element pickup value (arbitrarily set at 12). The setting 67SQ1TC is the torque-control setting for the negative-sequence overcurrent element (refer to *Figure 5.203* for the logic diagram). In this example, set 67SQ1TC = 1 (permanently enabled) to assert the bottom input of the timer AND gate in *Figure 5.203*. The last setting is 67SQ1D, the negative-sequence overcurrent element time delay, set in *Figure 5.208* to an arbitrary value of 15 cycles or 0.25 seconds.

This concludes the negative-sequence definite-time overcurrent settings for Terminal S.

Terminal T protection calls for a directional element 51.

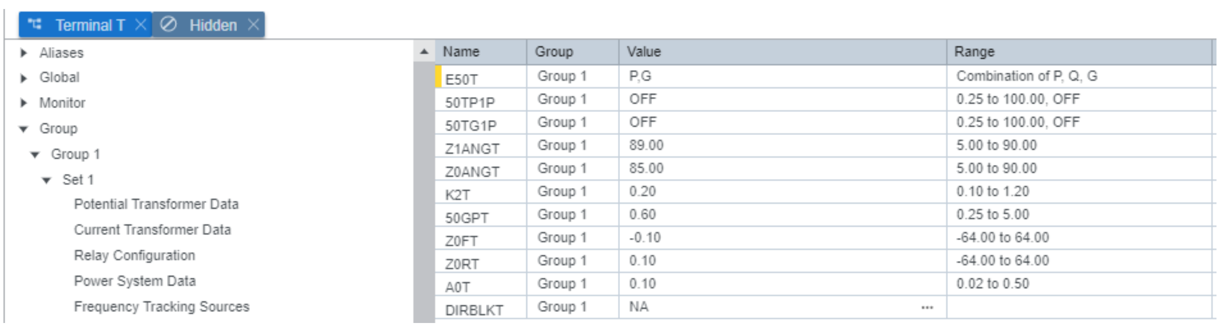


Figure 5.209 Overcurrent Configuration for Terminal T

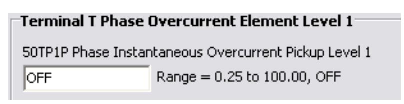


Figure 5.210 Disable Definite-Time Overcurrent Elements

Figure 5.206 shows the directional elements enabled by setting E67 = T, U. This makes the CTPT, Z1ANGT, Z0ANGT (E50T includes both P and G) and EAD-VST settings available. With 50TP1P = OFF and 50TG1P = OFF, the phase and ground overcurrent elements are disabled so that only the directional elements are active for Terminal T.

Figure 5.210 shows the settings for the Terminal T directional 51 element. For this example, do not use adaptive settings for the pickup and time-dial settings. Set the operating quantity (51O01 = IMAXTF), the pickup setting (51P01), Curve type (51C01), time dial (51TD01), and the type of reset (51RS01).

Use setting 51TC01 to add directional control to the 51 element. Setting 51TC01 = TF32G (negative- and zero-sequence direction) OR TF32P (phase direction) causes the 51 element to be active only for forward faults.

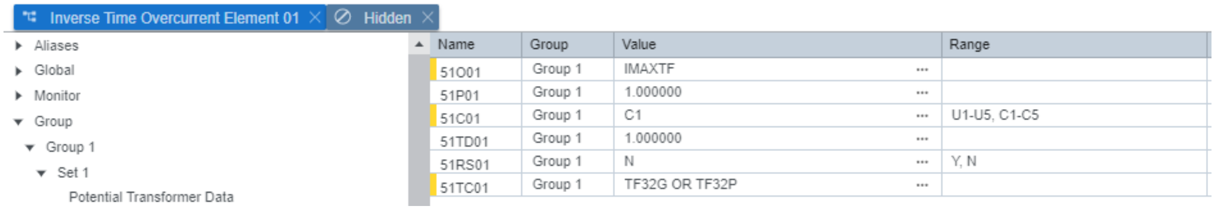


Figure 5.211 Terminal T Directional 51 Element Settings

This concludes the directional 51 settings for Terminal T.

Terminal U protection calls for one level of directional definite-time overcurrent protection. In this example, this element is frequency-tracked using the system frequency and polarized using the V voltage, as indicated in *Figure 5.207*. *Figure 5.206* shows the setting to enable the directional element (E67 = T, U).

With the directional elements enabled, set the 50 elements settings, as shown in *Figure 5.212*. To make the 50 elements directional, enter the forward directional Relay Word bits (UF32P and UF32G) in the 67UP1TC torque equation.

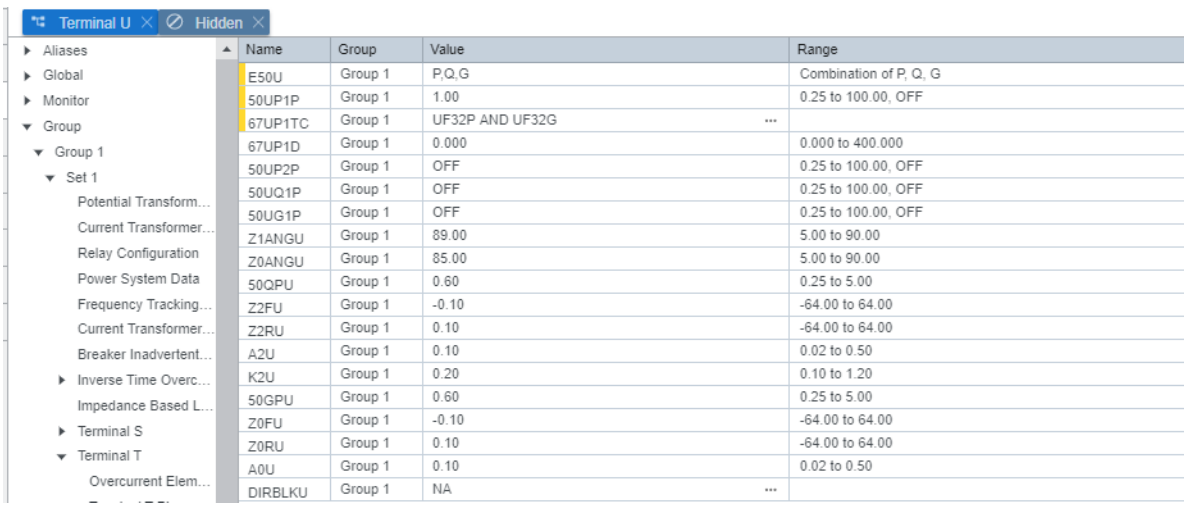


Figure 5.212 Overcurrent Configuration for Terminal U

Only one level of overcurrent protection is necessary, so leave 50UP2P = OFF. This concludes the directional 50 settings for Terminal U.

E50m (50 Function Enable)

After identifying the terminal(s) that requires definite-time overcurrent/directional protection with the E50 setting, select the specific instantaneous overcurrent element(s)/directional type for each terminal(s). Choose from among phase (P), negative-sequence (Q), zero-sequence (G), or any combination of P, Q, and G.

50mPaP (Phase Element Pickup)

Setting 50*m*P*a*P is the current pickup setting in secondary amperes for the phase instantaneous overcurrent element. For a 5 A relay, the range is 0.25–100.00 A, sec. The range for a 1 A relay is 0.05–20.00 A, sec.

67mPaTC (Phase Element Torque Control)

NOTE: This setting does not affect the 50mPa outputs (see Figure 5.202).

Use the torque-control setting to specify conditions under which the element must be active. The default setting is *m*F32P, so that the 67*m*P*a* and 67*m*P*a*T functions can only assert if the phase directional element declares a fault in the forward direction. With the torque equation set to 1 (67SP1TC = 1, Terminal S, Level 1), the overcurrent element is nondirectional and active constantly.

67mPaD (Phase Element Time Delay)

NOTE: This setting is active only if 67mPaTC asserts.

Set the duration of the phase element time delay with this setting.

50mQaP (Negative-Sequence Element Pickup)

Setting 50*m*Q*a*P is the current pickup setting in secondary amperes for the negative-sequence instantaneous overcurrent element. For a 5 A relay, the range is 0.25–100.00 A, sec. The range for a 1 A relay is 0.05–20.00 A, sec.

67mQaTC (Negative-Sequence Element Torque Control)

NOTE: This setting does not affect the 50mQa outputs (see Figure 5.203).

Use the torque-control setting to specify conditions under which the element must be active. The default setting is *m*F32Q, so that the 67*m*P*a* and 67*m*P*a*T functions can only assert if the negative-sequence directional element declares a fault in the forward direction. With the torque equation set to 1 (67SQ1TC = 1, Terminal S, Level 1), the overcurrent element is nondirectional and active constantly.

67mQaD (Negative-Sequence Element Time Delay)

NOTE: This setting is active only if 67mQaTC asserts.

Set the duration of the negative-sequence element time delay with this setting.

50mGaP (Zero-Sequence Element Pickup)

50*m*G*a*P is the current pickup setting in secondary amperes for the zero-sequence instantaneous overcurrent element (shown is the range for a 5 A relay; the range is 0.05 to 20 for a 1 A relay).

67mGaTC (Zero-Sequence Element Torque Control)

NOTE: This setting does not affect the 50mGa outputs (see Figure 5.204).

Use the torque-control setting to specify conditions under which the element must be active. The default setting is *m*F32G, so that the 67*m*P*a* and 67*m*P*a*T functions can only assert if the zero-sequence directional element declares a fault in the forward direction. With the torque equation set to 1 (67SG1TC = 1, Terminal S, Level 1), the overcurrent element is nondirectional and active constantly.

67mGaD (Zero-Sequence Element Time Delay)

NOTE: This setting is active only if 67mGaTC asserts.

Set the duration of the zero-sequence element time delay with this setting.

Selectable Time-Overcurrent Element

Instead of having dedicated inverse time-overcurrent elements (also known as inverse definite minimum time or IDMT) for each winding, the SEL-400G offers the flexibility of 10 unassigned time-overcurrent elements, each with the choice of five U.S. and five IEC operating curves. Unassigned means that the 51 elements are not assigned to a specific current terminal, but they are available for assignment, as the application requires (see *Table 5.73*).

Be sure to include the terminals selected as 51 element input quantities in the ESYSCT setting. For example, if IMAXSF (see *Table 5.73*) is the input for element 51O01 and if IMAXTF is the input for element 51O02, then set ESYSCT = S, T.

Inverse time-overcurrent elements are not enabled in the default settings. Enable the inverse time-overcurrent elements by setting E51 = *xx* (*xx* = 01–10). After you enable these elements, the inverse time-overcurrent elements up to and including the number *xx* you entered at the E51 = prompt are active. For example, if you want to use six inverse time-overcurrent elements for your application, set E51 = 6. Inverse time-overcurrent elements 1–6 become active.

Table 5.71 shows the five U.S. characteristics, and *Table 5.72* shows the five IEC characteristics. Each table shows the five operating time equations, together with the five electromechanical reset characteristic equations.

Table 5.71 U.S. Operate and Reset Curve Equations

Curve Type	Operating Time	Reset Time
U1 (Moderately Inverse)	$T_P = TD \bullet \left(0.0226 + \frac{0.0104}{M^{0.02} - 1}\right)$	$T_R = TD \bullet \left(\frac{1.08}{1 - M^2}\right)$
U2 (Inverse)	$T_P = TD \bullet \left(0.180 + \frac{5.95}{M^2 - 1}\right)$	$T_R = TD \bullet \left(\frac{5.95}{1 - M^2}\right)$
U3 (Very Inverse)	$T_P = TD \bullet \left(0.0963 + \frac{3.88}{M^2 - 1}\right)$	$T_R = TD \bullet \left(\frac{3.88}{1 - M^2}\right)$
U4 (Extremely Inverse)	$T_P = TD \bullet \left(0.02434 + \frac{5.64}{M^2 - 1}\right)$	$T_R = TD \bullet \left(\frac{5.64}{1 - M^2}\right)$
U5 (Short-Time Inverse)	$T_P = TD \bullet \left(0.00262 + \frac{0.00342}{M^{0.02} - 1}\right)$	$T_R = TD \bullet \left(\frac{0.323}{1 - M^2}\right)$

Table 5.72 IEC Operate and Reset Curve Equations (Sheet 1 of 2)

Curve Type	Operating Time	Reset Time
C1 (Standard Inverse)	$T_P = TD \bullet \left(\frac{0.14}{M^{0.02} - 1}\right)$	$T_R = TD \bullet \left(\frac{13.5}{1 - M^2}\right)$
C2 (Very Inverse)	$T_P = TD \bullet \left(\frac{13.5}{M - 1}\right)$	$T_R = TD \bullet \left(\frac{47.3}{1 - M^2}\right)$
C3 (Extremely Inverse)	$T_P = TD \bullet \left(\frac{80}{M^2 - 1}\right)$	$T_R = TD \bullet \left(\frac{80}{1 - M^2}\right)$

Table 5.72 IEC Operate and Reset Curve Equations (Sheet 2 of 2)

Curve Type	Operating Time	Reset Time
C4 (Long-Time Inverse)	$T_P = TD \bullet \left(\frac{120}{M-1}\right)$	$T_R = TD \bullet \left(\frac{120}{1-M}\right)$
C5 (Short-Time Inverse)	$T_P = TD \bullet \left(\frac{0.05}{M^{0.04}-1}\right)$	$T_R = TD \bullet \left(\frac{4.85}{1-M^2}\right)$

where:

T_P = Operate time
T_R = Reset time
TD = Time dial (multiplier)
M = Multiple of pickup current ($I_{measured}/I_{pickup}$)

Figure 5.213–Figure 5.215 show the five U.S. curves and the five IEC curves.

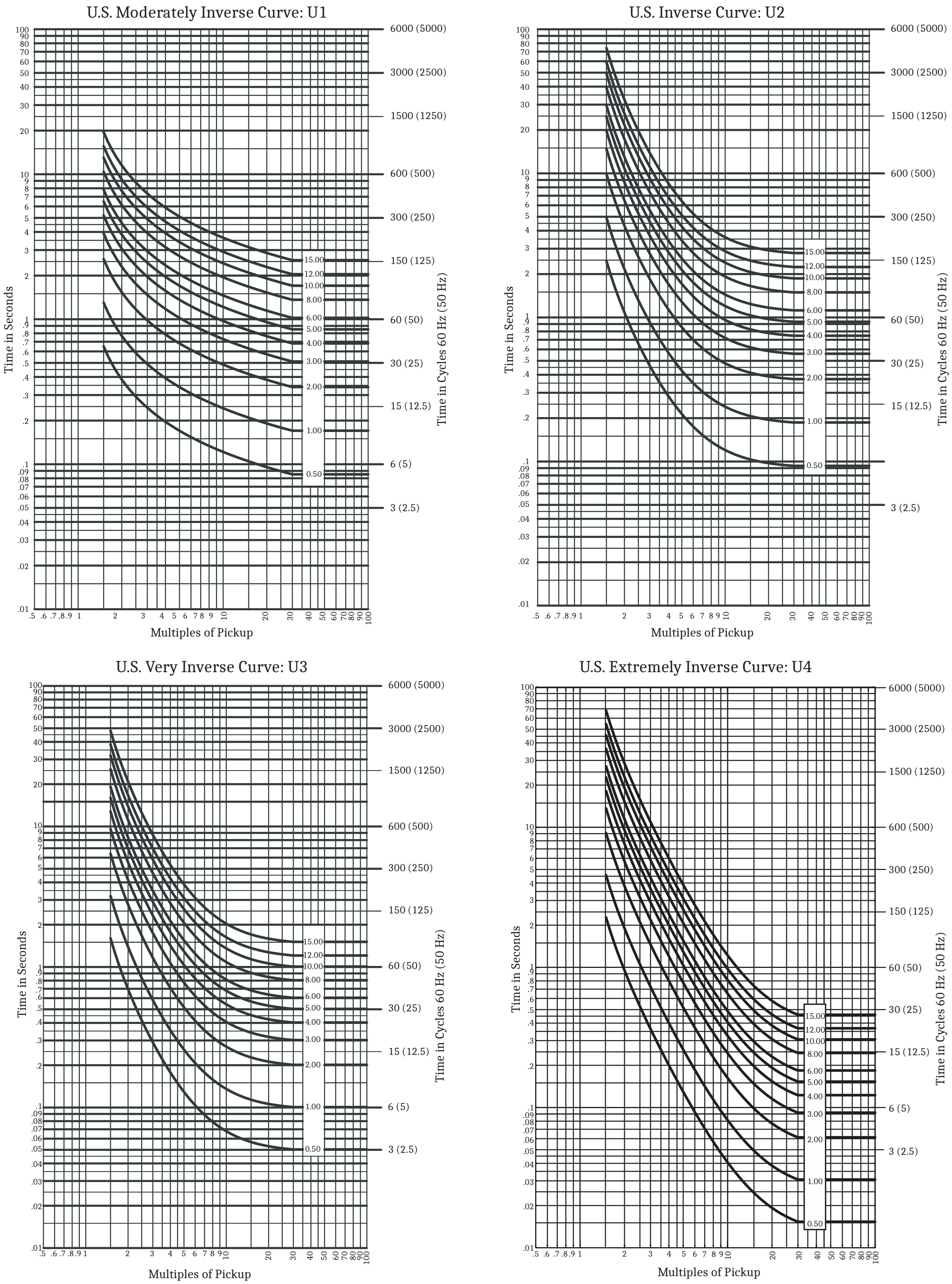


Figure 5.213 U.S. Curves: U1, U2, U3, and U4

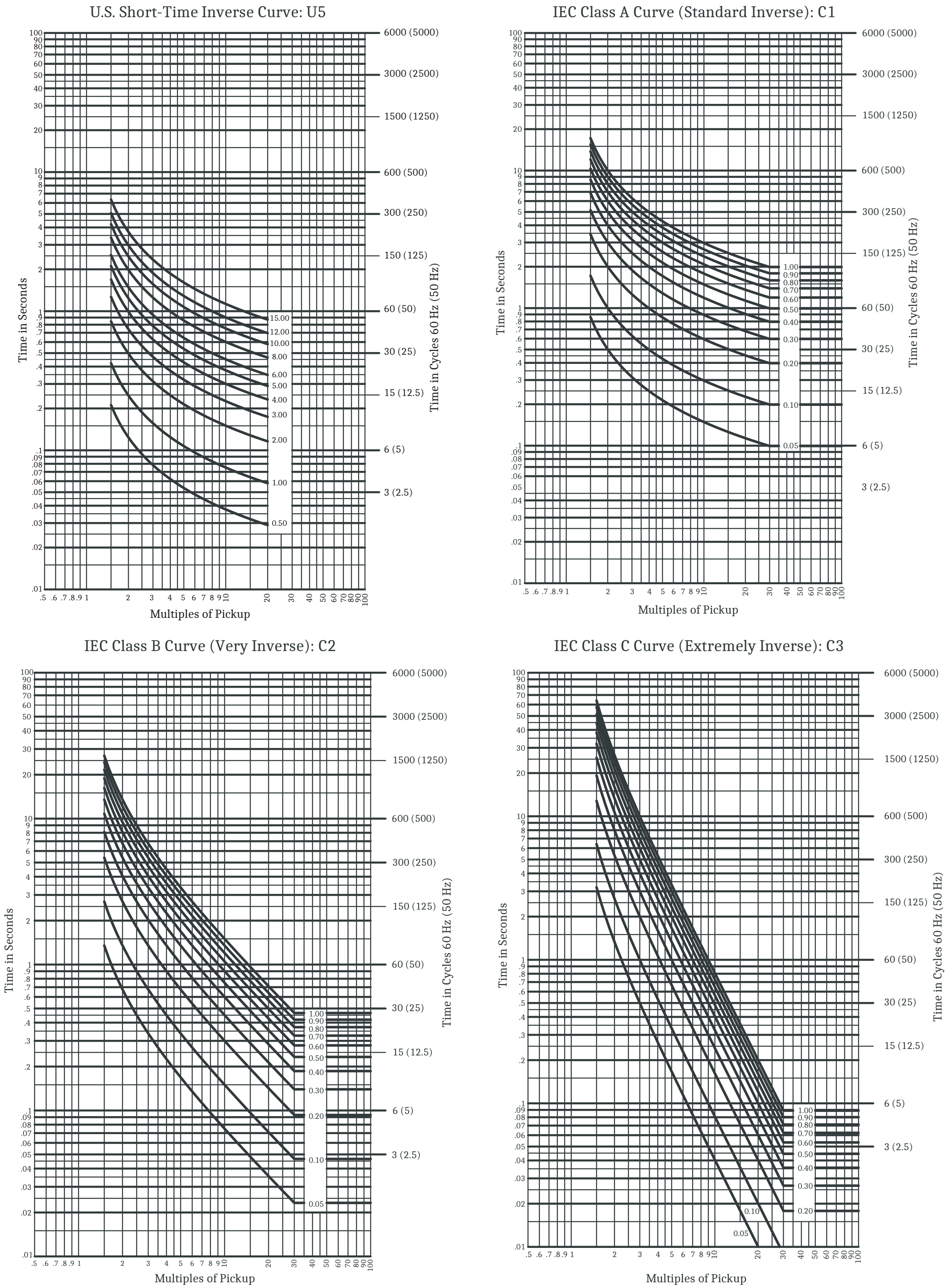


Figure 5.214 U.S. Curve U5 and IEC Curves C1, C2, and C3

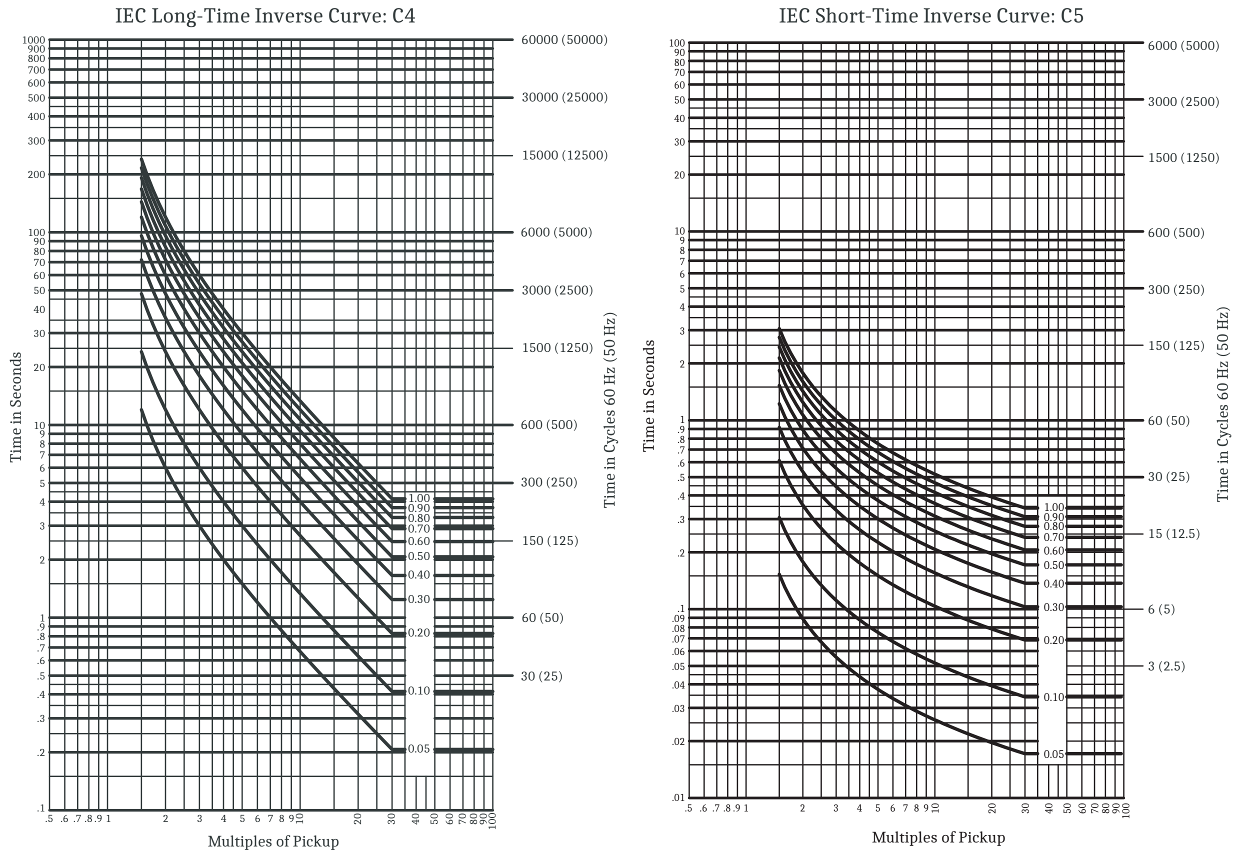


Figure 5.215 IEC Curves C4 and C5

Figure 5.216 uses Element 01 as an example to show the logic for the 51 element. All five inputs are Group settings. Essentially, the logic compares the magnitude of an operating quantity (51O01) to pickup setting 51P01.

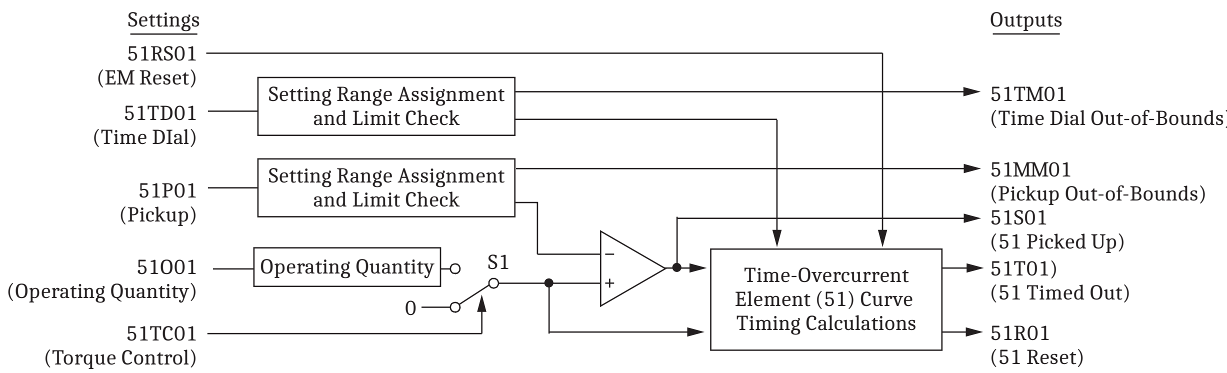


Figure 5.216 Time-Overcurrent Element

Operating Quantity

The 51 elements are unassigned, so you can select the operating quantity from many phase and sequence quantities in fundamental, as *Table 5.73* shows.

Table 5.73 Fundamental Operating Quantities[a]

	Fundamental Quantities
Phase	I*pm*FM, IMAX*m*F
Sequence	I1*m*M, 3I2*m*M, 3I0*m*M

[a] Where:
p = A, B, C
m = S, T, U, Y

Pickup and Time-Dial Settings

Pickup setting 51P01, operating on the ratio of the measured current to the pickup setting (multiple of pickup setting), moves the characteristic horizontally to vary the pickup current; time-dial (multiplier) setting 51TD01 moves the curve vertically to vary the operating time for a given multiple of pickup.

Both pickup (51P01) and time-dial (51TD01) settings are math variables instead of fixed settings. SEL math variables, unlike fixed settings that cannot be dynamically changed, allow for the adaptive changing of pickup and time-dial settings without the need for changing relay setting groups.

However, if your installation does not require adaptive pickup and/or time-dial settings changes, use the time-overcurrent element as a conventional 51 element. For a conventional element, simply enter the pickup and time-dial settings as numbers, such as:

51P01 := **1.5**
51TD01 := **1**

Setting Range Assignment and Limit Checks

Because the relay accepts both 1 A and 5 A secondary CTs, the relay assigns the element pickup setting range only after you select the operating quantity. For example, if the relay determines (from the part number) that Terminal S is a 5 A CT, then the relay assigns the range 0.25 to 16.00 as the pickup range of all 51 elements that use any of the Terminal S quantities.

Example 5.1

Single Terminal S—5 A CT secondary

Terminal S has a 5 A nominal CT input, so the range is 0.25 (lower limit) to 16.0 (upper limit).

Example 5.2

Single Terminal T—1 A CT secondary

Terminal T has a 1 A nominal CT input, so the range is 0.05 (lower limit) to 3.2 (upper limit).

Upper and Lower Range Limits

When you use SEL math variables, the selected analog value can exceed the upper value of the pickup range, or it can fall below the lower value of the pickup range. When this happens, the relay assigns the appropriate threshold value to the element and continues to calculate the trip time. For the 51P*nn* pickup settings, the upper threshold is 3.2 for 1 A relays and 16 for 5 A relays. The lower threshold is 0.05 for 1 A relays and 0.25 for 5 A relays. For the 51TD*nn* time-dial settings, the U.S. curve thresholds are 0.5 and 15, and the IEC thresholds are 0.05 and 1.0. In addition, the relay also asserts the appropriate Relay Word bits: 51MM01 (pickup value out of bounds) and/or 51TM01 (time-dial value out of bounds).

Example 5.3

For example, you want a 1 A relay to pick up at 1.5 A when IN101 asserts and to pick up at 2 A when IN102 asserts (IN101 deasserted). Program the following:

51P01 := IN101 • 1.5 + IN102 • 2

With IN101 asserted (logical 1), and IN102 deasserted (logical 0), the 51P01 setting is:

(1 • 1.5) + (0 • 2) = 1.5 + 0 = 1.5

When IN102 asserts (IN101 deasserted), the 51P01 setting is:

(0 • 1.5) + (1 • 2) = 0 + 2 = 2

If, however, IN102 asserts while IN101 is still asserted, the 51P01 setting is:

(1 • 1.5) + (1 • 2) = 1.5 + 2 = 3.5

Because 3.5 exceeds the upper range value of 3.2, the relay clamps the setting at 3.2 and asserts Relay Word bit 51MM01.

Torque Control

SELOGIC control equation 51TC01 allows you to state the conditions when the element must run. When 51TC01 asserts (logical 1), Switch S1 in *Figure 5.216* closes and the relay evaluates input 51O01. For example, if the element should only measure when the HV circuit breaker (Terminal S, for example) is closed, enter the following:

51TC01 := **52CLS**

With this setting, Switch S1 closes only when 52CLS is a logical 1. If the element must measure all the time, enter the following:

51TC01 := **1**

EM Reset

Setting 51RS01 defines whether the curve resets slowly like an electromechanical disk or after one power system cycle when current drops below pickup. If you set 51RS01 = Y, then the relay resets according to the Reset Timer equations for that particular curve (see *Table 5.71* or *Table 5.72*). If you set 51RS01 = N, then the relay resets after one power system cycle when current drops below pickup.

Directional Elements

The SEL-400G provides directional elements that are polarized using phase, negative-sequence, and zero-sequence voltage. Directional elements are provided for the S, T, U, and Y terminals.

The directional elements for each current terminal are polarized using the voltage terminal that is used to track frequency for that terminal. The FTSRC*m* setting (where *m* is the particular current terminal, S, T, U, Y) has a default setting of G (generator), which means the Z voltage input is assigned by default for frequency tracking and therefore polarizing. If ESYSPT is set to V and FTSRC*m* is set to S (system) then Current Terminal *m* will be frequency-tracked and polarized using the Terminal V voltage. Note that because directional elements require either a three-phase, negative-sequence, or zero-sequence voltage, E67*m* is forced to OFF if FTSRC*m* = S but PTCONV = 1PH.

The polarizing voltage is derived from the V voltage for the S, T, U, and Y currents for the system voltage referenced currents and the polarizing voltage is derived from the Z voltage for the generator voltage referenced currents. Therefore, the following definitions apply:

VREFm =	PTCONk	LOPk
V	*k* = V	*k* = V
Z	*k* = Z	*k* = Z

The directional elements can be used to supervise the definite-time and inverse-time overcurrent elements. The negative-sequence directional element can also be used in conjunction with the split-phase elements. Note that zero-sequence directional elements are not available for PTs connected in delta (PTCON*k* = D).

Zero-Sequence Directional Element

The zero-sequence-directional element is enabled when the E50*m* setting includes G. The enable logic is shown in *Figure 5.217*. This logic compares the zero-sequence current, 3I0*m*FM, to the pickup setting, 50GP*m*. It also checks the zero-sequence current to the product of the positive-sequence current and the positive-sequence restraint factor, a0m. The enable logic is blocked by the directional block SELOGIC control equation, DIRBLK*m*, and by a loss of potential associated with the polarizing voltage source.

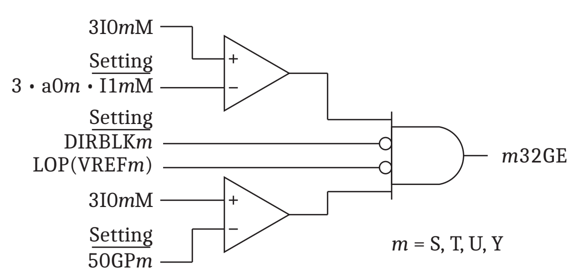


Figure 5.217 Zero-Sequence Directional Enable Logic

The complex zero-sequence impedance is calculated using the following equation. The variable, *q*, accounts for the polarity setting of the terminal.

$$Z0m = \frac{\mathrm{Re}(3V0(VREFm)CF \bullet ((-1)^q \bullet 3I0mF \bullet 1\angle Z0ANGm)^*)}{3I0mM^2}$$

Equation 5.76

where:

$q =$ 1 if CTPm = N
$q =$ 2 if CTPm = P

Depending on the sign of the forward direction threshold setting, Z0Fm, the forward threshold is determined as follows:

If Z0F$m \le 0$:

$$Z0FTHm = 0.75 \bullet Z0Fm - 0.25 \bullet \frac{3V0(VREFm)M}{3I0mM}$$

If Z0F$m > 0$:

$$Z0FTHm = 1.25 \bullet Z0Fm - 0.25 \bullet \frac{3V0(VREFm)M}{3I0mM}$$

Similarly, depending on the sign of the reverse direction threshold setting, Z0Rm, the reverse threshold is determined as follows:

If Z0R$m \ge 0$:

$$Z0RTHm = 0.75 \bullet Z0Rm + 0.25 \bullet \frac{3V0(VREFm)M}{3I0mM}$$

If Z0R$m < 0$:

$$Z0RTHm = 1.25 \bullet Z0Rm + 0.25 \bullet \frac{3V0(VREFm)M}{3I0mM}$$

This results in the following characteristic for the zero-sequence directional element.

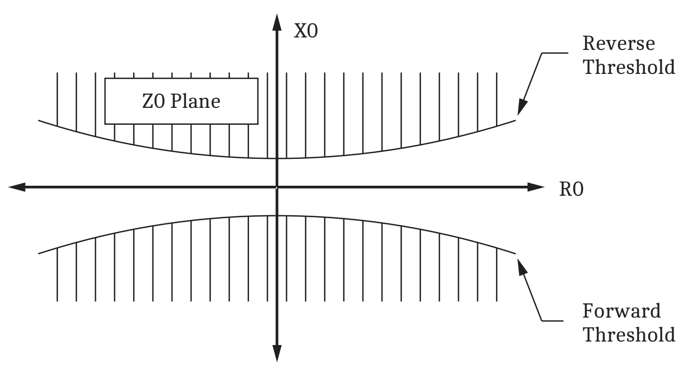


Figure 5.218 Zero-Sequence Directional Element Characteristic

The logic for the element is shown in *Figure 5.219*. The logic is executed every 5 ms.

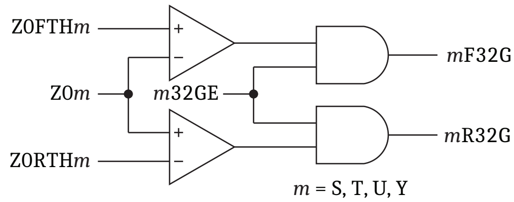


Figure 5.219 Zero-Sequence Directional Logic

Negative-Sequence Directional Element

The negative-sequence directional element is enabled when the E50*m* setting includes Q. The enable logic is shown in *Figure 5.220*. This logic compares the negative-sequence current, 3I2*m*FM to the pickup setting, 50QP*m*. It also checks the negative-sequence current to the product of the positive-sequence current and the positive-sequence restraint factor, a0*m* and to the product of the zero-sequence current and the zero-sequence restraint factor, k2*m*. The enable logic is blocked by the directional block SELOGIC control equation, DIRBLK*m*, and by a loss of potential associated with the polarizing voltage source.

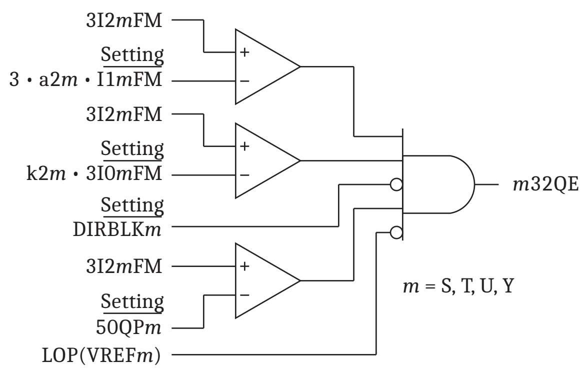


Figure 5.220 Negative-Sequence Directional Enable Logic

The complex negative-sequence impedance is calculated using the following equation. The variable, *q*, accounts for the polarity setting of the terminal.

$$Z2m = \frac{\mathrm{Re}(3V2(VREFm)F \bullet ((-1)^{q} \bullet 3I2mF \bullet 1\angle Z1ANGm)^{*})}{3I2mM^{2}}$$

Equation 5.77

where:

q = 1 if CTP*m* = N
q = 2 if CTP*m* = P

Depending on the sign of the forward direction threshold setting, Z2F*m*, the forward threshold is determined as follows:

If Z2F*m* ≤ 0:

$$Z2FTHm = 0.75 \bullet Z2Fm - 0.25 \bullet \frac{3V2(VREFm)M}{3I2mM}$$

If Z2Fm > 0:

$$Z2FTHm = 1.25 \cdot Z2Fm - 0.25 \cdot \frac{3V2(VREFm)M}{3I2mM}$$

Similarly, depending on the sign of the reverse direction threshold setting, Z0Rm, the reverse threshold is determined as follows:

If Z2Rm ≥ 0:

$$Z2RTHm = 0.75 \cdot Z2Rm + 0.25 \cdot \frac{3V2(VREFm)M}{3I2mM}$$

If Z2Rm < 0:

$$Z2RTHm = 1.25 \cdot Z2Rm + 0.25 \cdot \frac{3V2(VREFm)M}{3I2mM}$$

The logic for the element is shown in *Figure 5.221*. The logic is executed every 5 ms.

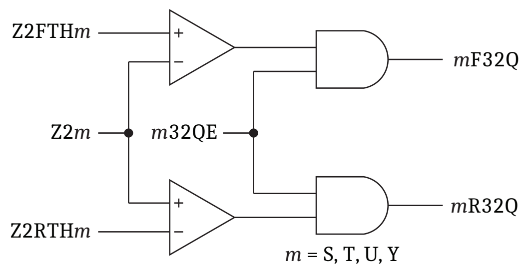


Figure 5.221 Negative-Sequence Directional Logic

Phase Directional Element

The phase directional element is enabled when the E50m setting includes P. The enable logic is shown in *Figure 5.222*. This logic checks that positive-sequence voltage and current are present and compares the angle between them. If the compared angle is between –60 degrees and 120 degrees then the element declares forward fault otherwise it declares reverse. The enable logic is blocked by the directional block SELOGIC control equation, DIRBLKm.

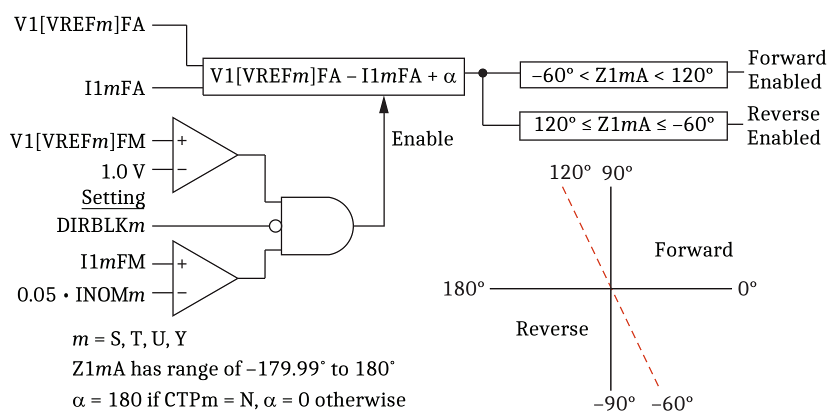


Figure 5.222 Phase Directional Enable Logic

Directional checks are calculated for each phase-to-phase loop as follows:

$$\mathrm{MABD}m := \mathrm{Re}((-1)^{q} \bullet \mathrm{IAB}m\mathrm{CF} \bullet e^{j \bullet \mathrm{Z1ANG}m} \bullet \overline{(\mathrm{VAB}(\mathrm{VREF}m)\mathrm{F})})$$

$$\mathrm{MBCD}m := \mathrm{Re}((-1)^{q} \bullet \mathrm{IBC}m\mathrm{CF} \bullet e^{j \bullet \mathrm{Z1ANG}m} \bullet \overline{(\mathrm{VBC}(\mathrm{VREF}m)\mathrm{F})})$$

$$\mathrm{MCAD}m := \mathrm{Re}((-1)^{q} \bullet \mathrm{ICA}m\mathrm{CF} \bullet e^{j \bullet \mathrm{Z1ANG}m} \bullet \overline{(\mathrm{VCA}(\mathrm{VREF}m)\mathrm{F})})$$

Equation 5.78

where:

q = 1 if CTP*n* = N
q = 2 if CTP*n* = P

As shown in *Figure 5.223*, a forward indication is declared if the directional checks are positive for all three loops and a reverse indication is declared in the directional checks are negative for all three loops. The logic is executed every 5 ms.

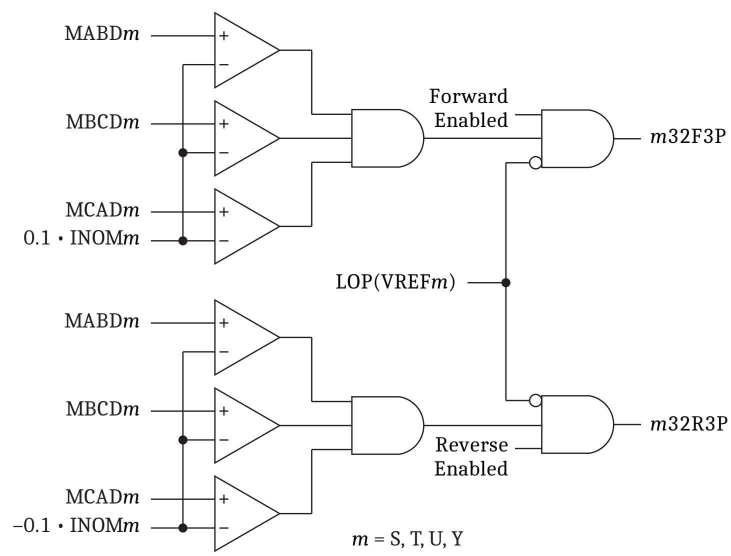


Figure 5.223 Phase Directional Declaration Logic

Setting Guidelines

Z1ANGm (Positive-Sequence Line Impedance Angle)

For each terminal, set the positive-sequence line angle in degrees. This setting is only available if setting E50*m* includes P or Q.

Z0ANGm (Zero-Sequence Line Impedance Angle)

For each terminal, set the zero-sequence line angle in degrees. This setting is only available if setting E67*m* = Y and if setting E50*m* includes G and VREF*m* is configured to measure zero-sequence voltage (PTCON*k* = Y or D1).

Z2Fm (Forward Direction Z2 Threshold)

Use Z2F to calculate the Forward Threshold for the negative-sequence voltage-polarized directional elements. This setting is only available if setting E50*m* includes Q. If setting EADVS = N, the relay internally sets Z2F*m* to –0.5 / $I_{NOM}m$.

Z2Rm (Reverse Direction Z2 Threshold)

Use Z2R to calculate the reverse threshold for the negative-sequence voltage-polarized directional elements. This setting is only available if setting E50*m* includes Q. If setting EADVS = N, the relay internally sets Z2R*m* to 0.5 / $I_{NOM}m$. When setting the element, be sure to set Z2R greater in value than setting Z2F by at least Z2F*m* + 0.5 / $I_{NOM}m$ secondary.

a2m (Positive-Sequence Restraint Factor—m32QE)

The a2 factor is the ratio of the negative-sequence current and the positive-sequence current (I2/I1). This factor increases the security of negative-sequence voltage-polarized directional elements by preventing these elements from operating for negative-sequence current (system unbalance). Negative-sequence current circulates because of line asymmetries, CT saturation during three-phase faults, etc. This setting is only available if setting E50*m* includes Q. If setting EADVS = N, the relay internally sets a2*m* to 0.1.

k2m (Zero-Sequence Current Restraint Factor, I2/I0)

The k2 factor increases the security of the zero-sequence voltage-polarized directional elements. It keeps the elements from operating for zero-sequence current (system unbalance), which circulates because of line asymmetries, CT saturation during three-phase faults, etc. This setting is only available if setting E50*m* includes Q. If setting EADVS = N, the relay internally sets k2*m* to 0.2.

Z0Fm (Forward Directional Z0 Threshold)

This setting is only available if setting E50*m* includes G and VREF*m* is configured to measure zero-sequence voltage (PTCON*k* = Y or D1). If setting EADVS*m* = N, the relay internally sets Z0F*m* to –0.5 / $I_{NOM}m$ (I_{NOM} = 1 for a 1 A relay and 5 for a 5 A relay). When setting Z0F*m* and Z0R*m*, be sure that Z0R is greater in value than setting Z0F by at least 0.1 Ω secondary.

Z0Rm (Reverse Directional Z0 Threshold)

This setting is only available if setting E67*m* = Y and if setting E50*m* includes G and VREF*m* is configured to measure zero-sequence voltage (PTCON*k* = Y or D1). If setting EADVS*m* = N, the relay internally sets Z0R*m* to 0.5 / $I_{NOM}m$ (I_{NOM} = 1 for a 1 A relay and 5 for a 5 A relay). When setting Z0F*m* and Z0R*m*, be sure that Z0R is greater in value than setting Z0F by at least 0.1 Ω secondary.

a0m (Positive-Sequence Current Restraint Factor, I0/I1)

This setting is only available if setting E50*m* = Y and if setting E50*m* includes G and VREF*m* is configured to measure zero-sequence voltage (PTCON*k* = Y or D1). The a0 factor increases the security of the zero-sequence voltage-polarized directional element. This factor keeps the elements from operating for zero-sequence current (system unbalance), which circulates because of line asymmetries, CT saturation during three-phase faults, etc. This setting is only available if setting E50*m* includes Q. If setting EADVS = N, then the relay internally sets a0*m* to 0.1.

DIRBLKm (Directional Element Blocking)

Customize a SELOGIC control equation to determine when to block the zero-sequence, Negative-sequence, and positive-sequence directional elements for Terminal *m*.

Trip Logic

To provide settings for selective tripping between generator unit faults and system faults, the SEL-400G includes eight trip elements and five trip logics. Use the logic in *Figure 5.224* for generator or transformer faults. There exists a separate Minimum Trip Duration timer (TDURD*nn*, where *nn* = 01 to 08) and a separate unlatch input (ULTR*nn*) for each of the eight elements.

In *Figure 5.224*, the Trip timer starts when SELOGIC control equation TR*nn* asserts for one processing interval. Assertion of this equation immediately asserts output TRIP*nn*. Output TRIP*nn* remains asserted for the Minimum Trip Duration timer (TDURD*nn*) setting regardless of the status of Input TR*nn*. When output TRIP*nn* asserts, the logic seals TRIP*nn* in through the AND gate when the unlatch input ULTR*nn* is deasserted.

Once latched, TRIP*nn* remains asserted until the unlatch input (ULTR*nn*) asserts. Generally, ULTR*nn* can have the target reset (TRGTR) or SELOGIC (RSTTRGT) input and should not be set to zero. Otherwise the trip logic will latch permanently.

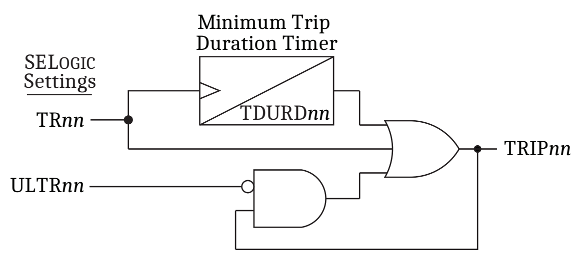


Figure 5.224 SEL-400G Trip Logic

Because not all the protection elements need to trip the breakers or exciter or prime mover or auxiliary breakers, the SEL-400G provides an additional five trip logics (OR gates) to selectively trip the breakers or exciters, etc. Those are TRIP*m*, TRIPEX, TRIPPM, TRIPAUX, or TRIP. TRIP*m* is a breaker trip element and is an OR output of the trip elements selected by TRIP*nn* setting. Where *m* indicates the terminals included in ESYSCT setting. Assertion of any of the TRIPEX, TRIPPM, TRIPAUX, or TRIP Relay Word bits will trigger an event report. If the trip logic is not used, the ER (event report trigger) equation should be configured to ensure that the relay triggers an event report for any protection operation. See *Table 7.17* for details.

Trip-Logic Settings

TRnn (Trip Elements)

Specify the conditions under which individual trip elements must assert with the TR*nn* setting. Default settings for the TR01–TR06 are as follows:

TR01 = 87Z1 OR 87Z2 OR REF OR 64GT OR 21PZ1T OR 21PZ2T
TR02 = 24D1T1 OR 24D2T1

TR03 = 32T01

TR04 = 40Z1T OR 40Z2T OR 40P1T OR 40P2T

TR05 = 81D1T OR 81D2T OR 81D3T OR 81D4T OR 81D5T OR 81D6T

TR06 = 78OST OR 46Q1T1 OR 46Q1T2

TR07 = NA

TR08 = NA

In your application, you can use several trip elements to implement a simultaneous, unit separation, or sequential trip with a different equation for each.

ULTRnn (Unlatch Trip Elements)

Specify the conditions to unlatch the trip element TR*nn*. The default setting is Relay Word bit TRGTR OR RSTTRGT.

TDURDnn (Minimum Trip Duration Timer)

Set this delay (in seconds) slightly longer than the trip time of the slowest circuit breaker for all the trip elements.

TRm (Trip Breaker)

Specify the trip elements under which each of the enabled circuit breakers must trip with the TR*m* setting. For example, if TRS = 1, 3, 5, TRS = TRIP01 OR TRIP03 OR TRIP05.

TREX (Trip Exciter)

Specify the trip elements under which exciter must trip with the TREX setting. For example, if TREX = 1, 3, 5, TREX = TRIP01 OR TRIP03 OR TRIP05.

TRPM (Trip Prime Mover)

Specify the trip elements under which prime mover must trip with the TRPM setting. For example, if TRPM = 1, 3, 5 then TRPM = TRIP01 OR TRIP03 OR TRIP05.

TRAUX (Trip Auxiliary)

Specify the trip elements under which auxiliary must trip or initiate transfer with the TRAUX setting. For example, if TRAUX = 1, 3, 5, TRAUX = TRIP01 OR TRIP03 OR TRIP05.

TRIP (General Trip)

Specify the trip elements under which general trip must assert with TREX setting. For example, if TRIP = 1, 3, 5, TRIP = TRIP01 OR TRIP03 OR TRIP05.

Close Logic

Figure 5.225 shows the close logic that removes the close command from the circuit breaker after a set time. If the ESYSCT setting includes the terminal name, and if the unlatch input SELOGIC control equation (ULCL*m*) is deasserted, the two bottom inputs of the AND gate are logical 1. When SELOGIC control equation CL*m* asserts, the AND gate turns on. When the gate turns on, the Close Failure timer asserts and seals itself in through the OR gate for a time equal to the CFD setting, or until ULCL*m* asserts. With the Close Failure timer sealed in, output CLS*m* is also sealed in for the CFD time setting. Once the Close Failure timer asserts, CF*m* Close Failure, Terminal *m* Relay Word bit asserts indicating a close failure.

The close failure timer is unaffected by a setting group change. The timer starts timing in the present setting group, continues to run for the intermediate time between setting groups, and completes timing in the new setting group.

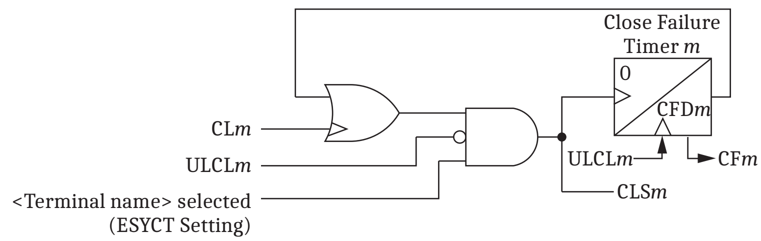


Figure 5.225 Close Logic for Breaker m

Close Logic Settings

CLm (Close SELOGIC Control Equation)

Specify the conditions under which the circuit breaker must close with the CL*m* setting. This settings category is hidden when ESYSCT = OFF.

ULCLm (Unlatch Close SELOGIC Control Equation)

Specify the conditions to unlatch the close output command (CLS*m*) and reset the close failure timer. The close output command and close failure timer will reset on the rising edge of the unlatch. Default settings are the 52CL*m* that assert when the breakers close.

CFDm (Close Failure Delay Breaker)

Set this delay (in seconds) slightly longer than the close time of the slowest circuit breaker. The default value is 0.08 s. If CFD*m* is set to OFF, there is no close fail status indication and CT*m* stays deasserted. Also, when CFD*m* = OFF, it runs as a normal dropout timer and resets when it receives a ULCL*m* assertion.

Circuit Breaker Status

The SEL-400G features advanced circuit breaker monitoring. The general features of the circuit breaker monitor are described in *Section 8: Monitoring in the SEL-400 Series Relays Instruction Manual*. The SEL-400G supports monitoring four three-pole breakers, designated S, T, U, and Y.

The SEL-400G provides status indication and alarm for each breaker. The logic is shown in *Figure 5.226*.

Normally open and normally closed breaker indications wired to relay inputs are assigned to 52A_*n* and 52B_*n* settings, respectively. The 52CL*n* Relay Word bit asserts when the 52A_*n* indication shows the breaker is closed. An alarm, 52AL*n*, is declared whenever the 52A_*n* and 52B_*n* indications both assert or both deassert. The alarm, 52AL*n*, is also declared when both indications show the breaker is open, but current is measured in at least one phase (OPH*k* is dropped out).

The logic in *Figure 5.226* is not evaluated if both 52A_*n* and 52B_*n* are set to NA. If only one of 52A_*n* or 52B_*n* is set to NA, 52AL*n* asserts and 52CL*n* does not assert. If only a normally open contact is wired to the relay, it can be assigned to 52A_*n* and also inverted (using a NOT operator) and assigned to 52B_*n*. This permits the assertion of 52CL*n* and prevents the incorrect assertion of 52AL*n*, but the alarming is not effective otherwise.

If the circuit breaker is the ganged-single-pole type, there will be 52a and 52b indications for each pole. In this case, the 52a indications for each pole should be wired in parallel and the 52b indications should be wired in series. In this way, the logic will indicate that the breaker is closed unless all three poles are open, and the 52AL*n* Relay Word bit will assert if there is a pole discrepancy.

Three-pole-open (3PO*n*) status is enabled by using the EPO setting. When enabled, 3PO asserts when both the breaker status (52A_*n*) and the current-based open-phase detector (OPH*n*) show the breaker to be open.

Note that if the three-pole open (3PO) Relay Word bit is used to supervise inadvertent energization, the 52A setting of the breaker monitor logic must be assigned to a normally open breaker status contact and EPO must be enabled for the breaker.

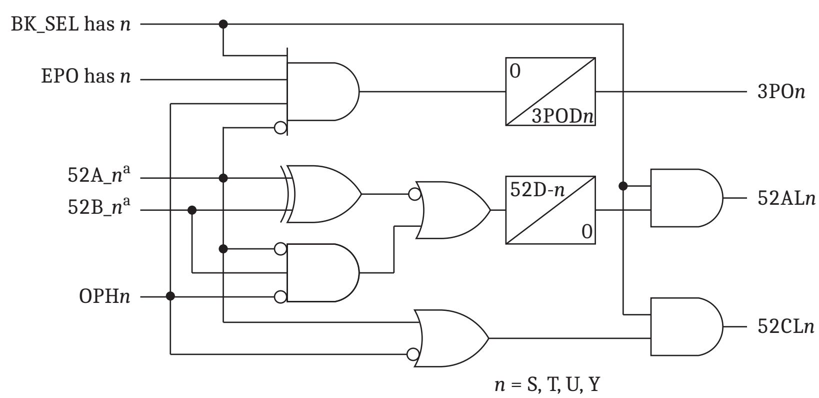


Figure 5.226 Breaker Status and Alarm Logic

SECTION 6

Protection Application Examples

This section provides instructions for setting the SEL-400G Advanced Generator Protection System protection functions. Use these application examples to help familiarize yourself with the relay and for assistance with your own protection settings configuration. This section is not intended to provide a complete settings guide for the relay. Instead, it focuses on configuring the current and voltage inputs and enabling commonly used protection elements. Settings guidelines for individual protection elements are provided in *Section 5: Protection Functions*.

This section covers the steps for configuration of the following:

- ➤ Potential transformer data
- ➤ Current transformer data
- ➤ Relay configuration (enabling selected protection functions)
- ➤ Power system data
- ➤ Configuration of the zone currents for the differential elements
- ➤ Configuration of operating signals for selected protection elements

NOTE: In this section, the Hide Hidden Settings filter is enabled in the setting software to show only those settings required by the application.

Figure 6.1 shows the three-line diagram for the example system. Protection is provided both for the generator and the generator step-up (GSU). CTs W and X will be used for the generator differential. CTs S and T will be used by the GSU differential.

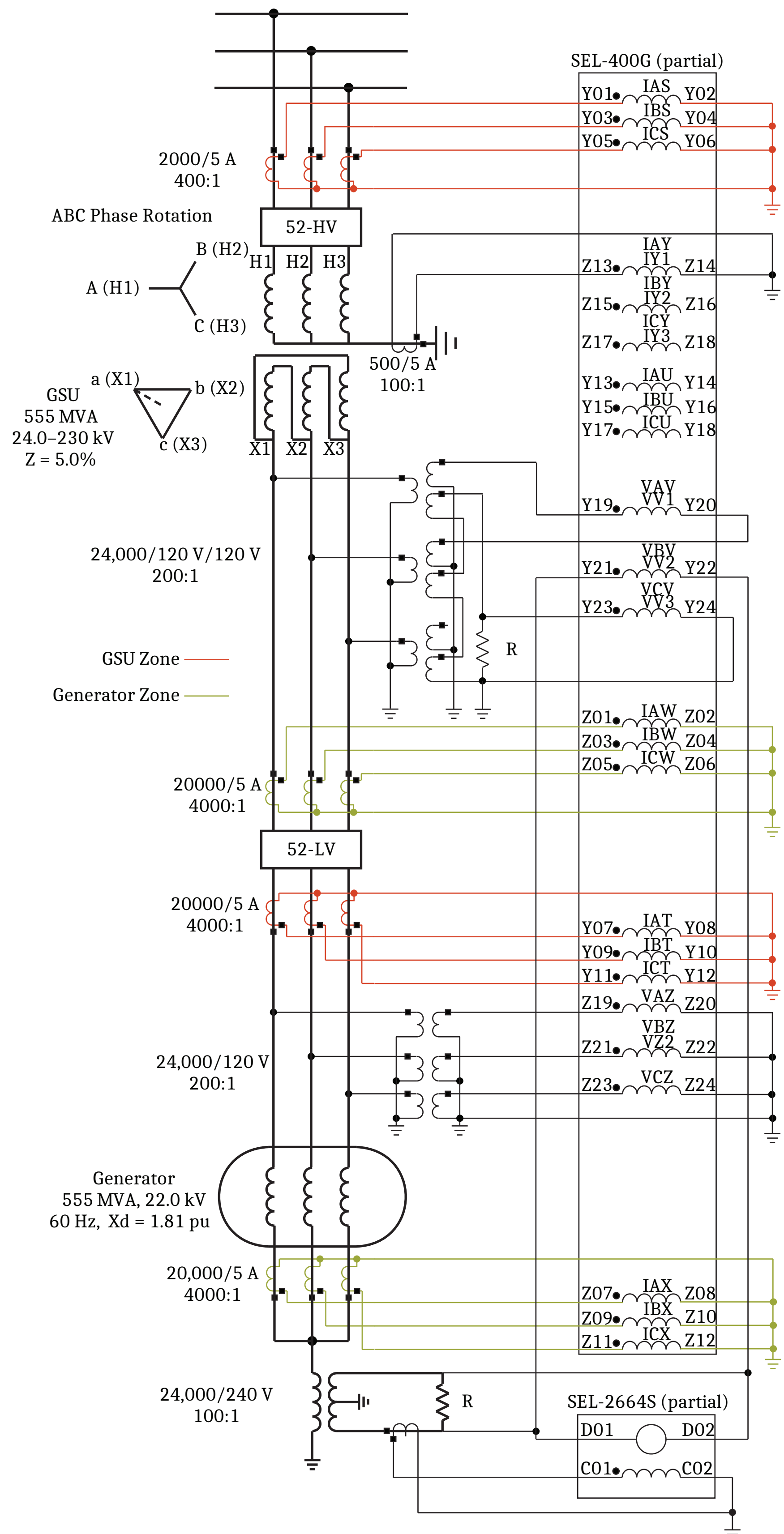


Figure 6.1 Example System Three-Line Diagram

Potential Transformer Data

The iso-phase bus (IPB) VTs have a dual secondary with one winding wye- (star) connected and the other broken-delta connected. The V voltage inputs are used in several applications: V1 is used for GSU V/Hz and synchronism check. V2 is used for stator ground fault protection. V3 is used for IPB ground fault protection. PTCONV is therefore set to 1PH. The ratio of this VT is 24000/120, so PTRV1 and PTRV3 are set to 200.

The generator VTs are wye-connected and connected to the Z voltage terminal. Accordingly, PTCONZ is set to Y and PTRZ is set to 200.

The neutral grounding transformer has a ratio of 24000/240, so PTRV2 is set to 100.

VNOMZ is set to the value of the secondary voltage when the generator is operated at its rated voltage.

$$\text{VNOMZ} = 22\text{ kV} \bullet \frac{120\text{ V}}{24\text{ kV}} = 110\text{ V}$$

Equation 6.1

VNOMV1 and VNOMV3 are set to the value of the secondary voltage when the GSU is operated at its rated voltage.

$$\text{VNOMV1} = \text{VNOMV3} = 24\text{ kV} \bullet \frac{120\text{ V}}{24\text{ kV}} = 120\text{ V}$$

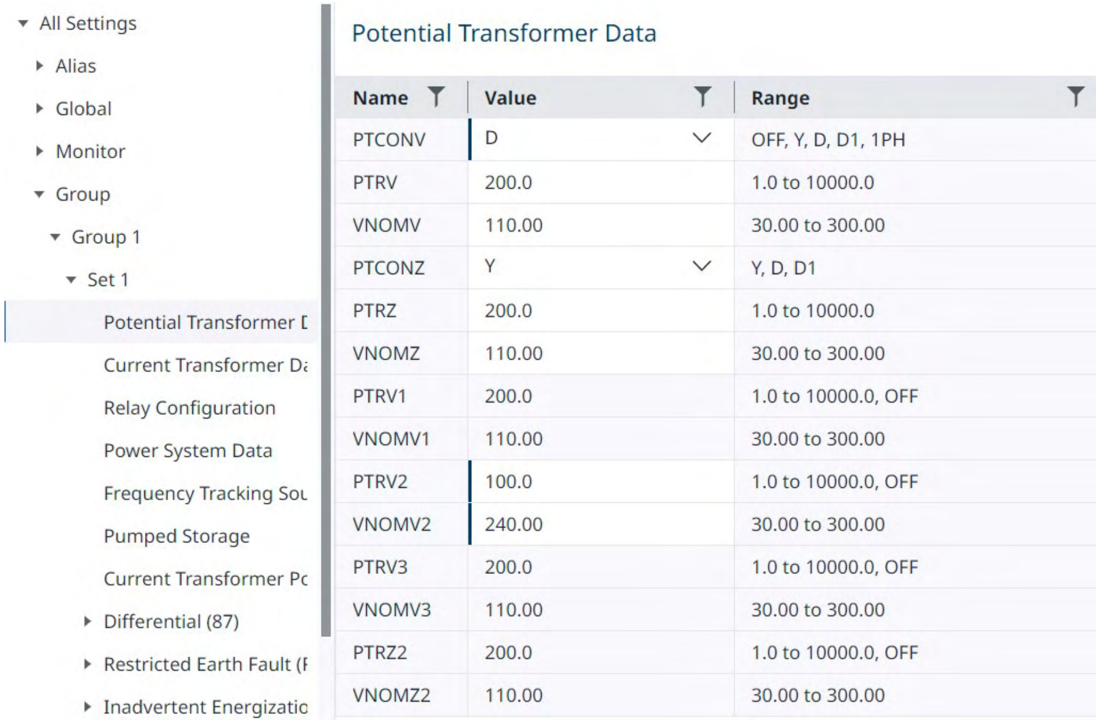
Equation 6.2

VNOMV2 is set to the value of the secondary voltage when the generator is operated at its rated voltage.

$$\text{VNOMV2} = 22\text{ kV} \bullet \frac{240\text{ V}}{24\text{ kV}} = 220\text{ V}$$

Equation 6.3

The selections for VNOMZ and VNOMV1 shown in *Equation 6.1* and *Equation 6.2* are necessary to ensure that the pickup settings of the V/Hz elements are expressed as a percentage of the rated voltage of the protected equipment.

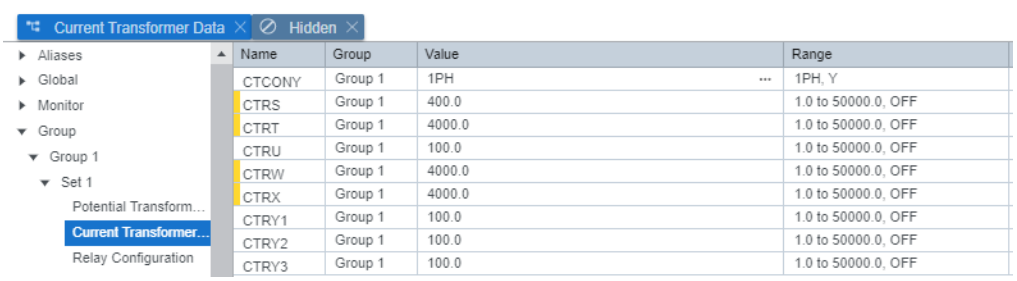


Name	Value	Range
PTCONV	D	OFF, Y, D, D1, 1PH
PTRV	200.0	1.0 to 10000.0
VNOMV	110.00	30.00 to 300.00
PTCONZ	Y	Y, D, D1
PTRZ	200.0	1.0 to 10000.0
VNOMZ	110.00	30.00 to 300.00
PTRV1	200.0	1.0 to 10000.0, OFF
VNOMV1	110.00	30.00 to 300.00
PTRV2	100.0	1.0 to 10000.0, OFF
VNOMV2	240.00	30.00 to 300.00
PTRV3	200.0	1.0 to 10000.0, OFF
VNOMV3	110.00	30.00 to 300.00
PTRZ2	200.0	1.0 to 10000.0, OFF
VNOMZ2	110.00	30.00 to 300.00

Figure 6.2 Potential Transformer

Current Transformer Data

Four sets of three-phase CTs are wired to the S, T, W, and X current terminals in this application. The CT ratios are entered directly. A single-phase CT at the GSU neutral is used to provide restricted earth fault (REF) protection. It is connected to the Y1 current terminal. Therefore, CTCONY is left at its default setting of 1PH and the CT ratio is entered for CTRY1.



Name	Group	Value	Range
CTCONY	Group 1	1PH	1PH, Y
CTRS	Group 1	400.0	1.0 to 50000.0, OFF
CTRT	Group 1	4000.0	1.0 to 50000.0, OFF
CTRU	Group 1	100.0	1.0 to 50000.0, OFF
CTRW	Group 1	4000.0	1.0 to 50000.0, OFF
CTRX	Group 1	4000.0	1.0 to 50000.0, OFF
CTRY1	Group 1	100.0	1.0 to 50000.0, OFF
CTRY2	Group 1	100.0	1.0 to 50000.0, OFF
CTRY3	Group 1	100.0	1.0 to 50000.0, OFF

Figure 6.3 Current Transformer

Relay Configuration

The V2 voltage input will be used to measure the generator neutral voltage. Accordingly, EGNPT is set to V2.

ESYSPT is set to V because a system frequency measurement is required for the synchronism-check and V/Hz functions.

EGNCT is set to X. This configures the generator neutral current to be the Terminal X current that will be used by the loss-of-field, out-of-step, and phase distance elements.

ESYSCT is set to S, T. These CTs are used for the transformer differential and for auxiliary protection functions.

Additionally, the following protection function are configured:

E24 := 2	Enable two V/Hz elements for protection of the generator and GSU
E25 := T	Enable synchronism check for Breaker T
E32 := 1	Enable one directional power element for anti-motoring protection
E40 := Z	Set loss-of-field protection to impedance
E46 := 1	Enable one current unbalance element
E59 := 1	Enable one overvoltage function for IPB ground fault protection
E64G := G1, G3	Enable the fundamental neutral overvoltage element to provide 90%–95% coverage for stator ground faults and the third-harmonic ratio check (G3) to provide protection for the first 15% of the winding. The subharmonic injection unit (SEL-2664S Stator Ground Protection Relay) will provide primary protection for stator ground faults.
E64S := Y	Enable the subharmonic injection element to be used in conjunction with the SEL-2264S
E78 := 1B	Set the out-of-step protection element to single-blinder
E81 := 2	Enable two frequency elements to provide over- and underfrequency protection
E87 := 2	Enable two differential elements for protection of the generator and GSU
EREF := Y1	Enable REF protection for the GSU
ELOP := Z	Enable loss-of-potential detection for the Z voltage terminal
EBUP := 21P	Set the backup protection to phase distance
EINAD := T	Enable inadvertent energization for Breaker T
EBFL := S, T	Enable breaker failure for Breakers S and T
EBFO := T	Enable breaker flashover for Breaker T

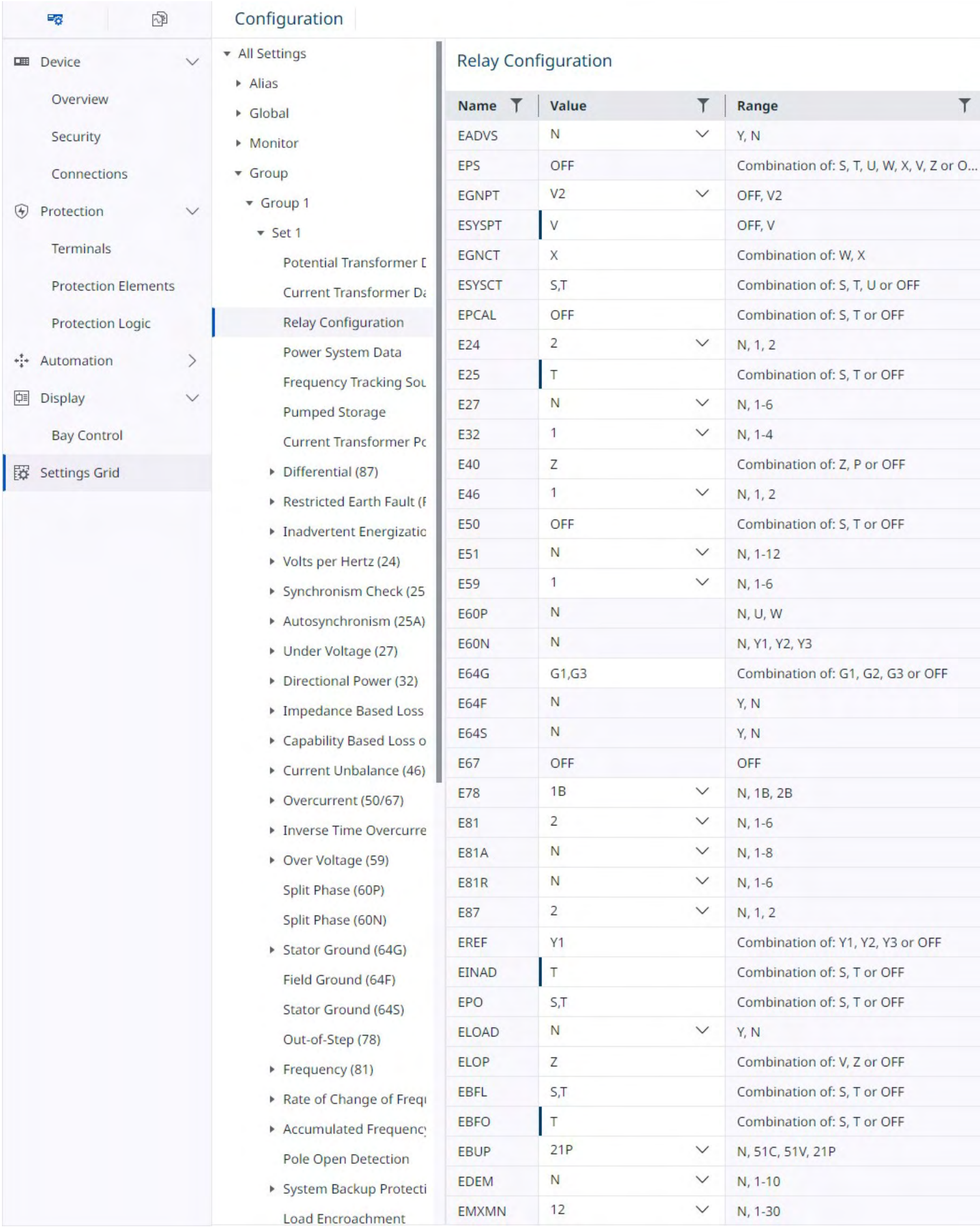
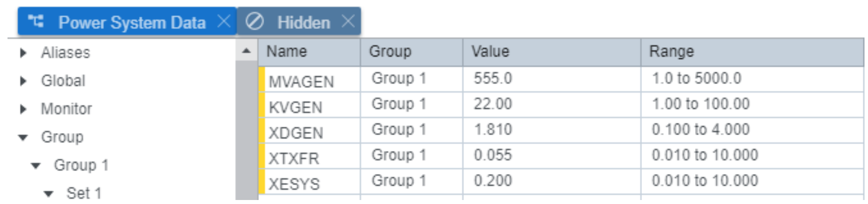


Figure 6.4 Relay Configuration

Power System Data

The generator rated apparent power and terminal voltage are entered for MVAGEN and KVGEN in primary MVA and kV. The generator direct axis synchronous impedance (XDGEN), the transformer leakage reactance (XTXFR), and system impedance (XESYS) are entered in per unit. XDGEN can be entered directly. XTXFR and XESYS must be converted to the generator base MVA (MVAGEN) and generator base voltage (XESYS).

These settings are used for generating characteristic plots for the loss-of-field, out-of-step, and backup distance elements. In addition, MVAGEN is used by the current unbalance element and XDGEN and XESYS are used by the capability-based loss-of-field element.

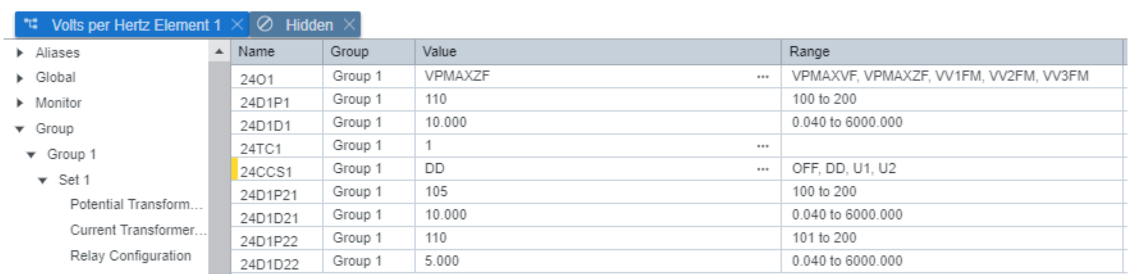


Name	Group	Value	Range
MVAGEN	Group 1	555.0	1.0 to 5000.0
KVGEN	Group 1	22.00	1.00 to 100.00
XDGEN	Group 1	1.810	0.100 to 4.000
XTXFR	Group 1	0.055	0.010 to 10.000
XESYS	Group 1	0.200	0.010 to 10.000

Figure 6.5 Power System Data

Volts-per-Hertz Element 1 (Generator)

This element will use the Z voltage input. Therefore, set 24O1 to VPMAXZF, which is the maximum of the three phase-to-phase voltage measurements.

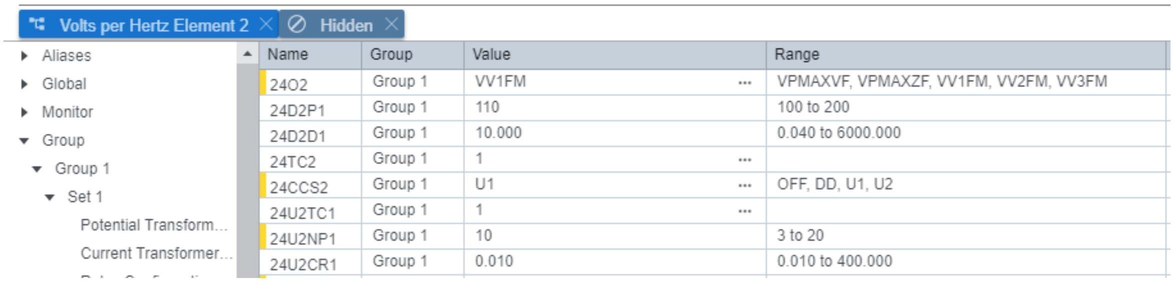


Name	Group	Value	Range
24O1	Group 1	VPMAXZF	VPMAXVF, VPMAXZF, VV1FM, VV2FM, VV3FM
24D1P1	Group 1	110	100 to 200
24D1D1	Group 1	10.000	0.040 to 6000.000
24TC1	Group 1	1	
24CCS1	Group 1	DD	OFF, DD, U1, U2
24D1P21	Group 1	105	100 to 200
24D1D21	Group 1	10.000	0.040 to 6000.000
24D1P22	Group 1	110	101 to 200
24D1D22	Group 1	5.000	0.040 to 6000.000

Figure 6.6 V/Hz Element 1

Volts-per-Hertz Element 2 (Generator Step-Up)

This element will use the V voltage input. Therefore, 24O1 is set to VV1FM, which is the magnitude of the AB voltage measurement from the IPB VT.



Name	Group	Value	Range
24O2	Group 1	VV1FM	VPMAXVF, VPMAXZF, VV1FM, VV2FM, VV3FM
24D2P1	Group 1	110	100 to 200
24D2D1	Group 1	10.000	0.040 to 6000.000
24TC2	Group 1	1	
24CCS2	Group 1	U1	OFF, DD, U1, U2
24U2TC1	Group 1	1	
24U2NP1	Group 1	10	3 to 20
24U2CR1	Group 1	0.010	0.010 to 400.000

Figure 6.7 Volts per Hertz Element 2

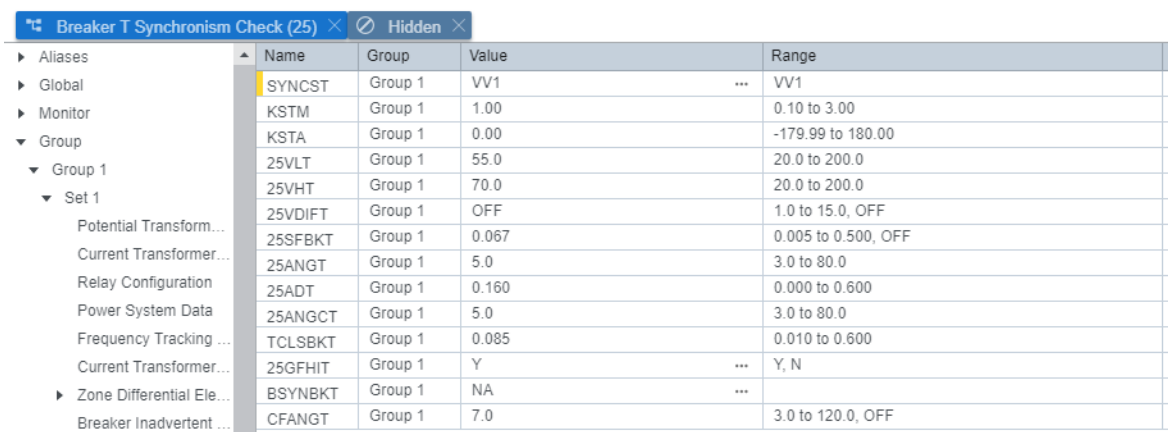
Synchronism Check

Because the AB voltage is connected to the VV1 input, VT is delta connected, and the three phase-to-phase voltages are available as polarizing voltages. Set SYNCP to VABZ.

Name	Group	Value	Range
SYNCP	Group 1	VABZ	VABZ, VBCZ, VCAZ

Figure 6.8 Synchronism Check SYNCP

The corresponding phase-to-phase voltage is selected for the Breaker T synchronism-check element by setting SYNCSS to VV1.



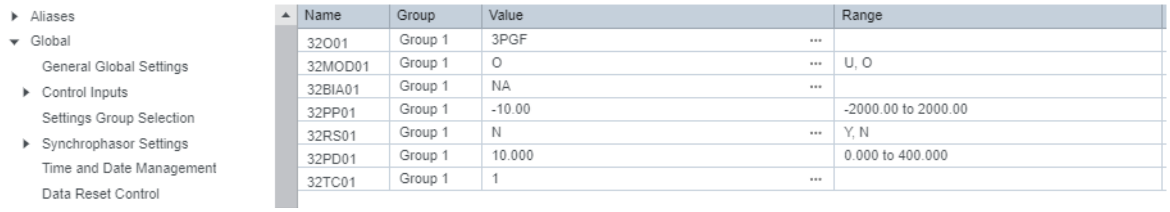
Name	Group	Value	Range
SYNCST	Group 1	VV1	VV1
KSTM	Group 1	1.00	0.10 to 3.00
KSTA	Group 1	0.00	-179.99 to 180.00
25VLT	Group 1	55.0	20.0 to 200.0
25VHT	Group 1	70.0	20.0 to 200.0
25VDIFT	Group 1	OFF	1.0 to 15.0, OFF
25SFBKT	Group 1	0.067	0.005 to 0.500, OFF
25ANGT	Group 1	5.0	3.0 to 80.0
25ADT	Group 1	0.160	0.000 to 0.600
25ANGCT	Group 1	5.0	3.0 to 80.0
TCLSBKT	Group 1	0.085	0.010 to 0.600
25GFHIT	Group 1	Y	Y, N
BSYNBKT	Group 1	NA	
CFANGT	Group 1	7.0	3.0 to 120.0, OFF

Figure 6.9 Synchronism Check Phase-to-Phase Voltage

Directional Power

The directional power element is configured to respond to the real power measured at the generator neutral, 3PGF.

For anti-motoring protection, the element is enabled as an over-power element with a negative pickup setting equal to the expected motoring power in secondary watts.



Name	Group	Value	Range
32O01	Group 1	3PGF	
32MOD01	Group 1	O	U, O
32BIA01	Group 1	NA	
32PP01	Group 1	-10.00	-2000.00 to 2000.00
32RS01	Group 1	N	Y, N
32PD01	Group 1	10.000	0.000 to 400.000
32TC01	Group 1	1	

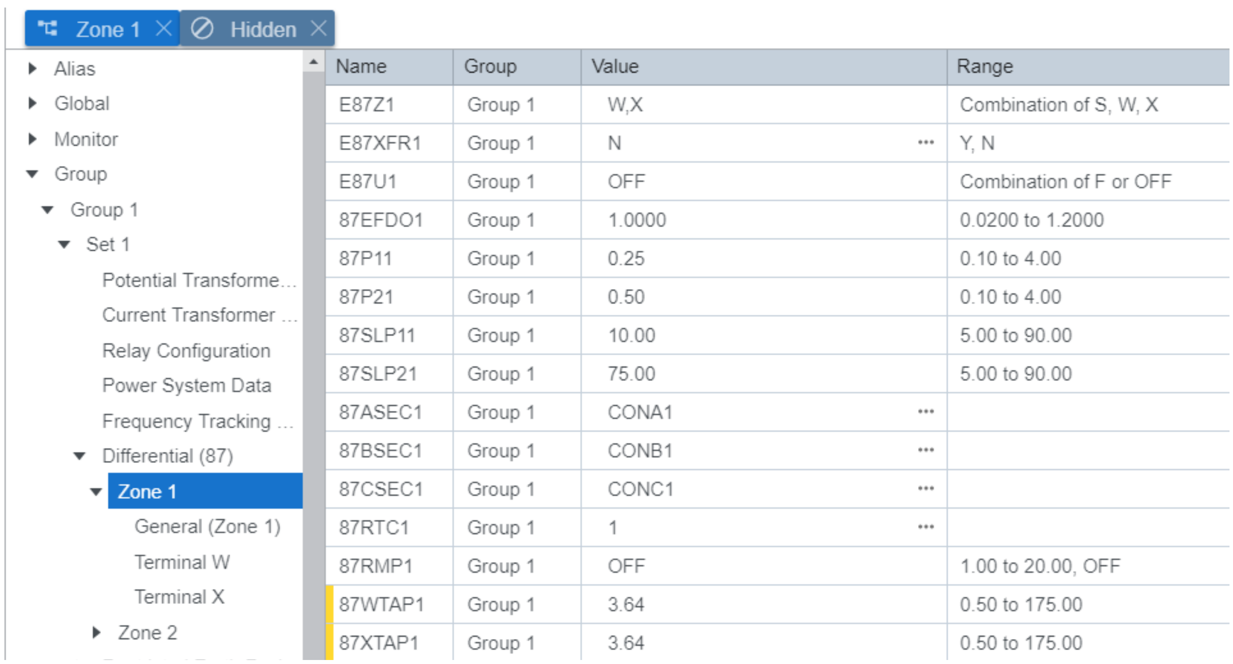
Figure 6.10 Directional Power

Zone 1 Differential (Generator Zone)

This zone uses the W and X CTs, so these are selected for the E87Z1 setting.

E87XFR1 is set to N because the zone does not have an in-zone transformer.

The unrestrained differential is not used, so E87U1 is set to OFF.



Name	Group	Value	Range
E87Z1	Group 1	W,X	Combination of S, W, X
E87XFR1	Group 1	N	Y, N
E87U1	Group 1	OFF	Combination of F or OFF
87EFDO1	Group 1	1.0000	0.0200 to 1.2000
87P11	Group 1	0.25	0.10 to 4.00
87P21	Group 1	0.50	0.10 to 4.00
87SLP11	Group 1	10.00	5.00 to 90.00
87SLP21	Group 1	75.00	5.00 to 90.00
87ASEC1	Group 1	CONA1	
87BSEC1	Group 1	CONB1	
87CSEC1	Group 1	CONC1	
87RTC1	Group 1	1	
87RMP1	Group 1	OFF	1.00 to 20.00, OFF
87WTAP1	Group 1	3.64	0.50 to 175.00
87XTAP1	Group 1	3.64	0.50 to 175.00

Figure 6.11 Zone 1 Differential

Zone 2 Differential (Generator Step-Up)

This zone uses the S and T CTs, so these are selected for the E87Z2 setting.

This zone has an in-zone transformer, so set E87XFR2 to Y.

Harmonic blocking is enabled, as well as the unrestrained and negative-sequence differentials.

MVA2 is set to the rated MVA of the transformer. VTERMS2 and VTERMT2 are set to the GSU-rated HV and LV voltages. The tap values 87STAP2 and 87TTAP2 are calculated automatically and displayed.

From *Figure 6.12*, note the following:

➤ The CTs are oriented in the primary circuit with opposite polarities.

➤ The polarity marks of both CTs are connected to the polarity marks on the relay.

➤ The CTs are wye- (star) connected.

➤ The primary and secondary phase relationships are maintained. In other words, the CT mounted on the A-Phase of the primary circuit is wired to the A input of the relay, and so on).

Therefore, if the transformer were replaced with a bus, the CT secondary currents would sum to zero under normal operation. This means that angle compensation is only required to account for the transformer.

The angle compensation rules from *Compensation Calculations on page 5.20* are applied. The delta winding is selected as the reference winding. The phase sequence is ABC, so phase shifts are measured in the counterclockwise direction. H1 is phase-shifted by 330° with respect to X1 in the counterclockwise direction. Accordingly, 87SCTC2 is set to 11 and 87TCTC2 is set to 0.

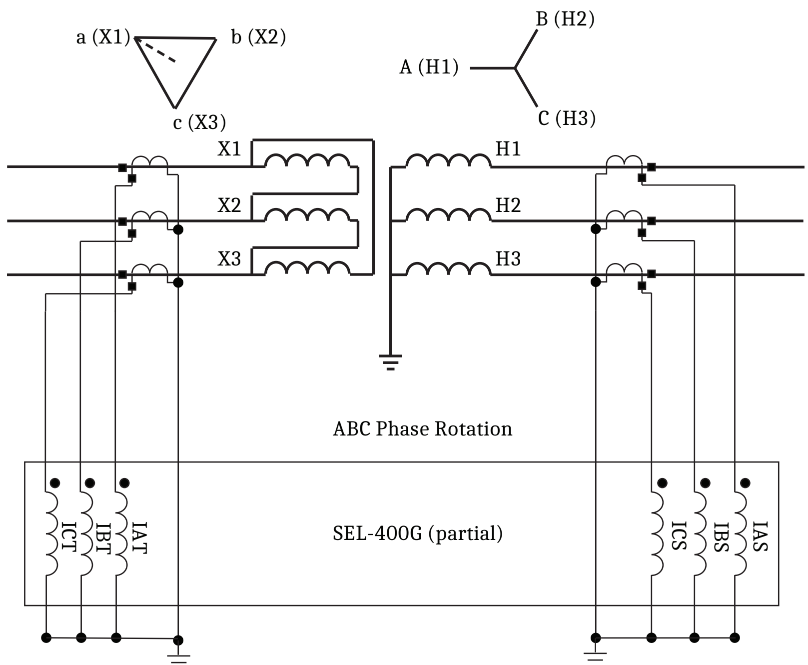
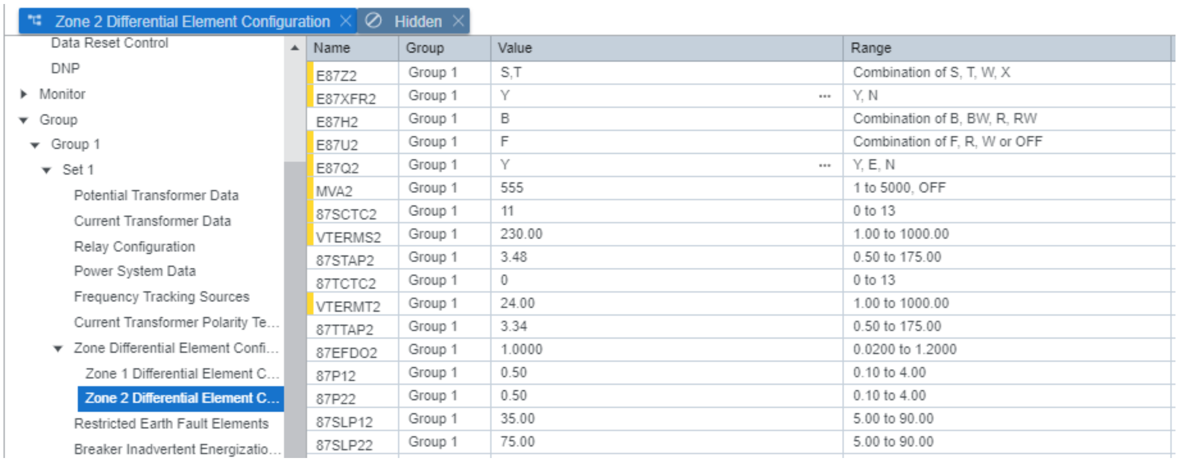


Figure 6.12 Example System Partial Three-Line Diagram

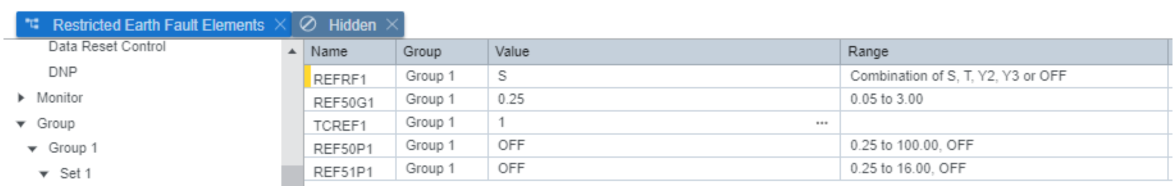


Name	Group	Value	Range
E87Z2	Group 1	S,T	Combination of S, T, W, X
E87XFR2	Group 1	Y	Y, N
E87H2	Group 1	B	Combination of B, BW, R, RW
E87U2	Group 1	F	Combination of F, R, W or OFF
E87Q2	Group 1	Y	Y, E, N
MVA2	Group 1	555	1 to 5000, OFF
87SCTC2	Group 1	11	0 to 13
VTERMS2	Group 1	230.00	1.00 to 1000.00
87STAP2	Group 1	3.48	0.50 to 175.00
87TCTC2	Group 1	0	0 to 13
VTERMT2	Group 1	24.00	1.00 to 1000.00
87TTAP2	Group 1	3.34	0.50 to 175.00
87EFDO2	Group 1	1.0000	0.0200 to 1.2000
87P12	Group 1	0.50	0.10 to 4.00
87P22	Group 1	0.50	0.10 to 4.00
87SLP12	Group 1	35.00	5.00 to 90.00
87SLP22	Group 1	75.00	5.00 to 90.00

Figure 6.13 Zone 2 Differential

Restricted Earth Fault

This element uses the IY1 and S current inputs. Therefore, set REFRF1 to S.



Name	Group	Value	Range
REFRF1	Group 1	S	Combination of S, T, Y2, Y3 or OFF
REF50G1	Group 1	0.25	0.05 to 3.00
TCREF1	Group 1	1	
REF50P1	Group 1	OFF	0.25 to 100.00, OFF
REF51P1	Group 1	OFF	0.25 to 16.00, OFF

Figure 6.14 Restricted Earth Fault

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SECTION 7

Metering, Monitoring, and Reporting

The SEL-400G Advanced Generator Protection System provides extensive capabilities for metering important power system parameters, monitoring transformer components, and reporting on system operation. The relay provides the following useful features:

- *Metering on page 7.2*
- *Circuit Breaker Monitor on page 7.18*
- *Station DC Battery System Monitor on page 7.18*
- *Analog Signal Profiling on page 7.18*
- *Reporting on page 7.23*

See *Section 7: Metering, Section 8: Monitoring* and *Section 9: Reporting in the SEL-400 Series Relays Instruction Manual* for general information. This section contains details specific to the SEL-400G.

Add the following new section just before the metering title

Phasor Reference

The phasor reference is the signal that is used as a reference for the angle of a phasor measurement.

Terminal G defaults to the Terminal Z, positive-sequence voltage for the phasor reference. If this signal is unavailable, then the Terminal G positive-sequence current is used as the phase reference.

If the SEL-400G is configured to track the system voltage (ESYSPT != OFF), Terminals S, T, U, and Y can be configured to use the system frequency for frequency tracking. In this case, the phasor reference defaults to the Terminal V positive-sequence voltage. If this signal is unavailable, the relay will check the availability of a Terminal V single-phase voltage (in order from VV1 to VV3). If none of these voltages are available, the relay will check the availability of the positive-sequence terminal currents (in order of S, T, U, and Y). If none of these are available, the relay will check for the availability of the generator reference (either Terminal Z positive-sequence voltage or Terminal G positive-sequence current in that order). *Table 7.1* summarizes the selection process.

Table 7.1 Valid Reference Quantities

Terminal	Source Terminal	Valid Value
Z, W, X, G	Z	Positive-sequence voltage > 0.1 • VNOMZ
	G	Positive-sequence current > 0.05 • INOMG[a]
S, T, U, V	Z	Positive-sequence voltage > 0.1 • VNOMZ
	G	Positive-sequence current > 0.05 • INOMG[a]
	V[b]	Positive-sequence voltage > 0.1 • VNOMV
	V[b]	VV1 voltage > 0.06 • VNOMV1
	V[b]	VV2 voltage > 0.06 • VNOMV1
	V[b]	VV3 voltage > 0.06 • VNOMV1
	S[b]	Positive-sequence current > 0.05 • INOMS
	T[b]	Positive-sequence current > 0.05 • INOMT
	U[b]	Positive-sequence current > 0.05 • INOMU
	Y[b]	Positive-sequence current > 0.05 • INOMY

[a] INOMG is INOMW if EGNCT= W or W, X. Otherwise INOMG = INOMX.
[b] Used when (ESYSPT != OFF) and FTSRCm = S.

Metering

The SEL-400G provides one-cycle average metering for measuring power system conditions and differential protection values. Each SEL-400G processes 18 currents, 6 voltages, and 1 battery monitor.

Table 7.2 shows all the **MET** commands available in the relay.

Table 7.2 MET Command (Sheet 1 of 2)

Command	Description
MET RMS *n*[a]	Display root-mean-square (rms) metering quantities (current and voltage only) for Terminal G
MET F *t n*[a, b]	Display fundamental metering quantities
MET F Y *n*[a]	Display Y-terminal fundamental metering quantities
MET SEC *t n*[a, b]	Display secondary metering quantities
MET D *n*[a]	Display demand and peak demand metering quantities
MET RD	Reset demand meter data
MET RP	Reset peak demand data
MET DIF Z*k* A *n*[a, c]	Display differential data
MET E *n*[a]	Display energy import and export metering quantities
MET RE	Reset energy data
MET H G *n*[a]	Display harmonic metering data
MET PM *n*[a]	Display synchrophasor data
MET PM	Triggers a synchrophasor measurement
MET RTD *n*[a]	SEL-2600 temperature quantities
MET SYN	Display synchronism check metering data
MET PMV *n*[a]	Display protection math variables

Table 7.2 MET Command (Sheet 2 of 2)

Command	Description
MET AMV *n*[a]	Display automation math variables
MET BAT *n*[a]	Display battery data
MET RBM	Reset station battery max/min measurements
MET ANA *n*[a]	Display analog values from MIRRORED BITS analog, and remote analogs

[a] n = the number of times the relay repeats the response.
[b] t = S, T, U, Y, G.
[c] k = 1, 2.

Because of the large number of analog channels, not all analog channels are required for every application. Furthermore, when the torque-control settings (of those analog quantities that have torque-control settings) deassert, those analog quantities are not shown in the meter report.

There are thus two different instances for not displaying analog quantities in the meter report: you either did not select the analog quantity, or the analog quantity is temporarily not calculated when the torque-control equation deasserts. To distinguish between these two conditions, the relay displays dashes (-----) when the analog quantity is not selected, and zeros (000.00) when the torque-control equation deasserts.

Phase and rms currents for the terminals are zeroed out if the measured secondary phase current is less than 2 percent of nominal current.

Sequence currents for the terminals are zeroed out if the measured secondary maximum phase current is less than 2 percent of nominal current.

Phase and rms voltages for the terminals are zeroed out if the measured secondary voltage is less than 5 percent of nominal voltage.

Sequence voltages for the terminals are zeroed out if the measured secondary maximum phase voltage is less than 5 percent of nominal voltage.

Instantaneous Metering

Fundamental Meter

Use the **MET** (**F**) ***w*** command (*w* = S, T, U, Y, G, V, Z) to view the fundamental (60 or 50 Hz) metering values. When you type **MET** without an argument, the report defaults to Terminal G. For each terminal, the fundamental meter report provides the quantities shown in *Table 7.4*.

Table 7.3 shows the order of valid reference quantities that the relay uses to display the angular relationship among the metering values.

Table 7.3 Valid Reference Quantities (Sheet 1 of 2)

Reference Quantity	Source	Valid Value
Positive-sequence voltage	PT V	Positive-sequence voltage > 0.1 • VNOMV
Positive-sequence voltage	PT Z	Positive-sequence voltage > 0.1 • VNOMZ
Positive-sequence current	Terminal G	Positive-sequence current > 0.05 • INOMG
Positive-sequence current	Terminal Y	Positive-sequence current > 0.05 • INOMY
Positive-sequence current	Terminal S	Positive-sequence current > 0.05 • INOMS

Table 7.3 Valid Reference Quantities (Sheet 2 of 2)

Reference Quantity	Source	Valid Value
Positive-sequence current	Terminal T	Positive-sequence current > 0.05 • INOMT
Positive-sequence current	Terminal U	Positive-sequence current > 0.05 • INOMU

For example, the positive-sequence voltage calculated from the PT V voltage inputs is reference for all metering quantities, provided that this positive-sequence voltage exceeds 10 percent of the VNOMV setting. If PT V is not available, then the positive-sequence voltage calculated from the PT Z voltage inputs is reference for all metering quantities, provided that this positive-sequence voltage exceeds 10 percent of the VNOMV settings. This sequence continues for all other reference quantities.

See *Phasor Reference on page 7.1* for the phasor reference definition.

Table 7.4 Quantities in the Fundamental Meter Report

Quantity	Description
IA, IB, IC	Terminal *w* A-Phase, B-Phase, and C-Phase primary current.
I1, 3I2, 3I0	Positive-, negative-, and zero-sequence components for Terminal *t*.
VA, VB, VC	Available when the PT is wye-connected and PTCON*k* = Y.
V1, 3V2, 3V0	Positive-, negative-, and zero-sequence components of the voltage terminal specified in *Table 7.3*. 3V0 is not available when the PTs are connected in delta (PTCON*k* = D).
PA, PB, PC, 3P	A-Phase, B-Phase, C-Phase, and three-phase active (real) power for Terminal *t*. Only three-phase real power is available when PTs are delta-connected.
QA, QB, QC, 3Q	A-Phase, B-Phase, C-Phase, and three-phase reactive power for Terminal *t*. Only three-phase reactive power is available when PTs are delta-connected.
SA, SB, SC, 3S	A-Phase, B-Phase, C-Phase, and three-phase apparent power for Terminal *t* Only three-phase power apparent is available when PTs are delta-connected.
Power factor	A-Phase, B-Phase, C-Phase, and three-phase power factor for Terminal *t*.
VAB, VBC, VCA	AB, BC, and CA line-to-line voltages
Frequency	Measured frequency
Frequency Tracking	When the relay tracks the frequency, the report display “Y,” and “N” when the relay does not track the frequency.
Battery Voltage	Measured battery voltage
Frequency Source	Generator (G) or system (S)

Enable current, voltage, and power meter quantities with the following settings:

- Current: include the terminal in ESYSCT
- Power (fundamental power only): include Terminal *t*. Power is always calculated for Terminal G and those terminals included in the EPCAL setting.

```
=>>MET F G <Enter>

Relay 1                                     Date: 02/17/2020  Time: 18:19:58.278
Station A                                   Serial Number: 1192110331

Fundamental Meter: Terminal G

               Phase Currents                  Sequence Currents
               IA        IB        IC           I1        3I2       3I0
MAG(A,pri)     0.00      0.00      0.00         0.00      0.00      0.00
ANG(deg)       0.00      0.00      0.00         0.00      0.00      0.00

            Phase Voltages - PT Z               Sequence Voltages
             VA        VB        VC            V1        3V2       3V0
MAG (kV)   -------   -------   -------        0.000     0.000     0.000
ANG(deg)   -------   -------   -------        0.00      0.00      0.00

Power Quantities
Active Power P (MW,pri)
    PA          PB          PC         3P
     0.00        0.00        0.00       0.00

Reactive Power Q (MVAr,pri)
    QA          QB          QC         3Q
     0.00        0.00        0.00       0.00

Apparent Power  S (MVA,pri)
    SA          SB          SC         3S
     0.00        0.00        0.00       0.00

Power Factor
 Phase A     Phase B     Phase C     3-Phase
 0.00 Lead   0.00 Lead   0.00 Lead   0.00 Lead

Line-to-Line Voltage
                   PT - Z
             VAB       VBC       VCA
MAG (kV)     0.000     0.000     0.000
ANG(deg)     0.00      0.00      0.00

          Neutral          Neutral 3rd     Terminal 3rd     Total 3rd
          Fundamental      Harmonic        Harmonic         Harmonic
             VN              VN3            3V03              VG3
MAG (kV)   -------         -------           0.003          -------
ANG(deg)   -------         -------         -21.36           -------

Generator Neutral Voltage Terminal = OFF

FREQ (Hz) 60.000          Frequency Tracking = N

VDC (V)    -0.02          Frequency Source = G

=>>
```

Figure 7.1 Fundamental Quantities Report for Terminal G

Power

Table 7.4 shows the power quantities that the relay measures. The instantaneous power measurements are derived from 1-cycle averages that the SEL-400G reports by using the generator condition of the positive power flow convention; for example, real and reactive power flowing out (export) is positive, and real and reactive power flowing in (import) is negative (see *Figure 7.2*). For power factor, LAG and LEAD refer to whether the current lags or leads the applied voltage. The reactive power Q is positive when the voltage angle is greater than the current angle ($\theta_V > \theta_I$), which is the case for inductive loads where the current lags the applied voltage. Conversely, Q is negative when the voltage angle is less than the current angle ($\theta_V < \theta_I$); this is when the current leads the voltage, as in the case of capacitive loads.

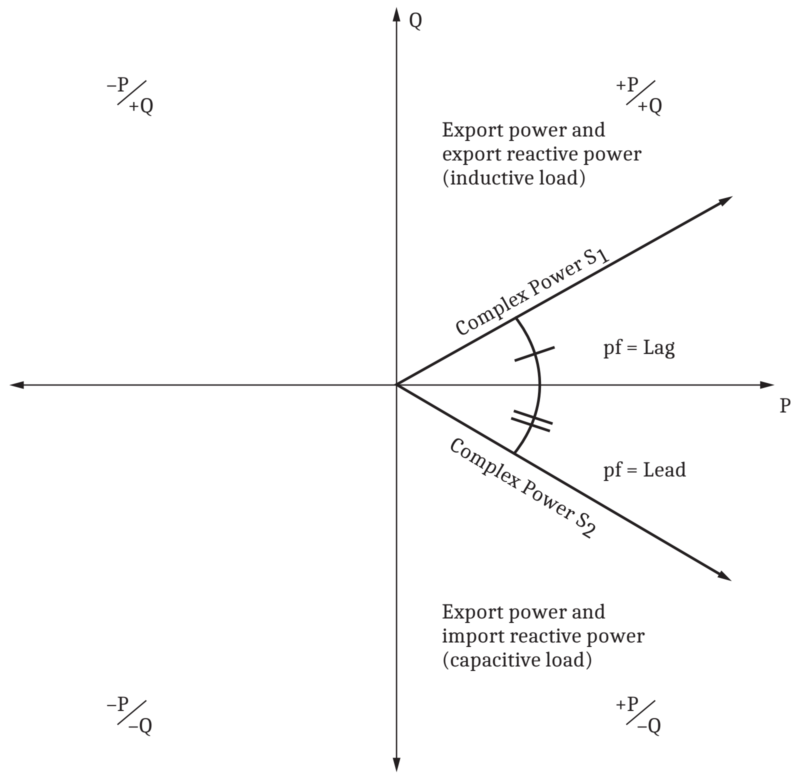

Figure 7.2 Complex Power (P/Q) Plane

The SEL-400G includes Relay Word bits to indicate the leading or lagging power factor (see *Section 11: Relay Word Bits*). In the case of a unity power factor or loss of phase or potential condition, the resulting power factor angle would be on this axis of the complex power (P/Q) plane shown in *Figure 7.2*. This would cause the power factor Relay Word bits to rapidly change state (chatter). Be aware of expected system conditions when monitoring the power factor Relay Word bits. SEL does not recommend the use of chattering Relay Word bits in the SER or anything that will trigger an event.

RMS Meter

Use the **MET RMS** command to view the rms current for Terminal G and voltage values for Terminal Z; the relay does not calculate rms power values. *Table 7.5* shows the quantities in the rms report.

Table 7.5 Quantities in the RMS Meter Report

Quantity	Description
IA, IB, IC	Terminal G A-Phase, B-Phase, and C-Phase primary current.
VAB, VBC, VCA	Primary voltage AB, BC, and CA line-to-line voltages for the Z terminal
Frequency	Measured generator frequency
Frequency Tracking	The report displays Y when the relay tracks the frequency, and N when the relay does not track the frequency
Battery Voltage	Measured battery voltage

Figure 7.3 shows an rms report for Terminal G. **MET RMS** is only available for the G terminal on the SEL-400G on the initial release.

```
=>>MET RMS <Enter>

Relay 1                                    Date: 03/01/2020  Time: 15:37:43.924
Station A                                  Serial Number: 1192110331

RMS Meter: Terminal G

Phase Currents, I (A,pri)
   IA         IB         IC
 4249.62    4239.78    4270.39

Phase Voltages (kV,pri)  - PT Z
  VA         VB         VC
 63.497    63.495    63.499

Line-to-Line Voltages (kV,pri)
  VAB        VBC        VCA
109.977   109.980   109.982

FREQ (Hz)  60.001         Frequency Tracking = Y
VDC (V)     0.06          Frequency Source = G

=>>
```

Figure 7.3 RMS Report for Terminal G

Secondary Meter

Use the **MET SEC** command to see the secondary fundamental current and voltage values for all terminals. Included with each value are the associated CT or PT ratio and the associated frequency tracking source—generator (G) or system (S). *Figure 7.4* shows the report for all terminals. *Table 7.6* shows the quantities in the secondary quantities report.

See *Phasor Reference on page 7.1* for the phasor reference definition.

Table 7.6 Quantities in the MET SEC Report

Quantity	Description
IA, IB, IC	A-Phase, B-Phase, and C-Phase in secondary current.
IY1, IY2, IY3	Single-phase currents are available when CTCONY = 1PH
VA, VB, VC	Secondary voltage
VAB, VBC, VCA	Secondary voltage AB, BC, and CA line-to-line voltages
VV1, VV2, VV3, VZ2	Single-phase voltages are available when PTCON*k* = D, D1 or PTCONV = 1PH
Frequency	Measured generator and system frequency
Frequency Tracking	The report displays Y when the relay tracks the frequency, and N when the relay does not track the frequency.
Battery Voltage	Measured battery voltage
Pumped Storage	The report displays Y when pumped-storage mode is active.

```
=>>MET SEC <Enter>

Relay 1                                     Date: 03/10/2020  Time: 11:47:41.670
Station A                                   Serial Number: 1192110331

Secondary Meter

          Secondary Currents
Terminal   MAG(A)  ANG(DEG)  CTR     Source
 IAS       4.0008     0.15   4000.0     S
 IBS       4.0006  -120.12   4000.0     S
 ICS       4.0013   119.94   4000.0     S
 IAT       4.0007     0.16    400.0     S
 IBT       4.0005  -120.15    400.0     S
 ICT       4.0016   119.96    400.0     S
 IAU       4.0014     0.12  12000.0     G
 IBU       4.0012  -120.13  12000.0     G
 ICU       4.0010   119.98  12000.0     G
 IAW       2.0016    10.68   4000.0     G
 IBW       2.0017  -110.68   4000.0     G
 ICW       2.0013   130.70   4000.0     G
 IAX       2.0015    10.69   4000.0     G
 IBX       2.0014  -110.70   4000.0     G
 ICX       2.0006   130.71   4000.0     G
 IY1       2.0015    10.69    100.0     S
 IY2       2.0016   130.69    100.0     G
 IY3       4.0015  -120.10    100.0     G

          Secondary Voltages
Terminal   MAG(V)  ANG(DEG)  PTR     Source
 VV1       60.0001    0.06    200.0     S
 VV2       59.9998 -119.93    200.0     G
 VV3       59.9999  120.16    200.0     G
 VAZ       60.0011   19.55    200.0     G
 VBZ       60.0014 -100.97    200.0     G
 VCZ       60.0013  141.39    200.0     G

Generator FREQ (Hz) 59.999         Frequency Tracking = Y
System    FREQ (Hz) 59.997         Frequency Tracking = Y
VDC (V)     0.00                   Pump Storage Mode  = N

=>>
```

Figure 7.4 MET SEC Report

Demand Meter

Figure 7.5 shows the demand report with four of the available ten elements enabled (see *Thermal Demand and Rolling Demand on page 7.6 in the SEL-400 Series Relays Instruction Manual* for more information). *Table 7.7* shows the quantities in the demand metering report. See *Table 7.8* for a list of quantities that may be included in the demand metering report. See *Section 7: Metering in the SEL-400 Series Relays Instruction Manual* for a complete description of how demand metering works.

Table 7.7 Quantities in the Demand Metering Report

Quantity	Description
DM01–DM04	Four of the available ten elements (DM01–DM10 available)
Op_Qty	Displays the analog quantities selected for each enabled element (see *Table 7.8* for a list of available analog quantities)
Type	Displays the selected type (rolling demand or thermal) of demand meter for each element (see *Thermal Demand and Rolling Demand on page 7.6 in the SEL-400 Series Relays Instruction Manual* for more information)
Demand	Displays the accumulated demand and the time and date of the recording
Peak	Displays the peak demand and the time and date of the recording

Table 7.8 Demand Metering Operating Quantities

Analog Quantity	Description
IϕGRS[a]	1-second average rms current ϕ phase, Terminal G
3I2*m*MS[b]	1-second average negative-sequence current angle, Terminal *m*
3I0*m*MS[b]	1-second average zero-sequence current angle, Terminal *m*

[a] ϕ = A, B, C.
[b] m = S, T, U, Y, G (S, T, U, G if CTCONY = 1PH).

```
=>>MET D <Enter>

Relay 1                                    Date: 03/10/2020  Time: 11:46:51.940
Station A                                  Serial Number: 1192110331

       Op_Qty    Type    Demand(A)   Peak(A)    Date         Time

DM01     IAGRS   THERM      1.864      2.580  02/18/2020  23:17:10.635
DM02    3I2TMS   ROLL       2.184      2.184  03/01/2020  20:20:14.898
DM03    3I0GMS   THERM      0.277      1.664  01/13/2020  03:32:27.834
DM04     ICGRS   ROLL       3.243      3.243  01/20/2020  20:30:08.536

LAST DEMAND RESET: 01/10/2020 11:46:24.881
LAST MAX DEMAND RESET: 01/10/2020 11:46:24.881

=>>
```

Figure 7.5 Demand Report With Four Elements Enabled

Differential Meter

Use the **MET DIF** command to see the differential operate, restraint, and percentage harmonic values. Type **MET DIF Z1** to view the Zone 1 report and **MET DIF Z2** to view the Zone 2 report. *Table 7.9* summarizes the quantities in the differential report. *Figure 7.6* and *Figure 7.7* show the differential element report. *Figure 7.8* shows the differential element reports, including individual terminal compensated currents in the differential zones.

Table 7.9 Quantities in the MET DIF Report

Quantity	Description
IOPA, IOPB, IOPC	Per-unit operating current for Differential Element A, Differential Element B, and Differential Element C
In-Zone Transformer	Displays Y when the zone is configured with an In-Zone Transformer
IRTA, IRTB, IRTC	Per-unit restraint current for Differential Element A, Differential Element B, and Differential Element C
IOPAF2, IOPBF2, IOPCF2	Second-harmonic currents, expressed as a percentage of the operating current
IOPAF4, IOPBF4, IOPCF4	Fourth-harmonic currents, expressed as a percentage of the operating current
IOPAF5, IOPBF5, IOPCF5	Fifth-harmonic currents, expressed as a percentage of the operating current
IOPRA, IOPRB, IOPRC	Per-unit rms operating currents
Enabled Terminals	Displays the terminals included in the differential calculations (based on the E87Z*n* setting)
Frequency	Frequency, Frequency Source, and Frequency Tracking Status

```
=>>MET DIF Z1 <Enter>

Relay 1                                    Date: 02/18/2020  Time: 14:41:56.043
Station A                                  Serial Number: 1192110331

Differential Zone 1             In-Zone Transformer = N
Operate Currents (per unit)     Restraint Currents (per unit)
IOPFA     IOPFB     IOPFC       IRTFA     IRTFB     IRTFC
 0.00      0.00      0.00        0.00      0.00      0.00

RMS Operate Currents (per unit)
IOPRA     IOPRB     IOPRC
 0.01      0.01      0.01

Enabled Terminals:  W, X

FREQ (Hz) 60.000         Frequency Tracking = N
                         Frequency Source = G

=>>
```

Figure 7.6 Differential-Element Zone 1 Report

```
=>>MET DIF Z2 <Enter>

Relay 1                                    Date: 02/18/2020  Time: 14:42:02.803
Station A                                  Serial Number: 1192110331

Differential Zone 2             In-Zone Transformer = Y
Operate Currents (per unit)     Restraint Currents (per unit)
IOPFA     IOPFB     IOPFC       IRTFA     IRTFB     IRTFC
 0.00      0.00      0.00        0.00      0.00      0.00

2nd Harmonic Currents (percentage of IOPFA, IOPFB, IOPFC)
IOPAF2    IOPBF2    IOPCF2
85.68     $$.$$     35.53

4th Harmonic Currents (percentage of IOPFA, IOPFB, IOPFC)
IOPAF4    IOPBF4    IOPCF4
53.00     33.92     52.36

5th Harmonic Currents (percentage of IOPFA, IOPFB, IOPFC)
IOPAF5    IOPBF5    IOPCF5
$$.$$     50.46     47.68

Enabled Terminals:  S, W

FREQ (Hz) 60.000         Frequency Tracking = N
                         Frequency Source = G

=>>
```

Figure 7.7 Differential-Element Zone 2 Report

The **MET DIF A** command shows the content from the **MET DIF** command, additional information for matrix compensation, differential settings, and differential Relay Word bits. You can use this extra information during commissioning and troubleshooting. For each phase (A, B, C), the currents for each enabled terminal (e.g., S, T) appear in a table format (see *Figure 7.8*). On the left side of the table, the primary and secondary current magnitudes appear along with the corresponding phase angles. The phase angles are referred to whichever terminal is listed first in the Enabled Terminals list. As described in *Universal Differential Elements on page 5.19*, the secondary currents are divided by taps to make per-unit values before undergoing matrix compensation. The right portion of the **MET DIF A** response shows the per-unit current magnitudes (after tap compensation), as well as the per-unit magnitudes and angles after matrix compensation. Use the **MET DIF Z1 A** and **MET DIF Z2 A** commands to view the Zone 1 and Zone 2 reports.

Beneath the current table, the **MET DIF A** command displays the CT connections (Y or D) for each enabled terminal, as well as the associated tap values and matrix compensation numbers (0–13). If Matrix 13 is chosen, the user-settable angle shift appears, along with the value for the zero-sequence removal setting option.

The final portion of the **MET DIF A** command response displays the differential Relay Word bits from the restrained differential logic, as well as the Relay Word bits from the unrestrained differential logic. To aid in troubleshooting, the command response also displays Relay Word bits associated with harmonic blocking.

```
=>>MET DIF Z2 A <ENTER>

Relay 1                                     Date: 2020/10/23  Time: 11:21:03.547
Station A                                   Serial Number: 1200990546

Differential Zone 2               In-Zone Transformer = Y
Operate Currents (per unit)       Restraint Currents (per unit)
IOPFA     IOPFB     IOPFC         IRTFA     IRTFB     IRTFC
 2.83      2.79      2.15          2.93      2.87      2.33

2nd Harmonic Currents (percentage of IOPFA, IOPFB, IOPFC)
IOPAF2    IOPBF2    IOPCF2
 0.00      0.00      0.00

4th Harmonic Currents (percentage of IOPFA, IOPFB, IOPFC)
IOPAF4    IOPBF4    IOPCF4
 0.00      0.00      0.00

5th Harmonic Currents (percentage of IOPFA, IOPFB, IOPFC)
IOPAF5    IOPBF5    IOPCF5
 0.01      0.01      0.01

Enabled Terminals:  W, X, Y

FREQ (Hz)  60.000         Frequency Tracking = N
                          Frequency Source = G

Tap and Matrix Compensation:                              Reference Terminal = W
                  Terminal Currents          Tap Comp.        Matrix Comp.
Phase A     (A,pri)    (A,sec)     (DEG)    (per unit)   (per unit)    (DEG)
 IAW       2249.01       2.50       0.00        0.71         1.14     -85.95
 IAX      77778.41       3.50    -120.03        0.29         0.25    -144.53
 IAY       1010.70       4.49     119.90        1.80         1.53     -97.14
Phase B
 IBW       3150.17       3.50    -120.03        1.00         1.01     140.63
 IBX      99774.46       4.49     119.89        0.37         0.33      94.02
 IBY        562.58       2.50      -0.05        1.00         1.52     127.89
Phase C
 ICW       4041.42       4.49     119.96        1.28         0.86      35.49
 ICX      55570.03       2.50      -0.01        0.21         0.30     -39.41
 ICY        788.01       3.50    -120.10        1.40         1.17      15.80

Compensation Settings:
87WTAP:   3.50    87WCTC:  9
87XTAP:  12.00    87XCTC: 11
87YTAP:   2.50    87YCTC: 13    87YANG: 135.6

Relay Word Bits:
87AB21  87BB21  87CB21  87B21   87B51   87Z2    87R2    87U2
0       0       0       0       0       1       1       0

87CRHR2 87AHB2  87BHB2  87CHB2  87AHR2  87BHR2  87CHR2  87XB22
0       0       0       0       1       1       1       0

87B22   87B52   87TM1   87TMA1  87TMB1  87TMC1  87TS1   87TSA1
0       0       0       0       0       0       0       0
=>
```

Figure 7.8 Expanded Differential-Element Report

Energy Meter

Use the **MET E** command to view the imported, exported, and total energy for Terminal G and those terminals specified in the EPCAL group setting. You can view the energy metering quantities by using a communications port or the relay front-panel LCD screen.

NOTE: When PTCONV = 1PH, energy calculations are zeroed for terminals associated with Terminal V.

To reset the energy values, use the **MET RE** command from a communications terminal or answer **YES** and press **ENT** at the Energy Meter submenu reset prompt on the front-panel LCD screen. You can also reset energy metering with Global SELOGIC setting RST_ENE.

Table 7.10 shows the quantities in the energy meter report. *Figure 7.9* shows the report for Terminal G and Terminal S.

Table 7.10 Quantities in the Energy Meter Report

Quantities	Description
Terminal	Terminal G and Terminal S (Terminal G plus those in EPCAL)
Import	MWh and MVarh imported in primary
Export	MWh and MVarh exported in primary
Total	Sum of imported and exported in primary
VREF	Voltage reference terminal

The relay updates energy values once per second. The relay also stores energy values to nonvolatile storage once every four hours, referenced from 23:50 hours (it overwrites the previously stored value if it is exceeded). Should the relay lose control power, it restores the energy values saved at the end of the last four-hour period.

```
=>>MET E <Enter>

Relay 1                                    Date: 03/10/2020  Time: 12:46:16.861
Station A                                  Serial Number: 1192110331

     IMPORT(MWh/MVArh)    EXPORT(MWh/MVArh)    TOTAL(MWh/MVArh)
Ter  Active   Reactive    Active   Reactive    Active   Reactive    VREF
 G      0.00      0.00      87.49    79.04       87.49    79.04      Z
 S      0.00     -0.64       3.83     2.67        3.83     2.03      V

Pump Storage Mode = N

Last Energy Reset:  02/09/2020  14:57:11.708

=>>
```

Figure 7.9 Energy Meter Reports for Terminals G and S

Harmonic Meter

Use the **MET H** command to view the harmonic components of the secondary voltages and currents. *Table 7.11* shows the quantities in the harmonic meter report, *Figure 7.10* shows the harmonic data. **MET H G** can be used to view the generator harmonic data, as shown in *Figure 7.10*.

Table 7.11 Quantities in the Harmonic Meter Report

Quantities	Description
IA*n*, IB*n*, IC*n*[a]	Current Terminal *n*, A-Phase, B-Phase, C-Phase secondary current (Harmonics 1–15)
IAG, IBG, ICG	Generator terminal current, A-Phase, B-Phase, C-Phase secondary current (Harmonics 1–15) (only for **MET H G**)
VA*k*, VB*k*, VC*k*[b]	Voltage Terminal *k*, A-Phase, B-Phase, C-Phase secondary voltage (Harmonics 1–15)
VGN	Generator neutral secondary voltage (Harmonics 1–15) (only for **MET H G**)
Generator FREQ	Measured generator island frequency
System FREQ	Measured system island frequency
Frequency Tracking	The report displays **Y** when the relay tracks the frequency and **N** when the relay does not track the frequency (separately for both generator and system frequency)

[a] n = S, T, U, W, X, Y.
[b] k = V, Z.

```
=>MET H <Enter>

Relay 1                                         Date: 03/06/2020  Time: 16:58:45.449
Station A                                       Serial Number: 1192110331


Magnitudes of Harmonic Inputs (Amps Sec)
 H  IAS    IBS    ICS    IAT    IBT    ICT    IAU    IBU    ICU
 1  0.000  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.000
 2  0.001  0.001  0.000  0.001  0.000  0.000  0.001  0.000  0.001
 3  0.000  0.000  0.000  0.001  0.001  0.000  0.001  0.001  0.001
 4  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.000  0.001
 5  0.000  0.000  0.000  0.000  0.001  0.000  0.001  0.001  0.000
 6  0.001  0.001  0.001  0.000  0.000  0.000  0.000  0.001  0.001
 7  0.000  0.001  0.000  0.000  0.001  0.001  0.001  0.000  0.000
 8  0.001  0.000  0.000  0.000  0.000  0.000  0.000  0.001  0.001
 9  0.001  0.000  0.000  0.000  0.000  0.000  0.000  0.001  0.000
10  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001
11  0.000  0.001  0.000  0.000  0.001  0.000  0.000  0.001  0.001
12  0.000  0.001  0.000  0.000  0.000  0.001  0.001  0.001  0.000
13  0.001  0.000  0.001  0.000  0.001  0.000  0.001  0.000  0.000
14  0.000  0.001  0.000  0.000  0.000  0.000  0.001  0.000  0.001
15  0.001  0.000  0.001  0.000  0.000  0.001  0.001  0.000  0.001

Magnitudes of Harmonic Inputs (Amps Sec)
 H  IAW    IBW    ICW    IAX    IBX    ICX    IAY    IBY    ICY
 1  0.000  0.001  0.001  0.001  0.000  0.001  0.001  0.001  0.000
 2  0.001  0.001  0.001  0.001  0.001  0.000  0.001  0.001  0.000
 3  0.001  0.000  0.001  0.000  0.000  0.000  0.001  0.001  0.001
 4  0.001  0.000  0.001  0.001  0.001  0.001  0.001  0.000  0.001
 5  0.000  0.000  0.000  0.000  0.000  0.001  0.001  0.001  0.001
 6  0.001  0.001  0.001  0.000  0.001  0.001  0.000  0.001  0.001
 7  0.000  0.000  0.000  0.001  0.000  0.001  0.001  0.001  0.000
 8  0.001  0.000  0.001  0.000  0.000  0.001  0.000  0.001  0.001
 9  0.001  0.000  0.000  0.000  0.001  0.000  0.001  0.000  0.001
10  0.000  0.000  0.000  0.001  0.001  0.001  0.001  0.000  0.001
11  0.000  0.000  0.000  0.001  0.000  0.001  0.001  0.001  0.001
12  0.000  0.000  0.001  0.000  0.000  0.001  0.001  0.001  0.001
13  0.000  0.000  0.000  0.000  0.000  0.001  0.000  0.000  0.000
14  0.001  0.000  0.000  0.000  0.000  0.000  0.001  0.000  0.001
15  0.001  0.000  0.001  0.001  0.000  0.001  0.001  0.001  0.001

Magnitudes of Harmonic Inputs (Volt Sec)
 H   VAV     VBV     VCV     VAZ     VBZ     VCZ
 1   0.001   0.002   0.003   0.001   0.003   0.003
 2   0.000   0.000   0.001   0.001   0.001   0.001
 3   0.002   0.001   0.001   0.002   0.001   0.002
 4   0.002   0.003   0.003   0.003   0.003   0.003
 5   0.002   0.000   0.001   0.002   0.001   0.000
 6   0.002   0.002   0.001   0.002   0.001   0.001
 7   0.001   0.002   0.001   0.001   0.001   0.001
 8   0.002   0.003   0.003   0.003   0.003   0.003
 9   0.001   0.002   0.001   0.001   0.002   0.002
10   0.001   0.002   0.003   0.000   0.002   0.002
11   0.002   0.002   0.001   0.001   0.002   0.002
12   0.002   0.001   0.001   0.002   0.001   0.001
13   0.002   0.001   0.002   0.001   0.000   0.001
14   0.001   0.001   0.001   0.000   0.003   0.001
15   0.001   0.001   0.001   0.002   0.001   0.000

Generator FREQ (Hz)  60.000          Frequency Tracking = N
System    FREQ (Hz)  60.000          Frequency Tracking = N
```

Figure 7.10 Harmonic Meter Report

```
=>MET H G <Enter>

Relay 1                                      Date: 03/06/2020  Time: 18:44:02.389
Station A                                    Serial Number: 1192110331


Magnitudes of Harmonic Inputs (Amps Sec, Volt Sec)
 H  IAG   IBG   ICG    VAZ    VBZ    VCZ    VGN
 1  0.00  0.00  0.00   0.00   0.00   0.00   0.00
 2  0.00  0.00  0.00   0.00   0.00   0.00   0.00
 3  0.00  0.00  0.00   0.00   0.00   0.00   0.00
 4  0.00  0.00  0.00   0.00   0.00   0.00   0.00
 5  0.00  0.00  0.00   0.00   0.00   0.00   0.00
 6  0.00  0.00  0.00   0.00   0.00   0.00   0.00
 7  0.00  0.00  0.00   0.00   0.00   0.00   0.00
 8  0.00  0.00  0.00   0.00   0.00   0.00   0.00
 9  0.00  0.00  0.00   0.00   0.00   0.00   0.00
10  0.00  0.00  0.00   0.00   0.00   0.00   0.00
11  0.00  0.00  0.00   0.00   0.00   0.00   0.00
12  0.00  0.00  0.00   0.00   0.00   0.00   0.00
13  0.00  0.00  0.00   0.00   0.00   0.00   0.00
14  0.00  0.00  0.00   0.00   0.00   0.00   0.00
15  0.00  0.00  0.00   0.00   0.00   0.00   0.00

Generator FREQ (Hz)  60.000         Frequency Tracking = N
```

Figure 7.11 Generator Harmonic Report

Synchrophasor Meter

Use the **MET PM** command to display the synchrophasor values, as shown in *Figure 7.12* (see *Synchrophasors on page 10.61* for more information).

```
=>>MET PM <Enter>

Relay 1                                      Date: 02/27/2020  Time: 12:35:02.000
Station A                                    Serial Number: 1192110331

Time Quality   Maximum time synchronization error:    0.000 (ms)  TSOK = 1
Serial Port Configuration Error: N                    PMU in TEST MODE = Y


Synchrophasors

                      VV Phase Voltages           VV Pos. Sequence Voltage
                   VA         VB         VC                 V1V
MAG (kV)           0.000      0.000      0.000               0.000
ANG (DEG)          0.000      0.000      0.000               0.000


                      VZ Phase Voltages           VZ Pos. Sequence Voltage
                   VA         VB         VC                 V1Z
MAG (kV)          79.982     99.992    119.973              99.982
ANG (DEG)         24.773    -95.233    144.763              24.767


                      IS Phase Currents           IS Pos. Sequence Current
                   IA         IB         IC                 I1S
MAG (A)          100.053    199.828    299.877             194.184
ANG (DEG)         34.880    -75.192    134.777              28.115


                      IT Phase Currents           IT Pos. Sequence Current
                   IA         IB         IC                 I1T
MAG (A)          100.111    199.940    299.962             194.236
ANG (DEG)         34.777    -75.144    134.724              28.089


                      IU Phase Currents           IU Pos. Sequence Current
                   IA         IB         IC                 I1U
MAG (A)          100.032    199.995    300.038             194.269
ANG (DEG)         34.893    -75.173    134.761              28.117


                      IW Phase Currents           IW Pos. Sequence Current
                   IA         IB         IC                 I1W
MAG (A)          449.767    229.938    359.856             227.854
ANG (DEG)         44.797    -25.252     84.741              29.666
```

Figure 7.12 Synchrophasor Report

```
                  IX Phase Currents           IX Pos. Sequence Current
               IA         IB         IC                 I1X
MAG (A)         449.759    229.992    359.888             227.920
ANG (DEG)        44.774    -25.301     84.731              29.643

                  IY Phase Currents           IY Pos. Sequence Current
               IA         IB         IC                 I1Y
MAG (A)         449.714    230.022    359.891             227.914
ANG (DEG)        44.796    -25.271     84.761              29.669

FREQ (Hz) 60.000          Frequency Tracking = Y
Rate-of-change of FREQ (Hz/s)    0.01

Digitals

PSV08  PSV07  PSV06  PSV05  PSV04  PSV03  PSV02  PSV01
  0      0      0      0      0      0      0      0
PSV16  PSV15  PSV14  PSV13  PSV12  PSV11  PSV10  PSV09
  0      0      0      0      0      0      0      0
PSV24  PSV23  PSV22  PSV21  PSV20  PSV19  PSV18  PSV17
  0      0      0      0      0      0      0      0
PSV32  PSV31  PSV30  PSV29  PSV28  PSV27  PSV26  PSV25
  0      0      0      0      0      0      0      0
PSV40  PSV39  PSV38  PSV37  PSV36  PSV35  PSV34  PSV33
  0      0      0      0      0      0      0      0
PSV48  PSV47  PSV46  PSV45  PSV44  PSV43  PSV42  PSV41
  0      0      0      0      0      0      0      0
PSV56  PSV55  PSV54  PSV53  PSV52  PSV51  PSV50  PSV49
  0      0      0      0      0      0      0      0
PSV64  PSV63  PSV62  PSV61  PSV60  PSV59  PSV58  PSV57
  0      0      0      0      0      0      0      0

Analogs

PMV49      1.000  PMV50      2.000  PMV51      3.000  PMV52      4.498
PMV53      2.300  PMV54      3.600  PMV55     39.997  PMV56     50.004
PMV57      0.000  PMV58     49.998  PMV59   -100.000  PMV60    109.955
PMV61     10.125  PMV62    -50.020  PMV63     59.964  PMV64     20.024

=>>
```

Figure 7.12 Synchrophasor Report (Continued)

RTD Meter

Use the **MET RTD** command to display the RTD values, as shown in *Figure 7.13*, which shows the RTD values from both SEL-2600 RTD modules and the configured Remote Analog temperature measurements (see *Thermal Monitoring on page 7.19* for more information).

```
=>MET RTD <Enter>

Relay 1                                     Date: 03/03/2020  Time: 12:18:12.260
Station A                                   Serial Number: 1192110331

Serial Port RTD Input Temperature Data (deg. C)
RTS01TV  =  -50
RTS02TV  =  -37
RTS03TV  =  -24
RTS04TV  =  -11
RTS05TV  =   -1
RTS06TV  =   15
RTS07TV  =   28
RTS08TV  =   41
RTS09TV  =   54
RTS10TV  =   67
RTS11TV  =   80
RTS12TV  =   93
RTS13TV  =  106
RTS14TV  =  119
RTS15TV  =  132
RTS16TV  =  145
RTS17TV  =  158
RTS18TV  =  171
RTS19TV  =  184
RTS20TV  =  197
RTS21TV  =  210
RTS22TV  =  223
RTS23TV  =  236
RTS24TV  =  250

Configured Remote Temperature Data (deg. C)
RTC01TV  =  -50
RTC02TV  =  -37
RTC03TV  =  -24
RTC04TV  =  -11
RTC05TV  =   -1
RTC06TV  =   15
RTC07TV  =   28
RTC08TV  =   41
RTC09TV  =   54
RTC10TV  =   67
RTC11TV  =   80
RTC12TV  =   93
RTC13TV  =  106
RTC14TV  =  119
RTC15TV  =  132
RTC16TV  =  145
RTC17TV  =  158
RTC18TV  =  171
RTC19TV  =  184
RTC20TV  =  197
RTC21TV  =  210
RTC22TV  =  223
RTC23TV  =  236
RTC24TV  =  250
```

Figure 7.13 MET RTD Report

Synchronism-Check Meter

Use the **MET SYN** command to view the synchronism-check metering data enabled breaker, as shown in *Figure 7.14*. *Table 7.12* summarizes the quantities in the sync-check meter report.

Table 7.12 Synchronism-Check Meter Quantities (Sheet 1 of 2)

Quantities	Description
VPFM	Polarizing voltage magnitude (secondary)
NVS*n*FM[a]	Breaker *n*, synchronizing voltage magnitude
DifV*n*[a]	Breaker *n*, voltage difference in percentage
Angle*n*[a]	Breaker *n*, angle difference in degrees
Slip*n*[a]	Breaker *n*, slip
Generator FREQ	Measured generator island frequency

Table 7.12 Synchronism-Check Meter Quantities (Sheet 2 of 2)

Quantities	Description
System FREQ	Measured system island frequency
Frequency Tracking	The report displays **Y** when the relay tracks the frequency and **N** when the relay does not track the frequency (separately for both generator and system frequency)

[a] n = S, T, U, Y (enabled).

```
=>MET SYN <Enter>

Relay 1                                     Date: 03/06/2020  Time: 17:58:45.449
Station A                                   Serial Number: 1192110331

Breaker T                            Breaker Status: OPEN

  VPFM      NVSTFM      DifVT      AngleT      SlipT
   (V)        (V)         (%)       (deg)      (Hz)
  67.12      67.11        0.01       0.50       0.000

Generator FREQ (Hz) 60.000           Frequency Tracking = Y
System    FREQ (Hz) 60.000           Frequency Tracking = Y
```

Figure 7.14 MET SYN Report

Min/Max Meter

Use the **MET M** command to see the recorded minimum and maximum values for the selected analog quantities (or its alias if set) in the Group settings MMOQ(01–30). See *Section 12: Analog Quantities* for available quantities, descriptions, and units. *Table 7.8* shows the default quantities in the min/max metering report. Included within the report are the date and time when each value was recorded. The last reset time concludes the report as shown in *Figure 7.6*.

Table 7.13 Min/Max Metering Report Default Quantities

Quantity	Description
3PGF	Generator instantaneous fundamental three-phase active power
3QGF	Generator instantaneous fundamental three-phase reactive power
3SGF	Generator instantaneous fundamental three-phase apparent power
IAGFM	Generator instantaneous fundamental A-Phase current magnitude
IBGFM	Generator instantaneous fundamental B-Phase current magnitude
ICGFM	Generator instantaneous fundamental C-Phase current magnitude
VABZFM	Generator instantaneous fundamental AB line-to-line voltage magnitude
VBCZFM	Generator instantaneous fundamental BC line-to-line voltage magnitude
VCAZFM	Generator instantaneous fundamental CA line-to-line voltage magnitude
VNFM	Generator neutral instantaneous fundamental voltage magnitude
FREQPG	Generator source frequency
FREQPS	System source frequency

```
=>>MET M <Enter>

Relay 1                                       Date: 02/07/2020  Time: 09:46:31.100
Station A                                     Serial Number: 1192110331

Op_Qty     Min       Date       Time          Max       Date       Time

3PGF       810.303 02/07/2020 09:45:47.014    810.728 02/07/2020 09:45:29.672
3QGF      -202.335 02/07/2020 09:45:49.047   -201.936 02/07/2020 09:46:12.004
3SGF       835.151 02/07/2020 09:45:09.782    835.574 02/07/2020 09:45:45.384
IAGFM        4.023 02/07/2020 09:45:18.712      4.027 02/07/2020 09:45:45.389
IBGFM        4.048 02/07/2020 09:45:06.327      4.053 02/07/2020 09:45:59.022
ICGFM        4.028 02/07/2020 09:44:57.542      4.033 02/07/2020 09:46:31.084
VABZFM     119.512 02/07/2020 09:45:40.109    119.523 02/07/2020 09:46:12.422
VBCZFM     119.512 02/07/2020 09:45:39.909    119.524 02/07/2020 09:45:04.909
VCAZFM     119.517 02/07/2020 09:46:23.992    119.529 02/07/2020 09:45:56.789
VNFM         3.246 02/07/2020 09:46:27.649      3.253 02/07/2020 09:46:21.352
FREQPG      60.000 02/07/2020 09:45:42.354     60.001 02/07/2020 09:44:55.524
FREQPS      59.999 02/07/2020 09:45:47.247     60.001 02/07/2020 09:45:38.904

LAST MAX/MIN RESET:   02/07/2020  09:44:53.710

=>>
```

Figure 7.15 Min/Max Meter Report

Circuit Breaker Monitor

The SEL-400G features advanced circuit breaker monitoring. The general features of the circuit breaker monitor are described in *Section 8: Monitoring in the SEL-400 Series Relays Instruction Manual*. The SEL-400G supports monitoring four three-pole breakers, designated S, T, U, and Y.

Station DC Battery System Monitor

The SEL-400G automatically monitors one station battery system health by measuring the dc voltage, ac ripple, and voltage between each battery terminal and ground. See *Section 8: Monitoring in the SEL-400 Series Relays Instruction Manual* for a complete description of the battery monitor.

Analog Signal Profiling

Use the analog signal profiling function to record and track values of as many as 20 analog quantities. This function provides data in CASCII that is compatible to import directly into applications like spreadsheets. Specify the specific analog quantities for profiling with the SPAQ Report settings.

At the data acquisition rate of 5 minutes, the SEL-400G stores at least 10 days of all analog signals selected for profiling in nonvolatile memory. The report includes the time of acquisitions and the magnitude of each selected analog quantity. By defining conditions in the signal profiling enable SELOGIC variable setting (SPEN), you can record analog values at particular periods or conditions of interest.

SPAQgg (Analog Quantities for Signal Profiling)

Enter any analog quantity available in the relay from the Analog Quantity list (see *Section 12: Analog Quantities*) in this freeform setting.

SPAR (Signal Profile Acquisition Rate)

NOTE: The signal profile update rate does not have an immediate effect. For example, if SPAR is set to update every 60 minutes, then changed to 1 minute, the original timer will expire before the new rate takes effect.

Although you can select as many as 20 analog quantities, the signal acquisition rate is the same for all analog quantities. Select an acquisition rate of 1, 5, 15, 30, or 60 minutes.

SPEN (Signal Profile Enable)

Use this SELOGIC control equation to specify conditions under which the profiling must take place. If there are no conditions, be sure to set SPEN = 1, else no data are recorded (default value of NA disables the function).

Use the Compressed ASCII **CPR** command to view the profile data, as shown in *Figure 7.16*.

```
=>>CPR <Enter>
"#","DATE","TIME","VA_MAG","VB_MAG","VC_MAG","AI301","AI302","AI303","AI304","AI
305","AI306","13D7"
1,"03/17/2005","04:20:51.603",20.000,25.769,15.811,0.020,0.027,0.032,0.034,0.054
,0.045,"1066"

=>>
```

Figure 7.16 Compressed ASCII Data Display

Because the data are optimally formatted for machine-to-machine compatibility, use software such as Excel to display the profile data. *Figure 7.17* shows the data from *Figure 7.16* after importing the data (comma-delimited) into an Excel spreadsheet.

J17 =

	A	B	C	D	E	F	G	H	I	J	K	L	M
1													
2	□"#"	DATE	TIME	VA_MAG	VB_MAG	VC_MAG	AI301	AI302	AI303	AI304	AI305	AI306	13D7
3	1	3/17/2005	10:51.6	9.52	10	2.795	0.02	0.028	0.032	0.034	0.054	0.045	1000
4	2	3/17/2005	05:51.6	9.52	10	2.795	0.02	0.028	0.032	0.034	0.054	0.045	100C
5	3	3/17/2005	00:51.7	9.52	10	2.795	0.02	0.028	0.032	0.034	0.054	0.045	1005
6	□												
7	□=>>□												

Figure 7.17 Profile Data in Excel Spreadsheet

Use the **PRO C**(lear) command to clear all profile data, as shown in *Figure 7.18*.

```
=>>PRO C <Enter>
Clear signal profile for this port
Are you sure (Y/N)? Y <Enter>

Signal profile cleared for this port

=>>
```

Figure 7.18 Profile Data Reset

Thermal Monitoring

RTD Monitoring

The SEL-400G provides RTD monitoring using temperature measurements derived from remote RTD devices such as the SEL-2600 RTD module or the SEL-2411 Programmable Automation Controller.

Configuration of SEL-2600 Temperature Measurements

The relay can connect to a maximum of two SEL-2600 RTD Modules for a total of 24 RTD measurements. Each SEL-2600 connects to a dedicated EIA-232 port on the SEL-400G and communicates using the RTD protocol.

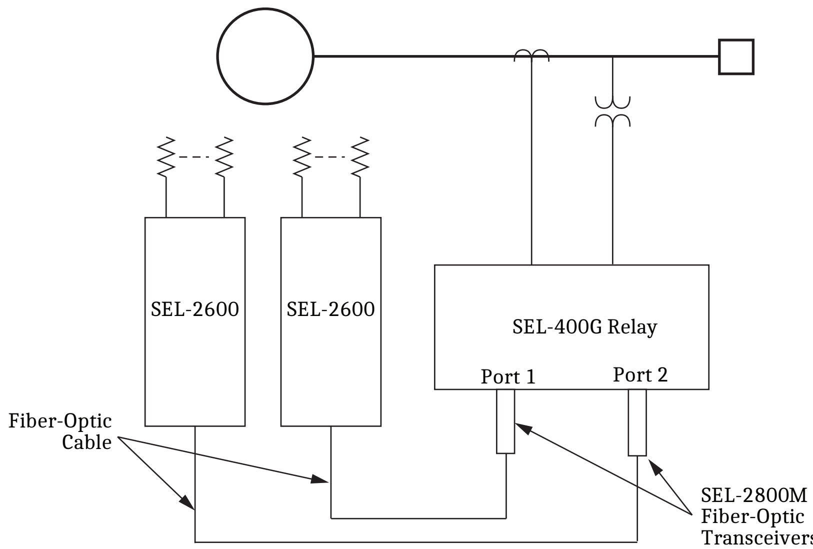

Figure 7.19 Connection of SEL-2600 RTD Modules to the SEL-400G

If a single RTD module is connected to the relay, set the protocol (PROTO) for this port to **RTDA**. The relay designates the RTDs for this module as 1–12. If a second RTD module is connected to the relay, set the protocol (PROTO) for the second port to **RTDB**. The relay designates the RTDs for this module as 13–24.

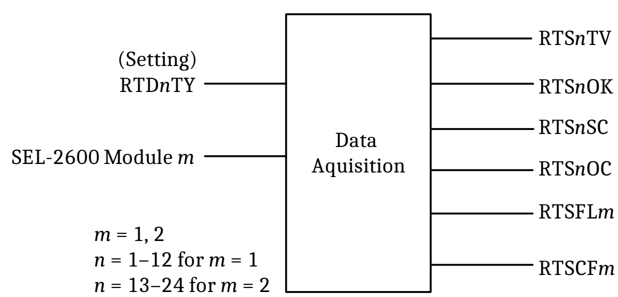

Figure 7.20 SEL-2600 RTD Monitoring Logic

The relay receives an indication if an RTD is open- or short-circuited and asserts the RTS*n*OC and RTS*n*SC Relay Word bits. Otherwise, RTS*n*OK is asserted. If the relay receives an indication of a problem with the module, the RTSFL*s* Relay Word bit asserts. If communication with the module is lost, the RTSCF*s* Relay Word bit asserts.

Using the RTS*n*TY setting to configure the RTD type in the SEL-400G. For each RTD, select from the following:

- NA
- 100-ohm platinum (Pt100)
- 100-ohm nickel (Ni100)
- 120-ohm nickel (Ni120)
- 10-ohm copper (Cu10)

The relay uses the RTD type setting to derive the temperature based on *Table 7.14*.

Table 7.14 RTD Resistance Versus Temperature

Temp (°F)	Temp (°C)	100 Platinum	120 Nickel	100 Nickel	10 Copper
–58	–50.00	80.31	86.17	74.30	7.10
–40	–40.00	84.27	92.76	79.10	7.49
–22	–30.00	88.22	99.41	84.20	7.88
–4	–20.00	92.16	106.15	89.30	8.26
14	–10.00	96.09	113.00	94.60	8.65
32	0.00	100.00	120.00	100.00	9.04
50	10.00	103.90	127.17	105.60	9.42
68	20.00	107.79	134.52	111.20	9.81
86	30.00	111.67	142.06	117.10	10.19
104	40.00	115.54	149.79	123.00	10.58
122	50.00	119.39	157.74	129.10	10.97
140	60.00	123.24	165.90	135.30	11.35
158	70.00	127.07	174.25	141.70	11.74
176	80.00	130.89	182.84	148.30	12.12
194	90.00	134.70	191.64	154.90	12.51
212	100.00	138.50	200.64	161.80	12.90
230	110.00	142.29	209.85	168.80	13.28
248	120.00	146.06	219.29	176.00	13.67
266	130.00	149.83	228.96	183.30	14.06
284	140.00	153.58	238.85	190.90	14.44
302	150.00	157.32	248.95	198.70	14.83
320	160.00	161.05	259.30	206.60	15.22
338	170.00	164.77	269.91	214.80	15.61
356	180.00	168.47	280.77	223.20	16.00
374	190.00	172.17	291.96	231.80	16.39
392	200.00	175.85	303.46	240.70	16.78
410	210.00	179.15	315.31	249.80	17.17
428	220.00	183.17	327.54	259.20	17.56
446	230.00	186.82	340.14	268.90	17.95
464	240.00	190.45	353.14	278.90	18.34
482	250.00	194.08	366.53	289.10	18.73

Configuration of Remote Analog Temperature Measurements

The relay can connect to multiple remote devices, such as the SEL-2411. The relay can receive a total of 24 RTD measurements via the Ethernet communications port. The measurements are mapped to remote analogs using the IEC-61850 protocol. Each temperature measurement must be manually assigned to a remote analog RA001–RA256. Refer to *IEC 61850 Communication on page 10.30* for details on the IEC-61850 protocol.

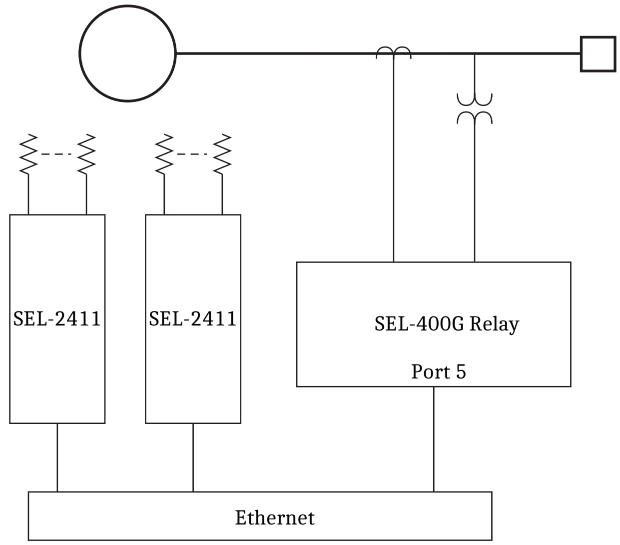

Figure 7.21 Connection of RTDs to the SEL-400G

For the case of remote analogs, the RTD type is not set in the SEL-400G. Instead, this setting is located in the remote device.

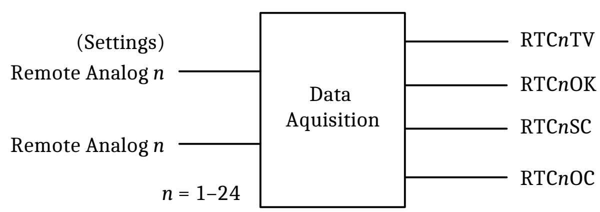

Figure 7.22 Remote Analog RTD Monitoring Logic

The relay receives the actual RTD temperature from the remote module. If the temperature is greater than 250°C, the RTC*n*OC bit will assert and the RTC*n*OK Relay Word bit deasserts. If the temperature is less than –50°C, The RTC*n*SC bit will assert and the RTC*n*OK Relay Word bit deasserts. Otherwise, RTC*n*OK is asserted.

When the received temperature is above +250°C or below –50°C, RTC*n*TV takes the clamped temperature value of +250°C or –50°C, respectively.

A quality bit from the connected device can be mapped to the SELOGIC Relay Word bit RTC*n*Q. If RTC*n*Q deasserts, then RTC*n*OK also deasserts.

RTD Ambient Probe

The SEL-400G supports biasing of each of the three IEC thermal model elements through use of an ambient temperature measurement. The source of the ambient temperature measurement is specified using the TAMB*n* setting. You can assign any of the SEL-2600 or remote analog measurements.

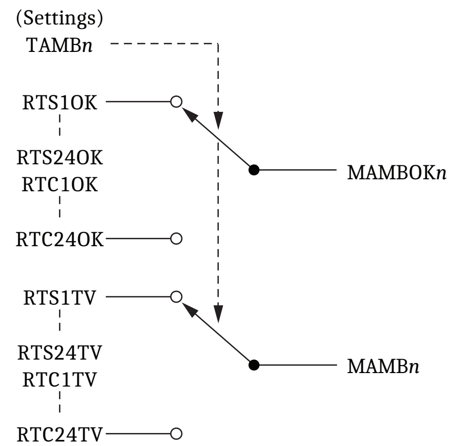

Figure 7.23 Ambient Probe

Reporting

The SEL-400G features comprehensive power system data analysis capabilities. These are described in *Section 9: Reporting in the SEL-400 Series Relays Instruction Manual*. This section describes reporting characteristics that are unique to the SEL-400G.

Data Capture Types

The relay features the following data capture types:

- Raw (HR) data—effective sampling rate as fast as 8000 samples/second
- Filtered (LR) data—2.5 ms resolution (400 samples/second)—including 20 settable analog quantities
- Filtered Disturbance (DR) data—20 ms resolution (50 samples/second)—includes the same 20 settable analog quantities as the LR data

Use high-resolution raw data to view transient conditions in the power system. You can set the relay to report these high-resolution data at 8000 samples/second, 4000 samples/second, 2000 samples/second, and 1000 samples/second effective sampling rates.

The filtered data give you accurate information on the relay protection and automation processing quantities.

The high-resolution raw, filtered, and disturbance data are available as files through the use of Ymodem file transfer and File Transfer Protocol (FTP) in the binary COMTRADE file format output (IEEE C37.111-2013, Common Format for Transient Data Exchange [COMTRADE] for Power Systems).

Duration of Data Captures and Event Reports

The SEL-400G stores high-resolution raw data and filtered data. The number of stored high-resolution raw data captures and event reports is a function of the amount of data contained in each capture.

Table 7.15 lists the maximum number of data captures/event reports the relay stores in nonvolatile memory when ERDIG = S for various report lengths and sample rates. The relay automatically overwrites the oldest events with the newest events when the nonvolatile storage capacity is exceeded.

NOTE: Consider the total capture time when choosing a value for setting LER at the SRATE := 8 kHz. At LER := 3.0, the relay records at least 12 data captures when ERDIG = S. These and smaller LER settings are sufficient for most power system disturbances.

NOTE: High-resolution, filtered, and disturbance event reports are stored using the IEEE C37.111-2013 COMTRADE standard.

The relay stores high-resolution raw and filtered event data in nonvolatile memory. *Table 7.15* lists the storage capability of the SEL-400G for common event reports.

The lower rows of *Table 7.15* show the number of event reports the relay stores at the maximum data capture times for each SRATE sampling rate setting. Table entries are the maximum number of stored events; these can vary by 10 percent according to relay memory usage.

Table 7.15 Event Report Nonvolatile Storage Capability When ERDIG = S

Event Report Length	Maximum Number of Stored Reports			
	8 kHz	4 kHz	2 kHz	1 kHz
0.25 seconds	95	116	131	149
0.5 seconds	56	73	85	99
1.0 seconds	31	42	49	60
3.0 seconds	11	15	19	23
6.0 seconds	N/A	7	10	12
12.0 seconds	N/A	N/A	4	6
24.0 seconds	N/A	N/A	N/A	3

When the event report digital setting is set to include all Relay Word bits in the event report (ERDIG = A), the maximum number of stored reports is reduced, as shown in *Table 7.16*.

Table 7.16 Event Report Nonvolatile Storage Capability When ERDIG = A

Event Report Length	Maximum Number of Stored Reports			
	8 kHz	4 kHz	2 kHz	1 kHz
0.25 seconds	78	92	101	112
0.75 seconds	30	39	44	50
1.0 seconds	N/A	20	23	27
3.0 seconds	N/A	N/A	12	14
6.0 seconds	N/A	N/A	N/A	7
12.0 seconds	N/A	N/A	N/A	N/A
24.0 seconds	N/A	N/A	N/A	N/A

Raw Data Oscillography

The relay stores raw (high-resolution [HR]), filtered (low-resolution [LR]), and filtered disturbance (disturbance resolution [DR]) data in binary format and uses COMTRADE file types to output these data:

- .HDR—header file
- .CFG—configuration file
- .DAT—high-resolution raw data file

The .HDR file contains summary information about the event in ASCII format. The .DAT file is in binary format and contains the values for each input channel for each sample in the record. These data conform to the IEEE C37.111-2013 COMTRADE standard. The .CFG file is an ASCII configuration file that describes the layout of the .DAT file. The .CFG file contains data such as sample rates, number of channels, generator and system frequency, channel information, and report digitals. *Figure 7.24* shows a typical IEEE C37.111-2013 COMTRADE file format for the high-resolution event report. For more information relating the .CFG, .DAT, and .HDR files refer to *Section 9: Reporting in the SEL-400 Series Relays Instruction Manual*.

StationA,FID=SEL-400G-1-X413-V0-Z001001-D20200208,2013	Relay Information (2013 = COMTRADE Standard)
267,27A,240D	267 = sum of analogs and digitals 27A = total number of analog channels 240D = total number of digital points[a]
1,IAS,A,,A,16.20295715,0,0,-32767,32767,2000.0,1,P 2,IBS,B,,A,16.20295715,0,0,-32767,32767,2000.0,1,P 3,ICS,C,,A,16.20295715,0,0,-32767,32767,2000.0,1,P 4,IAT,A,,A,8.10147858,0,0,-32767,32767,1000.0,1,P 5,IBT,B,,A,8.10147858,0,0,-32767,32767,1000.0,1,P 6,ICT,C,,A,8.10147858,0,0,-32767,32767,1000.0,1,P 7,IAU,A,,A,8.10147858,0,0,-32767,32767,1000.0,1,P 8,IBU,B,,A,8.10147858,0,0,-32767,32767,1000.0,1,P 9,ICU,C,,A,8.10147858,0,0,-32767,32767,1000.0,1,P 10,IAW,A,,A,16.20295715,0,0,-32767,32767,2000.0,1,P 11,IBW,B,,A,16.20295715,0,0,-32767,32767,2000.0,1,P 12,ICW,C,,A,16.20295715,0,0,-32767,32767,2000.0,1,P 13,IAX,A,,A,16.20295715,0,0,-32767,32767,2000.0,1,P 14,IBX,B,,A,16.20295715,0,0,-32767,32767,2000.0,1,P 15,ICX,C,,A,16.20295715,0,0,-32767,32767,2000.0,1,P 16,IAY,A,,A,0.81014782,0,0,-32767,32767,100.0,1,P 17,IBY,B,,A,0.81014782,0,0,-32767,32767,100.0,1,P 18,ICY,C,,A,0.81014782,0,0,-32767,32767,100.0,1,P 19,VAV,A,,kV,0.00297000,0,0,-32767,32767,183.3,1,P 20,VBV,B,,kV,0.00093167,0,0,-32767,32767,57.5,1,P 21,VCV,C,,kV,0.00297000,0,0,-32767,32767,183.3,1,P 22,VAZ,A,,kV,0.00297000,0,0,-32767,32767,183.3,1,P 23,VBZ,B,,kV,0.00297000,0,0,-32767,32767,183.3,1,P 24,VCZ,C,,kV,0.00297000,0,0,-32767,32767,183.3,1,P 25,VDC,,,V,0.011178,-0.000000,0,-32767,32767,1,1,P 26,FREQPG,,,Hz,0.01,0,0,0,32767,1,1,P 27,FREQPS,,,Hz,0.01,0,0,0,32767,1,1,P	27 Analog Channels
1,TLED_8,,,0 2,TLED_7,,,0 3,TLED_6,,,0 4,TLED_5,,,0 5,TLED_4,,,0 6,TLED_3,,,0 7,TLED_2,,,0 8,TLED_1,,,0 9,TLED_16,,,0 . . . 237,21PZ2TC,,,0 238,21PZ1TC,,,0 239,21PRCA2,,,0 240,21PRBC2,,,0	240 Digital Points
60	Nominal Frequency (NFREQ Setting)
1	
2000,1000	2000 = Sample Rate (SRATE setting) 1000 = Samples in the Report (LER x SRATE)
13/02/2020,18:26:09.368083	Time Stamp of the Report First Data Point
13/02/2020,18:26:09.469817	Time Stamp of the Trigger Point
BINARY 1 0,-8 0,0	

Figure 7.24 COMTRADE .CFG File Data for High-Resolution Data

[a] If ERDIG is set to S, the digital points are all the Relay Word bits set in ERDG as well as the Relay Word bits that are always included in the event report. If ERDIG is set to A, the digital points are all the Relay Word bits in the device.

Filtered Data Oscillography

All filtered (LR) data are stored at 400 Hz resolution and contains generator and power system events at the system fundamental frequency (NFREQ setting).

`StationA,FID=SEL-400G-1-X413-V0-Z001001-D20200208,2013`	Relay Information (2013 = COMTRADE Standard)
`354,114A,240D`	354 = sum of analogs and digitals 114A = total number of analog channels 240D = total number of digital points[a]

`1,IASF,Am,,A,2000.0,0,0,0,3.4028235E38,2000.0,1,P`
`2,IASF,Aa,,deg,1,0,0,-180,180,1,1,P`
`3,IBSF,Bm,,A,2000.0,0,0,0,3.4028235E38,2000.0,1,P`
`4,IBSF,Ba,,deg,1,0,0,-180,180,1,1,P`
`5,ICSF,Cm,,A,2000.0,0,0,0,3.4028235E38,2000.0,1,P`
`6,ICSF,Ca,,deg,1,0,0,-180,180,1,1,P`
`7,IATF,Am,,A,1000.0,0,0,0,3.4028235E38,1000.0,1,P`
`8,IATF,Aa,,deg,1,0,0,-180,180,1,1,P`
`9,IBTF,Bm,,A,1000.0,0,0,0,3.4028235E38,1000.0,1,P`
.
.
.
`111,ANA17,,,,1,0,0,-3.4028235E38,3.4028235E38,1,1,P`
`112,ANA18,,,,1,0,0,-3.4028235E38,3.4028235E38,1,1,P`
`113,ANA19,,,,1,0,0,-3.4028235E38,3.4028235E38,1,1,P`
`114,ANA20,,,,1,0,0,-3.4028235E38,3.4028235E38,1,1,P`
	114 Analog Channels

`1,TLED_8,,,0`
`2,TLED_7,,,0`
`3,TLED_6,,,0`
`4,TLED_5,,,0`
`5,TLED_4,,,0`
`6,TLED_3,,,0`
`7,TLED_2,,,0`
`8,TLED_1,,,0`
`9,TLED_16,,,0`
.
.
.
`237,21PZ2TC,,,0`
`238,21PZ1TC,,,0`
`239,21PRCA2,,,0`
`240,21PRBC2,,,0`
	240 Digital Points

`60`	Nominal Frequency (NFREQ Setting)
`1`	
`400,201`	400 = Sample Rate (400 Hz) 201 = Samples in the Report (LER x Sample Rate)
`13/02/2020,18:26:09.367317`	Time Stamp of the Report First Data Point
`13/02/2020,18:26:09.469817`	Time Stamp of the Trigger Point

`FLOAT32`
`1`
`0,-8`
`0,0`	

Figure 7.25 COMTRADE .CFG File Data for Filtered 2.5 ms Resolution Data

[a] If ERDIG is set to S, the digital points are all the Relay Word bits set in ERDG as well as the Relay Word bits that are always included in the event report. If ERDIG is set to A, the digital points are all the Relay Word bits in the device.

Disturbance Recording Data Oscillography

Disturbance recording data (DR) are available when the relay report setting EDR is set to Y. The relay stores disturbance event information in nonvolatile memory. Disturbance, high-resolution, and filtered event data are recorded in parallel. Disturbance data includes the same analogs as LR data as specified in the Event Reporting Analog Quantities in Report settings. Refer to the .CFG file in *Figure 7.26*. All disturbance event reports are stored at 50 Hz resolution. Report setting DRLER determines the length of the stored event report. The relay can store approximately 20 minutes of disturbance event report data, corresponding to 4 stored events at the maximum DRLER setting of 300 seconds, or approximately 20 stored events at the minimum DRLER setting of 60 seconds. The length of time reserved within the stored disturbance event report for the capture of pre-trigger (pre-fault) data are adjusted by the report setting DRPRE with a range of 30 to 24 seconds less than the DRLER setting. Disturbance event report memory can be cleared along with event report memory on a port-by-port basis.

StationA,FID=SEL-400G-1-X413-V0-Z001001-D20200208,2013	Relay Information (2013 = COMTRADE Standard)
260,20A,240D	260 = sum of analogs and digitals 20A = total number of analog channels 240D = total number of digital points[a]
1,I2GP,,,,1,0,0,-3.4028235E38,3.4028235E38,1,1,P 2,VG3FM,,,,1,0,0,-3.4028235E38,3.4028235E38,1,1,P 3,VG3FA,,,,1,0,0,-3.4028235E38,3.4028235E38,1,1,P 4,VNFM,,,,1,0,0,-3.4028235E38,3.4028235E38,1,1,P 5,VNFA,,,,1,0,0,-3.4028235E38,3.4028235E38,1,1,P 6,25ANGS,,,,1,0,0,-3.4028235E38,3.4028235E38,1,1,P 7,25SLIPS,,,,1,0,0,-3.4028235E38,3.4028235E38,1,1,P 8,78GCN,,,,1,0,0,-3.4028235E38,3.4028235E38,1,1,P 9,3PGF,,,,1,0,0,-3.4028235E38,3.4028235E38,1,1,P 10,3QGF,,,,1,0,0,-3.4028235E38,3.4028235E38,1,1,P 11,REFGEN,,,,1,0,0,-3.4028235E38,3.4028235E38,1,1,P 12,REFSYS,,,,1,0,0,-3.4028235E38,3.4028235E38,1,1,P 13,ANA13,,,,1,0,0,-3.4028235E38,3.4028235E38,1,1,P 14,ANA14,,,,1,0,0,-3.4028235E38,3.4028235E38,1,1,P 15,ANA15,,,,1,0,0,-3.4028235E38,3.4028235E38,1,1,P 16,ANA16,,,,1,0,0,-3.4028235E38,3.4028235E38,1,1,P 17,ANA17,,,,1,0,0,-3.4028235E38,3.4028235E38,1,1,P 18,ANA18,,,,1,0,0,-3.4028235E38,3.4028235E38,1,1,P 19,ANA19,,,,1,0,0,-3.4028235E38,3.4028235E38,1,1,P 20,ANA20,,,,1,0,0,-3.4028235E38,3.4028235E38,1,1,P	20 Analog Channels
1,TLED_8,,,0 2,TLED_7,,,0 3,TLED_6,,,0 4,TLED_5,,,0 5,TLED_4,,,0 6,TLED_3,,,0 7,TLED_2,,,0 8,TLED_1,,,0 9,TLED_16,,,0 . . . 237,21PZ2TC,,,0 238,21PZ1TC,,,0 239,21PRCA2,,,0 240,21PRBC2,,,0	240 Digital Points
60	Nominal Frequency (NFREQ Setting)
1	
50,3000	50 = Sample Rate (50 Hz) 3000 = Samples in the Report (DRLER setting x Sample Rate)
13/02/2020,18:25:39.469817	Time Stamp of the Report First Data Point
13/02/2020,18:26:09.469817	Time Stamp of the Trigger Point
FLOAT32 1 0,-8 0,0	

Figure 7.26 COMTRADE .CFG File Data for Filtered 20 ms Resolution Data

[a] If ERDIG is set to S, the digital points are all the Relay Word bits set in ERDG as well as the Relay Word bits that are always included in the event report. If ERDIG is set to A, the digital points are all the Relay Word bits in the device.

Event Reports, Event Summaries, and Event Histories

See *Section 9: Reporting in the SEL-400 Series Relays Instruction Manual* for an overview of event reports, event summaries, and event histories. This section describes the characteristics of these that are unique to the SEL-400G.

Base Set of Relay Word Bits

The following Relay Word bits are always included in COMTRADE event reports: TLED_1, TLED_9, TLED_17, TRIP01, TRIP02, TRIP03, TRIP04, TRIP05, TRIP06, TRIP07, TRIP08, TRIPS, BFITS, CLSS, 52CLS, REF, 21PAB1P, 21PZ1T, 25CS, 24D11, 32P01, 46Q11, 40Z1T, 40Z2T, 40P1T, 40P2T, 59VPS, 64G1T, 64G2T, 64G3T, 64GT, 78OST, BSYNBKS, CON1, CON2, FREQOKG, INADTS, LPSEC, LOPZ, ONLINE.

COMTRADE Relay Word Bit Behavior

The ERDG setting specifies Relay Word bits to include in event reporting. In COMTRADE files, the relay captures and records the status of all Relay Word bits in the same row of a Relay Word bit specified in the ERDG setting list. Therefore, additional Relay Word bit statuses are captured in a COMTRADE file that are not specified in the ERDG setting list. See *Section 11: Relay Word Bits* for Relay Word bits and their common row with other bits.

Event Summary

You can retrieve a summary version of stored event reports as event summaries. These short-form reports present vital information about a triggered event. The relay generates an event in response to power system faults and other trigger events. See *Figure 7.27* for a sample event summary.

Report Header

```
Relay 1                                    Date: 02/03/2020  Time: 12:10:45.327
Station A                                  Serial Number: 1181300592
```

Event Information

```
Event: 87 ZONE 2                                            Time Source: OTHER
Event Number: 10001                                                   Group: 1
Targets: TLED_2 TLED_13 TLED_14 TLED_15 TLED_16
Generator Frequency (Hz): 60.000                  System Frequency (Hz): 60.000
```

Breaker Status

```
Breaker S: OPEN             Trip Time: 12:10:45.327
```

Fault Data

```
Fault Analog Data

         IAS    IBS    ICS    IAT    IBT    ICT    IAU    IBU    ICU
MAG(A)   15308  13549  15091   1530   1356   1508  45966  40637  45338
ANG(DEG)   -0.6 -117.8  126.6   -0.5 -117.9  126.7   -3.9 -121.2  123.3

         IAW    IBW    ICW    IAX    IBX    ICX    IY1    IY2    IY3
MAG(A)       5      2      5      3      8      3    383    338    378
ANG(DEG) -117.0  -37.7  135.1    8.0  -94.9 -105.7   -0.6 -121.4  123.3

         VAV     VBV     VCV     VV1     VV2     VV3
MAG(kV)     0       0       0      11       9      11
ANG(DEG)    0.0     0.0     0.0    -3.3  -120.4   123.7

         VAZ     VBZ     VCZ     VZ2
MAG(kV)    11       9      11       0.0000
ANG(DEG)   -3.3  -120.4   123.7     0.0

87 Differential Current Magnitudes (pu)
         IOPA    IRTA    IOPB    IRTB    IOPC    IRTC
ZONE 1    0.00    0.00    0.00    0.00    0.00    0.00
ZONE 2    7.65    7.65    6.78    6.78    7.54    7.54

87 RMS Differential Currents (pu)
         IOPRA   IOPRB   IOPRC
ZONE 1    0.01    0.00    0.01
ZONE 2    3.25    3.01    2.95
```

Figure 7.27 Sample Event Summary Report

The event summary contains the following information:

- Standard report header
  - Relay and terminal identification
  - Event date and time

- Event type
- Time source (HIRIG or OTHER)
- Event number
- System frequency
- Active group at trigger time
- Targets
- Circuit breaker trip and close times; and auxiliary contact(s) status
- Fault voltages, currents, sequence current, and operate and restraint currents (from the event report row with the largest current)
- MIRRORED BITS communications channel status (if enabled)

The relay derives the summary target information and circuit breaker trip and close times from the rising edge of relevant Relay Word bits during the event. If no trip or circuit breaker element asserted during the event, the relay uses the last row of the event.

The information in the summary portion of the event report is the same information in the event summary.

The SEL-400G reports the event type and *Table 7.17* lists event types in fault reporting priority. Differential and restricted earth fault indications have reporting priority over other fault events. For example, you can trigger an event when there is no fault condition on the power system by using the **TRI** command. In this case, when there is no fault, the relay reports the event type as TRIG. Consider assigning normally open and normally closed indications of the generator breaker to the ER equation. This will trigger an event report whenever the breaker changes state. Implementation of cross-triggering between relays through use of the ER equation is another good practice.

Table 7.17 Event Types

Event	Description
87 ZONE 1, 87 ZONE 2, REF	Differential elements involvement for event reports generated by 87Z1 or 87Z2. REF is the OR combination of REFF1, REFF2, and REFF3
EX TRIP	Rising edge of TRIPEX
PM TRIP	Rising edge of TRIPPM
AUX TRIP	Rising edge of TRIPAUX
TRIP	Rising edge of Relay Word bit TRIP
ER (event report trigger)	Rising edge of ER (SELOGIC control equation)
TRIG	Execution of the **TRIGGER** (**TRI**) command (manually triggered)

Event History

The event history gives you a quick look at recent relay activity. The relay labels each new event with a unique number from 10000 to 42767. (At 42767, the top of the numbering range, the relay returns to 10000 for the next event number and then continues to increment.)

The event history contains the following:

- Standard report header
  - Relay and terminal identification
  - Date and time of report

- Event number
- Event date and time
- Event type
- Active group at the trigger instant
- Targets

The event types in the event history are the same as the event types in the event summary (see *Table 7.17* for event types). The event history report indicates events stored in relay nonvolatile memory. The relay places a blank row in the history report output; items that are above the blank row are available for viewing (use the **HIS** command). Items that are below the blank row are no longer in relay memory; these events appear in the history report to indicate past power system performance.

The relay does not ordinarily modify the numerical or time order in the history report. However, if an event report is corrupted (power was lost during storage, for example), the relay lists the history report line for this event after the blank row.

SECTION 8

Settings

Section 12: Settings in the SEL-400 Series Relays Instruction Manual describes common platform settings. This section contains tables of relay settings for the SEL-400G Advanced Generator Protection System.

⚠WARNING
Isolate the relay trip circuits while changing settings. When changing settings for multiple classes, it is possible to be in an intermediate state that will cause an unexpected trip.

The relay hides some settings based upon the state of other settings. For example, if you set an enable setting to OFF (disabling the function), the relay hides all settings associated with that function.

The settings prompts in this section are similar to the ASCII terminal and SEL Grid Configurator Software prompts. Prompts in this section are unabbreviated and show all possible setting options.

For information on using settings in protection and automation, see the examples in *Section 6: Protection Application Examples*. The section contains information on the following settings classes.

Alias Settings

See *Section 12: Settings in the SEL-400 Series Relays Instruction Manual* for a complete description of alias settings. *Table 8.1* lists the default alias settings for the SEL-400G.

Table 8.1 Default Alias Settings

Label	Default
EN	RLY_EN

Global Settings

Table 8.2 Global Setting Categories

Settings	Reference
General Global Settings	*Table 8.3*
Global Enables	*Table 8.4*
Control Inputs (Global)	*Table 8.5*
Interface Board #1 Control Inputs	*Table 8.6*
Interface Board #2 Control Inputs	*Table 8.7*
Interface Board #3 Control Inputs	*Table 8.8*
Settings Group Selection	*Table 8.9*
Synchronized Phasor Configuration Settings	*Table 8.10–Table 8.15*
Time and Date Management	*Table 8.16*
Data Reset Controls	*Table 8.17*
DNP	*Table 8.19*

Table 8.3 General Global Settings

Setting	Prompt	Default
SID	Station Identifier (40 characters)	Station A
RID	Relay Identifier (40 characters)	Relay 1
CONAM	Company Name (5 characters)	abcde
NFREQ	Nominal System Frequency (50, 60 Hz)	60
PHROT	System Phase Rotation (ABC, ACB)	ABC

Table 8.4 Global Enables

Setting	Prompt	Default
EICIS	Independent Control Input Settings (Y, N)	N
EPMU	Synchronized Phasor Measurement (Y, N)	N
EINVPOL[a]	Enable Invert Polarity (OFF or combo of terminals)[b]	OFF

[a] Cannot set from front-panel HMI.

[b] Use any combination of Terminals V, Z, S, T, U, W, X, or Y and A-, B-, or C-Phases, or Terminals V and Y and Inputs 1, 2, or 3. For example, EINVPOL := SA, SB, X, Y3 inverts the polarity of the A- and B-Phases for Terminal S, all phases for Terminal X, and Input 3 for Terminal Y.

Table 8.5 settings are available when Global enable setting EICIS := N.

Table 8.5 Control Inputs

Setting	Prompt	Default	Increment
IN2XXD[a]	Int Board #1 Debounce Time (0.0–30 ms)	2	0.5
IN3XXD[b]	Int Board #2 Debounce Time (0.0–30 ms)	2	0.5
IN4XXD[c]	Int Board #3 Debounce Time (0.0–30 ms)	2	0.5

[a] Setting applies to all the Interface Board #1 input contacts.

[b] Setting applies to all the Interface Board #2 input contacts.

[c] Setting applies to all the Interface Board #3 input contacts.

Table 8.6 settings are available for Interface Board #1 when Global enable setting EICIS := Y.

Table 8.6 Interface Board #1 Control Inputs

Setting	Prompt	Default	Increment
IN201PU	Input IN201 Pickup Delay (0.0–30 ms)	2[a]	0.5
IN201DO	Input IN201 Dropout Delay (0.0–30 ms)	2[a]	0.5
• • •	• • •	• • •	• • •
IN2*mm*PU[b]	Input IN2*mm* Pickup Delay (0.0–30 ms)	2[a]	0.5
IN2*mm*DO[b]	Input IN2*mm* Dropout Delay (0.0–30 ms)	2[a]	0.5

[a] Set to Global setting IN2XXD when EICIS := N.
[b] mm is the number of available input contacts on the interface board.

Table 8.7 settings are available for Interface Board #2 when Global enable setting EICIS := Y.

Table 8.7 Interface Board #2 Control Inputs

Setting	Prompt	Default	Increment
IN301PU	Input IN301 Pickup Delay (0.0–30 ms)	2[a]	0.5
IN301DO	Input IN301 Dropout Delay (0.0–30 ms)	2[a]	0.5
• • •	• • •	• • •	• • •
IN3*mm*PU[b]	Input IN3*mm* Pickup Delay (0.0–30 ms)	2[a]	0.5
IN3*mm*DO[b]	Input IN3*mm* Dropout Delay (0.0–30 ms)	2[a]	0.5

[a] Set to Global setting IN3XXD when EICIS := N.
[b] mm is the number of available input contacts on the interface board.

Table 8.8 settings are available for Interface Board #3 when Global enable setting EICIS := Y.

Table 8.8 Interface Board #3 Control Inputs

Setting	Prompt	Default	Increment
IN401PU	Input IN401 Pickup Delay (0.0–30 ms)	2[a]	0.5
IN401DO	Input IN401 Dropout Delay (0.0–30 ms)	2[a]	0.5
• • •	• • •	• • •	• • •
IN4*mm*PU[b]	Input IN4*mm* Pickup Delay (0.0–30 ms)	2[a]	0.5
IN4*mm*DO[b]	Input IN4*mm* Dropout Delay (0.0–30 ms)	2[a]	0.5

[a] Set to Global setting IN4XXD when EICIS := N.
[b] mm is the number of available input contacts on the interface board.

Table 8.9 Settings Group Selection (Sheet 1 of 2)

Setting	Prompt	Default
SS1	Select Setting Group 1 (SELOGIC Equation)	NA
SS2	Select Setting Group 2 (SELOGIC Equation)	NA

Table 8.9 Settings Group Selection (Sheet 2 of 2)

Setting	Prompt	Default
SS3	Select Setting Group 3 (SELOGIC Equation)	NA
SS4	Select Setting Group 4 (SELOGIC Equation)	NA
SS5	Select Setting Group 5 (SELOGIC Equation)	NA
SS6	Select Setting Group 6 (SELOGIC Equation)	NA
TGR	Group Change Delay (0–1500 s)	4.5

Table 8.10–Table 8.15 settings are available when Global enable setting EPMU := Y.

Table 8.10 Synchronized Phasor Configuration Settings

Setting[a]	Prompt	Default
NUMPHDC	Number of Data Configurations (1–5)	1
PMAPP*q*[b]	PMU Application (P)	P
MRATE*q*[c, d]	Messages per Second (1, 2, 4, 5, 10, 12, 15, 20, 30, 60)	2
PMSTN*q*	Station Name (16 characters)	STATION A
PMID*q*	PMU Hardware ID (1–65534)	1

[a] q = 1–NUMPHDC, not 1–5.
[b] PMAPP2–PMAPP5 will be forced to PMAPP1 and will be only shown, not settable.
[c] If NFREQ = 50, then the range is 1, 2, 5, 10, 25, 50.
[d] MRATE2–MRATE5 will be forced to MRATE1 and will be only shown, not settable.

Phasors Included in the Data q
Terminal Name, Relay Word Bit, Alternative Terminal Name

Specify the terminal for synchrophasor measurement and transmission in the synchrophasor data stream *q*.

This is a freeform setting category for enabling the terminals for synchrophasor measurement and transmission. This freeform setting has three arguments. Specify the terminal name (any one of S, T, U, V, W, X, Y, or Z) for the first argument. Specify any Relay Word bit for the second argument. Specify the alternative terminal name (any one of S, T, U, V, W, X, Y, or Z) for the third argument.

The second and third arguments are optional unless switching between terminals is required. Whenever the Relay Word bit in the second argument is asserted the terminal synchrophasor data are replaced by the alternative terminal data.

Table 8.11 Phasors Included in the Data q

Setting[a]	Prompt	Default
PHDV*q*	Phasor Data Set, Voltages (V1, PH, ALL)	V1
PHDI*q*	Phasor Data Set, Currents (I1, PH, ALL)	ALL
PHNR*q*	Phasor Num. Representation (I = Integer, F = Float)	I
PHFMT*q*	Phasor Format (R = Rectangular, P = Polar)	R
FNR*q*	Freq. Num. Representation (I = Integer, F = Float)	I

[a] q = 1–NUMPHDC.

Phasor Aliases in Data Configuration q
Phasor Name, Alias Name

This is a freeform setting category with two arguments. Specify the phasor name and an optional 16-character alias to be included in the synchrophasor data stream *q*. See *Table 10.28* and *Table 10.29* for a list of phasor names that the PMU supports. The PMU can be configured for as many as 32 unique phasors for each PMU configuration.

Table 8.12 Phasor Aliases in Data Configuration q

Setting	Prompt	Default
PMSP*qee*[a, b]	Name of the Synchrophasor (Default Name of Any Synchrophasor)	(blank)
PMSA*qee*[a, b]	Alias of the Synchrophasor (16 characters)	(blank)

[a] q = 1–NUMPHDC.
[b] ee = 1–32.

From a terminal emulation program, the setting name is now shown and a freeform settings line appears after a prompt. In Grid Configurator, the setting name is shown and a field is available to enter the setting.

Synchrophasor Analog Quantities in Data Configuration q
Analog Quantity Name, Alias Name

This is a freeform setting category with two arguments. Specify the analog quantity name or its alias to be included in the synchrophasor data stream *q* (see *Section 12: Analog Quantities* for a list of analog quantities that the PMU supports). Optionally provide an alias name to use in the synchrophasor configuration message. The PMU can be configured for as many as 16 unique analog quantities for each data configuration *q*. The analog quantities are floating-point values, so each analog quantity the PMU includes will take four bytes.

From a terminal emulation program, the setting name is not shown and a freeform settings line appears after a prompt. In Grid Configurator, the setting name is shown and a field is available to enter the setting.

Synchrophasor Digitals in Data Configuration q
Digital Name, Alias Name

This is a freeform setting category with two arguments. Specify the Relay Word bit name or its alias that you need to include in the synchrophasor data stream *q* (see *Section 11: Relay Word Bits* for a list of Relay Word bits that the PMU supports). Optionally, include an alias name as the second parameter to use the synchrophasor configuration message. You can configure the PMU for as many as 64 unique digitals for each data configuration *q*.

Table 8.13 Synchronized Phasor Configuration Settings Part 2

Setting	Prompt	Default	Increment
TREA[4]	Trigger Reason Bit [4] (SELOGIC Equation)	NA	
PMTRIG	Trigger (SELOGIC Equation)	NA	
PMTEST	PMU in Test Mode (SELOGIC Equation)	NA	
V*k*COMP[a]	Comp. Angle Terminal *k* (–179.99° to 180°)	0.00	0.01
I*n*COMP[b]	Comp. Angle Terminal *n* (–179.99° to 180°)	0.00	0.01
PMFRQST	PMU Primary Frequency Source Terminal (V, Z)	V	

[a] k = V and Z.
[b] n = S, T, U, W, X, Y.

Table 8.14 Synchronized Phasor Recorder Settings

Setting	Prompt	Default
EPMDR	Enable PMU Data Recording (Y, N)	N
SPMDR	Select Data Configuration for PMU Recording (1–NUMPHDC)	1
PMLER	Length of PMU Triggered Data (2–120 s)	30
PMPRE	Length of PMU Pre-Triggered Data (1–20 s)	5

Table 8.15 Synchronized Phasor Real-Time Control

Setting	Prompt	Default
RTCRATE	Remote Messages Per Second (1, 2, 5, 10, 25, or 50 When NFREQ := 50) (1, 2, 4, 5, 10, 12, 15, 20, 30, or 60 When NFREQ := 60)	2
MRTCDLY	Maximum RTC Synchrophasor Packet Delay (20–1000 ms)	500

Table 8.16 Time and Date Management

Setting	Prompt	Default
DATE_F	Date Format (MDY, YMD, DMY)	MDY
IRIGC[a]	IRIG-B Control Bits Definition (None, C37.118)	None
UTCOFF[b]	Offset From UTC to Local Time (–15.5 to 15.5)	–8.0
BEG_DST[c]	Begin DST (hh, n, d, mm, or OFF)	"2, 2, 1, 3"
END_DST	End DST (hh, n, d, mm)	"2, 1, 1, 11"

[a] When EPMU = Y, IRIGC is forced to C37.118.

[b] All data, reports, and commands from the relay are stored and displayed in local time, referenced to an internal UTC master clock. Use the UTCOFF setting to specify the time offset from UTC time reference with respect to the relay location. (The only data still displayed in UTC time is streaming synchrophasor and IEC 61850 data.)

[c] The BEG_DST (and END_DST) daylight-saving time setting consists of four fields or OFF:
hh = local time hour (0–23); defines when daylight-saving time begins.
n = the week of the month when daylight-saving time begins (1–3, L); occurs in either the first, second, third, or last week of the month.
d = day of week (1–7); Sunday is the first day of the week.
mm = month (1–12).
OFF = hides the daylight-saving time settings.

Table 8.17 Data Reset Control

Setting	Prompt	Default
RST_DEM	Reset Demand Metering (SELogic Equation)	NA
RST_PDM	Reset Peak Demand Metering (SELogic Equation)	NA
RST_ENE	Reset Energy Metering (SELogic Equation)	NA
RSTTRGT	Target Reset (SELogic Equation)	NA
RSTDNPE	Reset DNP Fault Summary Data (SELogic Equation)	TRGTR
RST_HAL	Reset Warning Alarm Pulsing (SELogic Equation)	NA

Table 8.18 Access Control

Setting	Prompt	Default
EACC	Enable ACC access level (SELogic Equation)	1
E2AC	Enable ACC–2AC access levels (SELogic Equation)	1

Table 8.19 DNP

Setting	Prompt	Default
EVELOCK	Event Summary Lock Period (0–1000 s)	0
DNPSRC	DNP Session Time Base (LOCAL, UTC)	UTC

Monitor Settings

Table 8.20 Monitor Setting Categories

Settings	Reference
Enables	*Table 8.21*
Station DC Monitor	*Table 8.22*
Breaker Monitor Settings	*Table 8.23*
IEC Thermal (49) Elements	*Table 8.24*
Thermal Ambient Compensation	*Table 8.25*

Table 8.21 Enables

Setting	Prompt	Default	Increment
EDCMON	Station DC Battery Monitor (Y, N)	N	
BK_SEL	Breaker Selection (OFF or combo of S, T, U, Y)[a]	S	
ERTD	Enable Temperature Source (OFF or combo of A, B, C)	OFF	
EBMON	Enable BK Monitoring (OFF or combo of S, T, U, Y)[a]	OFF	
E49RTD[b]	Enable Remote Temperature Elements (N, 1–12)	N	1
ETHRIEC	Enable IEC Thermal Element (N, 1–3)	N	1

[a] "Combo" means "combination of"; enter these "combo" settings delimited with either commas or spaces.
[b] Hidden and forced to default if ERTD = OFF.

Table 8.22 settings are available if EDCMON = Y.

Table 8.22 Station DC Monitor

Setting	Prompt	Default	Increment
DCLFP	Low Level Fail Pickup (OFF, 15–300 Vdc)	100	1
DCLWP	Low Level Warn Pickup (OFF, 15–300 Vdc)	127	1
DCHWP	High Level Warn Pickup (OFF, 15–300 Vdc)	137	1
DCHFP	High Level Fail Pickup (OFF, 15–300 Vdc)	142	1
DCRP	Peak-to-Peak AC Ripple Pickup (1–300 Vac)	9	1
DCGF	Ground Detection Factor (1.00–5.00)	1.05	0.01
RST_BAT	Reset Battery Monitoring (SELOGIC Equation)	NA	

Table 8.23 Breaker Monitor Settings (Sheet 1 of 2)

Setting[a]	Prompt	Default	Increment
B*m*_ID	Breaker *m* Identifier (40 characters)	Breaker *m*	
52A_*m*	NO Contact Input—BK*m* (SELOGIC Equation)	NA	
52B_*m*	NC Contact Input—BK*m* (SELOGIC Equation)	NA	

Table 8.23 Breaker Monitor Settings (Sheet 2 of 2)

Setting[a]	Prompt	Default	Increment
52D_*m*	BK*m* Transition Delay (0.0500–0.2 s)	0.1	0.0025
BM*m*TRP	Breaker Monitor Trip—BK*m* (SELOGIC Equation)	TRIP*m*	
BM*m*CLS	Breaker Monitor Close—BK*m* (SELOGIC Equation)	CLS*m*	
B*m*COSP1	Close/Open Set Point 1—BK*m* (1–65000 Operations)	1000	1
B*m*COSP2	Close/Open Set Point 2—BK*m* (1–65000 Operations)	100	1
B*m*COSP3	Close/Open Set Point 3—BK*m* (1–65000 Operations)	10	1
B*m*KASP1[b]	kA Interrupted Set Point 1—BK*m* (1.0–999 kA)	20.0	0.1
B*m*KASP2	kA Interrupted Set Point 2—BK*m* (1.0–999 kA)	60.0	0.1
B*m*KASP3[b]	kA Interrupted Set Point 3—BK*m* (1.0–999 kA)	100.0	0.1
B*m*BCWAT	Contact Wear Alarm Threshold—BK*m* (0–100%)	90	0.1
B*m*ESTRT	Electrical Slow Trip Alarm Threshold—BK*m* (1–999 ms)	50	1
B*m*ESCLT	Electrical Slow Close Alarm Threshold—BK*m* (1–999 ms)	120	1
B*m*MSTRT	Mechanical Slow Trip Alarm Threshold—BK*m* (1–999 ms)	50	1
B*m*MSCLT	Mechanical Slow Close Alarm Threshold—BK*m* (1–999 ms)	120	1
B*m*ITAT	Inactivity Time Alarm Threshold—BK*m* (N, 1–9999 days)	365	1
B*m*MRTIN	Motor Run Time Contact Input—BK*m* (SELOGIC Equation)	NA	
B*m*MRTAT	Motor Run Time Alarm Threshold—BK*m* (1–999 s)	25	1
B*m*KAIAT	kA Interrupt Capacity Alarm Threshold—BK*m* (N, 1–100%)	90	0.1
B*m*MKAI	Maximum kA Interrupt Rating—BK*m* (1–999 kA)	50	1
RST_BK*m*	Reset Monitoring Breaker *m* (SELOGIC Equation)	PLT04	

[a] m = S, T, U, Y.
[b] The ratio of settings BmKASP3/BmKASP1 must be in the range: 5 ≤BmKASP3/BmKASP1 ≤100.

Table 8.24 settings are available if ETHRIEC := 1, 2, or 3.

Table 8.24 IEC Thermal (49) Elements (Sheet 1 of 2)

Setting	Prompt	Default
THRO1	Thermal Model 1 Operating Quantity	I1GMB
THRO2	Thermal Model 2 Operating Quantity	IMAXSR
THRO3	Thermal Model 3 Operating Quantity	IMAXSR
IBAS1	Basic Current Value in PU 1 (0.1–3)	1.1
IBAS2	Basic Current Value in PU 2 (0.1–3)	1.1
IBAS3	Basic Current Value in PU 3 (0.1–3)	1.1
IEQPU1	Eq. Heating Current Pick Up Value in PU 1 (0.05–1)	0.05
IEQPU2	Eq. Heating Current Pick Up Value in PU 2 (0.05–1)	0.05
IEQPU3	Eq. Heating Current Pick Up Value in PU 3 (0.05–1)	0.05
KCONS11	Basic Cur. Correction Factor 1 State 1 (0.50–1.5)	1
KCONS21	Basic Cur. Correction Factor 2 State 1 (0.50–1.5)	1

Table 8.24 IEC Thermal (49) Elements (Sheet 2 of 2)

Setting	Prompt	Default
KCONS31	Basic Cur. Correction Factor 3 State 1 (0.50–1.5)	1
KCONS12	Basic Cur. Correction Factor 1 State 2 (0.50–1.5)	1
KCONS22	Basic Cur. Correction Factor 2 State 2 (0.50–1.5)	1
KCONS32	Basic Cur. Correction Factor 3 State 2 (0.50–1.5)	1
TCONH11	Heating Thermal Time Cons 1 State 1 (1–500 min)	60
TCONH21	Heating Thermal Time Cons 2 State 1 (1–500 min)	60
TCONH31	Heating Thermal Time Cons 3 State 1 (1–500 min)	60
TCONH12	Heating Thermal Time Cons 1 State 2 (1–500 min)	60
TCONH22	Heating Thermal Time Cons 2 State 2 (1–500 min)	60
TCONH32	Heating Thermal Time Cons 3 State 2 (1–500 min)	60
TCONC11	Cooling Thermal Time Cons 1 State 1 (1–500 min)	60
TCONC21	Cooling Thermal Time Cons 2 State 1 (1–500 min)	60
TCONC31	Cooling Thermal Time Cons 3 State 1 (1–500 min)	60
TCONC12	Cooling Thermal Time Cons 1 State 2 (1–500 min)	60
TCONC22	Cooling Thermal Time Cons 2 State 2 (1–500 min)	60
TCONC32	Cooling Thermal Time Cons 3 State 2 (1–500 min)	60
THLA1	Thermal Level Alarm Limit 1 (1.00–100%)	50
THLA2	Thermal Level Alarm Limit 2 (1.00–100%)	50
THLA3	Thermal Level Alarm Limit 3 (1.00–100%)	50
THLAR1	Thermal Level Alarm Reset Ratio 1 (0.50–1)	0.98
THLAR2	Thermal Level Alarm Reset Ratio 2 (0.50–1)	0.98
THLAR3	Thermal Level Alarm Reset Ratio 3 (0.50–1)	0.98
THLT1	Thermal Level Trip Limit 1 (1.00–150%)	80
THLT2	Thermal Level Trip Limit 2 (1.00–150%)	80
THLT3	Thermal Level Trip Limit 3 (1.00–150%)	80
THLTR1	Thermal Level Alarm Reset Ratio 1 (0.50–1)	0.98
THLTR2	Thermal Level Alarm Reset Ratio 2 (0.50–1)	0.98
THLTR3	Thermal Level Alarm Reset Ratio 3 (0.50–1)	0.98

Table 8.25 Thermal Ambient Compensation (Sheet 1 of 2)

Setting	Prompt	Default
TAMB1	Amb Temp. Meas. Probe 1 (NA, RTS01–24, RTC01–24)	NA
TAMB2	Amb Temp. Meas. Probe 2 (NA, RTS01–24, RTC01–24)	NA
TAMB3	Amb Temp. Meas. Probe 3 (NA, RTS01–24, RTC01–24)	NA
DAMB1	Default Ambient Temperature 1 (–50 to 100 C)	25
DAMB2	Default Ambient Temperature 2 (–50 to 100 C)	25
DAMB3	Default Ambient Temperature 3 (–50 to 100 C)	25
AMBRTF1	Default Temp if Amb Temp RTD Fails 1 (BUFF, SET)	SET
AMBRTF2	Default Temp if Amb Temp RTD Fails 2 (BUFF, SET)	SET
AMBRTF3	Default Temp if Amb Temp RTD Fails 3 (BUFF, SET)	SET

Table 8.25 Thermal Ambient Compensation (Sheet 2 of 2)

Setting	Prompt	Default
TMAX1	Maximum Temperature of the Equipment 1 (80–300 C)	155
TMAX2	Maximum Temperature of the Equipment 2 (80–300 C)	155
TMAX3	Maximum Temperature of the Equipment 3 (80–300 C)	155

Group Settings

Table 8.26 Group Setting Categories (Sheet 1 of 2)

Settings	Reference
Relay Configuration	*Table 8.27*
Current Transformer Data	*Table 8.28*
Potential Transformer Data	*Table 8.29*
Power System Data	*Table 8.30*
Frequency Tracking Sources	*Table 8.31*
Pumped Storage	*Table 8.32*
Current Transformer Polarity Terminal Selection	*Table 8.33*
Zone 1 and Zone 2 Differential Element Configuration	*Table 8.34*
Restricted Earth Fault Element	*Table 8.35*
Restricted Earth Fault 50 Element	*Table 8.36*
Restricted Earth Fault 51 Element	*Table 8.37*
Breaker *n* Inadvertent Energization Protection Logic	*Table 8.38*
Volts Per Hertz Element *a*[a]	*Table 8.39*
Volts Per Hertz Element *a* Level 2 Definite Time	*Table 8.40*
Volts Per Hertz Element *a* Level 2, User-Defined Curve *h*[b]	*Table 8.41*
Synchronism-Check (25) Elements	*Table 8.42*
Breaker *n* Synchronism-Check (25)	*Table 8.43*
Autosynchronism Check Configuration (25A)	*Table 8.44*
Breaker *n* Autosynchronism Check (25A)	*Table 8.45*
Undervoltage (27) Elements	*Table 8.46*
Overpower (32) Elements	*Table 8.47*
Underpower (32) Elements	*Table 8.47*
Impedance Based Loss of Field (40Z) Element	*Table 8.48*
PQ-Based Loss-of-Field (40P) Element	*Table 8.49*
Current Unbalance (46) Elements 1 and 2	*Table 8.50*
Terminal *n* Overcurrent Elements	*Table 8.51*
Terminal *n* Phase Overcurrent Element Level *c*	*Table 8.52*
Terminal *n* Negative-Sequence Overcurrent Element Level *c*	*Table 8.53*
Terminal *n* Zero-Sequence Overcurrent Element Level *c*	*Table 8.54*
Terminal *n* Directional (67) Elements	*Table 8.55*
Inverse Time Overcurrent Elements 1–12	*Table 8.56*
Overvoltage (59) Elements	*Table 8.57*

Table 8.26 Group Setting Categories (Sheet 2 of 2)

Settings	Reference
Split Phase (60P) Element	*Table 8.58*
Stator Ground (64G) Element	*Table 8.59*
Field Ground (64F) Element	*Table 8.60*
Stator Ground (64S) Element	*Table 8.61*
Out-of-Step (78) Element	*Table 8.62*
Frequency (81) Elements	*Table 8.63*
Rate-of-Change-of-Frequency (81R) Elements	*Table 8.64*
Accumulated Frequency (81A) Elements	*Table 8.65*
Pole Open Detection	*Table 8.66*
System Backup Protection	*Table 8.67*
Phase Distance (21P) Element	*Table 8.68*
Voltage-Controlled Time-Overcurrent (51C) Element	*Table 8.69*
Voltage-Restrained Time Overcurrent (51V) Element	*Table 8.70*
Load Encroachment	*Table 8.71*
Loss of Potential	*Table 8.72*
Breaker Failure Logic	*Table 8.73*
Breaker *n* Failure Logic	*Table 8.74*
Breaker *n* Flashover Logic	*Table 8.75*
Demand Metering Elements	*Table 8.76*
Max/Min Metering Elements	*Table 8.77*
Online Logic	*Table 8.78*
Trip Logic	*Table 8.79*
Close Logic	*Table 8.80*

[a] a = 1–2.
[b] h = 1 or 2.

Table 8.27 Relay Configuration (Sheet 1 of 2)

Setting	Prompt	Default	Increment
EADVS	Advanced Settings (Y, N)	N	
EPS	En. Pump Storage (OFF or combo of S, T, U, W, X, Y, V, Z)	OFF	
EGNPT	Enable Gen Neut Volt Term (OFF, V2, Z2)	V2	
ESYSPT	Enable Sys Volt Term (OFF, V, or combo of V1,V2,V3)	V1	
EGNCT	Enable Gen Neut Cur Terms (Combo of X, Y)	X	
ESYSCT	Enable System Cur Terms (OFF or combo of S, T, U, Y)	S,T	
EPCAL	En. Power Calc Term (OFF or combo of S, T, U, Y)	S	
E24	Enable Volts per Hertz Elements (N, 1–2)	2	
E25	Enable Synch. Check (OFF or combo of S, T, U, Y)	S	
E27	Enable Under Voltage Elements (N, 1–6)	N	1
E32	Enable Directional Power (N, 1–4)	1	1
E40	Enable Loss of Field (OFF or combo of Z, P)	Z	
E46	Enable Current Unbalance Elements (N, 1–2)	1	1

Table 8.27 Relay Configuration (Sheet 2 of 2)

Setting	Prompt	Default	Increment
E50	Enable 50 Elements (OFF or combo of S, T, U, Y)	OFF	
E51	Enable Inverse Time Overcurrent Elements (N, 1–12)	N	1
E59	Enable Over Voltage Elements (N, 1–6)	1	1
E60P	Enable 60P Split Phase Element (N, S, T, U, W, X, Y[a, b])	N	
E60N	Enable 60N Split Phase Element (N, Y1, Y2, Y3)	N	
E64G	Enable 64G Element (OFF or combo of G1, G2, G3)	G1, G3	
E64F	Enable 64F Field Ground Element (Y, N)	N	
E64S	Enable 64S Stator Ground Element (Y, N)	N	
E67	Enable 67 Dir. Elements (OFF or combo of S, T, U, Y)	OFF	
E78	Enable Out-of-Step Element (N, 1B, 2B)	1B	
E81	Enable Frequency Elements (N, 1–6)	2	1
E81A	Enable Accumulated Freq Elements (N, 1–8)	N	1
E81R	Enable Rate of Change of Freq Elements (N, 1–6)	N	1
E87	Enable Differential Elements (N, 1–2)	2	1
EREF	Enable REF Element (OFF or combo of Y1, Y2, Y3)	Y1	1
EINAD	Enable Inad. Ener. Prot. (OFF or combo of S, T, U, Y)	S	
EPO	Enable Pole Open (OFF or combo of S, T, U, Y)	S,T	
ELOAD	Enable Load Encroachment (Y, N)	N	
ELOP	Enable Loss of Potential (OFF or combo of V, Z)	Z	
EBFL	Enable Brkr Fail. Prot. (OFF or combo of S, T, U, Y)	S,T	
EBFO	Enable Brkr Flash Ovr. (OFF or combo of S, T, U, Y)	S	
EBUP	Enable System Backup Protection (OFF or combo of 51C, 51V, 21P)	21P	
EDEM	Enable Demand Metering (N, 1–10)	N	1
EMXMN	Enable Max/Min Metering (N, 1–30)	12	1

[a] W is unavailable if EGNCT contains W.
X is unavailable if EGNCT contains X.
[b] m is unavailable if ESYSCT contains m, where m = S, T, U, or Y.

Table 8.28 Current Transformer Data

Setting	Prompt	Default	Increment
CTCONY	CT connection for Term Y (1PH, Y)	1PH	
CTR*n*[a]	CT Ratio Term *n* (OFF, 1.0–50000)	12000	0.1
CTRY*x*[b]	CT Ratio Term Y*x* (OFF, 1.0–50000)	100	0.1

[a] n = S, T, U, W, X, Y.
[b] x = 1, 2, 3.

Table 8.29 Potential Transformer Data (Sheet 1 of 2)

Setting	Prompt	Default	Increment
PTCONV	PT connection for Term V (OFF, Y, D, D1, 1PH)	1PH	
PTCONZ	PT connection for Term Z (Y, D, D1)	Y	
PTR*k*[a]	PT Ratio Term *k* (1.0–10000)	200.0	0.1
VNOM*k*[a]	PT Nom. Voltage (L-L) Term *k* (30.00–300 V, sec)	110.00	0.01

Table 8.29 Potential Transformer Data (Sheet 2 of 2)

Setting	Prompt	Default	Increment
PTR*b*[b]	PT Ratio Term *b* (OFF, 1.0–10000)	200.0	0.1
VNOM*b*[b]	PT Nom. Voltage (L-L) Term *b* (30.00–300 V, sec)	110.00	0.01

[a] k = V, Z.
[b] b = V1, V2, V3, Z2.

Table 8.30 Power System Data

Setting	Prompt	Default	Increment
MVAGEN	Generator Max. MVA (1–5000 MVA)	555	1
KVGEN	Generator L-L Voltage (1.00–100 kV)	24	0.01
XDGEN	Generator D-Axis Synch Reactance (0.100–4)	1.81	0.001
XTXFR	Transformer Leakage Reactance (0.010–10)	0.042	0.001
XESYS	Equivalent System Reactance (0.010–10)	0.2	0.001

Table 8.31 Frequency Tracking Sources

Setting	Prompt	Default	Increment
FTSRC*n*[a]	Frequency Source for Current Term *n* (G, S)	G	
FTSRCY*x*[b]	Frequency Source for Current Term Y*x* (G, S)	G	
FTSRC*k*[c]	Frequency Source for Voltage Term *k* (G, S)	G	
FTSRCV*x*[b]	Frequency Source for Voltage Term V*x* (G, S)	G	
FTSSV*x*[b]	Select Term V*x* Source for Sys Freq (SELOGIC Eqn)	0	

[a] n = S, T, U, W, X, Y.
[b] x = 1–3.
[c] k = V, Z.

Table 8.32 Pumped Storage

Setting	Prompt	Default	Increment
PSPHREV	Transposed Phases (AB, BC, CA)	BC	
PSMODE	Pumped Storage Mode Indication (SELOGIC Eqn)	NA	

Table 8.33 Current Transformer Polarity Terminal Selection

Setting	Prompt	Default	Increment
CTP*n*[a]	CT Polarity For Terminal *n* (P, N)	P	

[a] n = S, T, U, W, X, Y.

Table 8.34 Zone 1 and Zone 2 Differential Element Configuration (Sheet 1 of 2)

Setting	Prompt	Default	Increment
E87Z*a*[a]	87 Zone *a* Terminals (Combo of S, T, U, W, X, Y)	W,X	
E87XFR*a*[a]	87 Zone *a* In-Zone Transformer (Y, N)	N	
E87H*a*[a]	87 Zone *a* Harm. Blk. & Restr. (Combo of B, BW, R, RW)	B	
E87U*a*[a]	87 Zone *a* En. Unres. Diff. (OFF or combo of F, R,W)	OFF	
E87Q*a*[a]	87 Zone *a* Enable Neg. Seq. Differential (Y, E, N)	N	

Table 8.34 Zone 1 and Zone 2 Differential Element Configuration (Sheet 2 of 2)

Setting	Prompt	Default	Increment
87CORE*a*[a]	87 Zone *a* XFMR Core Type, Three or Single (T, S)	T	
E87UNB*a*[a]	87 Zone *a* Enable Wave Shape Unblocking (Y, N)	N	
87*n*CTC*a*[a, b]	87 Zone *a* Term. *n* CT Conn. Compensation (0–13)	0	1
87*n*ANG*a*[a, b]	87 Zone *a* Term. *n* Ang. Comp. (–179.99 to 180 deg)	30	0.01
MVA*a*[a]	87 Zone *a* Transformer Max. MVA (OFF, 1–5000 MVA)	OFF	1
VTERM*na*[a, b]	87 Zone *a* Term. *n* L-L Voltage (1.00–1000 kV)	275	0.01
87*n*TAP*a*[a, b]	87 Zone *a* Term. *n* Current Tap (0.50–175 A, sec)	1	0.01
87EFDO*a*[a]	87 Zone *a* External Fault Detect DO (0.0200–1.2 s)	1	0.0025
87P1*a*[a]	87 Zone *a* Oper. Current Sensitive PU (0.10–4)	0.25	0.01
87P2*a*[a]	87 Zone *a* Oper. Current Secure PU (0.10–4)	0.5	0.01
87SLP1*a*[a]	87 Zone *a* Slope 1 Percentage (5.00–90%)	10	0.01
87SLP2*a*[a]	87 Zone *a* Slope 2 Percentage (5.00–90%)	75	0.01
87*p*SEC*a*[a, c]	87 Zone *a* Switch to Secure (SELOGIC Eqn)	CON*pa*	
87RTC*a*[a]	87 Zone *a* Restrained Element TC (SELOGIC Eqn)	1	
87UP*a*[a]	87 Zone *a* Unrestrained Element PU (1.00–20)	8	0.01
87UTC*a*[a]	87 Zone *a* Unrestrained Element TC (SELOGIC Eqn)	1	
87RMP*a*[a]	87 Zone *a* RMS Element PU (OFF, 1.00–20)	OFF	0.01
87RMTC*a*[a]	87 Zone *a* RMS Element TC (SELOGIC Eqn)	1	
87PCT2*a*[a]	87 Zone *a* 2nd-Harmonic Percentage (OFF, 5–100%)	OFF	1
87PCT4*a*[a]	87 Zone *a* 4th-Harmonic Percentage (OFF, 5–100%)	OFF	1
87PCT5*a*[a]	87 Zone *a* 5th-Harmonic Percentage (OFF, 5–100%)	OFF	1
87TH5P*a*[a]	87 Zone *a* 5th-Harmonic Alarm PU (OFF, 0.02–3.2)	OFF	0.01
87TH5D*a*[a]	87 Zone *a* 5th-Harmonic Alarm Delay (0.0000–200 s)	0.5	0.0025
87QP*a*[a]	87 Zone *a* Neg. Seq. Operate Current PU (0.05–1)	0.3	0.01
87QSLP*a*[a]	87 Zone *a* Neg. Seq. Slope (5–100%)	25	1
87QD*a*[a]	87 Zone *a* Neg. Seq. Delay (0.0000–200 s)	0.2	0.0025
87QTC*a*[a]	87 Zone *a* Neg. Seq. TC (SELOGIC Eqn)	NOT 87QB*a* AND NOT CON*a*	

[a] a = 1, 2.
[b] n = S, T, U, W, X, Y.
[c] p = A, B, C.

Table 8.35 Restricted Earth Fault Element

Setting	Prompt	Default	Increment
REFRF*a*[a]	Rest Qty REF *a* (OFF or combo of S, T, U, W, X, Y1, Y2, Y3)	OFF	
REF50G*a*[a]	Residual Current Sensitivity Pickup (0.05–3)	0.25	0.01
TCREF*a*[a]	Torque Control REF Element *a* (SELOGIC Eqn)	1	

[a] a = 1–3.

Table 8.36 Restricted Earth Fault 50 Element

Setting	Prompt	Default	Increment
REF50P*a*[a]	REF Op. Current Inst O/C *a* Pickup (OFF, 0.25–100)	OFF	0.01
REF50D*a*[a]	REF Inst O/C *a* Delay (0.0000–400 s)	0.2	0.0025
RF50TC*a*[a]	REF Inst O/C *a* Torque Cont (SELOGIC Eqn)	1	

[a] a = 1–3.

Table 8.37 Restricted Earth Fault 51 Element

Setting	Prompt	Default	Increment
REF51P*a*[a]	REF Inv. Time O/C *a* PU (OFF, 0.25–16)	OFF	0.01
REF51C*a*[a]	REF Inv. Time O/C *a* Curve (U1–U5, C1–C5)	U1	
RF51TD*a*[a]	REF Inv. Time O/C *a* Time Dial (0.50–15)	0.5	0.01
RF51RS*a*[a]	REF Inv. Time O/C *a* EM Reset (Y, N)	N	
RF51TC*a*[a]	REF Inv. Time O/C *a* Torque Cont (SELOGIC Eqn)	1	

[a] a = 1–3.

Table 8.38 Breaker n Inadvertent Energization Protection Logic

Setting	Prompt	Default	Increment
INADIP*n*[a]	Inad. Ener. O/C PU –BKR *n* (0.25–10 A,sec)	1	0.01
INADVP*n*[a]	Inad. Ener. U/V PU –BKR *n* (1.00–300 V,sec)	10	0.01
INADTC*n*[a]	Inad. Ener. TC –BKR *n* (SELOGIC Equation)	3PO*n* AND NOT LOPZ	
INADAD*n*[a]	Inad. Ener. Arm. Dly. –BKR *n* (0.0000–100 s)	2	0.0025
INADDD*n*[a]	Inad. Ener. Disarm. Dly. –BKR *n* (0.0000–100 s)	1	0.0025
INADD*n*[a]	Inad. Ener. PU Delay –BKR *n* (0.0000–10 s)	0.25	0.0025

[a] n = S, T, U, Y.

Table 8.39 Volts per Hertz Element a

Setting	Prompt	Default	Increment
24O*a*[a]	24 Element *a* Operating Quantity	VPMAXZF	
24D*a*P1[a]	24 Element *a* Level 1 Pick Up (100–200%)	110	1
24D*a*D1[a]	24 Element *a* Level 1 Time Delay (0.040–6000 s)	10	0.005
24TC*a*[a]	24 Element *a* Torque Control (SELOGIC Eqn)	1	
24CCS*a*[a]	24 Element *a* Level 2 Comp. Curve (OFF, DD, U1, U2)	OFF	

[a] a = 1–2.

Table 8.40 Volts per Hertz Element a Level 2 Definite Time

Setting	Prompt	Default	Increment
24D*a*P21[a]	24 Element *a* Level 2 Pick Up 1 (100–200%)	105	1
24D*a*D21[a]	24 Element *a* Level 2 Time Delay 1 (0.040–6000 s)	10	0.005
24D*a*P22[a]	24 Element *a* Level 2 Pick Up 2 (101–200%)	110	1
24D*a*D22[a]	24 Element *a* Level 2 Time Delay 2 (0.040–6000 s)	5	0.005

[a] a = 1–2.

Table 8.41 Volts per Hertz Element a Level 2, User Defined Curve a

Setting[a]	Prompt	Default	Increment
24U*a*TC*a*	24 Element *a* Curve *a* Torque Control (SELOGIC Eqn)	1	
24U*a*NP*a*	24 Element *a* No. of Point on User *a* Curve (3–20)	10	1
24U*aaii*[b]	24 Ele. *a* Cur. *a*, Pnt. [ii] (100–200%, 0.040–6000 s)	200, 400	1, 0.005
24U*aa*1*ii*		200	1
24U*aa*2*ii*		400	0.005
24U*a*CR*a*	24 Element *a* Curve *a* Reset Time (0.010–400 s)	0.01	0.005

[a] a = 1, 2.
[b] ii = 1–20.

Table 8.42 Synchronism Check (25) Reference

Setting	Prompt	Default	Increment
SYNCP	Synch Reference (VAZ, VBZ, VCZ, VABZ, VBCZ, VCAZ)	VABZ	

Table 8.43 Breaker n Synchronism Check (25)

Setting[a]	Prompt	Default	Increment
SYNCS*n*	SynchSource*n*(VAV,VBV,VCV,VABV,VBCV,VCAV, VV1, VV2, VV3)	VV1	
KS*n*M	Synch Source *n* Ratio Factor (0.10–3)	1	0.01
KS*n*A	Synch Source *n* Angle Shift (–179.99 to 180 deg)	0	0.01
25VL*n*	Voltage Window Low Thresh –BK*n* (20.0–200 V, sec)	55	0.1
25VH*n*	Voltage Window High Thresh –BK*n* (20.0–200 V, sec)	70	0.1
25VDIF*n*	Max. Voltage Difference –BK*n* (OFF, 1.0–15%)	5	0.1
25GVHI*n*	Generator Voltage High Required –BK*n* (Y, N)	Y	
25SFBK*n*	Maximum Slip Frequency –BK*n* (OFF, 0.005–0.5 Hz)	0.067	0.001
25ANG*n*	Max. Ang. Diff. Uncompensated –BK*n* (0.1–80 deg)	5	0.1
25AD*n*	Uncompensated Angle Delay –BK*n* (0.000–0.6 s)	0.16	0.005
25ANGC*n*	Max. Ang. Diff. Compensated –BK*n* (0.1–80 deg)	5	0.1
TCLSBK*n*	Breaker *n* Close Time (0.010–0.6 s)	0.085	0.005
25GFHI*n*	Generator Frequency High Required –BK*n* (Y, N)	Y	
BSYNBK*n*	Block Synchronism Check –BK*n* (SELOGIC Eqn)	NA	
CFANG*n*	Close Failure Angle –BK*n* (OFF, 3.0–120 deg)	7	0.1

[a] n = S, T, U, Y.

Table 8.44 Autosynchronism Check Configuration (25A) (Sheet 1 of 2)

Setting	Prompt	Default	Increment
25AVMOD	25A Voltage Control Pulse Mode (OFF, PW, FD, PF)	OFF	
25AVSLP	25A Voltage Control Slope (0.01–100 V/s)	1	0.01
25AVPER	25A Voltage Control Pulse Period (0.000–60 s)	10	0.005
25AVDUR	25A Voltage Control Pulse Duration (0.000–60 s)	2	0.005
25AFMOD	25A Frequency Control Pulse Mode (OFF, PW, FD, PF)	OFF	
25AFSLP	25A Frequency Control Slope (0.01–100 Hz/s)	1	0.01
25AFPER	25A Frequency Control Pulse Period (0.000–60 s)	10	0.005

Table 8.44 Autosynchronism Check Configuration (25A) (Sheet 2 of 2)

Setting	Prompt	Default	Increment
25AFDUR	25A Frequency Control Pulse Duration (0.000–60 s)	2	0.005
25ACD	25A Control Expiration Delay (0.000–400 s)	30	0.005

Table 8.45 Breaker n Autosynchronism Check (25A)

Setting[a]	Prompt	Default	Increment
25AST*n*	Start Auto-Sync. Check –BK*n* (SELOGIC Eqn)	NA	
25ACN*n*	Cancel Auto-Sync. Check –BK*n* (SELOGIC Eqn)	BSYNBK*n* OR 52CL*n*	

[a] n = S, T, U, Y.

Table 8.46 Undervoltage (27) Elements 1–6

Setting	Prompt	Default	Increment
27O*x*[a]	U/V Element *x* Operating Quantity	VNMINZF	
27P*x*P*a*[a, b]	U/V Element *x* Level *a* PU (OFF, 2.00–300 V, sec)	OFF	0.01
27P*x*C*a*[a, b]	U/V Element *x* Level *a* Curve (D, I)	D	
27P*x*D*a*[a, b]	U/V Element *x* Level *a* Delay (0.000–400 s)	10	0.005
27TC*x*[a]	U/V Element *x* Torque Control (SELOGIC Eqn)	1	

[a] x = 1–6.
[b] a = 1, 2.

Table 8.47 Directional Power (32) Element 01–04

Setting[a]	Prompt	Default	Increment
32O*n*	Dir Power Element *n* Operating Quantity	3PGF	
32MOD*n*	Dir Power Element *n* Operating Mode (U, O)	O	
32BIA*n*	Dir Power Element *n* Bias (SELOGIC Eqn)	NA	
32ANG*n*	Dir Power Element *n* Bias Angle (–5.00 to 5 deg)	1	0.01
32PP*n*	Dir Power Element *n* PU (–2000.00 to 2000 VA, sec)	–10.0	0.02
32RS*n*	Dir Power Element *n* Inst Reset (Y, N)	Y	
32PD*n*	Dir Power Element *n* Time Delay (0.000–400 s)	2	0.005
32TC*n*	Dir Power Element *n* Torque Cont (SELOGIC Eqn)	1	

[a] n = 01–04.

Table 8.48 Impedance Based Loss of Field (40Z) Element

Setting	Prompt	Default	Increment
40Z*a*P[a]	40Z Zone *a* Mho Diameter (OFF, 0.1–100 ohms, sec)	13.4	0.1
40Z*a*XD[a]	40Z Zone *a* Off. Reactance (–50.0 to 50 ohms, sec)	–2.5	0.1
40Z*a*D[a]	40Z Zone *a* Time Delay (0.000–400 s)	0.25	0.005
40Z*a*TC[a]	40Z Zone *a* Torque Ctrl (SELOGIC Eqn)	NOT LOPZ	
40Z2DIR	40Z Zone 2 Directional Sup. Ang. (–20.0 to –5 deg)	–10	0.1

[a] a = 1, 2.

Table 8.49 PQ-Based Loss-of-Field (40P) Element (Sheet 1 of 2)

Setting	Prompt	Default	Increment
E40PZ	Enable 40P Zones (Combo of Z1, Z2, Z3, Z4)	Z1, Z2	
E40P2D	Enable Zone 2 Dynamic Capability (Y, N)	N	
E40P4D	Enable Zone 4 Dynamic Capability (Y, N)	N	
40PDAM	40P Dynamic Zone Analog Meas (SEL Math Eqn)	RTS01TV	
40PDAQ	40P Dynamic Zone Analog Quality (SELOGIC Eqn)	RTS01OK	
40PDAMX	40P Analog Meas Max Curve (–99999.000 to 99999)	30.0	0.001
40PDAMN	40P Analog Meas Min Curve (–99999.000 to 99999)	50.0	0.001
40P1P	40P Zone 1 Pickup (–2000.00 to –1 VA, sec)	–100	0.01
40P1D	40P Zone 1 Time Delay (0.000–400 s)	0.25	0.005
40P1TC	40P Zone 1 Torque Cont (SELOGIC Eqn)	NOT LOPZ	
40P1DIR	40P Zone 1 Directional Sup Ang (–30.0 to 30 deg)	10	0.1
40P2SEG	40P Zone 2 Segment shape (C,L)	C	
40PUP5	40P Zone 2 P Power Pt 5 (1.00–2000 VA, sec)	80	0.01
40PUQ5	40P Zone 2 Q Power Pt 5 (–2000.00 to 2000 VA, sec)	–60	0.01
40PUP6	40P Zone 2 P Power Pt 6 (1.00–2000 VA, sec)	40	0.01
40PUQ6	40P Zone 2 Q Power Pt 6 (–2000.00 to 0 VA, sec)	–80	0.01
40PUQ7	40P Zone 2 Q Power Pt 7 (–2000.00 to –1 VA, sec)	–100	0.01
40P2M	40P Zone 2 Margin from UEL (1.05–1.25)	1.2	0.01
40PK	40P Zone Voltage Coefficient (0–2)	2	1
40PUP5D	40P Z2 P Power Dyn Pt 5 (1.00–2000 VA, sec)	130	0.01
40PUQ5D	40P Z2 Q Power Dyn Pt 5 (–2000.00 to 2000 VA, sec)	–110	0.01
40PUP6D	40P Z2 P Power Dyn Pt 6 (1.00–2000 VA, sec)	90	0.01
40PUQ6D	40P Z2 Q Power Dyn Pt 6 (–2000.00 to 0 VA, sec)	–130	0.01
40PUQ7D	40P Z2 Q Power Dyn Pt 7 (–2000.00 to –1 VA, sec)	–100	0.01
40P2D	40P Zone 2 Time Delay (0.000–400 s)	0.5	0.005
40P2TC	40P Zone 2 Torque Cont (SELOGIC Eqn)	NOT LOPZ	
40P3D	40P Zone 3 Time Delay (0.000–400 s)	10	0.005
40P3TC	40P Zone 3 Torque Cont (SELOGIC Eqn)	NOT LOPZ	
40PUVP	40P U/V Element PU (OFF, 2.00–300 V, sec)	OFF	0.01
40PAD	40P Accelerated Time Delay (0.000–400 s)	10	0.005
40P4SEG	40P Zone 4 Underexcited Segment Shape (C, L)	C	
40PQ1	40P Q Power Pt 1 (1.00–2000 VA, sec)	100	0.01
40PP2	40P P Power Pt 2 (1.00–2000 VA, sec)	40	0.01
40PQ2	40P Q Power Pt 2 (1.00–2000 VA, sec)	80	0.01
40PP3	40P P Power Pt 3 (1.00–2000 VA, sec)	80	0.01
40PQ3	40P Q Power Pt 3 (1.00–2000 VA, sec)	60	0.01
40PP4	40P P Power Pt 4 (1.00–2000 VA, sec)	100	0.01
40PQ4	40P Q Power Pt 4 (–2000.00 to 2000 VA, sec)	0	0.01
40PP5	40P P Power Pt 5 (1.00–2000 VA, sec)	80	0.01
40PQ5	40P Q Power Pt 5 (–2000.00 to 2000 VA, sec)	–60	0.01
40PP6	40P P Power Pt 6 (1.00–2000 VA, sec)	40	0.01

Table 8.49 PQ-Based Loss-of-Field (40P) Element (Sheet 2 of 2)

Setting	Prompt	Default	Increment
40PQ6	40P Q Power Pt 6 (–2000.00 to 0 VA, sec)	–80	0.01
40PQ7	40P Q Power Pt 7 (–2000.00 to –1 VA, sec)	–100	0.01
40P4M	40P Zone 4 Margin from Capability Curve (0.60–1)	0.8	0.01
40PRU	40P P Rated (1.00–2000 VA, sec)	100	0.01
40PQ1D	40P Q Power Dynamic Pt 1 (1.00–2000 VA, sec)	150	0.01
40PP2D	40P P Power Dynamic Pt 2 (1.00–2000 VA, sec)	90	0.01
40PQ2D	40P Q Power Dynamic Pt 2 (1.00–2000 VA, sec)	130	0.01
40PP3D	40P P Power Dynamic Pt 3 (1.00–2000 VA, sec)	130	0.01
40PQ3D	40P Q Power Dynamic Pt 3 (1.00–2000 VA, sec)	110	0.01
40PP4D	40P P Power Dynamic Pt 4 (1.00–2000 VA, sec)	150	0.01
40PQ4D	40P Q Power Dynamic Pt 4 (–2000.00 to 2000 VA, sec)	0	0.01
40PP5D	40P P Power Dynamic Pt 5 (1.00–2000 VA, sec)	130	0.01
40PQ5D	40P Q Power Dynamic Pt 5 (–2000.00 to 2000 VA, sec)	–110	0.01
40PP6D	40P P Power Dynamic Pt 6 (1.00–2000 VA, sec)	90	0.01
40PQ6D	40P Q Power Dynamic Pt 6 (–2000.00 to 0 VA, sec)	–130	0.01
40PQ7D	40P Q Power Dynamic Pt 7 (–2000.00 to –1 VA, sec)	–100	0.01
40PRUD	40P P Rated Dynamic (1.00–2000 VA, sec)	150	0.01
40P4D	40P Zone 4 Time Delay (0.000–400 s)	10	0.005
40P4TC	40P Zone 4 Torque Cont (SELOGIC Eqn)	NOT LOPZ	

Table 8.50 Current Unbalance (46) Elements 1 and 2

Setting	Prompt	Default	Increment
46QO*a*[a]	46 Element *a* Operate Quantity	I2GP	
46Q*a*P*a*[a]	46 Element *a* Level *a* PU (OFF, 2.0–100 %)	8	0.1
46Q*a*D1[a]	46 Element *a* Level 1 Delay (0.000–1000 s)	30	0.005
46Q*a*K2[a]	46 Element *a* Level 2 Time Dial (1–100 s)	10	1
46Q*a*TC[a]	46 Element *a* Torque Control (SELOGIC Eqn)	1	

[a] a = 1, 2.

Table 8.51 Terminal n Overcurrent Elements

Setting	Prompt	Default	Increment
E50*n*[a]	Type of O/C Elems Enabled Term. *n* (Combo of P, Q, G)	P	

[a] n = S, T, U, Y.

Table 8.52 Terminal n Phase Overcurrent Element Level c

Setting[a, b]	Prompt	Default	Increment
50*n*P*c*P	Phase Inst O/C Pickup Lvl *c* (OFF, 0.25–100.00 A, sec)	OFF	0.01
67*n*P*c*TC	Phase Inst O/C Lvl *c* Torque Ctrl (SELOGIC Eqn)	1	
67*n*P*c*D	Phase Inst O/C Lvl *c* Delay (0.000–400 s)	0	0.005

[a] n = S, T, U, Y.
[b] c = 1–3.

Table 8.53 Terminal n Negative-Sequence Overcurrent Element Level c

Setting[a, b]	Prompt	Default	Increment
50*n*Q*c*P	NegSeq Inst O/C Pickup Lvl *c* (OFF, 0.25–100.00)	OFF	0.01
67*n*Q*c*TC	NegSeq Inst O/C Lvl *c* Torque Ctrl (SELOGIC Eqn)	1	
67*n*Q*c*D	NegSeq Inst O/C Lvl *c* Delay (0.000–400 s)	0	0.005

[a] n = S, T, U, Y.
[b] c = 1–3.

Table 8.54 Terminal n Zero-Sequence Overcurrent Element Level c

Setting[a, b]	Prompt	Default	Increment
50*n*G*c*P	ZeroSeq Inst O/C Pickup Lvl *c* (OFF, 0.25–100.00)	OFF	0.01
67*n*G*c*TC	ZeroSeq Inst O/C Lvl *c* Torque Ctrl (SELOGIC Eqn)	1	
67*n*G*c*D	ZeroSeq Inst O/C Lvl *c* Delay (0.000–400 s)	0	0.005

[a] n = S, T, U, Y.
[b] c = 1–3.

Table 8.55 Terminal n Directional (67) Elements

Setting[a]	Prompt	Default	Increment
Z1ANG*n*	Pos.-Seq. Line Impedance Angle (5.00–90 deg)	89	0.01
Z0ANG*n*	Zero-Seq. Line Impedance Angle (5.00–90 deg)	85	0.01
50QP*n*	Neg.-Seq. Dir. O/C Pickup (0.25–5 A, sec)	0.6	0.01
Z2F*n*	Fwd Dir Z2 Threshold (–64.00 to 64.00 ohms, sec)	–0.1	0.01
Z2R*n*	Rev Dir Z2 Threshold (–64.00 to 64.00 ohms, sec)	0.1	0.01
A2*n*	Pos.-Seq. Restraint Factor, I2/I1 (0.02–0.50)	0.1	0.01
K2*n*	Zero-Seq. Restraint Factor, I2/I0 (0.10–1.20)	0.2	0.01
50GP*n*	Zero-Seq. Dir. O/C Pickup (0.25–5 A, sec)	0.6	0.01
Z0F*n*	Fwd Dir Z0 Threshold (–64.00 to 64.00 ohms, sec)	–0.1	0.01
Z0R*n*	Rev Dir Z0 Threshold (–64.00 to 64.00 ohms, sec)	0.1	0.01
A0*n*	Pos.-Seq. Restraint Factor, I0/I1 (0.02–0.50)	0.1	0.01
DIRBLK*n*	Block *n* Directional Elem. (SELOGIC Eqn)	NA	

[a] n = S, T, U, Y.

Table 8.56 Inverse Time Overcurrent Elements 1–12

Setting	Prompt	Default	Increment
51O1–51O12	Inv. Time O/C 1–12 Operate Quantity	IMAXSF	
51P1–51P12	Inv. Time O/C 1–12 Pickup Value (SEL Math Eqn)	1	
51C1–51C12	Inv. Time O/C 1–12 Curve Selection (U1–U5, C1–C5)	U1	
51TD1–51TD12	Inv. Time O/C 1–12 Time Dial (SEL Math Eqn)	1	
51RS1–51RS12	Inv. Time O/C 1–12 EM Reset (Y, N)	N	
51TC1–51TC12	Inv. Time O/C 1–12 Torque Control (SELOGIC Eqn)	1	

Table 8.57 Overvoltage (59) Elements 1–6

Setting	Prompt	Default	Increment
59O*s*[a]	O/V Element *s* Operating Quantity	VPMAXZF	
59P*s*P*a*[a, b]	O/V Element *s* Level *a* PU (OFF, 2.00–300 V, sec)	OFF	0.01
59P*s*C*a*[a, b]	O/V Element *s* Level *a* Curve (D, I)	D	
59P*s*D*a*[a, b]	O/V Element *s* Level *a* Delay (0.000–400 s)	10	0.005
59TC*s*[a, b]	O/V Element *s* Torque Control (SELOGIC Eqn)	1	

[a] s = 1–6.
[b] a = 1, 2.

Table 8.58 Split Phase (60P) Element

Setting	Prompt	Default	Increment
60P*p*HP[a]	60P High Set Lvl Ph *p* Pickup (OFF, 0.10–100 A, sec)	OFF	0.01
60PHD	60P High Set Lvl Delay (0.000–400 s)	0.005	0.005
60P*p*HSS[a]	60P High Set Lvl Ph *p* Switch to Sec (SELOGIC Eqn)	CON*p*1	
60PHTC	60P High Set Lvl Torque Control (SELOGIC Eqn)	1	
60P*p*LP[a]	60P Low Set Lvl Ph *p* Pickup (OFF, 0.10–100 A, sec)	OFF	0.01
60PLD	60P Low Set Lvl Delay (0.000–400 s)	0.005	0.005
60PLR	60P Low Set Lvl Reset (SELOGIC Eqn)	NA	
60PLT	60P Low Set Lvl Time Constant (1–2400 s)	100	1
60P*p*LSS[a]	60P Low Set Lvl Ph *p* Switch to Sec (SELOGIC Eqn)	CON*p*1	
60PLTC	60P Low Set Lvl Torque Control (SELOGIC Eqn)	1	
60NHP	60N High Set Lvl Pickup (OFF, 0.10–100 A, sec)	OFF	0.01
60NHD	60N High Set Lvl Delay (0.000–400 s)	0.005	0.005
60NHSS	60N High Set Lvl Switch to Sec (SELOGIC Eqn)	CON1	
60NHTC	60N High Set Lvl Torque Control (SELOGIC Eqn)	1	
60NLP	60N Low Set Lvl Pickup (OFF, 0.10–100 A, sec)	OFF	0.01
60NLD	60N Low Set Lvl Delay (0.000–400 s)	0.005	0.005
60NLR	60N Low Set Lvl Reset (SELOGIC Eqn)	NA	
60NLT	60N Low Set Lvl Time Constant (1–2400 s)	100	1
60NLSS	60N Low Set Lvl Switch to Sec (SELOGIC Eqn)	CON1	
60NLTC	60N Low Set Lvl Torque Control (SELOGIC Eqn)	1	

[a] p = A, B, C.

Table 8.59 Stator Ground (64G) Element (Sheet 1 of 2)

Setting	Prompt	Default	Increment
64G1P*a*[a]	64G1 Neutral O/V Level *a* PU (OFF, 0.1–150 V, sec)	OFF	0.1
64G1D*a*[a]	64G1 Level *a* Delay (0.000–400 s)	1	0.005
64G1TC*a*[a]	64G1 Level *a* Torque Cont (SELOGIC Eqn)	1	
64GALT	64G Alternate Setting (SELOGIC Eqn)	NA	
64GANCL	64G Angle Check Low (–179.99 to 180 deg)	45	0.01
64GANCH	64G Angle Check High (–179.99 to 180 deg)	–135	0.01
64G2R*a*[a]	64G2 Ratio Correction *a* (0.10–10)	1	0.01

Table 8.59 Stator Ground (64G) Element (Sheet 2 of 2)

Setting	Prompt	Default	Increment
64G2PMN	64G2 Minimum Power (OFF, 1.00–2000 VA, sec)	OFF	0.01
64G2PMX	64G2 Maximum Power (OFF, 1.00–2000 VA, sec)	OFF	0.01
64G2P*a*[a]	64G2 Voltage Pickup *a* (0.10–150 V, sec)	2	0.01
64G2D	64G2 Element Delay (0.000–400 s)	1	0.005
64G2TC	64G2 Element Torque Cont (SELOGIC Eqn)	1	
64G3R*a*[a]	64G3 Ratio Correction *a* (0.01–1)	0.15	0.01
64G3P1	64G3 Voltage Pickup 1 (0.10–150 V, sec)	2	0.01
64G3D	64G3 Element Delay (0.000–400 s)	1	0.005
64G3TC	64G3 Element Torque Cont (SELOGIC Eqn)	1	
64GTIN	64G Normal Trip Input (SELOGIC Eqn)	64G1T OR 64G2T OR 64G3T	
64GAIN	64G Accelerated Input (SELOGIC Eqn)	64G1 OR 64G2 OR 64G3	
64GATC	64G Accelerated Torque Cont (SELOGIC Eqn)	NA	
64GAPU	64G Accelerated PU Delay (0.000–400 s)	0.2	0.005
64GADO	64G Accelerated DO Delay (0.000–400 s)	15	0.005

[a] a = 1, 2.

Table 8.60 Field Ground (64F) Element

Setting	Prompt	Default	Increment
64FIRM[a]	64F Field Insulation Resistance Mapping	PORT1	
64FIQ	64F Field Insulation Quality (SELOGIC Eqn)	NOT 64FFLT	
64F*a*P[b]	64F Level *a* Pickup (OFF, 0.5–200 kOhms)	OFF	0.1
64F*a*D[b]	64F Level *a* Delay (0.000–400 s)	60	0.005
64F*a*TC[b]	64F Level *a* Torque Cont (SELOGIC Eqn)	1	

[a] Range = PORT1–PORT3, RA001–RA256
[b] a = 1, 2.

Table 8.61 Stator Ground (64S) Element

Setting	Prompt	Default	Increment
64SIRM[a]	64S Stator Insulation Resistance Mapping	RA002	
64SICM[a]	64S Stator Insulation Capacitance Mapping	RA003	
64SIQ	64S Stator Insulation Quality (SELOGIC Eqn)	NA	
64S*a*P[b]	64S Level *a* Pickup (OFF, 0.1–10 kOhms)	OFF	0.1
64S*a*D[b]	64S Level *a* Delay (0.000–400 s)	60	0.005
64S*a*TC[b]	64S Level *a* Torque Cont (SELOGIC Eqn)	1	

[a] Range = RA001–RA256
[b] a = 1, 2.

Table 8.62 Out-of-Step (78) Element

Setting	Prompt	Default	Increment
78FWD	78 Forward Mho Reach (0.05–100 ohms, sec)	8	0.01
78REV	78 Reverse Mho Reach (0.05–100 ohms, sec)	8	0.01
78RB*a*P[a]	78 Resi Blinder *a* Reach (0.05–100)	8	0.01
50ABCP	78 Pos.-Seq Current Supervision (1.00–100 A, sec)	1	0.01
78D	78 Out-of-Step Delay (0.000–1 s)	0.05	0.005
78TD	78 Out-of-Step Trip Delay (0.000–1 s)	0	0.005
78TDUR	78 Out-of-Step Trip Duration (0.000–5 s)	0	0.005
78TC	78 Out-of-Step Torque Cont (SELOGIC Eqn)	NOT LOPZ	
78XP	78 Slip Counter Zone Reach (OFF, 0.05–100 ohms, sec)	OFF	0.01
78GSCP	78 Generator Slip Counter Pickup (1–5)	2	1
78SSCP	78 System Slip Counter Pickup (OFF, 1–10)	OFF	1
78TSCP	78 Total Slip Counter Pickup (OFF, 1–10)	OFF	1
78SCD	78 Slip Counter Reset Delay (0.000–1 s)	0.05	0.005

[a] a = 1, 2.

Table 8.63 Frequency (81) Elements

Setting	Prompt	Default	Increment
81UVSP	81 Element U/V Supervision (OFF, 20.00–200 V, sec)	85	0.01
81O*s*[a]	81 O/U Element *s* Operating Quantity	FREQPG	
81D*s*P[a]	81 O/U Element *s* Pickup (5.01–119.99 Hz)	61	0.01
81D*s*D[a]	81 O/U Element *s* Time Delay (0.050–400 s)	2	0.005
81D*s*TC[a]	81 O/U Element *s* Torque Control (SELOGIC Eqn)	1	

[a] s = 1–6.

Table 8.64 Rate-of-Change-of-Frequency (81R) Elements

Setting	Prompt	Default	Increment
81RUVSP	81R Element U/V Supervision (OFF, 20.00–200 V, sec)	85	0.01
81RO*s*[a]	81R O/U Element *s* Operating Quantity	DFREQPG	
81R*s*P[a]	81R O/U Element *s* Pickup (–29.95 to 29.95 Hz/s)	0.1	0.05
81R*s*PU[a]	81R O/U Element *s* Time PU Delay (0.050–80 s)	2	0.005
81R*s*DO[a]	81R O/U Element *s* Time DO Delay (0.000–80 s)	0	0.005
81R*s*TC[a]	81R O/U Element *s* Torque Control (SELOGIC Eqn)	1	

[a] s = 1–6.

Table 8.65 Accumulated Frequency (81A) Elements (Sheet 1 of 2)

Setting	Prompt	Default	Increment
E81ABD	81A Enable Conventional Frequency Band (Y, N)	N	
81AD	81AC Element PU Time Delay (0.000–400 s)	0.2	0.005
81ATC	81AC Element Torque Control (SELOGIC Eqn)	1	
81AU*r*P[a]	81AC Ele. Band *r* Upper Limit PU (5.01–119.99 Hz)	59.5	0.01

Table 8.65 Accumulated Frequency (81A) Elements (Sheet 2 of 2)

Setting	Prompt	Default	Increment
81AL*r*P	81AC Ele. Band *r* Lower Limit PU (5.01–119.99 Hz)	58.8	0.01
81A*r*D	81AC Ele. Band *r* Time Limit (OFF, 0.5–6000 s)	3000	0.5

[a] r = 1–8.

Table 8.66 Pole Open Detection

Setting	Prompt	Default	Increment
3POD*r*[a]	Three-Pole Open DO Delay BKR *n* (0.0000–2 s)	0.01	0.0025

[a] r = 1–8.

Table 8.67 System Backup Protection

Setting	Prompt	Default	Increment
GSUCA	GSU Compensation Angle (0, –30, 30 deg)	30	

Table 8.68 Phase Distance (21P) Element

Setting	Prompt	Default	Increment
21PZ*a*MP[a]	21P Zone *a* Reac Reach (OFF, 0.05–100 ohms, sec)	8	0.01
21PZ*a*RP[a]	21P Zone *a* Resi Reach (OFF, 0.05–100 ohms, sec)	8	0.01
21PZ*a*D[a]	21P Zone *a* Delay (0.000–400 s)	10	0.005
21PZ*a*TC[a]	21P Zone *a* Torque Cont (SELOGIC Eqn)	(NOT LOPZ) AND (NOT ZLOAD)	
21PANG	21P Zone Characteristic Angle (45.0–90 deg)	88	0.1
21POFF	21P Zone Offset Impedance (0.00–10 ohms, sec)	0	0.01

[a] a = 1, 2.

Table 8.69 Voltage-Controlled Time-Overcurrent (51C) Element

Setting	Prompt	Default	Increment
51CP	51C Inv. Time O/C PU (0.25–16)	2	0.01
51CC	51C Inv. Time O/C Curve (U1–U5, C1–C5)	U1	
51CTD	51C Inv. Time O/C Time Dial (0.50–15)	0.5	0.01
51CRS	51C Inv. Time O/C EM Reset (Y, N)	N	
51CTC	51C Inv. Time O/C Torque Cont (SELOGIC Eqn)	NOT LOPZ	

Table 8.70 Voltage-Restrained Time Overcurrent (51V) Element

Setting	Prompt	Default	Increment
51VP	51V Inv. Time O/C PU (2.00–16)	2	0.01
51VC	51V Inv. Time O/C Curve (U1–U5, C1–C5)	U1	
51VTD	51V Inv. Time O/C Time Dial (0.50–15)	0.5	0.01
51VRS	51V Inv. Time O/C EM Reset (Y, N)	N	
51VTC	51V Inv. Time O/C Torque Cont (SELOGIC Eqn)	NOT LOPZ	

Table 8.71 Load Encroachment

Setting	Prompt	Default	Increment
ZLF	Forward Load Impedance (0.05–64 ohms, sec)	9.22	0.01
ZLR	Reverse Load Impedance (0.05–64 ohms, sec)	9.22	0.01
PLAF	Forward Load Positive Angle (–90.0 to 90 deg)	30	0.1
NLAF	Forward Load Negative Angle (–90.0 to 90 deg)	–30	0.1
PLAR	Reverse Load Positive Angle (90.0 to 270 deg)	150	0.1
NLAR	Reverse Load Negative Angle (90.0 to 270 deg)	210	0.1

Table 8.72 Loss of Potential

Setting[a]	Prompt	Default	Increment
60LVP	60 LOP Unbalance Pickup (OFF, 0.10–300 V, sec)	OFF	0.01
60LVR	60 LOP Unbalance Ratio Correction (0.5000–2)	1	0.0001
LOPVR*k*[b]	LOP *k* Incremental Voltage Ratio (OFF, 0.50–0.98)	0.9	0.01
LOPIS*k*[b]	LOP *k* Current Source (S, T, U, Y, G)	G	
LOPTC*k*[b]	LOP *k* Torque Control (SELOGIC Eqn)	1	
LOPS*k*[b]	LOP *k* Set (SELOGIC Eqn)	LOPI*k* OR LOPQ*k* OR 60LOP*k* OR LOP3PH*k*	
LOPSD*k*[b]	LOP *k* Set Delay (0.000–1 s)	0.3	0.005
LOPR*k*[b]	LOP *k* Reset (SELOGIC Eqn)	LOPRS*k*	
LOPRD*k*[b]	LOP *k* Reset Delay (0.000–1 s)	0.5	0.005

[a] Category hidden if ELOP = OFF.
[b] k = V, Z.

Table 8.73 Breaker Failure Logic

Setting	Prompt	Default	Increment
BF_SCHM	Breaker Failure Scheme (Y, Y1)	Y	

Table 8.74 Breaker n Failure Logic (Sheet 1 of 2)

Setting[a]	Prompt	Default	Increment
EXBF*n*	Enable External Breaker Fail –BKR *n* (SELOGIC Eqn)	NA	
EXBFSP*n*	External Bkr Fail Superv –BKR *n* (SELOGIC Eqn)	NA	
EBFPU*n*	Ext. Bkr Fail Init PU Delay –BKR *n* (0.0000–100 s)	0.1	0.0025
50FPU*n*	Fault Current Pickup –BKR *n* (0.50–50 A, sec)	10	0.01
BFPU*n*	Brkr Fail Init Pickup Delay –BKR *n* (0.0000–100 s)	0.1	0.0025
RTPU*n*	Retrip Delay –BKR *n* (0.0000–100 s)	0.05	0.0025
BFI*n*	Breaker Fail Initiate –BKR *n* (SELOGIC Eqn)	NA	
ATBFI*n*	Alt Breaker Fail Initiate –BKR *n* (SELOGIC Eqn)	NA	
ENINBF*n*	Enable Neutral Bkr Failure –BKR *n* (SELOGIC Eqn)	NA	
INFPU*n*	Neutral Current Pickup –BKR *n* (0.50–50 A, sec)	0.5	0.01
EBFIS*n*	Breaker Fail Initiate Seal-In –BKR *n* (Y, N)	N	

Table 8.74 Breaker n Failure Logic (Sheet 2 of 2)

Setting[a]	Prompt	Default	Increment
BFISP*n*	Bkr Fail Init Seal-In Delay –BKR *n* (0.0000–20 s)	0.05	0.0025
BFIDO*n*	Bkr Fail Init Dropout Delay –BKR *n* (0.0000–20 s)	0.025	0.0025

[a] n = S, T, U, Y.

Table 8.75 Breaker n Flashover Logic

Setting[a]	Prompt	Default	Increment
EFOBF*n*	Enable Flash Over –BKR *n* (P, G)	P	
50FOPU*n*	Flash Over Current PU –BKR *n* (0.50–50 A, sec)	10	0.01
FOPU*n*	Flash Over Init PU Delay –BKR *n* (0.0000–100 s)	0.1	0.0025
BLKFO*n*	Block Flash Over –BKR *n* (SELOGIC Eqn)	NA	

[a] n = S, T, U, Y.

Table 8.76 Demand Metering Elements 1–10

Setting[a]	Prompt	Default	Increment
DMTY*g*	Demand Met. Type Element *g* (THM, ROL)	THM	
DMOQ*g*	Demand Met. Op. Qty. Element *g*	IAGRS	
DMPU*g*	Demand Met. PU Element *g* (0.50–16.00 A, sec)	2	0.01
DMTC*g*	Demand Met. Time Const. Elm *g* (5, 10, ..., 300 min)	5	5
EDM*g*	Enable Demand Metering Element *g* (SELOGIC Eqn)	1	

[a] g = 1–10.

Table 8.77 Max/Min Metering Elements

Setting	Prompt	Default	Increment
MMOQ01–MMOQ30	Max/Min Met. An. Qty. Element 01–30	3PGF	

Table 8.78 Online Logic

Setting	Prompt	Default	Increment
ONLINE	Generator Online Logic (SELOGIC Eqn)	52CLS	
FLDENRG	Generator Field Energized (SELOGIC Eqn)	NA	

Table 8.79 Trip Logic (Sheet 1 of 2)

Setting	Prompt	Default	Increment
TR01	Trip Element 01 (SELOGIC Eqn)	87Z1 OR 87Z2 OR REF OR 64GT OR 21PZ1T OR 21PZ2T	
TR02	Trip Element 02 (SELOGIC Eqn)	24D1T1 OR 24D2T1	
TR03	Trip Element 03 (SELOGIC Eqn)	32T01	
TR04	Trip Element 04 (SELOGIC Eqn)	40Z1T OR 40Z2T OR 40P1T OR 40P2T	
TR05	Trip Element 05 (SELOGIC Eqn)	81D1T OR 81D2T OR 81D3T OR 81D4T OR 81D5T OR 81D6T	
TR06	Trip Element 06 (SELOGIC Eqn)	78OST OR 46Q1T1 OR 46Q1T2	
TR07	Trip Element 07 (SELOGIC Eqn)	NA	

Table 8.79 Trip Logic (Sheet 2 of 2)

Setting	Prompt	Default	Increment
TR08	Trip Element 08 (SELOGIC Eqn)	NA	
ULTR*r*[a, b]	Unlatch Trip Element *r* (SELOGIC Eqn)	TRGTR OR RSTTRGT	
TDURD*r*[b]	Min. Trip Element *r* Duration (0.0200–400 s)	0.1	0.0025
TR*n*[c]	Trip Breaker *n* (OFF or combo of 1–8)	OFF	
TREX	Trip Exciter (OFF or combo of 1–8)	1, 3, 4	
TRPM	Trip Prime Mover (OFF or combo of 1–8)	1, 3	
TRAUX	Trip Auxiliary (OFF or combo of 1–8)	1, 3, 4	
TRIP	General Trip (OFF or combo of 1–8)	1, 2, 3, 4, 5, 6	
ER	Event Report Trigger Equation (SELOGIC Equation)	NA	
FAULT	Fault Condition Equation (SELOGIC Equation)	NA	

[a] Cannot be set to NA or 0.
[b] r = 01–08
[c] n = S, T, U, Y.

Table 8.80 Close Logic

Setting[a]	Prompt	Default	Increment
CL*n*	Close Breaker *n* (SELOGIC Equation)	CC*n*	
ULCL*n*	Unlatch Close Breaker *n* (SELOGIC Equation)	52CL*n*	
CFD*n*	Close Failure Delay Breaker *n* (OFF, 0.0200–2000 s)	0.08	0.0025

[a] n = S, T, U, Y.

Automation Freeform SELOGIC Control Equations

See *Section 12: Settings in the SEL-400 Series Relays Instruction Manual* for a description of automation SELOGIC control equations. The SEL-400G supports 10 blocks of 100 lines.

Output Settings

Section 12: Settings in the SEL-400 Series Relays Instruction Manual contains a description of the output settings of the relay.

Front-Panel Settings

See *Section 12: Settings in the SEL-400 Series Relays Instruction Manual* for a complete description of front-panel settings. This section lists the SEL-400G specific default settings values.

Table 8.81 Front-Panel Settings Defaults (Sheet 1 of 3)

Setting	Default
FP_TO	15
EN_LEDC	G
TR_LEDC	R
PB1_LED	NA
PB1_COL	AO
PB2_LED	NA
PB2_COL	AO
PB3_LED	AN
PB3_COL	AO
PB4_LED	NA
PB4_COL	AO
PB5_LED	NA
PB5_COL	AO
PB6_LED	NA
PB6_COL	AO
PB7_LED	NA
PB7_COL	AO
PB8_LED	NA
PB8_COL	AO
PB9_LED	NA
PB9_COL	AO
PB10LED	NA
PB10COL	AO
PB11LED	NA
PB11COL	AO
PB12LED	NA
PB12LED	AO
T1_LED	87Z1
T1LEDL	Y
T1LEDC	RO
T2_LED	87Z2
T2LEDL	Y
T2LEDC	RO
T3_LED	REF
T3LEDL	Y
T3LEDC	RO

Table 8.81 Front-Panel Settings Defaults (Sheet 2 of 3)

Setting	Default
T4_LED	24D1T1 OR 24D2T1
T4LEDL	Y
T4LEDC	RO
T5_LED	64GT
T5LEDL	Y
T5LEDC	RO
T6_LED	64F1T OR 64F2T
T6LEDL	Y
T6LEDC	RO
T7_LED	40Z1T OR 40Z2T OR 40P1T OR 40P2T
T7LEDL	Y
T7LEDC	RO
T8_LED	32T01
T8LEDL	Y
T8LEDC	RO
T9_LED	81D1T OR 81D2T OR 81D3T OR 81D4T OR 81D5T OR 81D6T
T9LEDL	Y
T9LEDC	RO
T10_LED	78OST
T10LEDL	Y
T10LEDC	RO
T11_LED	51CT OR 51VT OR 21PZ1T OR 21PZ2T
T11LEDL	Y
T11LEDC	RO
T12_LED	FBFS
T12LEDL	Y
T12LEDC	RO
T13_LED	TRIPS
T13LEDL	Y
T13LEDC	RO
T14_LED	TRIPEX
T14LEDL	Y
T14LEDC	RO
T15_LED	TRIPPM
T15LEDL	T
T15LEDC	RO
T16_LED	TRIPAUX
T16LEDL	Y
T16LEDC	RO
T17_LED	ONLINE
T17LEDL	N

Table 8.81 Front-Panel Settings Defaults (Sheet 3 of 3)

Setting	Default
T17LEDC	AO
T18_LED	46Q1T1 OR 46Q1T2 OR 46Q2T1 OR 46Q2T2
T18LEDL	Y
T18LEDC	RO
T19_LED	THRLT1 OR THRLT2 OR THRLT3
T19LEDL	Y
T19LEDC	RO
T20_LED	271P1T OR 591P1T
T20LEDL	Y
T20LEDC	RO
T21_LED	LOPZ
T21LEDL	Y
T21LEDC	AO
T22_LED	NA
T22LEDL	N
T22LEDC	RO
T23_LED	NA
T23LEDL	N
T23LEDC	RO
T24_LED	NA
T24LEDL	N
T24LEDC	RO

The SEL-400G does not use the selectable screens as shown in *Section 4: Front-Panel Operations in the SEL-400 Series Relays Instruction Manual*, but instead uses a freeform settings block for listing the selected screens. The SEL-400G rotating display default (RDD) is the single screen: `RMSZV`.

Report Settings

The SEL-400G contains the Report settings described in *Section 12: Settings in the SEL-400 Series Relays Instruction Manual*. Report settings unique to the SEL-400G are shown in *Table 8.82*. See *Reporting on page 7.23* for more information on disturbance event recording.

Table 8.82 Disturbance Event Recording

Setting	Prompt	Default
EDR	Enable Disturbance Recording Event (Y, N)	N
DRLER	Length of Disturbance Event (60–300 s)	180
DRPRE[a]	Pre-Fault Length of Disturbance Event (30–276 s)	50

[a] Upper range is equal to DRLER – 24.

Port Settings

The SEL-400G port settings are as described in *Section 12: Settings in the SEL-400 Series Relays Instruction Manual*.

The Fast Message read data access settings listed in *Table 12.8 in the SEL-400 Series Relays Instruction Manual* are all included in the SEL-400G.

Table 8.83 MIRRORED BITS Protocol Defaults

Setting	Default
MBANA1	PMV58
MBANA2	PMV59
MBANA3	PMV60
MBANA4	PMV61
MBANA5	PMV62
MBANA6	PMV63
MBANA7	PMV64

The Modbus TCP settings are listed in *Table 8.84*.

Table 8.84 Modbus TCP Protocol Defaults

Setting	Prompt	Default
EMOD	Enable Modbus TCP Sessions (0–2)	0
MODIP1[a]	Modbus TCP Master 1 IP Address (w.x.y.z)	192.168.1.201
MODNUM1[a]	Modbus TCP Port 1 (1–65534)	502
MTIMEO1[a]	Modbus TCP Timeout 1 (15–900 seconds)	15
MODIP2[a, b]	Modbus TCP Master 2 IP Address (w.x.y.z)	192.168.1.202
MODNUM2[a, b]	Modbus TCP Port 2 (1–65534)	502
MTIMEO2[a, b]	Modbus TCP Timeout 2 (15–900 seconds)	15

[a] Setting hidden when EMOD = 0.
[b] Setting hidden when EMOD = 1.

Modbus Settings—Custom Map

The SEL-400G Modbus register map defines one freeform category with as many as 1000 user-settable analogs. Discrete input and coil maps are fixed. See *Modbus TCP Communication on page 10.63* to see the fixed maps and default register map configurations.

DNP3 Settings—Custom Maps

The SEL-400G DNP3 custom map settings operate as described in *Section 12: Settings in the SEL-400 Series Relays Instruction Manual*. See *DNP3 Communication on page 10.8* to see the default map configuration.

Notes Settings

Use the notes settings like a text pad to leave notes about the relay in the Notes area of the relay. See *Section 12: Settings in the SEL-400 Series Relays Instruction Manual* for additional information on notes settings.

Bay Settings

Table 8.85 Bay Settings (Sheet 1 of 2)

Setting	Prompt	Default
MIMIC	Busbar One-line Screen Number (1–999)	1
BAYNAME	Bay Name (max 20 characters)	BAY 1
BAYLAB*x*[a]	Bay Label *x* (max 40 pixels, aprox. 8 char.)	BAYLAB*x*
BUSNAM*x*[a]	Busbar *x* Name (max 40 pixels, aprox. 8 char.)	BUSNAM*x*
EQPNAM*n*[f]	Equip. *n* Name (max 40 pixels, aprox. 8 char.)	EQ*n*
BK1	Bkr 1 Assignment (NA, S, T, U, Y)	S
BK2	Bkr 2 Assignment (NA, S, T, U, Y)	T
BK3	Bkr 3 Assignment (NA, S, T, U, Y)	U
BK4	Bkr 4 Assignment (NA, S, T, U, Y)	Y
B*y*HMINM[b]	Breaker *y* HMI Name (max 17 pixels, aprox. 3 char.)	BK*y*
B*y*CTLNM[b]	Breaker *y* Cntl. Scr. Name (max 15 characters)	Breaker *y*
52*y*CLSM[b]	Breaker *y* Close Status (SELOGIC Equation)	52CL*y*
52*y*_ALM[b]	Breaker *y* Alarm Status (SELOGIC Equation)	52AL*y*
52*y*RACK[b, c]	Breaker *y*[b] Racked Status (SELOGIC Equation)	1
52*y*TEST[b, c]	Breaker *y*[b] Test Status (SELOGIC Equation)	0
D*r*HMIN[d]	Disconnect *m* HMI Name (max 18 pixels, aprox. 4 char.)[e]	SW*m*
D*r*CTLN[d]	Disconnect *m* Control Scr. Name (max 15 char.)[e]	BB *m*
89AM*r*[d]	Disconnect *m* N/O Contact (SELOGIC Equation)[e]	1
89BM*r*[d]	Disconnect *m* N/C Contact (SELOGIC Equation)[e]	0
89ALP*r*[d]	Disconnect *m* Alarm Pickup Delay (0.020–2000 s)[e]	6
89CCN*r*[d]	Dis. *m* Remote Close Control (SELOGIC Equation)[e]	89CC*r*
89OCN*r*[d]	Dis. *m* Remote Open Control (SELOGIC Equation)[e]	89OC*r*
89CTL*r*[d]	Dis. *r* Front-Panel Ctl. Enable (SELOGIC Equation)[d]	1
89CST*r*[d]	Dis. *m* Close Seal-in Time (OFF, 0.020–2000 s)[e]	5.6
89CIT*r*[d]	Dis. *m* Close Immobility Time (OFF, 0.020–2000 s)[e]	0.4
89CRS*r*[d]	Disconnect *m* Close Reset (SELOGIC Equation)[e]	89CL*r* OR 89CSI*r*
89CBL*r*[d]	Disconnect *m* Close Block (SELOGIC Equation)[e]	NA
89OST*r*[d]	Dis. *m* Open Seal-in Time (OFF, 0.020–2000 s)	5.6

Table 8.85 Bay Settings (Sheet 2 of 2)

Setting	Prompt	Default
89OIT*r*[d]	Dis. *m* Open Immobility Time (OFF, 0.020–2000 s)[e]	0.4
89ORS*r*[d]	Disconnect *m* Open Reset (SELOGIC Equation)[e]	89OPN*r* OR 89OSI*r*
89OBL*r*[d]	Disconnect *m* Open Block (SELOGIC Equation)[e]	NA
89CIR*r*[d]	Dis. *m* Close Immob. Time Reset (SELOGIC Equation)[e]	NOT 89OPN*r*
89OIR*r*[d]	Dis. *m* Open Immob. Time Reset (SELOGIC Equation)[e]	NOT 89CL*r*
MDELE*n*[f]	Analog Quantity	<Blank>
MDNAM*z*[g]	Pre-text	<Blank>
MDSET*z*[g]	Text Formatting {w.d}	<Blank>
MDCLR*z*[g]	Post-text	<Blank>
MDSCA*z*[g]	Scale Format {s}	<Blank>
LOCAL	Local Control (SELOGIC Equation)	NA

[a] x = 1–9.
[b] y = S, T, U, Y.
[c] This setting only applies to rack-type breakers (see Section 5: Control in the SEL-400 Series Relays Instruction Manual). Non-rack-type breakers are not affected by this setting.
[d] r = 01–10.
[e] m = 1–10.
[f] n = 1–6.
[g] z = 1–24.

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SECTION 9

ASCII Command Reference

You can use a communications terminal or terminal emulation program to set and operate the relay. This section explains the commands that you send to the SEL-400G Advanced Generator Protection System through use of SEL ASCII communications protocol. The relay responds to commands such as settings, metering, and control operations.

This section lists all the commands supported by the relay, but most are described in *Section 14: ASCII Command Reference in the SEL-400 Series Relays Instruction Manual*. This section provides information on commands and command options that are unique to the SEL-400G.

This section lists ASCII commands alphabetically. Commands, command options, and command variables that you enter are shown in bold. Lowercase italic letters and words in a command represent command variables that you determine based on the application (for example, Circuit Breaker number *n* = 1 or 2, Remote Bit number *nn* = 01–32, and level).

Command options appear with brief explanations about the command function. Refer to the references listed with the commands for more information on the relay function corresponding to the command or examples of the relay response to the command.

You can simplify the task of entering commands by shortening any ASCII command to the first three characters; for example, **ACCESS** becomes **ACC**. Always send a carriage return <CR> character, or a carriage return character followed by a line feed character <CR><LF>, to command the relay to process the ASCII command. Usually, most terminals and terminal programs interpret the **<Enter>** key as a <CR>. For example, to send the **ACCESS** command, type **ACC <Enter>**.

Tables in this section show the access level(s) where the command or command option is active. Access levels in the SEL-400G are Access Level 0, Access Level 1, Access Level B (breaker), Access Level P (protection), Access Level A (automation), Access Level O (output), Access Level 2, and Access Level C.

Description of Commands

Table 9.1 lists all the commands supported by the relay with the corresponding links to the descriptions in *Section 14: ASCII Command Reference in the SEL-400 Series Relays Instruction Manual*.

Command List

Table 9.1 SEL-400G List of Commands (Sheet 1 of 3)

Command	Location of Command in *Section 14: ASCII Command Reference* in the SEL-400 Series Relays Instruction Manual
2ACCESS	*2ACCESS on page 14.1*
81A	*81A on page 9.4* in this section.
89CLOSE *k*	*89CLOSE n on page 14.2* (The SEL-400G supports 10 disconnects.)
89OPEN *k*	*89OPEN n on page 14.2* (The SEL-400G supports 10 disconnects.)
AACCESS	*AACCESS on page 14.3*
ACCESS	*ACCESS on page 14.3*
BACCESS	*BACCESS on page 14.3*
BNAME	*BNAME on page 14.4*
BREAKER *n*	*BREAKER on page 14.4* (The SEL-400G supports four circuit breakers, designated S, T, U, and Y.)
CAL	*CAL on page 14.5*
CASCII	*CASCII on page 14.6*
CBREAKER	*CBREAKER on page 14.6* (The SEL-400G supports four circuit breakers, designated S, T, U, and Y.)
CHISTORY	*CHISTORY on page 14.11*
CLOSE *n*	*CLOSE n on page 14.11* (The SEL-400G supports four circuit breakers, designated S, T, U, and Y.)
COMMUNICATIONS *c*	*COMMUNICATIONS on page 14.12*
COM HSR	*COM HSR on page 14.14*
COM PRP	*COM PRP on page 14.14*
COM PTP	*COM PTP on page 14.15*
COM RTC	*COM RTC on page 14.17*
COM SV	*COM SV on page 14.18*
CONTROL *nn*	*CONTROL nn on page 14.25*
COPY *m n*	*COPY on page 14.26*
CPR	*CPR on page 14.27*
CSER	*CSER on page 14.27*
CSTATUS	*CSTATUS on page 14.29*
CSUMMARY	*CSUMMARY on page 14.29*
DATE	*DATE on page 14.30*
DNAME X	*DNAME X on page 14.31*
DNP	*DNP on page 14.31*
ETHERNET	*ETHERNET on page 14.31*
EXIT	*EXIT on page 14.37*
FILE	*FILE on page 14.37*
GOOSE	*GOOSE on page 14.38*

Table 9.1 SEL-400G List of Commands (Sheet 2 of 3)

Command	Location of Command in *Section 14: ASCII Command Reference* in the SEL-400 Series Relays Instruction Manual
GROUP	*GROUP on page 14.41*
HELP	*HELP on page 14.41*
HISTORY	*HISTORY on page 14.41*
ID	*ID on page 14.43*
LOOPBACK	*LOOPBACK on page 14.44*
MAC	*MAC on page 14.46*
MAP	*MAP on page 14.46*
METER	*METER on page 14.47* (For all other **METER** options, see *METER on page 9.4* in this section.)
MET AMV	*MET AMV on page 14.47*
MET ANA	*MET ANA on page 14.48*
MET BAT	*MET BAT on page 14.48* (The SEL-400G provides battery metering for one battery monitor channel.)
MET D	*MET D on page 14.48*
MET DIF	See *MET DIF on page 9.5* in this section.
MET E	See *MET E on page 9.5* in this section.
MET H	See *MET H on page 9.6* in this section.
MET M	See *MET M on page 9.6* in this section.
MET PM	*MET PM on page 14.49*
MET PMV	*MET PMV on page 14.50*
MET RMS	See *MET RMS on page 9.6* in this section.
MET RTC	*MET RTC on page 14.50*
MET RTD	*MET T on page 14.50* (The **MET RTD** command in the SEL-400G is the same as the **MET T** command in other SEL-400 series relays.)
MET SEC	See *MET SEC on page 9.7* in this section.
MET SYN	See *MET SYN on page 9.7* in this section.
OACCESS	*OACCESS on page 14.51*
OPEN *n*	*OPEN n on page 14.51* (The SEL-400G supports five circuit breakers, designated S, T, U, W, X.)
PACCESS	*PACCESS on page 14.52*
PASSWORD	*PASSWORD on page 14.52*
PING	*PING on page 14.53*
PORT	*PORT on page 14.53*
PROFILE	*PROFILE on page 14.54*
PULSE	*PULSE on page 14.55*
QUIT	*QUIT on page 14.55*
RTC	*RTC on page 14.56*
SER	*SER on page 14.56*
SET	*SET on page 14.58* (*Table 9.12* lists the class and instance options available in the SEL-400G.)
SHOW	*SHOW on page 14.59* (*Table 9.13* lists the class and instance options available in the SEL-400G.)
SNS	*SNS on page 14.60*
STATUS	*STATUS on page 14.60*
SUMMARY	*SUMMARY on page 14.62*
TARGET	*TARGET on page 14.63*

Table 9.1 SEL-400G List of Commands (Sheet 3 of 3)

Command	Location of Command in *Section 14: ASCII Command Reference* in the SEL-400 Series Relays Instruction Manual
TEST DB	*TEST DB on page 14.65*
TEST DB2	*TEST DB2 on page 14.66*
TEST FM	*TEST FM on page 14.68*
THE	*THE on page 9.9* in this section.
TIME	*TIME on page 14.71*
TIME Q	*TIME Q on page 14.72*
TRIGGER	*TRIGGER on page 14.73*
VECTOR	*VECTOR on page 14.73*
VERSION	*VERSION on page 14.73*
VIEW	*VIEW on page 14.75*

81A

Use the **81A** command to view the accumulated frequency element quantities.

Table 9.2 81A Commands

Command	Description	Access Level
81A	Retrieves frequency accumulated time data for all bands	1, B, P, A, O, 2
81A ***n***[a] **R** or **C**	Clears frequency accumulated time data for Band *n*	B, P, A, O, 2
81A R or **C**	Clears all frequency bands accumulated time data	B, P, A, O, 2
81A P	Load preset value of accumulated time for frequency bands	B, P, A, O, 2

[a] n = 1–8.

When you issue the reset command **81A R** or **C**, the relay responds, `Clear All Frequency Bands accumulated time data, Are you sure (Y/N)?` If you answer **Y <Enter>**, the relay responds `Frequency Bands Accumulated Time Data Archives Cleared`. Similarly, for **81A *n* R** or **C**, the relay responds `Frequency Band n Accumulated Time Data Archives Cleared`. If you preset accumulated time values using the **81A P** command (format *dddd:hh:mm:ss.s*), the relay responds with `Are you sure (Y/N)?` If you answer **Y <Enter>**, the relay responds `Frequency Band Accumulated Time Values Preloaded`.

METER

The **METER** command displays reports about quantities the relay measures in the power system (voltages, currents, frequency, remote analogs, etc.) and internal relay operating quantities (math variables and analog quantities).

MET

Use the **MET** command to view fundamental metering quantities. The relay filters harmonics and subharmonics to present only measured quantities at the power system fundamental operating frequency.

Table 9.3 MET Command[a]

Command	Description	Access Level
MET	Display fundamental metering data	1, B, P, A, O, 2
MET [F] ***n***	Display Terminal *n* fundamental metering quantities	1, B, P, A, O, 2
MET [F] ***n k***	Display Terminal *n* fundamental metering quantities successively for *k* times	1, B, P, A, O, 2

[a] n = G, S, T, U, V, Y, Z.

The **MET** command without options shows the fundamental metering data of the generator (Terminal G). Specify a specific terminal by using the terminal parameter command options. For example, specify **MET T** to view the fundamental metering quantities of Terminal T.

Some situations require that you repeatedly monitor the power system for a brief period; specify a number after any **MET** command to automatically repeat the command.

MET DIF

Use the **MET DIF** command to view the differential current metering data, in multiples of tap.

Table 9.4 MET DIF Command

Command	Description	Access Level
MET DIF ***k***	Displays the differential operate and restraint quantities for Zone 1 successively for *k* times	1, B, P, A, O, 2
MET DIF Z*n*[a]	Displays the differential operate and restraint quantities for Zone *n*	1, B, P, A, O, 2
MET DIF Z*n* A	Displays the differential operate, restraint, and compensated current quantities for Zone *n*	1, B, P, A, O, 2

[a] n = 1, 2.

If the differential is disabled for a particular zone and the **MET DIF** command is issued for that zone, the relay displays the message `Differential Elements n Disabled`.

MET E

Use the **MET E** command to view the energy import and export quantities. Energy values are displayed for the generator and for any terminals enabled in the EPCAL setting (S, T, U, and Y).

Table 9.5 MET E Command

Command	Description	Access Level
MET E	Display energy metering data	1, B, P, A, O, 2
MET E ***k***	Display energy metering data successively for *k* times	1, B, P, A, O, 2
MET RE	Reset energy metering data	P, A, O, 2

The reset command, **MET RE**, resets the generator energy metering quantities. When you issue the **MET RE** command, the relay responds, `Reset Energy Metering (Y/N)?` If you answer **Y <Enter>**, the relay responds, `Energy Metering Reset`.

MET H

Use the **MET H** command to view secondary harmonic metering quantities.

Table 9.6 MET H Command

Command	Description	Access Level
MET H	Display harmonic metering data for all terminals	1, B, P, A, O, 2
MET H G	Display harmonic metering data for Terminal G	1, B, P, A, O, 2
MET H k	Display harmonic metering data for all terminals successively for *k* times	1, B, P, A, O, 2
MET H G *k*	Display harmonic metering data for Terminal G successively for *k* times	1, B, P, A, O, 2

MET M

Use the **MET M** command to view minimum/maximum metering quantities.

Table 9.7 MET M Command

Command	Description	Access Level
MET M	Display minimum/maximum metering data for the configured analogs	1, B, P, A, O, 2
MET M *k*	Display minimum/maximum metering data for the configured analogs successively for *k* times	1, B, P, A, O, 2
MET RM	Reset minimum/maximum metering data	P, A, O, 2

The reset command, **MET RM**, resets the minimum/maximum metering quantities. When you issue the **MET RM** command, the relay responds, `Reset Min/Max Metering (Y/N)?` If you answer **Y <Enter>**, the relay responds, `Min/Max Metering Reset`.

MET RMS

Use the **MET RMS** command to view fundamental metering quantities for the generator (Terminal G).

Table 9.8 MET RMS Command[a]

Command	Description	Access Level
MET RMS	Display root-mean-square (rms) metering quantities for Terminal G	1, B, P, A, O, 2
MET RMS *n*	Display Terminal *n* rms metering quantities	1, B, P, A, O, 2
MET RMS *n k*	Display Terminal *n* rms metering quantities successively for *k* times	1, B, P, A, O, 2

[a] n = G.

MET RTD

Use the **MET RTD** command to view RTD temperature data.

Table 9.9 MET RTD Command

Command	Description	Access Level
MET RTD	Display RTD temperature data	1, B, P, A, O, 2
MET RTD *k*	Display RTD temperature data successively for *k* times	1, B, P, A, O, 2

MET SEC

Use the **MET SEC** command to view secondary fundamental metering quantities.

Table 9.10 MET SEC Command

Command	Description	Access Level
MET SEC	Display secondary metering quantities of the terminal	1, B, P, A, O, 2
MET SEC *k*	Display secondary metering quantities successively for *k* times	1, B, P, A, O, 2

MET SYN

Use the **MET SYN** command to view synchronism-check metering quantities.

Table 9.11 MET SYN Command

Command	Description	Access Level
MET SYN	Display synchronism-check metering data for the first enabled terminal	1, B, P, A, O, 2
MET SYN *n*[a]	Display synchronism-check metering data for Terminal *n*	1, B, P, A, O, 2
MET SYN *n k*[a]	Display synchronism-check metering data for Terminal *n* successively for *k* times	1, B, P, A, O, 2

[a] n = S, T, U, Y.

SET

Table 9.12 lists the options specifically available in the SEL-400G.

Table 9.12 SET Command Overview (Sheet 1 of 2)

Command	Description	Access Level
SET	Set the Group relay settings, beginning at the first setting in the active group	P, 2
SET *n*[a]	Set the Group *n* relay settings, beginning at the first setting in the group	P, 2
SET A	Set the Automation SELOGIC control equation relay settings in Block 1	A, 2
SET A *m*[b]	Set the Automation SELOGIC control equation relay settings in Block *m*	A, 2
SET B	Bay control settings, beginning at the first setting in this class	P, B, 2

Table 9.12 SET Command Overview (Sheet 2 of 2)

Command	Description	Access Level
SET D	Set the DNP3 remapping settings, beginning at the first setting in this class for Instance 1	P, A, O, 2
SET D *instance*	Set the DNP3 remapping settings beginning at the first setting of Instance *instance*	P, A, O, 2
SET F	Set the front-panel relay settings, beginning at the first setting in this class	P, A, O, 2
SET G	Set the Global relay settings, beginning at the first setting in this class	P, A, O, 2
SET L	Set the Protection SELOGIC control equation relay settings for the active group	P, 2
SEL L *n*[a]	Set the Protection SELOGIC relay settings for Group *n*	P, 2
SET M	Monitor settings, beginning at the first setting in this class	P, 2
SET N	Enter text using the text-edit format	P, A, O, 2
SET O	Set the Output SELOGIC control equation relay settings, beginning at OUT101	O, 2
SET P	Set the port presently in use, beginning at the first setting for this port	P, A, O, 2
SET P *p*[c]	Set the communications port relay settings for PORT p, beginning at the first setting for this port	P, A, O, 2
SET R	Set the Report relay settings, beginning at the first setting for this class	P, A, O, 2
SET T	Set the alias settings	P, A, O, 2
SET U	Set the user Modbus settings	P, A, O, 2

[a] n = 1–6; representing Group 1 through Group 6.
[b] m = 1–10; representing Block 1 through Block 10.
[c] p = 1–3, F, or 5; corresponding to PORT 1—PORT 3, PORT F, or PORT 5.

SHOW

Table 9.13 lists the class and instance options available in the SEL-400G.

Table 9.13 SHO Command Overview (Sheet 1 of 2)

Command	Description	Access Level
SHO	Show the Group relay settings, beginning at the first setting in the active group	1, B, P, A, O, 2
SHO *n*[a]	Show the Group *n* relay settings, beginning at the first setting in each instance	1, B, P, A, O, 2
SHO A	Show the Automation SELOGIC control equation relay settings in Block 1	1, B, P, A, O, 2
SHO A *m*[b]	Show the Automation SELOGIC control equation relay settings in Block *m*	1, B, P, A, O, 2
SHO B	Show the Bay control settings, beginning at the first setting in this class	1, B, P, A, O, 2
SHO D	Show the DNP3 remapping settings for Instance 1	P, A, O, 2
SHO D *instance*	Show the DNP3 remapping settings for Instance *instance*	P, A, O, 2
SHO F	Show the Front-panel relay settings, beginning at the first setting in this class	1, B, P, A, O, 2

Table 9.13 SHO Command Overview (Sheet 2 of 2)

Command	Description	Access Level
SHO G	Show the Global relay settings, beginning at the first setting in this class	1, B, P, A, O, 2
SHO L	Show the Protection SELOGIC control equation relay settings for the active group	1, B, P, A, O, 2
SHO L *n*[a]	Show the Protection SELOGIC control equation relay settings for Group *n*	1, B, P, A, O, 2
SHO M	Show the Monitor relay settings, beginning at the first setting in this class	1, B, P, A, O, 2
SHO N	Show notes in the relay	1, B, P, A, O, 2
SHO O	Show the Output SELOGIC control equation relay settings, beginning at OUT101	1, B, P, A, O, 2
SHO P	Show the relay settings for the port presently in use, beginning at the first setting	1, B, P, A, O, 2
SHO P *p*[c]	Show the communications port relay settings for PORT p, beginning at the first setting for this port	1, B, P, A, O, 2
SHO R	Show the Report relay settings beginning at the first setting for this class	1, B, P, A, O, 2
SHO T	Show the alias settings	1, B, P, A, O, 2
SHO U	Show the user Modbus settings	P, A, O, 2

[a] n = 1–6; representing Group 1 through Group 6.
[b] m = 1–10; representing Block 1 through Block 10.
[c] p = 1–3, F, and 5; which corresponds to PORT 1—PORT 3, PORT F, and PORT 5.

THE

Use the **THE** command to display the IEC Thermal model element quantities.

Table 9.14 THE Command Overview

Command	Description	Access Level
THE	Display all IEC thermal elements statuses	1, B, P, A, O, 2
THE R or **C**	Reset all thermal records and total loss-of-life	B, P, A, O, 2
THE *n*[a] **R** or **C**	Reset thermal records for Element *n*	B, P, A, O, 2
THE P	Load preset thermal level value for all elements	B, P, A, O, 2

[a] n = 1–3.

When you issue the reset command **THE R** or **C** the relay responds, `Clear All IEC Thermal Elements data? Are you sure (Y/N)?` If you answer **Y <Enter>**, the relay responds `IEC Thermal Level data Reset`. Similarly, for **THE *n* R** or **C**, the relay responds `IEC Thermal Level Element n Reset`. If you preset the thermal values using **THE P** command, the relay responds with `Are you sure (Y/N)?` If you answer **Y <Enter>**, the relay responds `IEC Thermal Element Values Preloaded`.

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SECTION 10

Communications Interfaces

Section 15: Communications Interfaces–Section 19: Digital Secondary Systems in the SEL-400 Series Relays Instruction Manual describe the various communications interfaces and protocols used in SEL-400 series products. This section describes aspects of the communications protocols that are unique to the SEL-400G Advanced Generator Protection System. The following topics are discussed:

Communications Database

The SEL-400G maintains a database to describe itself to external devices via the Fast Message Data Access protocol. This database includes a variety of data within the relay that are available to devices connected in a serial or Ethernet network. The database includes the regions and data described in *Table 10.1*. Use the **MAP** and **VIEW** commands to display maps and contents of the database regions. See *Section 9: ASCII Command Reference* for more information on the **MAP** and **VIEW** commands.

Table 10.1 SEL-400G Database Regions

Region Name	Contents	Update Rate
LOCAL	Relay identification data including FID, Relay ID, Station ID, and active protection settings group	Updated on settings change and whenever monitored values change
METER	Metering and measurement data	0.5 s
DEMAND	Demand and peak demand measurement data	15 s
TARGET	Selected rows of Relay Word bit data	0.5 s
HISTORY	Relay event history records for the 10 most recent events	Within 15 s of any new event
BREAKER	Summary circuit breaker monitor data	15 s
STATUS	Self-test diagnostic status data	5 s
ANALOGS	Protection and automation math variables	0.5 s

Data within the Ethernet card regions are available for access by external devices via the SEL Fast Message protocol.

The LOCAL region contains the device FID, SID, and RID. It will also provide appropriate status points. This region is updated on settings changes and whenever monitored status points change (see *Table 10.2*).

Table 10.2 SEL-400G Database Structure—LOCAL Region

Address (Hex)	Name	Type	Description
0000	FID	char[48]	FID string
0030	BFID	char[48]	SELBOOT FID string
0060	SER_NUM	char[16]	Device serial number, from factory settings
0070	PART_NUM	char[24]	Device part number, from factory settings
0088	CONFIG	char[8]	Device configuration string (as reported in ID command)
0090	SPECIAL	char[8]	Special device configuration string (as reported in ID command)
0098	DEVICE_ID	char[40]	Relay ID setting, from Global settings
00C0	NODE_ID	char[40]	Station ID from Global settings
00E8	GROUP	int	Active group
00E9	STATUS	int	Status indication: 0 for okay, 1 for failure

The METER region contains all the basic meter and energy information. This region is updated every 0.5 seconds. See *Table 10.3* for the map.

Table 10.3 SEL-400G Database Structure—METER Region (Sheet 1 of 3)

Address (Hex)	Name	Type	Description
1000	_YEAR	int	4-digit year when data were sampled
1001	DAY_OF_YEAR	int	1–366 day when data were sampled
1002	TIME(ms)	long int	Time of day in ms when data were sampled (0–86,400,000)
1004	FREQPG	float	Generator frequency
1006	FREQPS	float	System frequency
1008	VDC	float	Battery voltage
100A	IS(A)	float[6]	Terminal S, 40 ms average filtered phase current magnitude and angle (IASFMC, IASFAC, IBSFMC, IBSFAC, ICSFMC, ICSFAC)
1016	IT(A)	float[6]	Terminal T, 40 ms average filtered phase current magnitude and angle (IATFMC, IATFAC, IBTFMC, IBTFAC, ICTFMC, ICTFAC)
1022	IU(A)	float[6]	Terminal U, 40 ms average filtered phase current magnitude and angle (IAUFMC, IAUFAC, IBUFMC, IBUFAC, ICUFMC, ICUFAC)
102E	IY(A)	float[6]	Terminal Y, 40 ms average filtered phase current magnitude and angle (IAYFMC, IAYFAC, IBYFMC, IBYFAC, ICYFMC, ICYFAC)
103A	IG(A)	float[6]	Terminal G, 40 ms average filtered phase current magnitude and angle (IAGFMC, IAGFAC, IBGFMC, IBGFAC, ICGFMC, ICGFAC)
1046	VV(V)	float[6]	Terminal V, 40 ms average filtered phase voltage magnitude and angle (VAVFMC * 1000, VAVFAC, VBVFMC * 1000, VBVFAC, VCVFMC * 1000, VCVFAC)
1052	VZ(V)	float[6]	Terminal Z, 40 ms average filtered phase voltage magnitude and angle (VAZFMC * 1000, VAZFAC, VBZFMC * 1000, VBZFAC, VCZFMC * 1000, VCZFAC)
105E	ISEQ_S(A)	float[6]	Terminal S, 40 ms average sequence current magnitude and angle (3I0SMC/3, 3I0SAC, I1SMC, I1SAC, 3I2SMC/3, 3I2SAC)
106A	ISEQ_T(A)	float[6]	Terminal T, 40 ms average sequence current magnitude and angle (3I0TMC/3, 3I0TAC, I1TMC, I1TAC, 3I2TMC/3, 3I2TAC)
1076	ISEQ_U(A)	float[6]	Terminal U, 40 ms average sequence current magnitude and angle (3I0UMC/3, 3I0UAC, I1UMC, I1UAC, 3I2UMC/3, 3I2UAC)
1082	ISEQ_Y(A)	float[6]	Terminal Y, 40 ms average sequence current magnitude and angle (3I0YMC/3, 3I0YAC, I1YMC, I1YAC, 3I2YMC/3, 3I2YAC)

Table 10.3 SEL-400G Database Structure—METER Region (Sheet 2 of 3)

Address (Hex)	Name	Type	Description
108E	ISEQ_G(A)	float[6]	Terminal G, 40 ms average sequence current magnitude and angle (3I0GMC/3, 3I0GAC, I1GMC, I1GAC, 3I2GMC/3, 3I2GAC)
109A	VV_LL(V)	float[6]	Terminal V, 40 ms average filtered phase-to-phase voltage magnitude and angle (VABVFMC * 1000, VABVFAC, VBCVFMC * 1000, VBCVFAC, VCAVFMC * 1000, VCAVFAC)
10A6	VZ_LL(V)	float[6]	Terminal Z, 40 ms average filtered phase-to-phase voltage magnitude and angle (VABZFMC * 1000, VABZFAC, VBCZFMC * 1000, VBCZFAC, VCAZFMC * 1000, VCAZFAC)
10B2	VSEQ_V(V)	float[6]	Terminal V, 40 ms average sequence voltage magnitude and angle (3V0VMC/3 * 1000, 3V0VAC, V1VMC * 1000, V1VAC, 3V2VMC/3 * 1000, 3V2VAC)
10BE	VSEQ_Z(V)	float[6]	Terminal Z, 40 ms average sequence voltage magnitude and angle (3V0ZMC/3 * 1000, 3V0ZAC, V1ZMC * 1000, V1ZAC, 3V2ZMC/3 * 1000, 3V2ZAC)
10CA	PS(kW)	float[4]	Terminal S, 40 ms avg fundamental active power (PASFC * 1000, PBSFC * 1000, PCSFC * 1000, 3PSFC * 1000)
10D2	QS(kVAR)	float[4]	Terminal S, 40 ms avg fundamental reactive power (QASFC * 1000, QBSFC * 1000, QCSFC * 1000, 3QSFC * 1000)
10DA	SS(kVA)	float[4]	Terminal S, 40 ms avg fundamental apparent power (SASFC * 1000, SBSFC * 1000, SCSFC * 1000, 3SSFC * 1000)
10E2	PT(kW)	float[4]	Terminal T, 40 ms avg fundamental active power (PATFC * 1000, PBTFC * 1000, PCTFC * 1000, 3PTFC * 1000)
10EA	QT(kVAR)	float[4]	Terminal T, 40 ms avg fundamental reactive power (QATFC * 1000, QBTFC * 1000, QCTFC * 1000, 3QTFC * 1000)
10F2	ST(kVA)	float[4]	Terminal T, 40 ms avg fundamental apparent power (SATFC * 1000, SBTFC * 1000, SCTFC * 1000, 3STFC * 1000)
10FA	PU(kW)	float[4]	Terminal U, 40 ms avg fundamental active power (PAUFC * 1000, PBUFC * 1000, PCUFC * 1000, 3PUFC * 1000)
1102	QU(kVAR)	float[4]	Terminal U, 40 ms avg fundamental reactive power (QAUFC * 1000, QBUFC * 1000, QCUFC * 1000, 3QUFC * 1000)
110A	SU(kVA)	float[4]	Terminal U, 40 ms avg fundamental apparent power (SAUFC * 1000, SBUFC * 1000, SCUFC * 1000, 3SUFC * 1000)
1112	PY(kW)	float[4]	Terminal Y, 40 ms avg fundamental active power (PAYFC * 1000, PBYFC * 1000, PCYFC * 1000, 3PYFC * 1000)
111A	QY(kVAR)	float[4]	Terminal Y, 40 ms avg fundamental reactive power (QAYFC * 1000, QBYFC * 1000, QCYFC * 1000, 3QYFC * 1000)
1122	SY(kVA)	float[4]	Terminal Y, 40 ms avg fundamental apparent power (SAYFC * 1000, SBYFC * 1000, SCYFC * 1000, 3SYFC * 1000)
112A	PG(kW)	float[4]	Terminal G, 40 ms avg fundamental active power (PAGFC * 1000, PBGFC * 1000, PCGFC * 1000, 3PGFC * 1000)
1132	QG(kVAR)	float[4]	Terminal G, 40 ms avg fundamental reactive power (QAGFC * 1000, QBGFC * 1000, QCGFC * 1000, 3QGFC * 1000)
113A	SG(kVA)	float[4]	Terminal G, 40 ms avg fundamental apparent power (SAGFC * 1000, SBGFC * 1000, SCGFC * 1000, 3SGFC * 1000)
1142	PFS	float[4]	Terminal S, phase displacement power factor (PFASC, PFBSC, PFCSC, 3PFSC)
114A	PFT	float[4]	Terminal T, phase displacement power factor (PFATC, PFBTC, PFCTC, 3PFTC)
1152	PFU	float[4]	Terminal U, phase displacement power factor (PFAUC, PFBUC, PFCUC, 3PFUC)
115A	PFY	float[4]	Terminal Y, phase displacement power factor (PFAYC, PFBYC, PFCYC, 3PFYC)
1162	PFG	float[4]	Terminal G, phase displacement power factor (PFAGC, PFBGC, PFCGC, 3PFGC)
116A	ES(kWh)	float[4]	Terminal S, three-phase energy exported/imported in kWh (3PSMWHP * 1000, 3PSMWHN * 1000, 3QSMVHP * 1000, 3QSMVHN * 1000)

Table 10.3 SEL-400G Database Structure—METER Region (Sheet 3 of 3)

Address (Hex)	Name	Type	Description
1172	ET(kWh)	float[4]	Terminal T, three-phase energy exported/imported in kWh (3PTMWHP * 1000, 3PTMWHN * 1000, 3QTMVHP * 1000, 3QTMVHN * 1000)
117A	EU(kWh)	float[4]	Terminal U, three-phase energy exported/imported in kWh (3PUMWHP * 1000, 3PUMWHN * 1000, 3QUMVHP * 1000, 3QUMVHN * 1000)
1182	EY(kWh)	float[4]	Terminal Y, three-phase energy exported/imported in kWh (3PYMWHP * 1000, 3PYMWHN * 1000, 3QYMVHP * 1000, 3QYMVHN * 1000)
118A	EG(kWh)	float[4]	Terminal G, three-phase energy exported/imported in kWh (3PGMWHP * 1000, 3PGMWHN * 1000, 3QGMVHP * 1000, 3QGMVHN * 1000)

The DEMAND region contains demand and peak demand information. This region is updated every 15 seconds. See *Table 10.4* for the map.

Table 10.4 SEL-400G Database Structure—DEMAND Region

Address (Hex)	Name	Type	Description
2000	_YEAR	int	4-digit year when data were sampled
2001	DAY_OF_YEAR	int	1–366 day when data were sampled
2002	TIME(ms)	long int	Time of day in ms when data were sampled (0–86,400,000)
2004	DM	float[10]	Demand quantity (DM01–DM10)
2018	DMP	float[10]	Peak demand quantity (DMM01–DMM10)

The TARGET region contains the entire visible Relay Word plus the rows designated specifically for the TARGET region. This region is updated every 0.5 seconds. See *Table 10.5* for the map. See *Section 11: Relay Word Bits* for detailed information on the Relay Word bits.

Table 10.5 SEL-400G Database Structure—TARGET Region

Address (Hex)	Name	Type	Description
3000	_YEAR	int	4-digit year when data were sampled
3001	DAY_OF_YEAR	int	1–366 day when data were sampled
3002	TIME(ms)	long int	Time of day in ms when data were sampled (0–86,400,000)
3004	TARGET	char[~571]	Entire Relay Word with bit labels

The HISTORY region contains all information available in a History report for the most recent 10 events. This region is updated within 15 seconds of any new events. See *Table 10.6* for the map.

Table 10.6 SEL-400G Database Structure—HISTORY Region (Sheet 1 of 2)

Address (Hex)	Name	Type	Description
4000	_YEAR	int	4-digit year when data were sampled
4001	DAY_OF_YEAR	int	1–366 day when data were sampled
4002	TIME(ms)	long int	Time of day in ms when data were sampled (0–86,400,000)
4004	REF_NUM	int[10]	Event serial number (10000–42767)

Table 10.6 SEL-400G Database Structure—HISTORY Region (Sheet 2 of 2)

Address (Hex)	Name	Type	Description
400E	MONTH	int[10]	Month of event
4018	DAY	int[10]	Day of event
4022	YEAR	int[10]	Year of event
402C	HOUR	int[10]	Hour of event
4036	MIN	int[10]	Minute of event
4040	SEC	int[10]	Second of event
404A	MSEC	int[10]	Milliseconds of event
4054	EVENT	char[100]	Event type string
40B8	GROUP	int[10]	Active group during fault
40C2	TAR_SMALL	char[320]	System targets from event (32 characters per event)
4202	TARGETS	char[1000]	System targets from event (100 characters per event)

The BREAKER region contains some of the information available in a summary Breaker report. This region is updated every 15 seconds. See *Table 10.7* for the map.

Table 10.7 SEL-400G Database Structure—BREAKER Region

Address (Hex)	Name	Type	Description
5000	_YEAR	int	4-digit year when data were sampled
5001	DAY_OF_YEAR	int	1–366 day when data were sampled
5002	TIME(ms)	long int	Time of day in ms when data were sampled (0–86,400,000)
5004	BCW_S	float[3]	Breaker S phase breaker wear (%) (BSBCWPA, BSBCWPB, BSBCWPC)
500A	BCW_T	float[3]	Breaker T phase breaker wear (%) (BTBCWPA, BTBCWPB, BTBCWPC)
5010	BCW_U	float[3]	Breaker U phase breaker wear (%) (BUBCWPA, BUBCWPB, BUBCWPC)
5016	BCW_Y	float[3]	Breaker Y phase breaker wear (%) (BYBCWPA, BYBCWPB, BYBCWPC)
501C	CUR_S	float[3]	Breaker S phase accumulated current (kA) (IASrms_TRIP_ACC, IBSrms_TRIP_ACC, ICS-rms_TRIP_ACC)
5022	CUR_T	float[3]	Breaker T phase accumulated current (kA) (IATrms_TRIP_ACC, IBTrms_TRIP_ACC, ICTrms_TRIP_ACC)
5028	CUR_U	float[3]	Breaker U phase accumulated current (kA) (IAUrms_TRIP_ACC, IBUrms_TRIP_ACC, ICUrms_TRIP_ACC)
502E	CUR_Y	float[3]	Breaker Y phase accumulated current (kA) (IAYrms_TRIP_ACC, IBYrms_TRIP_ACC, ICYrms_TRIP_ACC)
5034	NOP_S	long int	Breaker S number of operations (BS_TRP_CNT)
5036	NOP_T	long int	Breaker T number of operations (BT_TRP_CNT)
5038	NOP_U	long int	Breaker U number of operations (BU_TRP_CNT)
503A	NOP_Y	long int	Breaker Y number of operations (BY_TRP_CNT)

The STATUS region contains complete relay status information. This region is updated every 5 seconds. See *Table 10.8* for the map.

Table 10.8 SEL-400G Database Structure—STATUS Region

Address (Hex)	Name	Type	Description
6000	_YEAR	int	4-digit year when data were sampled
6001	DAY_OF_YEAR	int	1–366 day when data were sampled
6002	TIME(ms)	long int	Time of day in ms when data were sampled (0–86,400,000)
6004	CH1_24(mV)	int[24]	Channel offsets, use 0 if not measured
601C	MOF(mV)	int	Master offset
601D	MOF2(mV)	int	Master offset 2
601E	OFF_WARN	char[8]	Offset warning string
6026	OFF_FAIL	char[8]	Offset failure string
602E	PS3(V)	float	3.3 Volt power supply voltage
6030	PS5(V)	float	5 Volt power supply voltage
6032	PS_N5(V)	float	–5 Volt regulated voltage
6034	PS15(V)	float	15 Volt power supply voltage
6036	PS_N15(V)	float	–15 Volt power supply voltage
6038	PS_WARN	char[8]	Power supply warning string
6040	PS_FAIL	char[8]	Power supply failure string
6048	HW_FAIL	char[40]	Hardware failure strings
6070	CC_STA	char[40]	Comm. card status strings
6098	PORT_STA	char[160]	Serial port status strings
6138	TIME_SRC	char[10]	Time source
6142	LOG_ERR	char[40]	SELOGIC error strings
616A	TEST_MD	char[160]	Test mode string
620A	WARN	char[32]	Warning strings for any active warnings
622A	FAIL	char[64]	Failure strings for any active failures

The ANALOGS region contains protection and automation variables. This region is updated every 0.5 seconds. See *Table 10.9* for the map.

Table 10.9 SEL-400G Database Structure—ANALOGS Region

Address (Hex)	Name	Type	Description
7000	_YEAR	int	4-digit year when data were sampled
7001	DAY_OF_YEAR	int	1–366 day when data were sampled
7002	TIME(ms)	long int	Time of day in ms when data were sampled (0–86,400,000)
7004	PMV01_64	float[64]	PMV01–PMV64
7084	AMV001_256	float[256]	AMV001–AMV256

The database is virtual device 1 in the relay. You can display the contents of a region using the **MAP 1:region** command (where region is one of the database region names listed in *Table 10.1*). An example of the **MAP** command is shown in *Figure 10.1*.

```
=>>MAP 1:meter <Enter>

Virtual Device 1, Data Region METER Map

Data Item    Starting Address   Type

_YEAR        1000h              int
DAY_OF_YEAR  1001h              int
TIME(ms)     1002h              int[2]
FREQPG       1004h              float
FREQPS       1006h              float
VDC          1008h              float
IS(A)        100ah              float[6]
IT(A)        1016h              float[6]
IU(A)        1022h              float[6]
IY(A)        102eh              float[6]
IG(A)        103ah              float[6]
VV(V)        1046h              float[6]
VZ(V)        1052h              float[6]
ISEQ_S(A)    105eh              float[6]
ISEQ_T(A)    106ah              float[6]
ISEQ_U(A)    1076h              float[6]
ISEQ_Y(A)    1082h              float[6]
ISEQ_G(A)    108eh              float[6]
VV_LL(V)     109ah              float[6]
VZ_LL(V)     10a6h              float[6]
VSEQ_V(V)    10b2h              float[6]
VSEQ_Z(V)    10beh              float[6]
PS(kW)       10cah              float[4]
QS(kVAR)     10d2h              float[4]
SS(kVA)      10dah              float[4]
PT(kW)       10e2h              float[4]
QT(kVAR)     10eah              float[4]
ST(kVA)      10f2h              float[4]
PU(kW)       10fah              float[4]
QU(kVAR)     1102h              float[4]
SU(kVA)      110ah              float[4]
PY(kW)       1112h              float[4]
QY(kVAR)     111ah              float[4]
SY(kVA)      1122h              float[4]
PG(kW)       112ah              float[4]
QG(kVAR)     1132h              float[4]
SG(kVA)      113ah              float[4]
PFS          1142h              float[4]
PFT          114ah              float[4]
PFU          1152h              float[4]
PFY          115ah              float[4]
PFG          1162h              float[4]
ES(kWh)      116ah              float[4]
ET(kWh)      1172h              float[4]
EU(kWh)      117ah              float[4]
EY(kWh)      1182h              float[4]
EG(kWh)      118ah              float[4]

=>>
```

Figure 10.1 MAP 1:METER Command Example

Control Points

SEL communications processors (SEL RTAC and SEL-2032) can automatically pass control messages, called Fast Operate messages, to the SEL-400G. You must enable Fast Operate messages by using the FASTOP setting in the SEL-400G Port settings for the port connected to the communications processor. You must also enable Fast Operate messages in the SEL communications processor.

When you enable Fast Operate functions, the SEL communications processor automatically sends messages to the relay for changes in remote bits RB01–RB32 or breaker bits BR1–BR14. For example, if you set RB01 in the SEL communications processor, it automatically sets RB01 in the SEL-400G.

Breaker bits operate differently than remote bits and require that the **BREAKER** jumper is in the **ON** position. When you set BR1, the SEL communications processor sends a message to the SEL-400G that asserts the manual open command bit OCS for one processing interval. If you clear BR1, the close command bit

CCS asserts for one processing interval. If you are using the default settings, OCS will open Circuit Breaker S and CCS will close Circuit Breaker S. Operation for Circuit Breaker T, U, and Y is similar.

To control the ten disconnects, communications processors use breaker bits BR5–BR14. Setting the BR5 bit in a communications processor sends a message to the SEL-400G that asserts Relay Word bit 89OC01 for one processing interval. Clearing the BR5 bit asserts 89CC01 for one processing interval. *Table 10.10* shows the communications processor bits and the corresponding relay bits for remote bit, breaker, and disconnect control. Note that when using the SEL RTAC, trip is used to set breaker bits and close is used to clear them.

Table 10.10 SEL-400G Fast Operate Control Bits

Communication Processor Bits	SEL-400G Bits
RB01	Set RB01: asserts RB01 Clear RB01: deasserts RB01 Pulse RB01: pulses RB01
…	
RB32	Set RB32: asserts RB32 Clear RB32: deasserts RB32 Pulse RB32: pulses RB32
BR1	Set BR1: pulses OCS Clear BR1: pulses CCS
BR2	Set BR2: pulses OCT Clear BR2: pulses CCT
BR3	Set BR3: pulses OCU Clear BR3: pulses CCU
BR4	Set BR4: pulses OCY Clear BR4: pulses CCY
BR5	Set BR5: pulses 89OC01 Clear BR5: pulses 89CC01
…	
BR14	Set BR14: pulses 89OC10 Clear BR14: pulses 89CC10

DNP3 Communication

DNP3 operation is described in *Section 16: DNP3 Communication in the SEL-400 Series Relays Instruction Manual*. This section describes aspects of DNP3 communication that are unique to the SEL-400G.

Reference Data Map

Table 10.11–Table 10.15 shows the SEL-400G DNP3 reference data maps. The reference data maps contain all of the data points available to the DNP3 protocol. You can select the default subset or use the custom DNP3 mapping functions of the SEL-400G to create or edit maps that contain the points required by your application.

Table 10.11 shows the Binary Input reference map. The entire Relay Word (see *Section 11: Relay Word Bits*) is part of the DNP3 reference map. You may include any label in the Relay Word as part of a DNP3 custom map. Note that Binary Inputs registered as SER points (SET R settings) will maintain SER-quality time stamps for DNP3 events.

Table 10.11 SEL-400G Binary Input Reference Data Map

Object	Label	Description
01, 02	RLYDIS	Relay disabled
01, 02	STFAIL	Relay diagnostic failure
01, 02	STWARN	Relay diagnostic warning
01, 02	STSET	Settings change or relay restart
01, 02	UNRDEV	New relay event available
01, 02	NUNREV	An unread event exists, newer than the event in the Event summary AIs
01, 02	Relay Word	Relay Word bit label. See *Section 11: Relay Word Bits*.

Table 10.12 shows the Binary Output reference map. See *Binary Outputs on page 10.22* for additional information.

Table 10.12 SEL-400G Binary Output Reference Data Map (Sheet 1 of 2)

Object	Label	Description
10, 12	RB01–RB64	Remote Bits RB01–RB64
10, 12	RB01:RB01 RB02:RB02 RB03:RB03 • • • RB32:RB32 RB01:RB02 RB03:RB04 RB05:RB06 • • • RB63:RB64	Remote Bit pulse operation, RB01 Remote Bit pulse operation, RB02 Remote Bit pulse operation, RB03 • • • Remote Bit pulse operation, RB32 Remote Bit pairs RB01–RB02 Remote Bit pairs RB03–RB04 Remote Bit pairs RB05–RB06 • • • Remote Bit pairs RB63–RB64
10, 12	OCS	Open Circuit Breaker S control
10, 12	CCS	Close Circuit Breaker S control
10, 12	OCT	Open Circuit Breaker T control
10, 12	CCT	Close Circuit Breaker T control
10, 12	OCU	Open Circuit Breaker U control
10, 12	CCU	Close Circuit Breaker U control
10, 12	OCY	Open Circuit Breaker Y control
10, 12	CCY	Close Circuit Breaker Y control
10, 12	OCS:CCS	Open/Close Circuit Breaker S control pair
10, 12	OCT:CCT	Open/Close Circuit Breaker T control pair
10, 12	OCU:CCU	Open/Close Circuit Breaker U control pair
10, 12	OCY:CCY	Open/Close Circuit Breaker Y control pair

Table 10.12 SEL-400G Binary Output Reference Data Map (Sheet 2 of 2)

Object	Label	Description
10, 12	89OC01–89OC10	Open Disconnect Control 1–10
10, 12	89CC01–89CC10	Close Disconnect Control 1–10
10, 12	89OC01:89CC01 89OC02:89CC02 • • • 89OC10:89CC10	Open/Close Disconnect Control Pair 1 Open/Close Disconnect Control Pair 2 • • • Open/Close Disconnect Control Pair 10
10, 12	RST_DEM	Reset demand meter data
10, 12	RST_PDM	Reset peak demand meter data
10, 12	RST_ENE	Reset accumulated energy meter data
10, 12	RST_BKS	Reset Breaker S monitor data
10, 12	RST_BKT	Reset Breaker T monitor data
10, 12	RST_BKU	Reset Breaker U monitor data
10, 12	RST_BKY	Reset Breaker Y monitor data
10, 12	RST_MM	Reset min/max metering
10, 12	RST_BAT	Reset battery monitoring
10, 12	RST_HAL	Reset alarm pulsing
10, 12	RSTTRGT	Reset targets
10, 12	RSTDNPE	Reset (clear) DNP event summary registers
10, 12	NXTEVE	Load next event into DNP event summary registers

Table 10.13 shows the Binary Counter reference map. See *Counters on page 16.23 in the SEL-400 Series Relays Instruction Manual* for additional information.

Table 10.13 SEL-400G Binary Counter Reference Data Map (Sheet 1 of 2)

Object	Label	Description
20, 22	ACTGRP	Active settings group
20, 22	BKRSOP	Number of Breaker S operations
20, 22	BKRTOP	Number of Breaker T operations
20, 22	BKRUOP	Number of Breaker U operations
20, 22	BKRYOP	Number of Breaker Y operations
20, 22	ACN01CV–ACN32CV	Automation SELOGIC counter values
20, 22	PCN01CV–PCN32CV	Protection SELOGIC counter values
20, 22	3PSKWHP[a]	Three-phase active energy exported (kWh), Terminal S
20, 22	3QSKVHP[a]	Three-phase reactive energy exported (kVARh), Terminal S
20, 22	3PSKWHN[a]	Three-phase active energy imported (kWh), Terminal S
20, 22	3QSKVHN[a]	Three-phase reactive energy imported (kVARh), Terminal S
20, 22	3PTKWHP[a]	Three-phase active energy exported (kWh), Terminal T
20, 22	3QTKVHP[a]	Three-phase reactive energy exported (kVARh), Terminal T
20, 22	3PTKWHN[a]	Three-phase active energy imported (kWh), Terminal T

Table 10.13 SEL-400G Binary Counter Reference Data Map (Sheet 2 of 2)

Object	Label	Description
20, 22	3QTKVHN[a]	Three-phase reactive energy imported (kVARh), Terminal T
20, 22	3PUKWHP[a]	Three-phase active energy exported (kWh), Terminal U
20, 22	3QUKVHP[a]	Three-phase reactive energy exported (kVARh), Terminal U
20, 22	3PUKWHN[a]	Three-phase active energy imported (kWh), Terminal U
20, 22	3QUKVHN[a]	Three-phase reactive energy imported (kVARh), Terminal U
20, 22	3PYKWHP[a]	Three-phase active energy exported (kWh), Terminal Y
20, 22	3QYKVHP[a]	Three-phase reactive energy exported (kVARh), Terminal Y
20, 22	3PYKWHN[a]	Three-phase active energy imported (kWh), Terminal Y
20, 22	3QYKVHN[a]	Three-phase reactive energy imported (kVARh), Terminal Y
20, 22	3PGKWHP[a]	Three-phase active energy exported (kWh), Terminal G
20, 22	3QGKVHP[a]	Three-phase reactive energy exported (kVARh), Terminal G
20, 22	3PGKWHN[a]	Three-phase active energy imported (kWh), Terminal G
20, 22	3QGKVHN[a]	Three-phase reactive energy imported (kVARh), Terminal G

[a] Converts to the absolute value and forces the counter to a positive value.

Table 10.14 shows the Analog Input reference map. The SEL-400G scales analog values by the indicated settings or fixed scaling. Analog inputs for event (fault) summary reporting use a default scale factor of 1 and deadband of ANADBM. Per-point scaling and deadband settings specified in a custom DNP3 map will override defaults.

Table 10.14 SEL-400G Analog Input Reference Data Map (Sheet 1 of 12)

Object	Label	Description
30, 32	FREQPP[a]	Frequency for P class synchrophasor data (Hz)
30, 32	DFDTPP[a]	Rate-of-change of frequency for P class synchrophasor data (Hz/s)
30, 32	VAVFMC, VAVFAC[b]	40 ms average filtered, A-Phase voltage magnitude (kV) and angle, V-PT
30, 32	VBVFMC, VBVFAC[b]	40 ms average filtered, B-Phase voltage magnitude (kV) and angle, V-PT
30, 32	VCVFMC, VCVFAC[b]	40 ms average filtered, C-Phase voltage magnitude (kV) and angle, V-PT
30, 32	VAZFMC, VAZFAC[b]	40 ms average filtered, A-Phase voltage magnitude (kV) and angle, Z-PT
30, 32	VBZFMC, VBZFAC[b]	40 ms average filtered, B-Phase voltage magnitude (kV) and angle, Z-PT
30, 32	VCZFMC, VCZFAC[b]	40 ms average filtered, C-Phase voltage magnitude (kV) and angle, Z-PT
30, 32	VABVFMC,VABVFAC[b]	40 ms average filtered, AB-Phase voltage magnitude (kV) and angle, V-PT
30, 32	VBCVFMC, VBCVFAC[b]	40 ms average filtered, BC-Phase voltage magnitude (kV) and angle, V-PT
30, 32	VCAVFMC,VCAVFAC[b]	40 ms average filtered, CA-Phase voltage magnitude (kV) and angle, V-PT
30, 32	VABZFMC, VABZFAC[b]	40 ms average filtered, AB-Phase voltage magnitude (kV) and angle, Z-PT
30, 32	VBCZFMC, VBCZFAC[b]	40 ms average filtered, BC-Phase voltage magnitude (kV) and angle, Z-PT
30, 32	VCAZFMC, VCAZFAC[b]	40 ms average filtered, CA-Phase voltage magnitude (kV) and angle, Z-PT
30, 32	VAZRC[c]	40 ms average rms, A-Phase voltage magnitude (kV), Z-PT
30, 32	VBZRC[c]	40 ms average rms, B-Phase voltage magnitude (kV), Z-PT
30, 32	VCZRC[c]	40 ms average rms, C-Phase voltage magnitude (kV), Z-PT
30, 32	VABZRC[c]	40 ms average rms, AB-Phase voltage magnitude (kV), Z-PT
30, 32	VBCZRC[c]	40 ms average rms, BC-Phase voltage magnitude (kV), Z-PT
30, 32	VCAZRC[c]	40 ms average rms, CA-Phase voltage magnitude (kV), Z-PT

Table 10.14 SEL-400G Analog Input Reference Data Map (Sheet 2 of 12)

Object	Label	Description
30, 32	V1VMC, V1VAC[b]	40 ms average, positive-sequence voltage magnitude (kV) and angle, V-PT
30, 32	V1ZMC, V1ZAC[b]	40 ms average, positive-sequence voltage magnitude (kV) and angle, Z-PT
30, 32	3V2VMC, 3V2VAC[b]	40 ms average, negative-sequence voltage magnitude (kV) and angle, V-PT
30, 32	3V2ZMC, 3V2ZAC[b]	40 ms average, negative-sequence voltage magnitude (kV) and angle, Z-PT
30, 32	3V0VMC, 3V0VAC[b]	40 ms average, zero-sequence voltage magnitude (kV) and angle, V-PT
30, 32	3V0ZMC, 3V0ZAC[b]	40 ms average, zero-sequence voltage magnitude (kV) and angle, Z-PT
30, 32	VN3FMC, VN3FAC[b]	40 ms average filtered, generator neutral third-harmonic voltage magnitude (kV) and angle
30, 32	3V0Z3MC, 3V0Z3AC[b]	40 ms average filtered, generator terminal third-harmonic voltage magnitude (kV) and angle
30, 32	VG3FMC, VG3FAC[b]	40 ms average filtered, total neutral third-harmonic voltage magnitude (kV) and angle
30, 32	VNFMC, VNFAC[b]	40 ms average filtered, generator neutral voltage magnitude (kV) and angle
30, 32	IASFMC, IASFAC[d]	40 ms average filtered phase current magnitude (amperes primary) and angle, A-Phase, Terminal S
30, 32	IBSFMC, IBSFAC[d]	40 ms average filtered phase current magnitude (amperes primary) and angle, B-Phase, Terminal S
30, 32	ICSFMC, ICSFAC[d]	40 ms average filtered phase current magnitude (amperes primary) and angle, C-Phase, Terminal S
30, 32	IATFMC, IATFAC[d]	40 ms average filtered phase current magnitude (amperes primary) and angle, A-Phase, Terminal T
30, 32	IBTFMC, IBTFAC[d]	40 ms average filtered phase current magnitude (amperes primary) and angle, B-Phase, Terminal T
30, 32	ICTFMC, ICTFAC[d]	40 ms average filtered phase current magnitude (amperes primary) and angle, C-Phase, Terminal T
30, 32	IAUFMC, IAUFAC[d]	40 ms average filtered phase current magnitude (amperes primary) and angle, A-Phase, Terminal U
30, 32	IBUFMC, IBUFAC[d]	40 ms average filtered phase current magnitude (amperes primary) and angle, B-Phase, Terminal U
30, 32	ICUFMC, ICUFAC[d]	40 ms average filtered phase current magnitude (amperes primary) and angle, C-Phase, Terminal U
30, 32	IAYFMC, IAYFAC[d]	40 ms average filtered phase current magnitude (amperes primary) and angle, A-Phase, Terminal Y
30, 32	IBYFMC, IBYFAC[d]	40 ms average filtered phase current magnitude (amperes primary) and angle, B-Phase, Terminal Y
30, 32	ICYFMC, ICYFAC[d]	40 ms average filtered phase current magnitude (amperes primary) and angle, C-Phase, Terminal Y
30, 32	IAGFMC, IAGFAC[d]	40 ms average filtered phase current magnitude (amperes primary) and angle, A-Phase, Terminal G
30, 32	IBGFMC, IBGFAC[d]	40 ms average filtered phase current magnitude (amperes primary) and angle, B-Phase, Terminal G
30, 32	ICGFMC, ICGFAC[d]	40 ms average filtered phase current magnitude (amperes primary) and angle, C-Phase, Terminal G
30, 32	IY1FMC, IY1FAC[d]	40 ms average filtered phase current magnitude (amperes primary) and angle, Channel 1, Terminal Y
30, 32	IY2FMC, IY2FAC[d]	40 ms average filtered phase current magnitude (amperes primary) and angle, Channel 2, Terminal Y
30, 32	IY3FMC, IY3FAC[d]	40 ms average filtered phase current magnitude (amperes primary) and angle, Channel 3, Terminal Y
30, 32	IAGRC[e]	40 ms average rms phase current magnitude (amperes primary), A-Phase, Terminal G
30, 32	IBGRC[e]	40 ms average rms phase current magnitude (amperes primary), B-Phase, Terminal G
30, 32	ICGRC[e]	40 ms average rms phase current magnitude (amperes primary), C-Phase, Terminal G
30, 32	I1SMC, I1SAC[d]	40 ms average positive-sequence current magnitude (amperes primary) and angle, Terminal S
30, 32	I1TMC, I1TAC[d]	40 ms average positive-sequence current magnitude (amperes primary) and angle, Terminal T
30, 32	I1UMC, I1UAC[d]	40 ms average positive-sequence current magnitude (amperes primary) and angle, Terminal U
30, 32	I1YMC, I1YAC[d]	40 ms average positive-sequence current magnitude (amperes primary) and angle, Terminal Y
30, 32	I1GMC, I1GAC[d]	40 ms average positive-sequence current magnitude (amperes primary) and angle, Terminal G
30, 32	3I2SMC, 3I2SAC[d]	40 ms average negative-sequence current magnitude (amperes primary) and angle, Terminal S
30, 32	3I2TMC, 3I2TAC[d]	40 ms average negative-sequence current magnitude (amperes primary) and angle, Terminal T
30, 32	3I2UMC, 3I2UAC[d]	40 ms average negative-sequence current magnitude (amperes primary) and angle, Terminal U

Table 10.14 SEL-400G Analog Input Reference Data Map (Sheet 3 of 12)

Object	Label	Description
30, 32	3I2YMC, 3I2YAC[d]	40 ms average negative-sequence current magnitude (amperes primary) and angle, Terminal Y
30, 32	3I2GMC, 3I2GAC[d]	40 ms average negative-sequence current magnitude (amperes primary) and angle, Terminal G
30, 32	3I0SMC, 3I0SAC[d]	40 ms average zero-sequence current magnitude (amperes primary) and angle, Terminal S
30, 32	3I0TMC, 3I0TAC[d]	40 ms average zero-sequence current magnitude (amperes primary) and angle, Terminal T
30, 32	3I0UMC, 3I0UAC[d]	40 ms average zero-sequence current magnitude (amperes primary) and angle, Terminal U
30, 32	3I0YMC, 3I0YAC[d]	40 ms average zero-sequence current magnitude (amperes primary) and angle, Terminal Y
30, 32	3I0GMC, 3I0GAC[d]	40 ms average zero-sequence current magnitude (amperes primary) and angle, Terminal G
30, 32	IAGRS[e]	1 s average rms phase current magnitude (amperes secondary), A-Phase, Terminal G
30, 32	IBGRS[e]	1 s average rms phase current magnitude (amperes secondary), B-Phase, Terminal G
30, 32	ICGRS[e]	1 s average rms phase current magnitude (amperes secondary), C-Phase, Terminal G
30, 32	3I2SMS[e]	1 s average negative-sequence current magnitude, (amperes secondary), Terminal S
30, 32	3I2TMS[e]	1 s average negative-sequence current magnitude, (amperes secondary), Terminal T
30, 32	3I2UMS[e]	1 s average negative-sequence current magnitude, (amperes secondary), Terminal U
30, 32	3I2YMS[e]	1 s average negative-sequence current magnitude, (amperes secondary), Terminal Y
30, 32	3I2GMS[e]	1 s average negative-sequence current magnitude, (amperes secondary), Terminal G
30, 32	3I0SMS[e]	1 s average zero-sequence current magnitude, (amperes secondary), Terminal S
30, 32	3I0TMS[e]	1 s average zero-sequence current magnitude, (amperes secondary), Terminal T
30, 32	3I0UMS[e]	1 s average zero-sequence current magnitude, (amperes secondary), Terminal U
30, 32	3I0YMS[e]	1 s average zero-sequence current magnitude, (amperes secondary), Terminal Y
30, 32	3I0GMS[e]	1 s average zero-sequence current magnitude, (amperes secondary), Terminal G
30, 32	PASFC[f]	40 ms average phase fundamental active power magnitude (megawatts primary), A-Phase, Terminal S
30, 32	PBSFC[f]	40 ms average phase fundamental active power magnitude (megawatts primary), B-Phase, Terminal S
30, 32	PCSFC[f]	40 ms average phase fundamental active power magnitude (megawatts primary), C-Phase, Terminal S
30, 32	PATFC[f]	40 ms average phase fundamental active power magnitude (megawatts primary), A-Phase, Terminal T
30, 32	PBTFC[f]	40 ms average phase fundamental active power magnitude (megawatts primary), B-Phase, Terminal T
30, 32	PCTFC[f]	40 ms average phase fundamental active power magnitude (megawatts primary), C-Phase, Terminal T
30, 32	PAUFC[f]	40 ms average phase fundamental active power magnitude (megawatts primary), A-Phase, Terminal U
30, 32	PBUFC[f]	40 ms average phase fundamental active power magnitude (megawatts primary), B-Phase, Terminal U
30, 32	PCUFC[f]	40 ms average phase fundamental active power magnitude (megawatts primary), C-Phase, Terminal U
30, 32	PAYFC[f]	40 ms average phase fundamental active power magnitude (megawatts primary), A-Phase, Terminal Y
30, 32	PBYFC[f]	40 ms average phase fundamental active power magnitude (megawatts primary), B-Phase, Terminal Y
30, 32	PCYFC[f]	40 ms average phase fundamental active power magnitude (megawatts primary), C-Phase, Terminal Y
30, 32	PAGFC[f]	40 ms average phase fundamental active power magnitude (megawatts primary), A-Phase, Terminal G
30, 32	PBGFC[f]	40 ms average phase fundamental active power magnitude (megawatts primary), B-Phase, Terminal G
30, 32	PCGFC[f]	40 ms average phase fundamental active power magnitude (megawatts primary), C-Phase, Terminal G

Table 10.14 SEL-400G Analog Input Reference Data Map (Sheet 4 of 12)

Object	Label	Description
30, 32	QASFC[f]	40 ms average phase fundamental reactive power magnitude (MVAR primary), A-Phase, Terminal S
30, 32	QBSFC[f]	40 ms average phase fundamental reactive power magnitude (MVAR primary), B-Phase, Terminal S
30, 32	QCSFC[f]	40 ms average phase fundamental reactive power magnitude (MVAR primary), C-Phase, Terminal S
30, 32	QATFC[f]	40 ms average phase fundamental reactive power magnitude (MVAR primary), A-Phase, Terminal T
30, 32	QBTFC[f]	40 ms average phase fundamental reactive power magnitude (MVAR primary), B-Phase, Terminal T
30, 32	QCTFC[f]	40 ms average phase fundamental reactive power magnitude (MVAR primary), C-Phase, Terminal T
30, 32	QAUFC[f]	40 ms average phase fundamental reactive power magnitude (MVAR primary), A-Phase, Terminal U
30, 32	QBUFC[f]	40 ms average phase fundamental reactive power magnitude (MVAR primary), B-Phase, Terminal U
30, 32	QCUFC[f]	40 ms average phase fundamental reactive power magnitude (MVAR primary), C-Phase, Terminal U
30, 32	QAYFC[f]	40 ms average phase fundamental reactive power magnitude (MVAR primary), A-Phase, Terminal Y
30, 32	QBYFC[f]	40 ms average phase fundamental reactive power magnitude (MVAR primary), B-Phase, Terminal Y
30, 32	QCYFC[f]	40 ms average phase fundamental reactive power magnitude (MVAR primary), C-Phase, Terminal Y
30, 32	QAGFC[f]	40 ms average phase fundamental reactive power magnitude (MVAR primary), A-Phase, Terminal G
30, 32	QBGFC[f]	40 ms average phase fundamental reactive power magnitude (MVAR primary), B-Phase, Terminal G
30, 32	QCGFC[f]	40 ms average phase fundamental reactive power magnitude (MVAR primary), C-Phase, Terminal G
30, 32	SASFC[f]	40 ms average phase fundamental apparent power magnitude (megavolt-ampere primary), A-Phase, Terminal S
30, 32	SBSFC[f]	40 ms average phase fundamental apparent power magnitude (megavolt-ampere primary), B-Phase, Terminal S
30, 32	SCSFC[f]	40 ms average phase fundamental apparent power magnitude (megavolt-ampere primary), C-Phase, Terminal S
30, 32	SATFC[f]	40 ms average phase fundamental apparent power magnitude (megavolt-ampere primary), A-Phase, Terminal T
30, 32	SBTFC[f]	40 ms average phase fundamental apparent power magnitude (megavolt-ampere primary), B-Phase, Terminal T
30, 32	SCTFC[f]	40 ms average phase fundamental apparent power magnitude (megavolt-ampere primary), C-Phase, Terminal T
30, 32	SAUFC[f]	40 ms average phase fundamental apparent power magnitude (megavolt-ampere primary), A-Phase, Terminal U
30, 32	SBUFC[f]	40 ms average phase fundamental apparent power magnitude (megavolt-ampere primary), B-Phase, Terminal U
30, 32	SCUFC[f]	40 ms average phase fundamental apparent power magnitude (megavolt-ampere primary), C-Phase, Terminal U
30, 32	SAYFC[f]	40 ms average phase fundamental apparent power magnitude (megavolt-ampere primary), A-Phase, Terminal Y
30, 32	SBYFC[f]	40 ms average phase fundamental apparent power magnitude (megavolt-ampere primary), B-Phase, Terminal Y
30, 32	SCYFC[f]	40 ms average phase fundamental apparent power magnitude (megavolt-ampere primary), C-Phase, Terminal Y
30, 32	SAGFC[f]	40 ms average phase fundamental apparent power magnitude (megavolt-ampere primary), A-Phase, Terminal G
30, 32	SBGFC[f]	40 ms average phase fundamental apparent power magnitude (megavolt-ampere primary), B-Phase, Terminal G
30, 32	SCGFC[f]	40 ms average phase fundamental apparent power magnitude (megavolt-ampere primary), C-Phase, Terminal G
30, 32	3PSFC[f]	40 ms average three-phase fundamental active power magnitude, (megawatts primary), Terminal S

Table 10.14 SEL-400G Analog Input Reference Data Map (Sheet 5 of 12)

Object	Label	Description
30, 32	3PTFC[f]	40 ms average three-phase fundamental active power magnitude, (megawatts primary), Terminal T
30, 32	3PUFC[f]	40 ms average three-phase fundamental active power magnitude, (megawatts primary), Terminal U
30, 32	3PYFC[f]	40 ms average three-phase fundamental active power magnitude, (megawatts primary), Terminal Y
30, 32	3PGFC[f]	40 ms average three-phase fundamental active power magnitude, (megawatts primary), Terminal G
30, 32	3QSFC[f]	40 ms average three-phase fundamental reactive power magnitude, (MVAR primary), Terminal S
30, 32	3QTFC[f]	40 ms average three-phase fundamental reactive power magnitude, (MVAR primary), Terminal T
30, 32	3QUFC[f]	40 ms average three-phase fundamental reactive power magnitude, (MVAR primary), Terminal U
30, 32	3QYFC[f]	40 ms average three-phase fundamental reactive power magnitude, (MVAR primary), Terminal Y
30, 32	3QGFC[f]	40 ms average three-phase fundamental reactive power magnitude, (MVAR primary), Terminal G
30, 32	3SSFC[f]	40 ms average three-phase fundamental apparent power magnitude, (megavolt-ampere primary), Terminal S
30, 32	3STFC[f]	40 ms average three-phase fundamental apparent power magnitude, (megavolt-ampere primary), Terminal T
30, 32	3SUFC[f]	40 ms average three-phase fundamental apparent power magnitude, (megavolt-ampere primary), Terminal U
30, 32	3SYFC[f]	40 ms average three-phase fundamental apparent power magnitude, (megavolt-ampere primary), Terminal Y
30, 32	3SGFC[f]	40 ms average three-phase fundamental apparent power magnitude, (megavolt-ampere primary), Terminal G
30, 32	3PSFS[f]	1 s average three-phase fundamental active power magnitude, (megawatts primary), Terminal S
30, 32	3PTFS[f]	1 s average three-phase fundamental active power magnitude, (megawatts primary), Terminal T
30, 32	3PUFS[f]	1 s average three-phase fundamental active power magnitude, (megawatts primary), Terminal U
30, 32	3PYFS[f]	1 s average three-phase fundamental active power magnitude, (megawatts primary), Terminal Y
30, 32	3PGFS[f]	1 s average three-phase fundamental active power magnitude, (megawatts primary), Terminal G
30, 32	3QSFS[f]	1 s average three-phase fundamental reactive power magnitude, (MVAR primary), Terminal S
30, 32	3QTFS[f]	1 s average three-phase fundamental reactive power magnitude, (MVAR primary), Terminal T
30, 32	3QUFS[f]	1 s average three-phase fundamental reactive power magnitude, (MVAR primary), Terminal U
30, 32	3QYFS[f]	1 s average three-phase fundamental reactive power magnitude, (MVAR primary), Terminal Y
30, 32	3QGFS[f]	1 s average three-phase fundamental apparent power magnitude, (MVAR primary), Terminal G
30, 32	3SSFS[f]	1 s average three-phase fundamental apparent power magnitude, (megavolt-ampere primary), Terminal S
30, 32	3STFS[f]	1 s average three-phase fundamental apparent power magnitude, (megavolt-ampere primary), Terminal T
30, 32	3SUFS[f]	1 s average three-phase fundamental apparent power magnitude, (megavolt-ampere primary), Terminal U
30, 32	3SYFS[f]	1 s average three-phase fundamental apparent power magnitude, (megavolt-ampere primary), Terminal Y
30, 32	3SGFS[f]	1 s average three-phase fundamental apparent power magnitude, (megavolt-ampere primary), Terminal G
30, 32	PFASC[f]	Phase displacement power factor, A-Phase, Terminal S
30, 32	PFBSC[f]	Phase displacement power factor, B-Phase, Terminal S
30, 32	PFCSC[f]	Phase displacement power factor, C-Phase, Terminal S
30, 32	PFATC[f]	Phase displacement power factor, A-Phase, Terminal T
30, 32	PFBTC[f]	Phase displacement power factor, B-Phase, Terminal T
30, 32	PFCTC[f]	Phase displacement power factor, C-Phase, Terminal T
30, 32	PFAUC[f]	Phase displacement power factor, A-Phase, Terminal U
30, 32	PFBUC[f]	Phase displacement power factor, B-Phase, Terminal U
30, 32	PFCUC[f]	Phase displacement power factor, C-Phase, Terminal U

Table 10.14 SEL-400G Analog Input Reference Data Map (Sheet 6 of 12)

Object	Label	Description
30, 32	PFAYC[f]	Phase displacement power factor, A-Phase, Terminal Y
30, 32	PFBYC[f]	Phase displacement power factor, B-Phase, Terminal Y
30, 32	PFCYC[f]	Phase displacement power factor, C-Phase, Terminal Y
30, 32	PFAGC[f]	Phase displacement power factor, A-Phase, Terminal G
30, 32	PFBGC[f]	Phase displacement power factor, B-Phase, Terminal G
30, 32	PFCGC[f]	Phase displacement power factor, C-Phase, Terminal G
30, 32	3PFSC[f]	Three-phase displacement power factor, Terminal S
30, 32	3PFTC[f]	Three-phase displacement power factor, Terminal T
30, 32	3PFUC[f]	Three-phase displacement power factor, Terminal U
30, 32	3PFYC[f]	Three-phase displacement power factor, Terminal Y
30, 32	3PFGC[f]	Three-phase displacement power factor, Terminal G
30, 32	DM01[e]	Demand metering Element 1 value, amperes secondary
30, 32	DM02[e]	Demand metering Element 2 value, amperes secondary
30, 32	DM03[e]	Demand metering Element 3 value, amperes secondary
30, 32	DM04[e]	Demand metering Element 4 value, amperes secondary
30, 32	DM05[e]	Demand metering Element 5 value, amperes secondary
30, 32	DM06[e]	Demand metering Element 6 value, amperes secondary
30, 32	DM07[e]	Demand metering Element 7 value, amperes secondary
30, 32	DM08[e]	Demand metering Element 8 value, amperes secondary
30, 32	DM09[e]	Demand metering Element 9 value, amperes secondary
30, 32	DM10[e]	Demand metering Element 10 value, amperes secondary
30, 32	DMM01[e]	Demand metering Element 1 maximum value, amperes secondary
30, 32	DMM02[e]	Demand metering Element 2 maximum value, amperes secondary
30, 32	DMM03[e]	Demand metering Element 3 maximum value, amperes secondary
30, 32	DMM04[e]	Demand metering Element 4 maximum value, amperes secondary
30, 32	DMM05[e]	Demand metering Element 5 maximum value, amperes secondary
30, 32	DMM06[e]	Demand metering Element 6 maximum value, amperes secondary
30, 32	DMM07[e]	Demand metering Element 7 maximum value, amperes secondary
30, 32	DMM08[e]	Demand metering Element 8 maximum value, amperes secondary
30, 32	DMM09[e]	Demand metering Element 9 maximum value, amperes secondary
30, 32	DMM10[e]	Demand metering Element 10 maximum value, amperes secondary
30, 32	RTS01TV–RTS24TV[h]	RTD temperature value in degrees C, RTS01–RTS24
30, 32	RTC01TV–RTC24TV[h]	Remote temperature value in degrees C, RTC01–RTC24
30, 32	MAMB1[h]	Ambient temperature value in degrees C, Element 1
30, 32	MAMB2[h]	Ambient temperature value in degrees C, Element 2
30, 32	MAMB3[h]	Ambient temperature value in degrees C, Element 3
30, 32	3PSMWHP[f]	Three-phase active energy exported, Terminal S (megawatt hours, primary)
30, 32	3PTMWHP[f]	Three-phase active energy exported, Terminal T (megawatt hours, primary)
30, 32	3PUMWHP[f]	Three-phase active energy exported, Terminal U (megawatt hours, primary)
30, 32	3PYMWHP[f]	Three-phase active energy exported, Terminal Y (megawatt hours, primary)
30, 32	3PGMWHP[f]	Three-phase active energy exported, Terminal G (megawatt hours, primary)

Table 10.14 SEL-400G Analog Input Reference Data Map (Sheet 7 of 12)

Object	Label	Description
30, 32	3QSMVHP[f]	Three-phase reactive energy exported, Terminal S (MVAR hours, primary)
30, 32	3QTMVHP[f]	Three-phase reactive energy exported, Terminal T (MVAR hours, primary)
30, 32	3QUMVHP[f]	Three-phase reactive energy exported, Terminal U (MVAR hours, primary)
30, 32	3QYMVHP[f]	Three-phase reactive energy exported, Terminal Y (MVAR hours, primary)
30, 32	3QGMVHP[f]	Three-phase reactive energy exported, Terminal G (MVAR hours, primary)
30, 32	3PSMWHN[f]	Three-phase active energy imported, Terminal S (megawatt hours, primary)
30, 32	3PTMWHN[f]	Three-phase active energy imported, Terminal T (megawatt hours, primary)
30, 32	3PUMWHN[f]	Three-phase active energy imported, Terminal U (megawatt hours, primary)
30, 32	3PYMWHN[f]	Three-phase active energy imported, Terminal Y (megawatt hours, primary)
30, 32	3PGMWHN[f]	Three-phase active energy imported, Terminal G (megawatt hours, primary)
30, 32	3QSMVHN[f]	Three-phase reactive energy imported, Terminal S (MVAR hours, primary)
30, 32	3QTMVHN[f]	Three-phase reactive energy imported, Terminal T (MVAR hours, primary)
30, 32	3QUMVHN[f]	Three-phase reactive energy imported, Terminal U (MVAR hours, primary)
30, 32	3QYMVHN[f]	Three-phase reactive energy imported, Terminal Y (MVAR hours, primary)
30, 32	3QGMVHN[f]	Three-phase reactive energy imported, Terminal G (MVAR hours, primary)
30, 32	3PSMWHT[f]	Total three-phase active energy, Terminal S (megawatt hours, primary)
30, 32	3PTMWHT[f]	Total three-phase active energy, Terminal T (megawatt hours, primary)
30, 32	3PUMWHT[f]	Total three-phase active energy, Terminal U (megawatt hours, primary)
30, 32	3PYMWHT[f]	Total three-phase active energy, Terminal Y (megawatt hours, primary)
30, 32	3PGMWHT[f]	Total three-phase active energy, Terminal G (megawatt hours, primary)
30, 32	3QSMVHT[f]	Total three-phase reactive energy, Terminal S (MVAR hours, primary)
30, 32	3QTMVHT[f]	Total three-phase reactive energy, Terminal T (MVAR hours, primary)
30, 32	3QUMVHT[f]	Total three-phase reactive energy, Terminal U (MVAR hours, primary)
30, 32	3QYMVHT[f]	Total three-phase reactive energy, Terminal Y (MVAR hours, primary)
30, 32	3QGMVHT[f]	Total three-phase reactive energy, Terminal G (MVAR hours, primary)
30, 32	40PQMX[f]	Loss-of-field Zone 4 maximum reactive power limit (VARs sec)
30, 32	40PPMX[f]	Loss-of-field Zone 4 maximum active power limit (W sec)
30, 32	40PQMN[f]	Loss-of-field Zone 4 minimum reactive power limit (VARs sec)
30, 32	40PPLG[f]	Loss-of-field Zone 4 active power lag PF limit (W sec)
30, 32	40PPLD[f]	Loss-of-field Zone 4 active power lead PF limit (W sec)
30, 32	40PPU[f]	Loss-of-field Zone 4 active power UPF limit (W sec)
30, 32	40PQZ2[f]	Loss-of-field Zone 2 reactive power limit (VARs sec)
30, 32	78GCN[h]	Out-of-step generator pole slip count
30, 32	78SCN[h]	Out-of-step system pole slip count
30, 32	78CN[h]	Out-of-step common pole slip count
30, 32	60LDVM[c]	60 LOP voltage unbalance magnitude (V sec)
30, 32	81AB1S[h]	81A element Band 1 accumulated time (s)
30, 32	81AB2S[h]	81A element Band 2 accumulated time (s)
30, 32	81AB3S[h]	81A element Band 3 accumulated time (s)
30, 32	81AB4S[h]	81A element Band 4 accumulated time (s)
30, 32	81AB5S[h]	81A element Band 5 accumulated time (s)

Table 10.14 SEL-400G Analog Input Reference Data Map (Sheet 8 of 12)

Object	Label	Description
30, 32	81AB6S[h]	81A element Band 6 accumulated time (s)
30, 32	81AB7S[h]	81A element Band 7 accumulated time (s)
30, 32	81AB8S[h]	81A element Band 8 accumulated time (s)
30, 32	THTCU1[h]	IEC thermal capacity used, Element 1
30, 32	THTCU2[h]	IEC thermal capacity used, Element 2
30, 32	THTCU3[h]	IEC thermal capacity used, Element 3
30, 32	I2GPEQ[g]	Generator negative-sequence equivalent harmonic current (%)
30, 32	I2GP[g]	Generator fundamental negative-sequence current (%)
30, 32	64SIR[h]	64S stator insulation resistance (kΩ)
30, 32	64SIC[h]	64S stator insulation capacitance (µF)
30, 32	64FIR[h]	64F field insulation resistance (kΩ)
30, 32	I60PAOF[e]	60P A-Phase offset current magnitude (A sec)
30, 32	I60PBOF[e]	60P B-Phase offset current magnitude (A sec)
30, 32	I60PCOF[e]	60P C-Phase offset current magnitude (A sec)
30, 32	I60PAOP[e]	60P A-Phase operating current magnitude (A sec)
30, 32	I60PBOP[e]	60P B-Phase operating current magnitude (A sec)
30, 32	I60PCOP[e]	60P C-Phase operating current magnitude (A sec)
30, 32	I60NOF[e]	60N offset current magnitude (A sec)
30, 32	I60NOP[e]	60N operating current magnitude (A sec)
30, 32	FREQPG[a]	Generator tracking frequency (Hz)
30, 32	FREQPS[a]	System tracking frequency (Hz)
30, 32	DFREQPG[a]	Generator rate-of-change of frequency (Hz/s)
30, 32	DFREQPS[a]	System rate-of-change of frequency (Hz/s)
30, 32	VDC[h]	Station battery dc voltage (V)
30, 32	DCPO[h]	Average positive-to-ground dc voltage (V)
30, 32	DCNE[h]	Average negative-to-ground dc voltage (V)
30, 32	DCRI[h]	AC ripple of dc voltage (V)
30, 32	DCMIN[h]	Minimum dc voltage (V)
30, 32	DCMAX[h]	Maximum dc voltage (V)
30, 32	HSRSRTP[h]	Round-trip time for HSR supervision frames on process bus (microseconds)
30, 32	HSRSRTS[h]	Round-trip time for HSR supervision frames on station bus (microseconds)
30, 32	PMV01–PMV64[h]	Protection SELOGIC math variable
30, 32	AMV001–AMV256[h]	Automation SELOGIC math variable
30, 32	PCN01CV–PCN32CV[h]	Protection SELOGIC counter current value
30, 32	ACN01CV–ACN32CV[h]	Automation SELOGIC counter current value
30, 32	ACTGRP[h]	Active group setting
30, 32	TODMS[h]	UTC time of day in milliseconds (0–86400000)
30, 32	THR[h]	UTC time, hour (0–23)
30, 32	TMIN[h]	UTC time, minute (0–59)
30, 32	TSEC[h]	UTC time, seconds (0–59)
30, 32	TMSEC[h]	UTC time, milliseconds (0–999)

Table 10.14 SEL-400G Analog Input Reference Data Map (Sheet 9 of 12)

Object	Label	Description
30, 32	DDOW[h]	UTC date, day of the week (1–SU, ..., 7–SA)
30, 32	DDOM[h]	UTC date, day of the month (1–31)
30, 32	DDOY[h]	UTC date, day of the year (1–366)
30, 32	DMON[h]	UTC date, month (1–12)
30, 32	DYEAR[h]	UTC date, year (2000–2200)
30, 32	TLODMS[h]	Local time of day in milliseconds (0–86400000)
30, 32	TLHR[h]	Local time, hour (0–23)
30, 32	TLMIN[h]	Local time, minute (0–59)
30, 32	TLSEC[h]	Local time, seconds (0–59)
30, 32	TLMSEC[h]	Local time, milliseconds (0–999)
30, 32	DLDOW[h]	Local date, day of the week (1-SU,.., 7-SA)
30, 32	DLDOM[h]	Local date, day of the month (1–31)
30, 32	DLDOY[h]	Local date, day of the year (1–366)
30, 32	DLMON[h]	Local date, month (1–12)
30, 32	DLYEAR[h]	Local date, year (2000–2200)
30, 32	TUTC[h]	Offset from IRIG-B time to UTC time
30, 32	TQUAL[h]	Worst case IRIG-B clock time error
30, 32	RA001–RA256[h]	Remote analogs
30,32	BSATRIA, BSATRIB, BSATRIC[e]	Accumulated trip interrupted current for Breaker S (A)
30,32	BSBCWPA, BSBCWPB, BSBCWPC[g]	Contact wear for Breaker S (%)
30,32	BSEOTTA, BSEOTTB, BSEOTTC[h]	Average electrical operating time to trip for Breaker S (ms)
30,32	BSEOTCA, BSEOTCB, BSEOTCC[h]	Average electrical operating time to close for Breaker S (ms)
30,32	BSMOTT[h]	Average mechanical operating time to trip for Breaker S (ms)
30,32	BSMOTC[h]	Average mechanical operating time to close for Breaker S (ms)
30,32	BSOPCN[h]	Number of trip operations for Breaker S
30,32	BSLTRIA, BSLTRIB, BSLTRIC[h]	Last trip interrupted current for Breaker S (%)
30,32	BSLEOTA, BSLEOTB, BSLEOTC[h]	Last electrical operating time to trip for Breaker S (ms)
30,32	BSLEOCA, BSLEOCB, BSLEOCC[h]	Last electrical operating time to close for Breaker S (ms)
30,32	BSLMOTT[h]	Last mechanical operating time to trip for Breaker S (ms)
30,32	BSLMOTC[h]	Last mechanical operating time to close for Breaker S (ms)
30,32	BTATRIA, BTATRIB, BTATRIC[e]	Accumulated trip interrupted current for Breaker T (A)
30,32	BTBCWPA, BTBCWPB, BTBCWPC[g]	Contact wear for Breaker T (%)
30,32	BTEOTTA, BTEOTTB, BTEOTTC[h]	Average electrical operating time to trip for Breaker T (ms)
30,32	BTEOTCA, BTEOTCB, BTEOTCC[h]	Average electrical operating time to close for Breaker T (ms)

Table 10.14 SEL-400G Analog Input Reference Data Map (Sheet 10 of 12)

Object	Label	Description
30,32	BTMOTT[h]	Average mechanical operating time to trip for Breaker T (ms)
30,32	BTMOTC[h]	Average mechanical operating time to close for Breaker T (ms)
30,32	BTOPCN[h]	Number of trip operations for Breaker T
30,32	BTLTRIA, BTLTRIB, BTLTRIC[h]	Last trip interrupted current for Breaker T (%)
30,32	BTLEOTA, BTLEOTB, BTLEOTC[h]	Last electrical operating time to trip for Breaker T (ms)
30,32	BTLEOCA, BTLEOCB, BTLEOCC[h]	Last electrical operating time to close for Breaker T (ms)
30,32	BTLMOTT[h]	Last mechanical operating time to trip for Breaker T (ms)
30,32	BTLMOTC[h]	Last mechanical operating time to close for Breaker T (ms)
30,32	BUATRIA, BUATRIB, BUATRIC[e]	Accumulated trip interrupted current for Breaker U (A)
30,32	BUBCWPA, BUBCWPB, BUBCWPC[g]	Contact wear for Breaker U (%)
30,32	BUEOTTA, BUEOTTB, BUEOTTC[h]	Average electrical operating time to trip for Breaker U (ms)
30,32	BUEOTCA, BUEOTCB, BUEOTCC[h]	Average electrical operating time to close for Breaker U (ms)
30,32	BUMOTT[h]	Average mechanical operating time to trip for Breaker U (ms)
30,32	BUMOTC[h]	Average mechanical operating time to close for Breaker U (ms)
30,32	BUOPCN[h]	Number of trip operations for Breaker U
30,32	BULTRIA, BULTRIB, BULTRIC[h]	Last trip interrupted current for Breaker U (%)
30,32	BULEOTA, BULEOTB, BULEOTC[h]	Last electrical operating time to trip for Breaker U (ms)
30,32	BULEOCA, BULEOCB, BULEOCC[h]	Last electrical operating time to close for Breaker U (ms)
30,32	BULMOTT[h]	Last mechanical operating time to trip for Breaker U (ms)
30,32	BULMOTC[h]	Last mechanical operating time to close for Breaker U (ms)
30,32	BYATRIA, BYATRIB, BYATRIC[e]	Accumulated trip interrupted current for Breaker Y (A)
30,32	BYBCWPA, BYBCWPB, BYBCWPC[g]	Contact wear for Breaker Y (%)
30,32	BYEOTTA, BYEOTTB, BYEOTTC[h]	Average electrical operating time to trip for Breaker Y (ms)
30,32	BYEOTCA, BYEOTCB, BYEOTCC[h]	Average electrical operating time to close for Breaker Y (ms)
30,32	BYMOTT[h]	Average mechanical operating time to trip for Breaker Y (ms)
30,32	BYMOTC[h]	Average mechanical operating time to close for Breaker Y (ms)
30,32	BYOPCN[h]	Number of trip operations for Breaker Y
30,32	BYLTRIA, BYLTRIB, BYLTRIC[h]	Last trip interrupted current for Breaker Y (%)
30,32	BYLEOTA, BYLEOTB, BYLEOTC[h]	Last electrical operating time to trip for Breaker Y (ms)
30,32	BYLEOCA, BYLEOCB, BYLEOCC[h]	Last electrical operating time to close for Breaker Y (ms)

Table 10.14 SEL-400G Analog Input Reference Data Map (Sheet 11 of 12)

Object	Label	Description
30,32	BYLMOTT[h]	Last mechanical operating time to trip for Breaker Y (ms)
30,32	BYLMOTC[h]	Last mechanical operating time to close for Breaker Y (ms)
30, 32	RLYTEMP[h]	Relay temperature (temperature of the box, degrees C)
30, 32	RAO01–RAO64[h]	Remote analog output
30, 32	25VPFM, 25VPFA[b]	25 synchronism-check polarizing voltage magnitude, (volts secondary) and angle
30, 32	25VSSFM, 25VSSFA[b]	25 synchronism-check synchronizing voltage magnitude for Breaker S (volts secondary) and angle
30, 32	25VSTFM, 25VSTFA[b]	25 synchronism-check synchronizing voltage magnitude for Breaker T (volts secondary) and angle
30, 32	25VSUFM, 25VSUFA[b]	25 synchronism-check synchronizing voltage magnitude for Breaker U (volts secondary) and angle
30, 32	25VSYFM, 25VSYFA[b]	25 synchronism-check synchronizing voltage magnitude for Breaker Y (volts secondary) and angle
30, 32	25ANGS[a]	25 synchronism-check angle difference for Breaker S
30, 32	25ANGT[a]	25 synchronism-check angle difference for Breaker T
30, 32	25ANGU[a]	25 synchronism-check angle difference for Breaker U
30, 32	25ANGY[a]	25 synchronism-check angle difference for Breaker Y
30, 32	25ANGCS[a]	25 synchronism-check compensated angle difference for Breaker S
30, 32	25ANGCT[a]	25 synchronism-check compensated angle difference for Breaker T
30, 32	25ANGCU[a]	25 synchronism-check compensated angle difference for Breaker U
30, 32	25ANGCY[a]	25 synchronism-check compensated angle difference for Breaker Y
30, 32	25SLIPS[a]	25 synchronism-check slip frequency for Breaker S (Hz)
30, 32	25SLIPT[a]	25 synchronism-check slip frequency for Breaker T (Hz)
30, 32	25SLIPU[a]	25 synchronism-check slip frequency for Breaker U (Hz)
30, 32	25SLIPY[a]	25 synchronism-check slip frequency for Breaker Y (Hz)
30, 32	25DIFVS[h]	25 synchronism-check voltage difference for Breaker S (%)
30, 32	25DIFVT[h]	25 synchronism-check voltage difference for Breaker T (%)
30, 32	25DIFVU[h]	25 synchronism-check voltage difference for Breaker U (%)
30, 32	25DIFVY[h]	25 synchronism-check voltage difference for Breaker Y (%)
30, 32	25AFCT[h]	25A autosynchronizer frequency pulse count
30, 32	25AVCT[h]	25A autosynchronizer voltage pulse count
30, 32	MAXGRP[h]	Maximum number of protection groups
30, 32	I850MOD[h]	IEC 61850 Mode/Behavior status
Event Summary Analog Inputs[i, j]		
30, 32	FTYPE	Fault type
30, 32	FTAR1	Fault targets (upper byte is 1st target row, lower byte is 2nd target row)
30, 32	FTAR2	Fault targets (upper byte is 3rd target row, lower byte is 0)
30, 32	FFREQG[k]	Generator fault frequency
30, 32	FFREQS[k]	System fault frequency
30, 32	FGRP	Fault active settings group (1–6)
30, 32	FTIMEH	Fault time (local) in DNP format, high 16 bits
30, 32	FTIMEM	Fault time (local) in DNP format, middle 16 bits
30, 32	FTIMEL	Fault time (local) in DNP format, low 16 bits
30, 32	FTIMEUH	Fault time (UTC) in DNP format, high 16 bits
30, 32	FTIMEUM	Fault time (UTC) in DNP format, middle 16 bits

Table 10.14 SEL-400G Analog Input Reference Data Map (Sheet 12 of 12)

Object	Label	Description
30, 32	FTIMEUL	Fault time (UTC) in DNP format, low 16 bits
30, 32	FUNR	Number of unread fault summary reports

[a] Default scale factor is 100 and deadband ANADBM.
[b] Default voltage scaling DECPLV on magnitudes and scale factor of 100 on angles. Deadband ANADBV on magnitudes and ANADBM on angles.
[c] Default scale factor is DECPLV and deadband is ANADBV.
[d] Default current scaling DECPLA on magnitudes and scale factor of 100 on angles. Deadband ANADBA on magnitudes and ANADBM on angles.
[e] Default scale factor is DECPLA and deadband is ANADBA.
[f] Default scale factor is DECPLM and deadband is ANADBM.
[g] Default scale factor is 10 and deadband ANADBM.
[h] Default scale factor is 1 and deadband ANADBM.
[i] Unless otherwise indicated, the default scale factor for these points is 1. The default deadband is ANADBM. Per-point scaling and deadband settings specified in a custom DNP map override these defaults.
[j] Event data shall be generated for all event summary analog inputs if any of them change beyond their deadband after scaling.
[k] Default scale factor is 100.

Table 10.15 shows the Analog Output reference map. See *Analog Outputs on page 16.23 in the SEL-400 Series Relays Instruction Manual* for additional information.

Table 10.15 SEL-400G Analog Output Reference Data Map

Object	Label	Description
40, 41	ACTGRP	Active settings group (1–6)
40, 41	RA001–RA256	Remote analogs

Binary Outputs

Use the Trip and Close, Latch On/Off and Pulse On operations with Object 12 control relay output block command messages to operate the points shown in *Table 10.16*. Pulse operations provide a pulse with a duration of one protection processing interval. Cancel an operation in progress by issuing a NUL Trip/Close Code with a NUL Operation Type.

Table 10.16 SEL-400G Object 12 Control Point Operations (Sheet 1 of 3)

Label	Close/Any	Trip/Any	NUL/Latch On	NUL/Latch Off	NUL/Pulse On	NUL/Pulse Off
RB01–RB64	Pulse on Remote Bits RB01–RB64	Pulse on Remote Bits RB01–RB64	Set Remote Bits RB01–RB64	Clear Remote Bits RB01–RB64	Pulse on Remote Bits RB01–RB64	Clear Remote Bits RB01–RB64
RB*xx*: RB*yy*	Pulse RB*yy*	Pulse RB*xx*	Pulse RB*yy*	Pulse RB*xx*	Pulse RB*yy*	Pulse RB*xx*
OCS	Open Circuit Breaker S (pulse OCS)	Open Circuit Breaker S (pulse OCS)	Set OCS	Clear OCS	Open Circuit Breaker S (pulse OCS)	Clear OCS
CCS	Close Circuit Breaker S (pulse CCS)	Close Circuit Breaker S (pulse CCS)	Set CCS	Clear CCS	Close Circuit Breaker S (pulse CCS)	Clear CCS
OCT	Open Circuit Breaker T (pulse OCT)	Open Circuit Breaker T (pulse OCT)	Set OCT	Clear OCT	Open Circuit Breaker T (pulse OCT)	Clear OCT
CCT	Close Circuit Breaker T (pulse CCT)	Close Circuit Breaker T (pulse CCT)	Set CCT	Clear CCT	Close Circuit Breaker T (pulse CCT)	Clear CCT
OCU	Open Circuit Breaker U (pulse OCU)	Open Circuit Breaker U (pulse OCU)	Set OCU	Clear OCU	Open Circuit Breaker U (pulse OCU)	Clear OCU

Table 10.16 SEL-400G Object 12 Control Point Operations (Sheet 2 of 3)

Label	Close/Any	Trip/Any	NUL/Latch On	NUL/Latch Off	NUL/Pulse On	NUL/Pulse Off
CCU	Close Circuit Breaker U (pulse CCU)	Close Circuit Breaker U (pulse CCU)	Set CCU	Clear CCU	Close Circuit Breaker U (pulse CCU)	Clear CCU
OCY	Open Circuit Breaker Y (pulse OCY)	Open Circuit Breaker Y (pulse OCY)	Set OCY	Clear OCY	Open Circuit Breaker Y (pulse OCY)	Clear OCY
CCY	Close Circuit Breaker Y (pulse CCY)	Close Circuit Breaker Y (pulse CCY)	Set CCY	Clear CCY	Close Circuit Breaker Y (pulse CCY)	Clear CCY
OCS: CCS	Pulse CCS, Circuit Breaker S close bit	Pulse OCS, Circuit Breaker S open bit	Pulse CCS, Circuit Breaker S close bit	Pulse OCS, Circuit Breaker S open bit	Pulse CCS, Circuit Breaker S close bit	Pulse OCS, Circuit Breaker S open bit
OCT: CCT	Pulse CCT, Circuit Breaker T close bit	Pulse OCT, Circuit Breaker T open bit	Pulse CCT, Circuit Breaker T close bit	Pulse OCT, Circuit Breaker T open bit	Pulse CCT, Circuit Breaker T close bit	Pulse OCT, Circuit Breaker T open bit
OCU: CCU	Pulse CCU, Circuit Breaker U close bit	Pulse OCU, Circuit Breaker U open bit	Pulse CCU, Circuit Breaker U close bit	Pulse OCU, Circuit Breaker U open bit	Pulse CCU, Circuit Breaker U close bit	Pulse OCU, Circuit Breaker U open bit
OCY: CCY	Pulse CCY, Circuit Breaker Y close bit	Pulse OCY, Circuit Breaker Y open bit	Pulse CCY, Circuit Breaker Y close bit	Pulse OCY, Circuit Breaker Y open bit	Pulse CCY, Circuit Breaker Y close bit	Pulse OCY, Circuit Breaker Y open bit
89OC01–89OC10	Pulse 89OC01–89OC10, disconnect open bit	Pulse 89OC01–89OC10, disconnect open bit	Set 89OC01–89OC10, disconnect open bit	Clear 89OC01–89OC10, disconnect open bit	Pulse 89OC01–89OC10, disconnect open bit	Clear 89OC01–89OC10, disconnect open bit
89CC01–89CC10	Pulse 89CC01–89CC10, disconnect close bit	Pulse 89CC01–89CC10, disconnect close bit	Set 89CC01–89CC10, disconnect close bit	Clear 89CC01–89CC10, disconnect close bit	Pulse 89CC01–89CC10, disconnect close bit	Clear 89CC01–89CC10, disconnect close bit
89OC*x*: 89CC*x*	Pulse 89CC*x*, disconnect close bit	Pulse 89OC*x*, disconnect open bit	Pulse 89CC*x*, disconnect close bit	Pulse 89OC*x*, disconnect open bit	Pulse 89CC*x*, disconnect close bit	Pulse 89OC*x*, disconnect open bit
RST_DEM	Reset demand meter data	Reset demand meter data	Reset demand meter data	No action	Reset demand meter data	No action
RST_PDM	Reset peak demand meter data	Reset peak demand meter data	Reset peak demand meter data	No action	Reset peak demand meter data	No action
RST_ENE	Reset energy accumulators	Reset energy accumulators	Reset energy accumulators	No action	Reset energy accumulators	No action
RST_BKS	Reset Breaker Monitor S (pulse RSS_BKS)	Reset Breaker Monitor S (pulse RSS_BKS)	Reset Breaker Monitor S (pulse RSS_BKS)	No action	Reset Breaker Monitor S (pulse RSS_BKS)	No action
RST_BKT	Reset Breaker Monitor T (pulse RSS_BKT)	Reset Breaker Monitor T (pulse RSS_BKT)	Reset Breaker Monitor T (pulse RSS_BKT)	No action	Reset Breaker Monitor T (pulse RSS_BKT)	No action
RST_BKU	Reset Breaker Monitor U (pulse RSS_BKU)	Reset Breaker Monitor U (pulse RSS_BKU)	Reset Breaker Monitor U (pulse RSS_BKU)	No action	Reset Breaker Monitor U (pulse RSS_BKU)	No action
RST_BKY	Reset Breaker Monitor Y (pulse RSS_BKY)	Reset Breaker Monitor Y (pulse RSS_BKY)	Reset Breaker Monitor Y (pulse RSS_BKY)	No action	Reset Breaker Monitor Y (pulse RSS_BKY)	No action
RST_MM	Reset min/max metering	Reset min/max metering	Reset min/max metering	No action	Reset min/max metering	No action
RST_BAT	Reset battery monitoring (pulse RSS_BAT)	Reset battery monitoring (pulse RSS_BAT)	Reset battery monitoring (pulse RSS_BAT)	No action	Reset battery monitoring (pulse RSS_BAT)	No action

Table 10.16 SEL-400G Object 12 Control Point Operations (Sheet 3 of 3)

Label	Close/Any	Trip/Any	NUL/Latch On	NUL/Latch Off	NUL/Pulse On	NUL/Pulse Off
RST_HAL	Reset alarm pulsing (pulse RSS_HAL)	Reset alarm pulsing (pulse RSS_HAL)	Reset alarm pulsing (pulse RSS_HAL)	No action	Reset alarm pulsing (pulse RSS_HAL)	No action
RSTTRGT	Reset front-panel targets (pulse RSTTRGT)	Reset front-panel targets (pulse RSTTRGT)	Reset front-panel targets	No action	Reset front-panel targets	No action
RSTDNPE	Reset DNP event summary	Reset DNP event summary	Reset DNP event summary	No action	Reset DNP event summary	No action
NXTEVE	Load oldest event summary (FIFO)	Load oldest event summary (FIFO)	Load oldest event summary (FIFO)	Load newest event summary (LIFO)	Load oldest event summary (FIFO)	Load newest event summary (LIFO)

Relay Fault Summary Data

When a relay event occurs (TRIP asserts, ER asserts, or TRI asserts), the data will be made available to DNP.

In either mode, DNP3 events for all event summary analog inputs (see *Table 10.14*) will be generated if any of them change beyond their deadband value after scaling (usually whenever a new relay event occurs and is loaded into the event summary analog inputs). Events are detected approximately twice a second by the scanning process.

See *Table 10.17* for the components of the FTYPE analog input point. If no bits are asserted, no fault summary is loaded.

Table 10.17 Object 30, 32, FTYPE Event Cause

Bit Position (Upper Byte)								Value	Event Cause
7	6	5	4	3	2	1	0		
							X	1	Trigger command
						X		2	Event report element
					X			4	Trip element
				X				8	Auxiliary trip
			X					16	Prime mover trip
		X						32	Excitation trip
	X							64	Restricted earth fault trip
X								128	Zone 2 differential trip
Bit Position (Lower Byte)									
7	6	5	4	3	2	1	0		
							X	1	Zone 1 differential trip

Default Data Map

Table 10.18–Table 10.22 shows the SEL-400G default data maps by DNP3 object or point type. The default data maps are automatically generated subsets of the reference map. All data maps are initialized to these default values. If the default maps do not fit your particular application, you can use the custom DNP mapping commands **SET D *n*** and **SHOW D *n***, where *n* is the map number, to edit or create the map you require.

Table 10.18 SEL-400G DNP3 Default Binary Input Data Map (Sheet 1 of 3)

Object	Default Index	Label	Description
01, 02	0	RLYDIS	Relay disabled
01, 02	1	TRIPLED	Trip LED
01, 02	2	STFAIL	Relay diagnostic failure
01, 02	3	STWARN	Relay diagnostic warning
01, 02	4	STSET	Settings have changed or relay restarted
01, 02	5	UNRDEV	New relay event available
01, 02	6	52CLS	Breaker closed, Terminal S
01, 02	7	52ALS	Breaker alarm, Terminal S
01, 02	8	52CLT	Breaker closed, Terminal T
01, 02	9	52ALT	Breaker alarm, Terminal T
01, 02	10	52CLU	Breaker closed, Terminal U
01, 02	11	52ALU	Breaker alarm, Terminal U
01, 02	12	52CLY	Breaker closed, Terminal Y
01, 02	13	52ALY	Breaker alarm, Terminal Y
01, 02	14	89CL01	Disconnect 1 closed
01, 02	15	89AL01	Disconnect 1 alarm
01, 02	16	89CL02	Disconnect 2 closed
01, 02	17	89AL02	Disconnect 2 alarm
01, 02	18	89CL03	Disconnect 3 closed
01, 02	19	89AL03	Disconnect 3 alarm
01, 02	20	89CL04	Disconnect 4 closed
01, 02	21	89AL04	Disconnect 4 alarm
01, 02	22	89CL05	Disconnect 5 closed
01, 02	23	89AL05	Disconnect 5 alarm
01, 02	24	89CL06	Disconnect 6 closed
01, 02	25	89AL06	Disconnect 6 alarm
01, 02	26	89CL07	Disconnect 7 closed
01, 02	27	89AL07	Disconnect 7 alarm
01, 02	28	89CL08	Disconnect 8 closed
01, 02	29	89AL08	Disconnect 8 alarm
01, 02	30	89CL09	Disconnect 9 closed
01, 02	31	89AL09	Disconnect 9 alarm
01, 02	32	89CL10	Disconnect 10 closed
01, 02	33	89AL10	Disconnect 10 alarm
01, 02	34	TLED_1	Target LED 1 on relay front panel
01, 02	35	TLED_2	Target LED 2 on relay front panel
01, 02	36	TLED_3	Target LED 3 on relay front panel
01, 02	37	TLED_4	Target LED 4 on relay front panel
01, 02	38	TLED_5	Target LED 5 on relay front panel
01, 02	39	TLED_6	Target LED 6 on relay front panel
01, 02	40	TLED_7	Target LED 7 on relay front panel

Table 10.18 SEL-400G DNP3 Default Binary Input Data Map (Sheet 2 of 3)

Object	Default Index	Label	Description
01, 02	41	TLED_8	Target LED 8 on relay front panel
01, 02	42	TLED_9	Target LED 9 on relay front panel
01, 02	43	TLED_10	Target LED 10 on relay front panel
01, 02	44	TLED_11	Target LED 11 on relay front panel
01, 02	45	TLED_12	Target LED 12 on relay front panel
01, 02	46	TLED_13	Target LED 13 on relay front panel
01, 02	47	TLED_14	Target LED 14 on relay front panel
01, 02	48	TLED_15	Target LED 15 on relay front panel
01, 02	49	TLED_16	Target LED 16 on relay front panel
01, 02	50	TLED_17	Target LED 17 on relay front panel
01, 02	51	TLED_18	Target LED 18 on relay front panel
01, 02	52	TLED_19	Target LED 19 on relay front panel
01, 02	53	TLED_20	Target LED 20 on relay front panel
01, 02	54	TLED_21	Target LED 21 on relay front panel
01, 02	55	TLED_22	Target LED 22 on relay front panel
01, 02	56	TLED_23	Target LED 23 on relay front panel
01, 02	57	TLED_24	Target LED 24 on relay front panel
01, 02	58	LOPV	Loss-of-potential Terminal V
01, 02	59	LOPZ	Loss-of-potential Terminal Z
01, 02	60	IN201	I/O Board 1, Input 1 asserted
01, 02	61	IN202	I/O Board 1, Input 2 asserted
01, 02	62	IN203	I/O Board 1, Input 3 asserted
01, 02	63	IN204	I/O Board 1, Input 4 asserted
01, 02	64	IN205	I/O Board 1, Input 5 asserted
01, 02	65	IN206	I/O Board 1, Input 6 asserted
01, 02	66	IN207	I/O Board 1, Input 7 asserted
01, 02	67	IN208	I/O Board 1, Input 8 asserted
01, 02	68	PSV01	Protection SELOGIC Variable 1
01, 02	69	PSV02	Protection SELOGIC Variable 2
01, 02	70	PSV03	Protection SELOGIC Variable 3
01, 02	71	PSV04	Protection SELOGIC Variable 4
01, 02	72	PSV05	Protection SELOGIC Variable 5
01, 02	73	PSV06	Protection SELOGIC Variable 6
01, 02	74	PSV07	Protection SELOGIC Variable 7
01, 02	75	PSV08	Protection SELOGIC Variable 8
01, 02	76	ASV001	Automation SELOGIC Variable 1
01, 02	77	ASV002	Automation SELOGIC Variable 2
01, 02	78	ASV003	Automation SELOGIC Variable 3
01, 02	79	ASV004	Automation SELOGIC Variable 4
01, 02	80	ASV005	Automation SELOGIC Variable 5
01, 02	81	ASV006	Automation SELOGIC Variable 6

Table 10.18 SEL-400G DNP3 Default Binary Input Data Map (Sheet 3 of 3)

Object	Default Index	Label	Description
01, 02	82	ASV007	Automation SELOGIC Variable 7
01, 02	83	ASV008	Automation SELOGIC Variable 8
01, 02	84	OUT201	I/O Board 1, Output 1 asserted
01, 02	85	OUT202	I/O Board 1, Output 2 asserted
01, 02	86	OUT203	I/O Board 1, Output 3 asserted
01, 02	87	OUT204	I/O Board 1, Output 4 asserted
01, 02	88	OUT205	I/O Board 1, Output 5 asserted
01, 02	89	OUT206	I/O Board 1, Output 6 asserted
01, 02	90	OUT207	I/O Board 1, Output 7 asserted
01, 02	91	OUT208	I/O Board 1, Output 8 asserted

Table 10.19 SEL-400G DNP3 Default Binary Output Data Map (Sheet 1 of 2)

Object	Default Index	Label	Description
10, 12	0–31	RB01–RB32	Remote Bits 1–32
10, 12	32	OCS	Breaker Open command, Terminal S
10, 12	33	CCS	Breaker Close command, Terminal S
10, 12	34	OCT	Breaker Open command, Terminal T
10, 12	35	CCT	Breaker Close command, Terminal T
10, 12	36	OCU	Breaker Open command, Terminal U
10, 12	37	CCU	Breaker Close command, Terminal U
10, 12	38	OCY	Breaker Open command, Terminal Y
10, 12	39	CCY	Breaker Close command, Terminal Y
10, 12	40	89OC01	Open Disconnect Control 1
10, 12	41	89CC01	Close Disconnect Control 1
10, 12	42	89OC02	Open Disconnect Control 2
10, 12	43	89CC02	Close Disconnect Control 2
10, 12	44	89OC03	Open Disconnect Control 3
10, 12	45	89CC03	Close Disconnect Control 3
10, 12	46	89OC04	Open Disconnect Control 4
10, 12	47	89CC04	Close Disconnect Control 4
10, 12	48	89OC05	Open Disconnect Control 5
10, 12	49	89CC05	Close Disconnect Control 5
10, 12	50	89OC06	Open Disconnect Control 6
10, 12	51	89CC06	Close Disconnect Control 6
10, 12	52	89OC07	Open Disconnect Control 7
10, 12	53	89CC07	Close Disconnect Control 7
10, 12	54	89OC08	Open Disconnect Control 8
10, 12	55	89CC08	Close Disconnect Control 8
10, 12	56	89OC09	Open Disconnect Control 9
10, 12	57	89CC09	Close Disconnect Control 9
10, 12	58	89OC10	Open Disconnect Control 10

Table 10.19 SEL-400G DNP3 Default Binary Output Data Map (Sheet 2 of 2)

Object	Default Index	Label	Description
10, 12	59	89CC10	Close Disconnect Control 10
10, 12	60	RSTTRGT	Reset front-panel targets
10, 12	61	RSTDNPE	Reset DNP fault summary data

Table 10.20 SEL-400G DNP3 Default Binary Counter Data Map

Object	Default Index	Label	Description
20, 22	0	BKRSOP	Number of Breaker S operations
20, 22	1	BKRTOP	Number of Breaker T operations
20, 22	2	BKRUOP	Number of Breaker U operations
20, 22	3	BKRYOP	Number of Breaker Y operations

Table 10.21 SEL-400G DNP3 Default Analog Input Map (Sheet 1 of 3)

Object	Default Index	Label	Description
30, 32	0	IASFMC	40 ms average filtered phase current magnitude, A-Phase, Terminal S
30, 32	1	IASFAC	40 ms average filtered phase current angle, A-Phase, Terminal S
30, 32	2	IBSFMC	40 ms average filtered phase current magnitude, B-Phase, Terminal S
30, 32	3	IBSFAC	40 ms average filtered phase current angle, B-Phase, Terminal S
30, 32	4	ICSFMC	40 ms average filtered phase current magnitude, C-Phase, Terminal S
30, 32	5	ICSFAC	40 ms average filtered phase current angle, C-Phase, Terminal S
30, 32	6	IATFMC	40 ms average filtered phase current magnitude, A-Phase, Terminal T
30, 32	7	IATFAC	40 ms average filtered phase current angle, A-Phase, Terminal T
30, 32	8	IBTFMC	40 ms average filtered phase current magnitude, B-Phase, Terminal T
30, 32	9	IBTFAC	40 ms average filtered phase current angle, B-Phase, Terminal T
30, 32	10	ICTFMC	40 ms average filtered phase current magnitude, C-Phase, Terminal T
30, 32	11	ICTFAC	40 ms average filtered phase current angle, C-Phase, Terminal T
30, 32	12	IAUFMC	40 ms average filtered phase current magnitude, A-Phase, Terminal U
30, 32	13	IAUFAC	40 ms average filtered phase current angle, A-Phase, Terminal U
30, 32	14	IBUFMC	40 ms average filtered phase current magnitude, B-Phase, Terminal U
30, 32	15	IBUFAC	40 ms average filtered phase current angle, B-Phase, Terminal U
30, 32	16	ICUFMC	40 ms average filtered phase current magnitude, C-Phase, Terminal U
30, 32	17	ICUFAC	40 ms average filtered phase current angle, C-Phase, Terminal U
30, 32	18	IAYFMC	40 ms average filtered phase current magnitude, A-Phase, Terminal Y
30, 32	19	IAYFAC	40 ms average filtered phase current angle, A-Phase, Terminal Y
30, 32	20	IBYFMC	40 ms average filtered phase current magnitude, B-Phase, Terminal Y
30, 32	21	IBYFAC	40 ms average filtered phase current angle, B-Phase, Terminal Y
30, 32	22	ICYFMC	40 ms average filtered phase current magnitude, C-Phase, Terminal Y
30, 32	23	ICYFAC	40 ms average filtered phase current angle, C-Phase, Terminal Y
30, 32	24	IAGFMC	40 ms average filtered phase current magnitude, A-Phase, Terminal G
30, 32	25	IAGFAC	40 ms average filtered phase current angle, A-Phase, Terminal G
30, 32	26	IBGFMC	40 ms average filtered phase current magnitude, B-Phase, Terminal G
30, 32	27	IBGFAC	40 ms average filtered phase current angle, B-Phase, Terminal G

Table 10.21 SEL-400G DNP3 Default Analog Input Map (Sheet 2 of 3)

Object	Default Index	Label	Description
30, 32	28	ICGFMC	40 ms average filtered phase current magnitude, C-Phase, Terminal G
30, 32	29	ICGFAC	40 ms average filtered phase current angle, C-Phase, Terminal G
30, 32	30	VAVFMC	40 ms average filtered phase-to-neutral voltage magnitude, A-Phase, Terminal V
30, 32	31	VAVFAC	40 ms average filtered phase-to-neutral voltage angle, A-Phase, Terminal V
30, 32	32	VBVFMC	40 ms average filtered phase-to-neutral voltage magnitude, B-Phase, Terminal V
30, 32	33	VBVFAC	40 ms average filtered phase-to-neutral voltage angle, B-Phase, Terminal V
30, 32	34	VCVFMC	40 ms average filtered phase-to-neutral voltage magnitude, C-Phase, Terminal V
30, 32	35	VCVFAC	40 ms average filtered phase-to-neutral voltage angle, C-Phase, Terminal V
30, 32	36	VAZFMC	40 ms average filtered phase-to-neutral voltage magnitude, A-Phase, Terminal Z
30, 32	37	VAZFAC	40 ms average filtered phase-to-neutral voltage angle, A-Phase, Terminal Z
30, 32	38	VBZFMC	40 ms average filtered phase-to-neutral voltage magnitude, B-Phase, Terminal Z
30, 32	39	VBZFAC	40 ms average filtered phase-to-neutral voltage angle, B-Phase, Terminal Z
30, 32	40	VCZFMC	40 ms average filtered phase-to-neutral voltage magnitude, C-Phase, Terminal Z
30, 32	41	VCZFAC	40 ms average filtered phase-to-neutral voltage angle, C-Phase, Terminal Z
30, 32	42	PASFC	40 ms average phase fundamental active power, A-Phase, Terminal S
30, 32	43	PBSFC	40 ms average phase fundamental active power, B-Phase, Terminal S
30, 32	44	PCSFC	40 ms average phase fundamental active power, C-Phase, Terminal S
30, 32	45	PATFC	40 ms average phase fundamental active power, A-Phase, Terminal T
30, 32	46	PBTFC	40 ms average phase fundamental active power, B-Phase, Terminal T
30, 32	47	PCTFC	40 ms average phase fundamental active power, C-Phase, Terminal T
30, 32	48	PAUFC	40 ms average phase fundamental active power, A-Phase, Terminal U
30, 32	49	PBUFC	40 ms average phase fundamental active power, B-Phase, Terminal U
30, 32	50	PCUFC	40 ms average phase fundamental active power, C-Phase, Terminal U
30, 32	51	PAYFC	40 ms average phase fundamental active power, A-Phase, Terminal Y
30, 32	52	PBYFC	40 ms average phase fundamental active power, B-Phase, Terminal Y
30, 32	53	PCYFC	40 ms average phase fundamental active power, C-Phase, Terminal Y
30, 32	54	PAGFC	40 ms average phase fundamental active power, A-Phase, Terminal G
30, 32	55	PBGFC	40 ms average phase fundamental active power, B-Phase, Terminal G
30, 32	56	PCGFC	40 ms average phase fundamental active power, C-Phase, Terminal G
30, 32	57	QASFC	40 ms average phase fundamental reactive power, A-Phase, Terminal S
30, 32	58	QBSFC	40 ms average phase fundamental reactive power, B-Phase, Terminal S
30, 32	59	QCSFC	40 ms average phase fundamental reactive power, C-Phase, Terminal S
30, 32	60	QATFC	40 ms average phase fundamental reactive power, A-Phase, Terminal T
30, 32	61	QBTFC	40 ms average phase fundamental reactive power, B-Phase, Terminal T
30, 32	62	QCTFC	40 ms average phase fundamental reactive power, C-Phase, Terminal T
30, 32	63	QAUFC	40 ms average phase fundamental reactive power, A-Phase, Terminal U
30, 32	64	QBUFC	40 ms average phase fundamental reactive power, B-Phase, Terminal U
30, 32	65	QCUFC	40 ms average phase fundamental reactive power, C-Phase, Terminal U
30, 32	66	QAYFC	40 ms average phase fundamental reactive power, A-Phase, Terminal Y
30, 32	67	QBYFC	40 ms average phase fundamental reactive power, B-Phase, Terminal Y
30, 32	68	QCYFC	40 ms average phase fundamental reactive power, C-Phase, Terminal Y

Table 10.21 SEL-400G DNP3 Default Analog Input Map (Sheet 3 of 3)

Object	Default Index	Label	Description
30, 32	69	QAGFC	40 ms average phase fundamental reactive power, A-Phase, Terminal G
30, 32	70	QBGFC	40 ms average phase fundamental reactive power, B-Phase, Terminal G
30, 32	71	QCGFC	40 ms average phase fundamental reactive power, C-Phase, Terminal G
30, 32	72	ACTGRP	Active settings group
30, 32	73	RLYTEMP	Relay temperature (°C temperature of the box)
30, 32	74	FREQPG	Generator tracking frequency
30, 32	75	FREQPS	System tracking frequency
30, 32	76	VDC	Station battery dc voltage
30, 32	77	FTYPE	Fault type
30, 32	78	FTAR1	Fault targets (upper byte is 1st target row, lower byte is 2nd target row)
30, 32	79	FTAR2	Fault targets (upper byte is 3rd target row, lower byte is 0)
30, 32	80	FFREQG	Generator fault frequency
30, 32	81	FFREQS	System fault frequency
30, 32	82	FGRP	Fault active settings group (1–6)
30, 32	83	FTIMEUH	Fault time (UTC) in DNP format, high 16 bits
30, 32	84	FTIMEUM	Fault time (UTC) in DNP format, middle 16 bits
30, 32	85	FTIMEUL	Fault time (UTC) in DNP format, low 16 bits
30, 32	86	FUNR	Number of unread faults

Table 10.22 SEL-400G DNP3 Default Analog Output Data Map

Object	Default Index	Label	Description
40, 41	0	ACTGRP	Active settings group

IEC 61850 Communication

General IEC 61850 operation is described in *Section 17: IEC 61850 Communication in the SEL-400 Series Relays Instruction Manual*. This section describes characteristics of IEC 61850 that are specific to the SEL-400G.

Logical Nodes

NOTE: With the introduction of the Flexible Server Model (FSM) in Architect for ICD files ClassFileVersion 010 or later, use FSM as the primary reference to view and edit the mapping between IEC 61850 data attributes and relay variables. The LN tables provided in this section serve as general guidelines.

Table 10.23 through *Table 10.25* show the logical nodes (LNs) supported in the SEL-400G and the Relay Word bits or Measured Values mapped to those LNs. Additionally, the relay supports the CON and ANN Logical Device logical nodes as described in *Section 17: IEC 61850 Communication in the SEL-400 Series Relays Instruction Manual*.

Table 10.23 shows the LNs associated with protection elements, defined as Logical Device PRO.

Table 10.23 Logical Device: PRO (Protection) (Sheet 1 of 23)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = CO			
DC01CSWI1	Pos.Oper.ctlVal	89CC01:89OC01[a]	ASCII close/open Disconnect 1 command
DC02CSWI1	Pos.Oper.ctlVal	89CC02:89OC02[a]	ASCII close/open Disconnect 2 command
DC03CSWI1	Pos.Oper.ctlVal	89CC03:89OC03[a]	ASCII close/open Disconnect 3 command
DC04CSWI1	Pos.Oper.ctlVal	89CC04:89OC04[a]	ASCII close/open Disconnect 4 command
DC05CSWI1	Pos.Oper.ctlVal	89CC05:89OC05[a]	ASCII close/open Disconnect 5 command
DC06CSWI1	Pos.Oper.ctlVal	89CC06:89OC06[a]	ASCII close/open Disconnect 6 command
DC07CSWI1	Pos.Oper.ctlVal	89CC07:89OC07[a]	ASCII close/open Disconnect 7 command
DC08CSWI1	Pos.Oper.ctlVal	89CC08:89OC08[a]	ASCII close/open Disconnect 8 command
DC09CSWI1	Pos.Oper.ctlVal	89CC09:89OC09[a]	ASCII close/open Disconnect 9 command
DC10CSWI1	Pos.Oper.ctlVal	89CC10:89OC10[a]	ASCII close/open Disconnect 10 command
SBKRCSWI1	Pos.Oper.ctlVal	CCS:OCS[a]	Circuit breaker close/open command, Terminal S
TBKRCSWI1	Pos.Oper.ctlVal	CCT:OCT[a]	Circuit breaker close/open command, Terminal T
UBKRCSWI1	Pos.Oper.ctlVal	CCU:OCU[a]	Circuit breaker close/open command, Terminal U
YBKRCSWI1	Pos.Oper.ctlVal	CCY:OCY[a]	Circuit breaker close/open command, Terminal Y
Functional Constraint = ST			
LLN0	Mod.stVal	I60MOD[b]	IEC 61850 mode/behavior status
LLN0	Loc.stVal	LOC	Control authority at local (bay) level
LLN0	LocSta.stVal	LOCSTA	Control authority at station level
LLN0	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
B81A1PTOF1	Str.general	81AB1	81A element Band 1 pickup
B81A1PTOF1	Op.general	81AB1T	81A element Band 1 delayed pickup
B81A2PTOF1	Str.general	81AB2	81A element Band 2 pickup
B81A2PTOF1	Op.general	81AB2T	81A element Band 2 delayed pickup
B81A3PTOF1	Str.general	81AB3	81A element Band 3 pickup
B81A3PTOF1	Op.general	81AB3T	81A element Band 3 delayed pickup
B81A4PTOF1	Str.general	81AB4	81A element Band 4 pickup
B81A4PTOF1	Op.general	81AB4T	81A element Band 4 delayed pickup
B81A5PTOF1	Str.general	81AB5	81A element Band 5 pickup
B81A5PTOF1	Op.general	81AB5T	81A element Band 5 delayed pickup
B81A6PTOF1	Str.general	81AB6	81A element Band 6 pickup
B81A6PTOF1	Op.general	81AB6T	81A element Band 6 delayed pickup
B81A7PTOF1	Str.general	81AB7	81A element Band 7 pickup
B81A7PTOF1	Op.general	81AB7T	81A element Band 7 delayed pickup
B81A8PTOF1	Str.general	81AB8	81A element Band 8 pickup
B81A8PTOF1	Op.general	81AB8T	81A element Band 8 delayed pickup
B81APTOF1	Str.general	81AC	81A element pickup
B81APTOF1	Op.general	81AT	81A element delayed pickup
BFRSRBRF1	Str.general	BFIS	Circuit Breaker S breaker failure initiate SELOGIC control equation
BFRSRBRF1	OpEx.general	FBFS	Circuit Breaker S failure

Table 10.23 Logical Device: PRO (Protection) (Sheet 2 of 23)

Logical Node	Attribute	Data Source	Comment
BFRSRBRF1	OpIn.general	RTS	Circuit Breaker S retrip
BFRTRBRF1	Str.general	BFIT	Circuit Breaker T breaker failure initiate SELOGIC control equation
BFRTRBRF1	OpEx.general	FBFT	Circuit Breaker T failure
BFRTRBRF1	OpIn.general	RTT	Circuit Breaker T retrip
BFRURBRF1	Str.general	BFIU	Circuit Breaker U breaker failure initiate SELOGIC control equation
BFRURBRF1	OpEx.general	FBFU	Circuit Breaker U failure
BFRURBRF1	OpIn.general	RTU	Circuit Breaker U retrip
BFRYRBRF1	Str.general	BFIY	Circuit Breaker Y breaker failure initiate SELOGIC control equation
BFRYRBRF1	OpEx.general	FBFY	Circuit Breaker Y failure
BFRYRBRF1	OpIn.general	RTY	Circuit Breaker Y retrip
BKSACSYN1	Rel.stVal	25AS	Breaker S voltage within sync angle window uncompensated
BKSACSYN1	VInd.stVal	25VDIFS	Breaker S voltage difference is within acceptable window
BKSACSYN1	HzInd.stVal	SFBKS	Breaker S slip frequency is within acceptable slip frequency window
BKSACSYN1	RV.stVal	25AVR	Voltage raise command
BKSACSYN1	LV.stVal	25AVL	Voltage lower command
BKSACSYN1	RHz.stVal	25AFR	Frequency raise command
BKSACSYN1	LHz.stVal	25AFL	Frequency lower command
BKSCCSYN1	RV.stVal	25AVR	Voltage raise command
BKSCCSYN1	LV.stVal	25AVL	Voltage lower command
BKSCCSYN1	RHz.stVal	25AFR	Frequency raise command
BKSCCSYN1	LHz.stVal	25AFL	Frequency lower command
BKSCCSYN1	VInd.stVal	25VDIFS	Breaker S voltage difference is within acceptable window
BKSCCSYN1	HzInd.stVal	SFBKS	Breaker S slip frequency is within acceptable slip frequency window
BKSCCSYN1	Rel.stVal	25CS	Breaker S voltages within sync angle window compensated
BKSRSYN1	Rel.stVal	25AS	Breaker S voltage within sync angle window uncompensated
BKTACSYN1	Rel.stVal	25AT	Breaker T voltage within sync angle window uncompensated
BKTACSYN1	VInd.stVal	25VDIFT	Breaker T voltage difference is within acceptable window
BKTACSYN1	HzInd.stVal	SFBKT	Breaker T slip frequency is within acceptable slip frequency window
BKTACSYN1	RV.stVal	25AVR	Voltage raise command
BKTACSYN1	LV.stVal	25AVL	Voltage lower command
BKTACSYN1	RHz.stVal	25AFR	Frequency raise command
BKTACSYN1	LHz.stVal	25AFL	Frequency lower command
BKTCCSYN1	RV.stVal	25AVR	Voltage raise command
BKTCCSYN1	LV.stVal	25AVL	Voltage lower command
BKTCCSYN1	RHz.stVal	25AFR	Frequency raise command
BKTCCSYN1	LHz.stVal	25AFL	Frequency lower command
BKTCCSYN1	VInd.stVal	25VDIFT	Breaker T voltage difference is within acceptable window

Table 10.23 Logical Device: PRO (Protection) (Sheet 3 of 23)

Logical Node	Attribute	Data Source	Comment
BKTCCSYN1	HzInd.stVal	SFBKT	Breaker T slip frequency is within acceptable slip frequency window
BKTCCSYN1	Rel.stVal	25CT	Breaker T voltages within sync angle window compensated
BKTRSYN1	Rel.stVal	25AT	Breaker T voltage within sync angle window uncompensated
BKUACSYN1	Rel.stVal	25AU	Breaker U voltage within sync angle window uncompensated
BKUACSYN1	VInd.stVal	25VDIFU	Breaker U voltage difference is within acceptable window
BKUACSYN1	HzInd.stVal	SFBKU	Breaker U slip frequency is within acceptable slip frequency window
BKUACSYN1	RV.stVal	25AVR	Voltage raise command
BKUACSYN1	LV.stVal	25AVL	Voltage lower command
BKUACSYN1	RHz.stVal	25AFR	Frequency raise command
BKUACSYN1	LHz.stVal	25AFL	Frequency lower command
BKUCCSYN1	RV.stVal	25AVR	Voltage raise command
BKUCCSYN1	LV.stVal	25AVL	Voltage lower command
BKUCCSYN1	RHz.stVal	25AFR	Frequency raise command
BKUCCSYN1	LHz.stVal	25AFL	Frequency lower command
BKUCCSYN1	VInd.stVal	25VDIFU	Breaker U voltage difference is within acceptable window
BKUCCSYN1	HzInd.stVal	SFBKU	Breaker U slip frequency is within acceptable slip frequency window
BKUCCSYN1	Rel.stVal	25CU	Breaker U voltages within sync angle window compensated
BKURSYN1	Rel.stVal	25AU	Breaker U voltage within sync angle window uncompensated
BKYACSYN1	Rel.stVal	25AY	Breaker Y voltage within sync angle window uncompensated
BKYACSYN1	RV.stVal	25AVR	Voltage raise command
BKYACSYN1	LV.stVal	25AVL	Voltage lower command
BKYACSYN1	RHz.stVal	25AFR	Frequency raise command
BKYACSYN1	LHz.stVal	25AFL	Frequency lower command
BKYACSYN1	VInd.stVal	25VDIFY	Breaker Y voltage difference is within acceptable window
BKYACSYN1	HzInd.stVal	SFBKY	Breaker Y slip frequency is within acceptable slip frequency window
BKYCCSYN1	RV.stVal	25AVR	Voltage raise command
BKYCCSYN1	LV.stVal	25AVL	Voltage lower command
BKYCCSYN1	RHz.stVal	25AFR	Frequency raise command
BKYCCSYN1	LHz.stVal	25AFL	Frequency lower command
BKYCCSYN1	VInd.stVal	25VDIFY	Breaker Y voltage difference is within acceptable window
BKYCCSYN1	HzInd.stVal	SFBKY	Breaker Y slip frequency is within acceptable slip frequency window
BKYCCSYN1	Rel.stVal	25CY	Breaker Y voltages within sync angle window compensated
BKYRSYN1	Rel.stVal	25AY	Breaker Y voltage within sync angle window uncompensated
BSSASCBR1	AbrAlm.stVal	BSBCWAL	Breaker contact wear alarm, Breaker S
BSSASCBR1	MechTmAlm.stVal	BSMSOAL	Mechanical slow operation alarm, Breaker S
BSSASCBR1	OpTmAlm.stVal	BSESOAL	Slow electrical operate alarm, Breaker S
BSSASCBR1	ColOpn.stVal	OCS	Breaker open command, Terminal S
BSSBSCBR1	AbrAlm.stVal	BSBCWAL	Breaker contact wear alarm, Breaker S

Table 10.23 Logical Device: PRO (Protection) (Sheet 4 of 23)

Logical Node	Attribute	Data Source	Comment
BSSBSCBR1	MechTmAlm.stVal	BSMSOAL	Mechanical slow operation alarm, Breaker S
BSSBSCBR1	OpTmAlm.stVal	BSESOAL	Slow electrical operate alarm, Breaker S
BSSBSCBR1	ColOpn.stVal	OCS	Breaker open command, Terminal S
BSSCSCBR1	AbrAlm.stVal	BSBCWAL	Breaker contact wear alarm, Breaker S
BSSCSCBR1	MechTmAlm.stVal	BSMSOAL	Mechanical slow operation alarm, Breaker S
BSSCSCBR1	OpTmAlm.stVal	BSESOAL	Slow electrical operate alarm, Breaker S
BSSCSCBR1	OpOpn.general	OCS	Breaker open command, Terminal S
BSTASCBR1	AbrAlm.stVal	BTBCWAL	Breaker contact wear alarm, Breaker T
BSTASCBR1	MechTmAlm.stVal	BTMSOAL	Mechanical slow operation alarm, Breaker T
BSTASCBR1	OpTmAlm.stVal	BTESOAL	Slow electrical operate alarm, Breaker T
BSTASCBR1	ColOpn.stVal	OCT	Breaker open command, Terminal T
BSTBSCBR1	AbrAlm.stVal	BTBCWAL	Breaker contact wear alarm, Breaker T
BSTBSCBR1	MechTmAlm.stVal	BTMSOAL	Mechanical slow operation alarm, Breaker T
BSTBSCBR1	OpTmAlm.stVal	BTESOAL	Slow electrical operate alarm, Breaker T
BSTBSCBR1	ColOpn.stVal	OCT	Breaker open command, Terminal T
BSTCSCBR1	AbrAlm.stVal	BTBCWAL	Breaker contact wear alarm, Breaker T
BSTCSCBR1	MechTmAlm.stVal	BTMSOAL	Mechanical slow operation alarm, Breaker T
BSTCSCBR1	OpTmAlm.stVal	BTESOAL	Slow electrical operate alarm, Breaker T
BSTCSCBR1	OpOpn.general	OCT	Breaker open command, Terminal T
BSUASCBR1	AbrAlm.stVal	BUBCWAL	Breaker contact wear alarm, Breaker U
BSUASCBR1	MechTmAlm.stVal	BUMSOAL	Mechanical slow operation alarm, Breaker U
BSUASCBR1	OpTmAlm.stVal	BUESOAL	Slow electrical operate alarm, Breaker U
BSUASCBR1	ColOpn.stVal	OCU	Breaker open command, Terminal U
BSUBSCBR1	AbrAlm.stVal	BUBCWAL	Breaker contact wear alarm, Breaker U
BSUBSCBR1	MechTmAlm.stVal	BUMSOAL	Mechanical slow operation alarm, Breaker U
BSUBSCBR1	OpTmAlm.stVal	BUESOAL	Slow electrical operate alarm, Breaker U
BSUBSCBR1	ColOpn.stVal	OCU	Breaker open command, Terminal U
BSUCSCBR1	AbrAlm.stVal	BUBCWAL	Breaker contact wear alarm, Breaker U
BSUCSCBR1	MechTmAlm.stVal	BUMSOAL	Mechanical slow operation alarm, Breaker U
BSUCSCBR1	OpTmAlm.stVal	BUESOAL	Slow electrical operate alarm, Breaker U
BSUCSCBR1	OpOpn.general	OCU	Breaker open command, Terminal U
BSYASCBR1	AbrAlm.stVal	BYBCWAL	Breaker contact wear alarm, Breaker Y
BSYASCBR1	MechTmAlm.stVal	BYMSOAL	Mechanical slow operation alarm, Breaker Y
BSYASCBR1	OpTmAlm.stVal	BYESOAL	Slow electrical operate alarm, Breaker Y
BSYASCBR1	ColOpn.stVal	OCY	Breaker open command, Terminal Y
BSYBSCBR1	AbrAlm.stVal	BYBCWAL	Breaker contact wear alarm, Breaker Y
BSYBSCBR1	MechTmAlm.stVal	BYMSOAL	Mechanical slow operation alarm, Breaker Y
BSYBSCBR1	OpTmAlm.stVal	BYESOAL	Slow electrical operate alarm, Breaker Y
BSYBSCBR1	ColOpn.stVal	OCY	Breaker open command, Terminal Y
BSYCSCBR1	AbrAlm.stVal	BYBCWAL	Breaker contact wear alarm, Breaker Y
BSYCSCBR1	MechTmAlm.stVal	BYMSOAL	Mechanical slow operation alarm, Breaker Y

Table 10.23 Logical Device: PRO (Protection) (Sheet 5 of 23)

Logical Node	Attribute	Data Source	Comment
BSYCSCBR1	OpTmAlm.stVal	BYESOAL	Slow electrical operate alarm, Breaker Y
BSYCSCBR1	OpOpn.general	OCY	Breaker open command, Terminal Y
D241T1PVPH1	Str.general	24D11	V/Hz Element 1 Level 1 asserted
D241T1PVPH1	Op.general	24D1T1	V/Hz Element 1 Level 1 timed out
D241T2PVPH1	Str.general	24D11	V/Hz Element 1 Level 1 asserted
D241T2PVPH1	Op.general	24D1T2	V/Hz Element 1 Level 2 timed out
D242T1PVPH1	Str.general	24D21	V/Hz Element 2 Level 1 asserted
D242T1PVPH1	Op.general	24D2T1	V/Hz Element 2 Level 1 timed out
D242T2PVPH1	Str.general	24D21	V/Hz Element 2 Level 1 asserted
D242T2PVPH1	Op.general	24D2T2	V/Hz Element 2 Level 2 timed out
D32P1PDOP1	Str.general	32P01	Directional power Element 1 asserted
D32P1PDOP1	Op.general	32T01	Directional power Element 1 timed out
D32P2PDOP1	Str.general	32P02	Directional power Element 2 asserted
D32P2PDOP1	Op.general	32T02	Directional power Element 2 timed out
D32P3PDOP1	Str.general	32P03	Directional power Element 3 asserted
D32P3PDOP1	Op.general	32T03	Directional power Element 3 timed out
D32P4PDOP1	Str.general	32P04	Directional power Element 4 asserted
D32P4PDOP1	Op.general	32T04	Directional power Element 4 timed out
D81L1PTOF1	BlkV.stVal	CSV29	Frequency elements undervoltage supervision (27B81G OR 27B81S)
D81L1PTOF1	Str.general	CSV05	Level 1 overfrequency element pickup (81D1OVR AND 81D1)
D81L1PTOF1	Op.general	CSV17	Level 1 overfrequency element time-out (81D1OVR AND 81D1T)
D81L1PTUF1	Str.general	CSV11	Level 1 underfrequency element pickup (81D1UDR AND 81D1)
D81L1PTUF1	Op.general	CSV23	Level 1 underfrequency element time-out (81D1UDR AND 81D1T)
D81L1PTUF1	BlkV.stVal	CSV29	Frequency elements undervoltage supervision (27B81G OR 27B81S)
D81L2PTOF1	BlkV.stVal	CSV29	Frequency elements undervoltage supervision (27B81G OR 27B81S)
D81L2PTOF1	Str.general	CSV06	Level 2 overfrequency element pickup (81D2OVR AND 81D2)
D81L2PTOF1	Op.general	CSV18	Level 2 overfrequency element time-out (81D2OVR AND 81D2T)
D81L2PTUF1	Str.general	CSV12	Level 2 underfrequency element pickup (81D2UDR AND 81D2)
D81L2PTUF1	Op.general	CSV24	Level 2 underfrequency element time-out (81D2UDR AND 81D2T)
D81L2PTUF1	BlkV.stVal	CSV29	Frequency elements undervoltage supervision (27B81G OR 27B81S)
D81L3PTOF1	BlkV.stVal	CSV29	Frequency elements undervoltage supervision (27B81G OR 27B81S)
D81L3PTOF1	Str.general	CSV07	Level 3 overfrequency element pickup (81D3OVR AND 81D3)

Table 10.23 Logical Device: PRO (Protection) (Sheet 6 of 23)

Logical Node	Attribute	Data Source	Comment
D81L3PTOF1	Op.general	CSV19	Level 3 overfrequency element time-out (81D3OVR AND 81D3T)
D81L3PTUF1	Str.general	CSV13	Level 3 underfrequency element pickup (81D3UDR AND 81D3)
D81L3PTUF1	Op.general	CSV25	Level 3 underfrequency element time-out (81D3UDR AND 81D3T)
D81L3PTUF1	BlkV.stVal	CSV29	Frequency elements undervoltage supervision (27B81G OR 27B81S)
D81L4PTOF1	BlkV.stVal	CSV29	Frequency elements undervoltage supervision (27B81G OR 27B81S)
D81L4PTOF1	Str.general	CSV08	Level 4 overfrequency element pickup (81D4OVR AND 81D4)
D81L4PTOF1	Op.general	CSV20	Level 4 overfrequency element time-out (81D4OVR AND 81D4T)
D81L4PTUF1	Str.general	CSV14	Level 4 underfrequency element pickup (81D4UDR AND 81D4)
D81L4PTUF1	Op.general	CSV26	Level 4 underfrequency element time-out (81D4UDR AND 81D4T)
D81L4PTUF1	BlkV.stVal	CSV29	Frequency elements undervoltage supervision (27B81G OR 27B81S)
D81L5PTOF1	BlkV.stVal	CSV29	Frequency elements undervoltage supervision (27B81G OR 27B81S)
D81L5PTOF1	Str.general	CSV09	Level 5 overfrequency element pickup (81D5OVR AND 81D5)
D81L5PTOF1	Op.general	CSV21	Level 5 overfrequency element time-out (81D5OVR AND 81D5T)
D81L5PTUF1	Str.general	CSV15	Level 5 underfrequency element pickup (81D5UDR AND 81D5)
D81L5PTUF1	Op.general	CSV27	Level 5 underfrequency element time-out (81D5UDR AND 81D5T)
D81L5PTUF1	BlkV.stVal	CSV29	Frequency elements undervoltage supervision (27B81G OR 27B81S)
D81L6PTOF1	BlkV.stVal	CSV29	Frequency elements undervoltage supervision (27B81G OR 27B81S)
D81L6PTOF1	Str.general	CSV10	Level 6 overfrequency element pickup (81D6OVR AND 81D6)
D81L6PTOF1	Op.general	CSV22	Level 6 overfrequency element time-out (81D6OVR AND 81D6T)
D81L6PTUF1	Str.general	CSV16	Level 6 underfrequency element pickup (81D6UDR AND 81D6)
D81L6PTUF1	Op.general	CSV28	Level 6 underfrequency element time-out (81D6UDR AND 81D6T)
D81L6PTUF1	BlkV.stVal	CSV29	Frequency elements undervoltage supervision (27B81G OR 27B81S)
D87Q1PDIF1	Op.general	87Q1	Negative-sequence differential Element 1 asserted (interturn fault detected)
D87Q2PDIF1	Op.general	87Q2	Negative-sequence differential Element 2 asserted (interturn fault detected)
D87R1PDIF1	Op.general	87R1	Restrained differential Element 1 picked up

Table 10.23 Logical Device: PRO (Protection) (Sheet 7 of 23)

Logical Node	Attribute	Data Source	Comment
D87R1PDIF1	Op.phsA	87AR1	A-Phase restrained differential Element 1 picked up
D87R1PDIF1	Op.phsB	87BR1	B-Phase restrained differential Element 1 picked up
D87R1PDIF1	Op.phsC	87CR1	C-Phase restrained differential Element 1 picked up
D87R2PDIF1	Op.general	87R2	Restrained differential Element 2 picked up
D87R2PDIF1	Op.phsA	87AR2	A-Phase restrained differential Element 2 picked up
D87R2PDIF1	Op.phsB	87BR2	B-Phase restrained differential Element 2 picked up
D87R2PDIF1	Op.phsC	87CR2	C-Phase restrained differential Element 2 picked up
D87RMS1PDIF1	Op.general	87RMS1	RMS differential Element 1 picked up
D87RMS1PDIF1	Op.phsA	87ARMS1	A-Phase rms differential Element 1 picked up
D87RMS1PDIF1	Op.phsB	87BRMS1	B-Phase rms differential Element 1 picked up
D87RMS1PDIF1	Op.phsC	87CRMS1	C-Phase rms differential Element 1 picked up
D87RMS2PDIF1	Op.general	87RMS2	RMS differential Element 2 picked up
D87RMS2PDIF1	Op.phsA	87ARMS2	A-Phase rms differential Element 2 picked up
D87RMS2PDIF1	Op.phsB	87BRMS2	B-Phase rms differential Element 2 picked up
D87RMS2PDIF1	Op.phsC	87CRMS2	C-Phase rms differential Element 2 picked up
D87U1PDIF1	Op.general	87UF1	Filtered unrestrained differential Element 1 picked up
D87U1PDIF1	Op.phsA	87AUF1	A-Phase filtered unrestrained differential Element 1 picked up
D87U1PDIF1	Op.phsB	87BUF1	B-Phase filtered unrestrained differential Element 1 picked up
D87U1PDIF1	Op.phsC	87CUF1	C-Phase filtered unrestrained differential Element 1 picked up
D87U2PDIF1	Op.general	87UF2	Filtered unrestrained differential Element 2 picked up
D87U2PDIF1	Op.phsA	87AUF2	A-Phase filtered unrestrained differential Element 2 picked up
D87U2PDIF1	Op.phsB	87BUF2	B-Phase filtered unrestrained differential Element 2 picked up
D87U2PDIF1	Op.phsC	87CUF2	C-Phase filtered unrestrained differential Element 2 picked up
DC01CILO1	EnaCls.stVal	89ENC01	Disconnect 1 close control operation enabled
DC01CILO1	EnaOpn.stVal	89ENO01	Disconnect 1 open control operation enabled
DC01CSWI1	Pos.stVal	89CL01|89OPN01?0:1:2:3[c]	Disconnect/Isolator 1 status
DC01CSWI1	OpOpn.general	89OPE01	Disconnect Open 1 output
DC01CSWI1	OpCls.general	89CLS01	Disconnect Close 1 output
DC01CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
DC01CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
DC01CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
DC02CILO1	EnaCls.stVal	89ENC02	Disconnect 2 close control operation enabled
DC02CILO1	EnaOpn.stVal	89ENO02	Disconnect 2 open control operation enabled
DC02CSWI1	Pos.stVal	89CL02|89OPN02?0:1:2:3[c]	Disconnect/Isolator 2 status
DC02CSWI1	OpOpn.general	89OPE02	Disconnect Open 2 output
DC02CSWI1	OpCls.general	89CLS02	Disconnect 2 Close 2 output
DC02CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
DC02CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
DC02CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
DC03CILO1	EnaCls.stVal	89ENC03	Disconnect 3 close control operation enabled
DC03CILO1	EnaOpn.stVal	89ENO03	Disconnect 3 open control operation enabled

Table 10.23 Logical Device: PRO (Protection) (Sheet 8 of 23)

Logical Node	Attribute	Data Source	Comment
DC03CSWI1	Pos.stVal	89CL03I89OPN03?0:1:2:3[c]	Disconnect/Isolator 3 status
DC03CSWI1	OpOpn.general	89OPE03	Disconnect Open 3 output
DC03CSWI1	OpCls.general	89CLS03	Disconnect Close 3 output
DC03CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
DC03CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
DC03CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
DC04CILO1	EnaCls.stVal	89ENC04	Disconnect 4 close control operation enabled
DC04CILO1	EnaOpn.stVal	89ENO04	Disconnect 4 open control operation enabled
DC04CSWI1	Pos.stVal	89CL04I89OPN04?0:1:2:3[c]	Disconnect/Isolator 4 status
DC04CSWI1	OpOpn.general	89OPE04	Disconnect Open 4 output
DC04CSWI1	OpCls.general	89CLS04	Disconnect Close 4 output
DC04CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
DC04CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
DC04CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
DC05CILO1	EnaCls.stVal	89ENC05	Disconnect 5 close control operation enabled
DC05CILO1	EnaOpn.stVal	89ENO05	Disconnect 5 open control operation enabled
DC05CSWI1	Pos.stVal	89CL05I89OPN05?0:1:2:3[c]	Disconnect/Isolator 5 status
DC05CSWI1	OpOpn.general	89OPE05	Disconnect Open 5 output
DC05CSWI1	OpCls.general	89CLS05	Disconnect Close 5 output
DC05CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
DC05CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
DC05CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LD in local mode
DC06CILO1	EnaCls.stVal	89ENC06	Disconnect 6 close control operation enabled
DC06CILO1	EnaOpn.stVal	89ENO06	Disconnect 6 open control operation enabled
DC06CSWI1	Pos.stVal	89CL06I89OPN06?0:1:2:3[c]	Disconnect/Isolator 6 status
DC06CSWI1	OpOpn.general	89OPE06	Disconnect Open 6 output
DC06CSWI1	OpCls.general	89CLS06	Disconnect Close 6 output
DC06CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
DC06CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
DC06CSWI1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
DC07CILO1	EnaCls.stVal	89ENC07	Disconnect 7 close control operation enabled
DC07CILO1	EnaOpn.stVal	89ENO07	Disconnect 7 open control operation enabled
DC07CSWI1	Pos.stVal	89CL07I89OPN07?0:1:2:3[c]	Disconnect/Isolator 7 status
DC07CSWI1	OpOpn.general	89OPE07	Disconnect Open 7 output
DC07CSWI1	OpCls.general	89CLS07	Disconnect Close 7 output
DC07CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
DC07CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
DC07CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
DC08CILO1	EnaCls.stVal	89ENC08	Disconnect 8 close control operation enabled
DC08CILO1	EnaOpn.stVal	89ENO08	Disconnect 8 open control operation enabled
DC08CSWI1	Pos.stVal	89CL08I89OPN08?0:1:2:3[c]	Disconnect/Isolator 8 status

Table 10.23 Logical Device: PRO (Protection) (Sheet 9 of 23)

Logical Node	Attribute	Data Source	Comment
DC08CSWI1	OpOpn.general	89OPE08	Disconnect Open 8 output
DC08CSWI1	OpCls.general	89CLS08	Disconnect Close 8 output
DC08CSWI1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
DC08CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
DC08CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
DC09CILO1	EnaCls.stVal	89ENC09	Disconnect 9 close control operation enabled
DC09CILO1	EnaOpn.stVal	89ENO09	Disconnect 9 open control operation enabled
DC09CSWI1	Pos.stVal	89CL09|89OPN09?0:1:2:3[c]	Disconnect/Isolator 9 status
DC09CSWI1	OpOpn.general	89OPE09	Disconnect Open 9 output
DC09CSWI1	OpCls.general	89CLS09	Disconnect Close 9 output
DC09CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
DC09CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
DC09CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
DC10CILO1	EnaCls.stVal	89ENC10	Disconnect 10 close control operation enabled
DC10CILO1	EnaOpn.stVal	89ENO10	Disconnect 10 open control operation enabled
DC10CSWI1	Pos.stVal	89CL10|89OPN10?0:1:2:3[c]	Disconnect/Isolator 10 status
DC10CSWI1	OpOpn.general	89OPE10	Disconnect Open 10 output
DC10CSWI1	OpCls.general	89CLS10	Disconnect Close 10 output
DC10CSWI1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
DC10CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
DC10CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
F641PTOC1	Str.general	64F1	64F instantaneous Level 1 pickup
F641PTOC1	Op.general	64F1T	64F time-delayed Level 1 pickup
F642PTOC1	Str.general	64F2	64F instantaneous Level 2 pickup
F642PTOC1	Op.general	64F2T	64F time-delayed Level 2 pickup
FLTRRDRE1	RcdMade.stVal	FLREP	Event report present
FLTRRDRE1	FltNum.stVal	FLRNUM	Event number
FLTRRDRE1	FltTyp.stVal	FLTYPE[d]	Affected phases for the latest event
FLTRRDRE1	FltCaus.stVal	FLTCAUS	Event cause for the latest event
FOBFSPIOC1	Op.general	FOBFS	Breaker S breaker flashover asserted
FOBFTPIOC1	Op.general	FOBFT	Breaker T breaker flashover asserted
FOBFUPIOC1	Op.general	FOBFU	Breaker U breaker flashover asserted
FOBFYPIOC1	Op.general	FOBFY	Breaker Y breaker flashover asserted
G641PTOC1	Str.general	64G1	64G Element 1 pickup
G641PTOC1	Op.general	64G1T	64G Element 1 delayed pickup
G642PTOC1	Ha3VolAngAlm.stVal	64GAAL	64G third-harmonic angle check alarm
G642PTOC1	Str.general	64G2	64G Element 2 pickup
G642PTOC1	Op.general	64G2T	64G Element 2 delayed pickup
G643PTOC1	Ha3VolAngAlm.stVal	64GAAL	64G third-harmonic angle check alarm
G643PTOC1	Str.general	64G3	64G Element 3 pickup
G643PTOC1	Op.general	64G3T	64G Element 3 delayed pickup

Table 10.23 Logical Device: PRO (Protection) (Sheet 10 of 23)

Logical Node	Attribute	Data Source	Comment
IT01PTOC1	Str.general	51S01	Inverse-time Element 01 picked up
IT01PTOC1	Op.general	51T01	Inverse-time Element 01 timed out
IT02PTOC1	Str.general	51S02	Inverse-time Element 02 picked up
IT02PTOC1	Op.general	51T02	Inverse-time Element 02 timed out
IT03PTOC1	Str.general	51S03	Inverse-time Element 03 picked up
IT03PTOC1	Op.general	51T03	Inverse-time Element 03 timed out
IT04PTOC1	Str.general	51S04	Inverse-time Element 04 picked up
IT04PTOC1	Op.general	51T04	Inverse-time Element 04 timed out
IT05PTOC1	Str.general	51S05	Inverse-time Element 05 picked up
IT05PTOC1	Op.general	51T05	Inverse-time Element 05 timed out
IT06PTOC1	Str.general	51S06	Inverse-time Element 06 picked up
IT06PTOC1	Op.general	51T06	Inverse-time Element 06 timed out
IT07PTOC1	Str.general	51S07	Inverse-time Element 07 picked up
IT07PTOC1	Op.general	51T07	Inverse-time Element 07 timed out
IT08PTOC1	Str.general	51S08	Inverse-time Element 08 picked up
IT08PTOC1	Op.general	51T08	Inverse-time Element 08 timed out
IT09PTOC1	Str.general	51S09	Inverse-time Element 09 picked up
IT09PTOC1	Op.general	51T09	Inverse-time Element 09 timed out
IT10PTOC1	Str.general	51S10	Inverse-time Element 10 picked up
IT10PTOC1	Op.general	51T10	Inverse-time Element 10 timed out
IT11PTOC1	Str.general	51S11	Inverse-time Element 11 picked up
IT11PTOC1	Op.general	51T11	Inverse-time Element 11 timed out
IT12PTOC1	Str.general	51S12	Inverse-time Element 12 picked up
IT12PTOC1	Op.general	51T12	Inverse-time Element 12 timed out
LOPVPTUV1	Str.general	LOPV	Loss-of-potential Terminal V
LOPVPTUV1	Op.general	LOPV	Loss-of-potential Terminal V
LOPZPTUV1	Str.general	LOPZ	Loss-of-potential Terminal Z
LOPZPTUV1	Op.general	LOPZ	Loss-of-potential Terminal Z
N60HPTOC1	Str.general	60NHS	60N high-set level picked up
N60HPTOC1	Op.general	60NHT	60N high-set level timed out
N60LPTOC1	Str.general	60NLS	60N low-set level picked up
N60LPTOC1	Op.general	60NLT	60N low-set level timed out
O1P1PTOV1	Str.general	591P1	Overvoltage Element 1, Level 1 asserted
O1P1PTOV1	Op.general	591P1T	Overvoltage Element 1, Level 1 timed out
O1P2PTOV1	Str.general	591P2	Overvoltage Element 1, Level 2 asserted
O1P2PTOV1	Op.general	591P2T	Overvoltage Element 1, Level 2 timed out
O2P1PTOV1	Str.general	592P1	Overvoltage Element 2, Level 1 asserted
O2P1PTOV1	Op.general	592P1T	Overvoltage Element 2, Level 1 timed out
O2P2PTOV1	Str.general	592P2	Overvoltage Element 2, Level 2 asserted
O2P2PTOV1	Op.general	592P2T	Overvoltage Element 2, Level 2 timed out
O3P1PTOV1	Str.general	593P1	Overvoltage Element 3, Level 1 asserted

Table 10.23 Logical Device: PRO (Protection) (Sheet 11 of 23)

Logical Node	Attribute	Data Source	Comment
O3P1PTOV1	Op.general	593P1T	Overvoltage Element 3, Level 1 timed out
O3P2PTOV1	Str.general	593P2	Overvoltage Element 3, Level 2 asserted
O3P2PTOV1	Op.general	593P2T	Overvoltage Element 3, Level 2 timed out
O4P1PTOV1	Str.general	594P1	Overvoltage Element 4, Level 1 asserted
O4P1PTOV1	Op.general	594P1T	Overvoltage Element 4, Level 1 timed out
O4P2PTOV1	Str.general	594P2	Overvoltage Element 4, Level 2 asserted
O4P2PTOV1	Op.general	594P2T	Overvoltage Element 4, Level 2 timed out
O5P1PTOV1	Str.general	595P1	Overvoltage Element 5, Level 1 asserted
O5P1PTOV1	Op.general	595P1T	Overvoltage Element 5, Level 1 timed out
O5P2PTOV1	Str.general	595P2	Overvoltage Element 5, Level 2 asserted
O5P2PTOV1	Op.general	595P2T	Overvoltage Element 5, Level 2 timed out
O6P1PTOV1	Str.general	596P1	Overvoltage Element 6, Level 1 asserted
O6P1PTOV1	Op.general	596P1T	Overvoltage Element 6, Level 1 timed out
O6P2PTOV1	Str.general	596P2	Overvoltage Element 6, Level 2 asserted
O6P2PTOV1	Op.general	596P2T	Overvoltage Element 6, Level 2 timed out
OSTPPAM1	Str.general	78OOS	Out-of-step protection picked up
OSTPPAM1	Op.general	78OST	Out-of-step protection timed out
P21AB1PDIS1	Str.general	21PAB1P	Zone 1 backup phase distance for AB loop picked up
P21AB1PDIS1	Op.general	21PAB1T	Zone 1 backup phase distance for AB loop timed out
P21AB2PDIS1	Str.general	21PAB2P	Zone 2 backup phase distance for AB loop picked up
P21AB2PDIS1	Op.general	21PAB2T	Zone 2 backup phase distance for AB loop timed out
P21BC1PDIS1	Str.general	21PBC1P	Zone 1 backup phase distance for BC loop picked up
P21BC1PDIS1	Op.general	21PBC1T	Zone 1 backup phase distance for BC loop timed out
P21BC2PDIS1	Str.general	21PBC2P	Zone 2 backup phase distance for BC loop picked up
P21BC2PDIS1	Op.general	21PBC2T	Zone 2 backup phase distance for BC loop timed out
P21CA1PDIS1	Str.general	21PCA1P	Zone 1 backup phase distance for CA loop picked up
P21CA1PDIS1	Op.general	21PCA1T	Zone 1 backup phase distance for CA loop timed out
P21CA2PDIS1	Str.general	21PCA2P	Zone 2 backup phase distance for CA loop picked up
P21CA2PDIS1	Op.general	21PCA2T	Zone 2 backup phase distance for CA loop timed out
P21TZ1PDIS1	Str.general	CSV01	21PAB1P OR 21PBC1P OR 21PCA1P
P21TZ1PDIS1	Op.general	21PZ1T	Zone 1 backup phase distance timed out
P21TZ2PDIS1	Str.general	CSV02	21PAB2P OR 21PBC2P OR 21PCA2P
P21TZ2PDIS1	Op.general	21PZ2T	Zone 2 backup phase distance timed out
P40P1PDUP1	Str.general	40P1	Loss-of-field PQ Zone 1 picked up
P40P1PDUP1	Op.general	40P1T	Loss-of-field PQ Zone 1 timed out
P40P2PDUP1	Str.general	40P2	Loss-of-field PQ Zone 2 picked up
P40P2PDUP1	Op.general	40P2T	Loss-of-field PQ Zone 2 timed out
P40P3PDUP1	Str.general	40P3	Steady-state stability limit Zone 3 picked up
P40P3PDUP1	Op.general	40P3T	Steady-state stability limit Zone 3 timed out
P40P4PDUP1	Str.general	40P4	Capability curve limit Zone 4 picked up
P40P4PDUP1	Op.general	40P4T	Capability curve limit Zone 4 timed out

Table 10.23 Logical Device: PRO (Protection) (Sheet 12 of 23)

Logical Node	Attribute	Data Source	Comment
P51CPVOC1	Str.general	51C	Voltage-controlled instantaneous OC picked up
P51CPVOC1	Str.phsA	51CA	A-Phase, voltage-controlled instantaneous OC picked up
P51CPVOC1	Str.phsB	51CB	B-Phase, voltage-controlled instantaneous OC picked up
P51CPVOC1	Str.phsC	51CC	C-Phase, voltage-controlled instantaneous OC picked up
P51CPVOC1	Op.general	51CT	Voltage-controlled OC timed out
P51CPVOC1	Op.phsA	51CAT	A-Phase, voltage-controlled OC timed out
P51CPVOC1	Op.phsB	51CBT	B-Phase, voltage-controlled OC timed out
P51CPVOC1	Op.phsC	51CCT	C-Phase, voltage-controlled OC timed out
P51VPVOC1	Str.general	51V	Voltage-restrained instantaneous OC picked up
P51VPVOC1	Str.phsA	51VA	A-Phase, voltage-restrained instantaneous OC picked up
P51VPVOC1	Str.phsB	51VB	B-Phase, voltage-restrained instantaneous OC picked up
P51VPVOC1	Str.phsC	51VC	C-Phase, voltage-restrained instantaneous OC picked up
P51VPVOC1	Op.general	51VT	Voltage-restrained OC timed out
P51VPVOC1	Op.phsA	51VAT	A-Phase, voltage-restrained OC timed out
P51VPVOC1	Op.phsB	51VBT	B-Phase, voltage-restrained OC timed out
P51VPVOC1	Op.phsC	51VCT	C-Phase, voltage-restrained OC timed out
P60HAPTOC1	Str.general	60PAHS	60P A-Phase high-set level picked up
P60HAPTOC1	Op.general	60PAHT	60P A-Phase high-set level timed out
P60HBPTOC1	Str.general	60PBHS	60P B-Phase high-set level picked up
P60HBPTOC1	Op.general	60PBHT	60P B-Phase high-set level timed out
P60HCPTOC1	Str.general	60PCHS	60P C-Phase high-set level picked up
P60HCPTOC1	Op.general	60PCHT	60P C-Phase high-set level timed out
P60LAPTOC1	Str.general	60PALS	60P A-Phase low-set level picked up
P60LAPTOC1	Op.general	60PALT	60P A-Phase low-set level timed out
P60LBPTOC1	Str.general	60PBLS	60P B-Phase low-set level picked up
P60LBPTOC1	Op.general	60PBLT	60P B-Phase low-set level timed out
P60LCPTOC1	Str.general	60PCLS	60P C-Phase low-set level picked up
P60LCPTOC1	Op.general	60PCLT	60P C-Phase low-set level timed out
PROLPHD1	PhyHealth.stVal	EN?3:1[e]	Relay enabled
Q4611PTOC1	Str.general	46Q11	Generator current unbalance Element 1 Level 1 picked up
Q4611PTOC1	Op.general	46Q1T1	Generator current unbalance Element 1 Level 1 timed out
Q4612PTOC1	Str.general	46Q12	Generator current unbalance Element 1 Level 2 picked up
Q4612PTOC1	Op.general	46Q1T2	Generator current unbalance Element 1 Level 2 timed out
Q4621PTOC1	Str.general	46Q21	Generator current unbalance Element 2 Level 1 picked up
Q4621PTOC1	Op.general	46Q2T1	Generator current unbalance Element 2 Level 1 timed out
Q4622PTOC1	Str.general	46Q22	Generator current unbalance Element 2 Level 2 picked up
Q4622PTOC1	Op.general	46Q2T2	Generator current unbalance Element 2 Level 2 timed out
R1PFRC1	Str.general	81R1	Definite-time rate-of-change-of-frequency element picked up, Level 1
R1PFRC1	Op.general	81R1T	Definite-time over/under rate-of-change-of-frequency element delay for Level 1

Table 10.23 Logical Device: PRO (Protection) (Sheet 13 of 23)

Logical Node	Attribute	Data Source	Comment
R2PFRC1	Str.general	81R2	Definite-time rate-of-change-of-frequency element picked up, Level 2
R2PFRC1	Op.general	81R2T	Definite-time over/under rate-of-change-of-frequency element delay for Level 2
R3PFRC1	Str.general	81R3	Definite-time rate-of-change-of-frequency element picked up, Level 3
R3PFRC1	Op.general	81R3T	Definite-time over/under rate-of-change-of-frequency element delay for Level 3
R4901S1PTTR1	Op.general	49R01S1	RTD Element 01 Level 1 asserted
R4901S2PTTR1	Op.general	49R01S2	RTD Element 01 Level 2 asserted
R4902S1PTTR1	Op.general	49R02S1	RTD Element 02 Level 1 asserted
R4902S2PTTR1	Op.general	49R02S2	RTD Element 02 Level 2 asserted
R4903S1PTTR1	Op.general	49R03S1	RTD Element 03 Level 1 asserted
R4903S2PTTR1	Op.general	49R03S2	RTD Element 03 Level 2 asserted
R4904S1PTTR1	Op.general	49R04S1	RTD Element 04 Level 1 asserted
R4904S2PTTR1	Op.general	49R04S2	RTD Element 04 Level 2 asserted
R4905S1PTTR1	Op.general	49R05S1	RTD Element 05 Level 1 asserted
R4905S2PTTR1	Op.general	49R05S2	RTD Element 05 Level 2 asserted
R4906S1PTTR1	Op.general	49R06S1	RTD Element 06 Level 1 asserted
R4906S2PTTR1	Op.general	49R06S2	RTD Element 06 Level 2 asserted
R4907S1PTTR1	Op.general	49R07S1	RTD Element 07 Level 1 asserted
R4907S2PTTR1	Op.general	49R07S2	RTD Element 07 Level 2 asserted
R4908S1PTTR1	Op.general	49R08S1	RTD Element 08 Level 1 asserted
R4908S2PTTR1	Op.general	49R08S2	RTD Element 08 Level 2 asserted
R4909S1PTTR1	Op.general	49R09S1	RTD Element 09 Level 1 asserted
R4909S2PTTR1	Op.general	49R09S2	RTD Element 09 Level 2 asserted
R4910S1PTTR1	Op.general	49R10S1	RTD Element 10 Level 1 asserted
R4910S2PTTR1	Op.general	49R10S2	RTD Element 10 Level 2 asserted
R4911S1PTTR1	Op.general	49R11S1	RTD Element 11 Level 1 asserted
R4911S2PTTR1	Op.general	49R11S2	RTD Element 11 Level 2 asserted
R4912S1PTTR1	Op.general	49R12S1	RTD Element 12 Level 1 asserted
R4912S2PTTR1	Op.general	49R12S2	RTD Element 12 Level 2 asserted
R49VTL1PTTR1	Op.general	49RLV1P	RTD element Location 1 voted trip asserted
R49VTL2PTTR1	Op.general	49RLV2P	RTD element Location 2 voted trip asserted
R49VTL3PTTR1	Op.general	49RLV3P	RTD element Location 3 voted trip asserted
R49VTL4PTTR1	Op.general	49RLV4P	RTD element Location 4 voted trip asserted
R4PFRC1	Str.general	81R4	Definite-time rate-of-change-of-frequency element picked up, Level 4
R4PFRC1	Op.general	81R4T	Definite-time over/under rate-of-change-of-frequency element delay for Level 4
R5PFRC1	Str.general	81R5	Definite-time rate-of-change-of-frequency element picked up, Level 5
R5PFRC1	Op.general	81R5T	Definite-time over/under rate-of-change-of-frequency element delay for Level 5

Table 10.23 Logical Device: PRO (Protection) (Sheet 14 of 23)

Logical Node	Attribute	Data Source	Comment
R6PFRC1	Str.general	81R6	Definite-time rate-of-change-of-frequency element picked up, Level 6
R6PFRC1	Op.general	81R6T	Definite-time over/under rate-of-change-of-frequency element delay for Level 6
REF501PIOC1	Str.general	REF501	Neutral instantaneous overcurrent Element 1 picked up
REF501PIOC1	Op.general	REF50T1	Neutral instantaneous overcurrent Element 1 timed out
REF502PIOC1	Str.general	REF502	Neutral instantaneous overcurrent Element 2 picked up
REF502PIOC1	Op.general	REF50T2	Neutral instantaneous overcurrent Element 2 timed out
REF503PIOC1	Str.general	REF503	Neutral instantaneous overcurrent Element 3 picked up
REF503PIOC1	Op.general	REF50T3	Neutral instantaneous overcurrent Element 3 timed out
REF511PTOC1	Str.general	REF511	REF Element 1 TOC element picked up
REF511PTOC1	Op.general	REF51T1	REF Element 1 TOC element timed out
REF512PTOC1	Str.general	REF512	REF Element 2 TOC element picked up
REF512PTOC1	Op.general	REF51T2	REF Element 2 TOC element timed out
REF513PTOC1	Str.general	REF513	REF Element 3 TOC element picked up
REF513PTOC1	Op.general	REF51T3	REF Element 3 TOC element timed out
REFF1PDIF1	Op.general	REFF1	Earth fault inside restricted Zone 1
REFF2PDIF1	Op.general	REFF2	Earth fault inside restricted Zone 2
REFF3PDIF1	Op.general	REFF3	Earth fault inside restricted Zone 3
REFPDIF1	Op.general	REF	Earth fault inside REF Element 1, 2, or 3 zones
REFR1PDIF1	Op.general	REFR1	Earth fault outside restricted Zone 1
REFR2PDIF1	Op.general	REFR2	Earth fault outside restricted Zone 2
REFR3PDIF1	Op.general	REFR3	Earth fault outside restricted Zone 3
S52AXCBR1	Loc.stVal	LOCAL	Control authority at local (bay) level
S52AXCBR1	Pos.stVal	52CLS?1:2[f]	Breaker closed, Terminal S
S52AXCBR1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
S641PTOC1	Str.general	64S1	64S instantaneous Level 1 pickup
S641PTOC1	Op.general	64S1T	64S time-delayed Level 1 pickup
S642PTOC1	Str.general	64S2	64S instantaneous Level 2 pickup
S642PTOC1	Op.general	64S2T	64S time-delayed Level 2 pickup
SBKRCILO1	EnaCls.stVal	BKENCS	Circuit Breaker S close control operation enabled
SBKRCILO1	EnaOpn.stVal	BKENOS	Circuit Breaker S open control operation enabled
SBKRCSWI1	ColOpn.stVal	OCS	Breaker open command, Terminal S
SBKRCSWI1	Loc.stVal	LOC	Control authority at local (bay) level
SBKRCSWI1	LocSta.stVal	LOCSTA	Control authority at station level
SBKRCSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
SBKRCSWI1	Pos.stVal	52CLS?1:2[f]	Breaker closed, Terminal S
SBKRCSWI1	OpCls.general	CCS	Breaker close command, Terminal S
SG1PIOC1	Op.general	50SG1	Residual definite-time Element 1, Terminal S asserted
SG1PTOC1	Str.general	67SG1	Residual directional/torque-controlled Element 1, Terminal S picked up

Table 10.23 Logical Device: PRO (Protection) (Sheet 15 of 23)

Logical Node	Attribute	Data Source	Comment
SG1PTOC1	Op.general	67SG1T	Residual directional/torque-controlled Element 1, Terminal S timed out
SG2PIOC1	Op.general	50SG2	Residual definite-time Element 2, Terminal S asserted
SG2PTOC1	Str.general	67SG2	Residual directional/torque-controlled Element 2, Terminal S picked up
SG2PTOC1	Op.general	67SG2T	Residual directional/torque-controlled Element 2, Terminal S timed out
SG3PIOC1	Op.general	50SG3	Residual definite-time Element 3, Terminal S asserted
SG3PTOC1	Str.general	67SG3	Residual directional/torque-controlled Element 3, Terminal S picked up
SG3PTOC1	Op.general	67SG3T	Residual directional/torque-controlled Element 3, Terminal S timed out
SP1PIOC1	Op.general	50SP1	Phase definite-time Element 1, Terminal S asserted
SP1PTOC1	Str.general	67SP1	Phase directional/torque-controlled Element 1, Terminal S picked up
SP1PTOC1	Op.general	67SP1T	Phase directional/torque-controlled Element 1, Terminal S timed out
SP2PIOC1	Op.general	50SP2	Phase definite-time Element 2, Terminal S asserted
SP2PTOC1	Str.general	67SP2	Phase directional/torque-controlled Element 2, Terminal S picked up
SP2PTOC1	Op.general	67SP2T	Phase directional/torque-controlled Element 2, Terminal S timed out
SP3PIOC1	Op.general	50SP3	Phase definite-time Element 3, Terminal S asserted
SP3PTOC1	Str.general	67SP3	Phase directional/torque-controlled Element 3, Terminal S picked up
SP3PTOC1	Op.general	67SP3T	Phase directional/torque-controlled Element 3, Terminal S timed out
SQ1PIOC1	Op.general	50SQ1	Negative-sequence definite-time Element 1, Terminal S asserted
SQ1PTOC1	Str.general	67SQ1	Negative-sequence directional/torque-controlled Element 1, Terminal S picked up
SQ1PTOC1	Op.general	67SQ1T	Negative-sequence directional/torque-controlled Element 1, Terminal S timed out
SQ2PIOC1	Op.general	50SQ2	Negative-sequence definite-time Element 2, Terminal S asserted
SQ2PTOC1	Str.general	67SQ2	Negative-sequence directional/torque-controlled Element 2, Terminal S picked up
SQ2PTOC1	Op.general	67SQ2T	Negative-sequence directional/torque-controlled Element 2, Terminal S timed out
SQ3PIOC1	Op.general	50SQ3	Negative-sequence definite-time Element 3, Terminal S asserted
SQ3PTOC1	Str.general	67SQ3	Negative-sequence directional/torque-controlled Element 3, Terminal S picked up
SQ3PTOC1	Op.general	67SQ3T	Negative-sequence directional/torque-controlled Element 3, Terminal S timed out
T52AXCBR1	Loc.stVal	LOCAL	Control authority at local (bay) level
T52AXCBR1	Pos.stVal	52CLT?1:2[f]	Breaker closed, Terminal T
T52AXCBR1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode

Table 10.23 Logical Device: PRO (Protection) (Sheet 16 of 23)

Logical Node	Attribute	Data Source	Comment
TBKRCILO1	EnaCls.stVal	BKENCT	Circuit Breaker T close control operation enabled
TBKRCILO1	EnaOpn.stVal	BKENOT	Circuit Breaker T open control operation enabled
TBKRCSWI1	ColOpn.stVal	OCT	Breaker open command, Terminal T
TBKRCSWI1	Loc.stVal	LOC	Control authority at local (bay) level
TBKRCSWI1	LocSta.stVal	LOCSTA	Control authority at station level
TBKRCSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
TBKRCSWI1	Pos.stVal	52CLT?1:2[f]	Breaker closed, Terminal T
TBKRCSWI1	OpCls.general	CCT	Breaker close command, Terminal T
TG1PIOC1	Op.general	50TG1	Residual definite-time Element 1, Terminal T asserted
TG1PTOC1	Str.general	67TG1	Residual directional/torque-controlled Element 1, Terminal T picked up
TG1PTOC1	Op.general	67TG1T	Residual directional/torque-controlled Element 1, Terminal T timed out
TG2PIOC1	Op.general	50TG2	Residual definite-time Element 2, Terminal T asserted
TG2PTOC1	Str.general	67TG2	Residual directional/torque-controlled Element 2, Terminal T picked up
TG2PTOC1	Op.general	67TG2T	Residual directional/torque-controlled Element 2, Terminal T timed out
TG3PIOC1	Op.general	50TG3	Residual definite-time Element 3, Terminal T asserted
TG3PTOC1	Str.general	67TG3	Residual directional/torque-controlled Element 3, Terminal T picked up
TG3PTOC1	Op.general	67TG3T	Residual directional/torque-controlled Element 3, Terminal T timed out
TP1PIOC1	Op.general	50TP1	Phase definite-time Element 1, Terminal T asserted
TP1PTOC1	Str.general	67TP1	Phase directional/torque-controlled Element 1, Terminal T picked up
TP1PTOC1	Op.general	67TP1T	Phase directional/torque-controlled Element 1, Terminal T timed out
TP2PIOC1	Op.general	50TP2	Phase definite-time Element 2, Terminal T asserted
TP2PTOC1	Str.general	67TP2	Phase directional/torque-controlled Element 2, Terminal T picked up
TP2PTOC1	Op.general	67TP2T	Phase directional/torque-controlled Element 2, Terminal T timed out
TP3PIOC1	Op.general	50TP3	Phase definite-time Element 3, Terminal T asserted
TP3PTOC1	Str.general	67TP3	Phase directional/torque-controlled Element 3, Terminal T picked up
TP3PTOC1	Op.general	67TP3T	Phase directional/torque-controlled Element 3, Terminal T timed out
TQ1PIOC1	Op.general	50TQ1	Negative-sequence definite-time Element 1, Terminal T asserted
TQ1PTOC1	Str.general	67TQ1	Negative-sequence directional/torque-controlled Element 1, Terminal T picked up
TQ1PTOC1	Op.general	67TQ1T	Negative-sequence directional/torque-controlled Element 1, Terminal T timed out
TQ2PIOC1	Op.general	50TQ2	Negative-sequence definite-time Element 2, Terminal T asserted

Table 10.23 Logical Device: PRO (Protection) (Sheet 17 of 23)

Logical Node	Attribute	Data Source	Comment
TQ2PTOC1	Str.general	67TQ2	Negative-sequence directional/torque-controlled Element 2, Terminal T picked up
TQ2PTOC1	Op.general	67TQ2T	Negative-sequence directional/torque-controlled Element 2, Terminal T timed out
TQ3PIOC1	Op.general	50TQ3	Negative-sequence definite-time Element 3, Terminal T asserted
TQ3PTOC1	Str.general	67TQ3	Negative-sequence directional/torque-controlled Element 3, Terminal T picked up
TQ3PTOC1	Op.general	67TQ3T	Negative-sequence directional/torque-controlled Element 3, Terminal T timed out
TRIPAUXPTRC1	Tr.general	TRIPAUX	Trip generator auxiliary asserted
TRIPEXPTRC1	Tr.general	TRIPEX	Trip generator exciter asserted
TRIPPMPTRC1	Tr.general	TRIPPM	Trip generator prime mover asserted
TRIPPTRC1	Tr.general	TRIP	General trip asserted
TRIPSPTRC1	Tr.general	TRIPS	Trip Breaker S asserted
TRIPTPTRC1	Tr.general	TRIPT	Trip Breaker T asserted
TRIPUPTRC1	Tr.general	TRIPU	Trip Breaker U asserted
TRIPYPTRC1	Tr.general	TRIPY	Trip Breaker Y asserted
U1P1PTUV1	Str.general	271P1	Undervoltage Element 1, Level 1 asserted
U1P1PTUV1	Op.general	271P1T	Undervoltage Element 1, Level 1 timed out
U1P2PTUV1	Str.general	271P2	Undervoltage Element 1, Level 2 asserted
U1P2PTUV1	Op.general	271P2T	Undervoltage Element 1, Level 2 timed out
U2P1PTUV1	Str.general	272P1	Undervoltage Element 2, Level 1 asserted
U2P1PTUV1	Op.general	272P1T	Undervoltage Element 2, Level 1 timed out
U2P2PTUV1	Str.general	272P2	Undervoltage Element 2, Level 2 asserted
U2P2PTUV1	Op.general	272P2T	Undervoltage Element 2, Level 2 timed out
U3P1PTUV1	Str.general	273P1	Undervoltage Element 3, Level 1 asserted
U3P1PTUV1	Op.general	273P1T	Undervoltage Element 3, Level 1 timed out
U3P2PTUV1	Str.general	273P2	Undervoltage Element 3, Level 2 asserted
U3P2PTUV1	Op.general	273P2T	Undervoltage Element 3, Level 2 timed out
U4P1PTUV1	Str.general	274P1	Undervoltage Element 4, Level 1 asserted
U4P1PTUV1	Op.general	274P1T	Undervoltage Element 4, Level 1 timed out
U4P2PTUV1	Str.general	274P2	Undervoltage Element 4, Level 2 asserted
U4P2PTUV1	Op.general	274P2T	Undervoltage Element 4, Level 2 timed out
U52AXCBR1	Loc.stVal	LOCAL	Control authority at local (bay) level
U52AXCBR1	Pos.stVal	52CLU?1:2[f]	Breaker closed, Terminal U
U52AXCBR1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
U5P1PTUV1	Str.general	275P1	Undervoltage Element 5, Level 1 asserted
U5P1PTUV1	Op.general	275P1T	Undervoltage Element 5, Level 1 timed out
U5P2PTUV1	Str.general	275P2	Undervoltage Element 5, Level 2 asserted
U5P2PTUV1	Op.general	275P2T	Undervoltage Element 5, Level 2 timed out
U6P1PTUV1	Str.general	276P1	Undervoltage Element 6, Level 1 asserted
U6P1PTUV1	Op.general	276P1T	Undervoltage Element 6, Level 1 timed out

Table 10.23 Logical Device: PRO (Protection) (Sheet 18 of 23)

Logical Node	Attribute	Data Source	Comment
U6P2PTUV1	Str.general	276P2	Undervoltage Element 6, Level 2 asserted
U6P2PTUV1	Op.general	276P2T	Undervoltage Element 6, Level 2 timed out
UBKRCILO1	EnaCls.stVal	BKENCU	Circuit Breaker U close control operation enabled
UBKRCILO1	EnaOpn.stVal	BKENOU	Circuit Breaker U open control operation enabled
UBKRCSWI1	ColOpn.stVal	OCU	Breaker open command, Terminal U
UBKRCSWI1	Loc.stVal	LOC	Control authority at local (bay) level
UBKRCSWI1	LocSta.stVal	LOCSTA	Control authority at station level
UBKRCSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
UBKRCSWI1	Pos.stVal	52CLU?1:2[f]	Breaker closed, Terminal U
UBKRCSWI1	OpCls.general	CCU	Breaker close command, Terminal U
UG1PIOC1	Op.general	50UG1	Residual definite-time Element 1, Terminal U asserted
UG1PTOC1	Str.general	67UG1	Residual directional/torque-controlled Element 1, Terminal U picked up
UG1PTOC1	Op.general	67UG1T	Residual directional/torque-controlled Element 1, Terminal U timed out
UG2PIOC1	Op.general	50UG2	Residual definite-time Element 2, Terminal U asserted
UG2PTOC1	Str.general	67UG2	Residual directional/torque-controlled Element 2, Terminal U picked up
UG2PTOC1	Op.general	67UG2T	Residual directional/torque-controlled Element 2, Terminal U timed out
UG3PIOC1	Op.general	50UG3	Residual definite-time Element 3, Terminal U asserted
UG3PTOC1	Str.general	67UG3	Residual directional/torque-controlled Element 3, Terminal U picked up
UG3PTOC1	Op.general	67UG3T	Residual directional/torque-controlled Element 3, Terminal U timed out
UP1PIOC1	Op.general	50UP1	Phase definite-time Element 1, Terminal U asserted
UP1PTOC1	Str.general	67UP1	Phase directional/torque-controlled Element 1, Terminal U picked up
UP1PTOC1	Op.general	67UP1T	Phase directional/torque-controlled Element 1, Terminal U timed out
UP2PIOC1	Op.general	50UP2	Phase definite-time Element 2, Terminal U asserted
UP2PTOC1	Str.general	67UP2	Phase directional/torque-controlled Element 2, Terminal U picked up
UP2PTOC1	Op.general	67UP2T	Phase directional/torque-controlled Element 2, Terminal U timed out
UP3PIOC1	Op.general	50UP3	Phase definite-time Element 3, Terminal U asserted
UP3PTOC1	Str.general	67UP3	Phase directional/torque-controlled Element 3, Terminal U picked up
UP3PTOC1	Op.general	67UP3T	Phase directional/torque-controlled Element 3, Terminal U timed out
UQ1PIOC1	Op.general	50UQ1	Negative-sequence definite-time Element 1, Terminal U asserted
UQ1PTOC1	Str.general	67UQ1	Negative-sequence directional/torque-controlled Element 1, Terminal U picked up
UQ1PTOC1	Op.general	67UQ1T	Negative-sequence directional/torque-controlled Element 1, Terminal U timed out

Table 10.23 Logical Device: PRO (Protection) (Sheet 19 of 23)

Logical Node	Attribute	Data Source	Comment
UQ2PIOC1	Op.general	50UQ2	Negative-sequence definite-time Element 2, Terminal U asserted
UQ2PTOC1	Str.general	67UQ2	Negative-sequence directional/torque-controlled Element 2, Terminal U picked up
UQ2PTOC1	Op.general	67UQ2T	Negative-sequence directional/torque-controlled Element 2, Terminal U timed out
UQ3PIOC1	Op.general	50UQ3	Negative-sequence definite-time Element 3, Terminal U asserted
UQ3PTOC1	Str.general	67UQ3	Negative-sequence directional/torque-controlled Element 3, Terminal U picked up
UQ3PTOC1	Op.general	67UQ3T	Negative-sequence directional/torque-controlled Element 3, Terminal U timed out
WB871PDIF1	Op.general	87WB1	87 waveshape inrush blocking logic asserted, Element 1
WB871PDIF1	Op.phsA	87WBA1	87 waveshape inrush blocking logic asserted, A-Phase, Element 1
WB871PDIF1	Op.phsB	87WBB1	87 waveshape inrush blocking logic asserted, B-Phase, Element 1
WB871PDIF1	Op.phsC	87WBC1	87 waveshape inrush blocking logic asserted, C-Phase, Element 1
WB872PDIF1	Op.general	87WB2	87 waveshape inrush blocking logic asserted, Element 2
WB872PDIF1	Op.phsA	87WBA2	87 waveshape inrush blocking logic asserted, A-Phase, Element 2
WB872PDIF1	Op.phsB	87WBB2	87 waveshape inrush blocking logic asserted, B-Phase, Element 2
WB872PDIF1	Op.phsC	87WBC2	87 waveshape inrush blocking logic asserted, C-Phase, Element 2
X89CL01XSWI1	Pos.stVal	89CL01?1:2[f]	Disconnect 1 closed
X89CL01XSWI1	Loc.stVal	LOCAL	Control authority at local (bay) level
X89CL01XSWI1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X89CL02XSWI1	Pos.stVal	89CL02?1:2[f]	Disconnect 2 closed
X89CL02XSWI1	Loc.stVal	LOCAL	Control authority at local (bay) level
X89CL02XSWI1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X89CL03XSWI1	Pos.stVal	89CL03?1:2[f]	Disconnect 3 closed
X89CL03XSWI1	Loc.stVal	LOCAL	Control authority at local (bay) level
X89CL03XSWI1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X89CL04XSWI1	Pos.stVal	89CL04?1:2[f]	Disconnect 4 closed
X89CL04XSWI1	Loc.stVal	LOCAL	Control authority at local (bay) level
X89CL04XSWI1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X89CL05XSWI1	Pos.stVal	89CL05?1:2[f]	Disconnect 5 closed
X89CL05XSWI1	Loc.stVal	LOCAL	Control authority at local (bay) level
X89CL05XSWI1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X89CL06XSWI1	Pos.stVal	89CL06?1:2[f]	Disconnect 6 closed
X89CL06XSWI1	Loc.stVal	LOCAL	Control authority at local (bay) level
X89CL06XSWI1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X89CL07XSWI1	Pos.stVal	89CL07?1:2[f]	Disconnect 7 closed

Table 10.23 Logical Device: PRO (Protection) (Sheet 20 of 23)

Logical Node	Attribute	Data Source	Comment
X89CL07XSWI1	Loc.stVal	LOCAL	Control authority at local (bay) level
X89CL07XSWI1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X89CL08XSWI1	Pos.stVal	89CL08?1:2[f]	Disconnect 8 closed
X89CL08XSWI1	Loc.stVal	LOCAL	Control authority at local (bay) level
X89CL08XSWI1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X89CL09XSWI1	Pos.stVal	89CL09?1:2[f]	Disconnect 9 closed
X89CL09XSWI1	Loc.stVal	LOCAL	Control authority at local (bay) level
X89CL09XSWI1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X89CL10XSWI1	Pos.stVal	89CL10?1:2[f]	Disconnect 10 closed
X89CL10XSWI1	Loc.stVal	LOCAL	Control authority at local (bay) level
X89CL10XSWI1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
Y52AXCBR1	Loc.stVal	LOCAL	Control authority at local (bay) level
Y52AXCBR1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
Y52AXCBR1	Pos.stVal	52CLY?1:2[f]	Breaker closed, Terminal Y
YBKRCILO1	EnaCls.stVal	BKENCY	Circuit Breaker Y close control operation enabled
YBKRCILO1	EnaOpn.stVal	BKENOY	Circuit Breaker Y open control operation enabled
YBKRCSWI1	ColOpn.stVal	OCY	Breaker open command, Terminal Y
YBKRCSWI1	Loc.stVal	LOC	Control authority at local (bay) level
YBKRCSWI1	LocSta.stVal	LOCSTA	Control authority at station level
YBKRCSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
YBKRCSWI1	Pos.stVal	52CLY?1:2[f]	Breaker closed, Terminal Y
YBKRCSWI1	OpCls.general	CCY	Breaker close command, Terminal Y
YG1PIOC1	Op.general	50YG1	Residual definite-time Element 1, Terminal Y asserted
YG1PTOC1	Str.general	67YG1	Residual directional/torque-controlled Element 1, Terminal Y picked up
YG1PTOC1	Op.general	67YG1T	Residual directional/torque-controlled Element 1, Terminal Y timed out
YG2PIOC1	Op.general	50YG2	Residual definite-time Element 2, Terminal Y asserted
YG2PTOC1	Str.general	67YG2	Residual directional/torque-controlled Element 2, Terminal Y picked up
YG2PTOC1	Op.general	67YG2T	Residual directional/torque-controlled Element 2, Terminal Y timed out
YG3PIOC1	Op.general	50YG3	Residual definite-time Element 3, Terminal Y asserted
YG3PTOC1	Str.general	67YG3	Residual directional/torque-controlled Element 3, Terminal Y picked up
YG3PTOC1	Op.general	67YG3T	Residual directional/torque-controlled Element 3, Terminal Y timed out
YP1PIOC1	Op.general	50YP1	Phase definite-time Element 1, Terminal Y asserted
YP1PTOC1	Str.general	67YP1	Phase directional/torque-controlled Element 1, Terminal Y picked up
YP1PTOC1	Op.general	67YP1T	Phase directional/torque-controlled Element 1, Terminal Y timed out
YP2PIOC1	Op.general	50YP2	Phase definite-time Element 2, Terminal Y asserted

Table 10.23 Logical Device: PRO (Protection) (Sheet 21 of 23)

Logical Node	Attribute	Data Source	Comment
YP2PTOC1	Str.general	67YP2	Phase directional/torque-controlled Element 2, Terminal Y picked up
YP2PTOC1	Op.general	67YP2T	Phase directional/torque-controlled Element 2, Terminal Y timed out
YP3PIOC1	Op.general	50YP3	Phase definite-time Element 3, Terminal Y asserted
YP3PTOC1	Str.general	67YP3	Phase directional/torque-controlled Element 3, Terminal Y picked up
YP3PTOC1	Op.general	67YP3T	Phase directional/torque-controlled Element 3, Terminal Y timed out
YQ1PIOC1	Op.general	50YQ1	Negative-sequence definite-time Element 1, Terminal Y asserted
YQ1PTOC1	Str.general	67YQ1	Negative-sequence directional/torque-controlled Element 1, Terminal Y picked up
YQ1PTOC1	Op.general	67YQ1T	Negative-sequence directional/torque-controlled Element 1, Terminal Y timed out
YQ2PIOC1	Op.general	50YQ2	Negative-sequence definite-time Element 2, Terminal Y asserted
YQ2PTOC1	Str.general	67YQ2	Negative-sequence directional/torque-controlled Element 2, Terminal Y picked up
YQ2PTOC1	Op.general	67YQ2T	Negative-sequence directional/torque-controlled Element 2, Terminal Y timed out
YQ3PIOC1	Op.general	50YQ3	Negative-sequence definite-time Element 3, Terminal Y asserted
YQ3PTOC1	Str.general	67YQ3	Negative-sequence directional/torque-controlled Element 3, Terminal Y picked up
YQ3PTOC1	Op.general	67YQ3T	Negative-sequence directional/torque-controlled Element 3, Terminal Y timed out
Z40P1PDUP1	Str.general	40Z1	Loss-of-field Zone 1 picked up
Z40P1PDUP1	Op.general	40Z1T	Loss-of-field Zone 1 timed out
Z40P2PDUP1	Str.general	40Z2	Loss-of-field Zone 2 picked up
Z40P2PDUP1	Op.general	40Z2T	Loss-of-field Zone 2 timed out
Functional Constraint = MX			
BKSACSYN1	DifAngClc.instMag.f	25ANGS	25 sync-check angle difference for Breaker S
BKSACSYN1	DifHzClc.instMag.f	25SLIPS	25 sync-check slip frequency Breaker S
BKSACSYN1	V2Clc.instMag.f	25VSSFM	25 sync-check synchronizing voltage magnitude for Breaker S
BKSACSYN1	V1Clc.instMag.f	25VPFM	25 sync-check polarizing voltage magnitude
BKSCCSYN1	DifHzClc.instMag.f	25SLIPS	25 sync-check slip frequency Breaker S
BKSCCSYN1	V1Clc.instMag.f	25VPFM	25 sync-check polarizing voltage magnitude
BKSCCSYN1	V2Clc.instMag.f	25VSSFM	25 sync-check synchronizing voltage magnitude for Breaker S
BKSCCSYN1	DifAngClc.instMag.f	25ANGCS	25 sync-check compensated angle difference for Breaker S
BKTACSYN1	DifAngClc.instMag.f	25ANGT	25 sync-check angle difference for Breaker T
BKTACSYN1	DifHzClc.instMag.f	25SLIPT	25 sync-check slip frequency Breaker T
BKTACSYN1	V2Clc.instMag.f	25VSTFM	25 sync-check synchronizing voltage magnitude for Breaker T
BKTACSYN1	V1Clc.instMag.f	25VPFM	25 sync-check polarizing voltage magnitude
BKTCCSYN1	V1Clc.instMag.f	25VPFM	25 sync-check polarizing voltage magnitude

Table 10.23 Logical Device: PRO (Protection) (Sheet 22 of 23)

Logical Node	Attribute	Data Source	Comment
BKTCCSYN1	DifHzClc.instMag.f	25SLIPT	25 sync-check slip frequency Breaker T
BKTCCSYN1	V2Clc.instMag.f	25VSTFM	25 sync-check synchronizing voltage magnitude for Breaker T
BKTCCSYN1	DifAngClc.instMag.f	25ANGCT	25 sync-check compensated angle difference for Breaker T
BKUACSYN1	DifAngClc.instMag.f	25ANGU	25 sync-check angle difference for Breaker U
BKUACSYN1	DifHzClc.instMag.f	25SLIPU	25 sync-check slip frequency Breaker U
BKUACSYN1	V2Clc.instMag.f	25VSUFM	25 sync-check synchronizing voltage magnitude for Breaker U
BKUACSYN1	V1Clc.instMag.f	25VPFM	25 sync-check polarizing voltage magnitude
BKUCCSYN1	V1Clc.instMag.f	25VPFM	25 sync-check polarizing voltage magnitude
BKUCCSYN1	DifHzClc.instMag.f	25SLIPU	25 sync-check slip frequency Breaker U
BKUCCSYN1	V2Clc.instMag.f	25VSUFM	25 sync-check synchronizing voltage magnitude for Breaker U
BKUCCSYN1	DifAngClc.instMag.f	25ANGCU	25 sync-check compensated angle difference for Breaker U
BKYACSYN1	DifAngClc.instMag.f	25ANGY	25 sync-check angle difference for Breaker Y
BKYACSYN1	DifHzClc.instMag.f	25SLIPY	25 sync-check slip frequency Breaker Y
BKYACSYN1	V1Clc.instMag.f	25VPFM	25 sync-check polarizing voltage magnitude
BKYACSYN1	V2Clc.instMag.f	25VSYFM	25 sync-check synchronizing voltage magnitude for Breaker Y
BKYCCSYN1	V1Clc.instMag.f	25VPFM	25 sync-check polarizing voltage magnitude
BKYCCSYN1	DifHzClc.instMag.f	25SLIPY	25 sync-check slip frequency Breaker Y
BKYCCSYN1	V2Clc.instMag.f	25VSYFM	25 sync-check synchronizing voltage magnitude for Breaker Y
BKYCCSYN1	DifAngClc.instMag.f	25ANGCY	25 sync-check compensated angle difference for Breaker Y
BSSASCBR1	AccAbr.instMag.f	BSBCWPA	Breaker S contact wear for Pole A
BSSBSCBR1	AccAbr.instMag.f	BSBCWPB	Breaker S contact wear for Pole B
BSSCSCBR1	AccAbr.instMag.f	BSBCWPC	Breaker S contact wear for Pole C
BSTASCBR1	AccAbr.instMag.f	BTBCWPA	Breaker T contact wear for Pole A
BSTBSCBR1	AccAbr.instMag.f	BTBCWPB	Breaker T contact wear for Pole B
BSTCSCBR1	AccAbr.instMag.f	BTBCWPC	Breaker T contact wear for Pole C
BSUASCBR1	AccAbr.instMag.f	BUBCWPA	Breaker U contact wear for Pole A
BSUBSCBR1	AccAbr.instMag.f	BUBCWPB	Breaker U contact wear for Pole B
BSUCSCBR1	AccAbr.instMag.f	BUBCWPC	Breaker U contact wear for Pole C
BSYASCBR1	AccAbr.instMag.f	BYBCWPA	Breaker Y contact wear for Pole A
BSYBSCBR1	AccAbr.instMag.f	BYBCWPB	Breaker Y contact wear for Pole B
BSYCSCBR1	AccAbr.instMag.f	BYBCWPC	Breaker Y contact wear for Pole C
Functional Constraint = DC			
LLN0	NamPlt.swRev	VERFID	Relay FID string
PROLPHD1	PhyNam.serNum	SERNUM	Relay serial number
PROLPHD1	PhyNam.model	PARNUM	Relay part number
PROLPHD1	PhyNam.hwRev	HWREV	Hardware version of the relay mainboard

Table 10.23 Logical Device: PRO (Protection) (Sheet 23 of 23)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = SP			
LLN0	GrRef.setSrcRef	IdName	Functional name
LLN0	MltLev.setVal	MLTLEV	Multi-level control authority

[a] Writing a value of 1 pulses the first bit. Writing a value of 0 pulses the second bit.
[b] I60MOD is an internal data source derived from the I850MOD analog quantity and it is not available to the user.
[c] If disconnect is closed, value = 2. If disconnect is open, value = 1. If disconnect is intermediate, value = 0. A value of 3 is invalid.
[d] FLTYPE is an internal data source derived from the event summary and is not available to the user. Refer to Table 10.26 for more details.
[e] If enabled, value = 1. If disabled, value = 3.
[f] If closed, value = 2. If open, value = 1.

Table 10.24 shows the LNs associated with measuring elements, defined as Logical Device MET.

Table 10.24 Logical Device: MET (Metering) (Sheet 1 of 8)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = ST			
LLN0	LocKey.stVal	NOOP	Physical key indication for switching LD in local mode
LLN0	Loc.stVal	LOC	Control authority at local (bay) level
LLN0	LocSta.stVal	LOCSTA	Control authority at station level
LLN0	Mod.stVal	I60MOD[a]	IEC 61850 mode/behavior status
DC1ZBAT1	BatWrn.stVal	DC1W	DC monitor warning alarm
DC1ZBAT1	BatFail.stVal	DC1F	DC monitor fail alarm
DC1ZBAT1	BatGndFlt.stVal	DC1G	DC monitor ground fault alarm
DC1ZBAT1	BatDvAlm.stVal	DC1R	DC monitor alarm for ac ripple
METGMMTR1	SupWh.actVal	3PGMWHP	Three-phase active energy exported, Terminal G
METGMMTR1	DmdWh.actVal	3PGMWHN	Three-phase active energy imported, Terminal G
METLPHD1	PhyHealth.stVal	EN?3:1[b]	Relay enabled
METSMMTR1	SupWh.actVal	3PSMWHP	Three-phase active energy exported, Terminal S
METSMMTR1	DmdWh.actVal	3PSMWHN	Three-phase active energy imported, Terminal S
METTMMTR1	SupWh.actVal	3PTMWHP	Three-phase active energy exported, Terminal T
METTMMTR1	DmdWh.actVal	3PTMWHN	Three-phase active energy imported, Terminal T
METUMMTR1	SupWh.actVal	3PUMWHP	Three-phase active energy exported, Terminal U
METUMMTR1	DmdWh.actVal	3PUMWHN	Three-phase active energy imported, Terminal U
METYMMTR1	SupWh.actVal	3PYMWHP	Three-phase active energy exported, Terminal Y
METYMMTR1	DmdWh.actVal	3PYMWHN	Three-phase active energy imported, Terminal Y
Functional Constraint = MX			
DC1ZBAT1	Vol.instMag.f	VDC	Station battery dc voltage
METGMMXU1	TotW.instMag.f	3PGFC	40 ms average three-phase fundamental active power, Terminal G
METGMMXU1	TotVAr.instMag.f	3QGFC	40 ms average three-phase fundamental reactive power, Terminal G
METGMMXU1	TotVA.instMag.f	3SGFC	40 ms average three-phase fundamental apparent power, Terminal G
METGMMXU1	TotPF.instMag.f	3PFGC	Three-phase displacement power factor, Terminal G
METGMMXU1	A.phsA.instCVal.mag.f	IAGFMC	40 ms average filtered phase current magnitude, A-Phase, Terminal G
METGMMXU1	A.phsA.instCVal.ang.f	IAGFAC	40 ms average filtered phase current angle, A-Phase, Terminal G
METGMMXU1	A.phsB.instCVal.mag.f	IBGFMC	40 ms average filtered phase current magnitude, B-Phase, Terminal G

Table 10.24 Logical Device: MET (Metering) (Sheet 2 of 8)

Logical Node	Attribute	Data Source	Comment
METGMMXU1	A.phsB.instCVal.ang.f	IBGFAC	40 ms average filtered phase current angle, B-Phase, Terminal G
METGMMXU1	A.phsC.instCVal.mag.f	ICGFMC	40 ms average filtered phase current magnitude, C-Phase, Terminal G
METGMMXU1	A.phsC.instCVal.ang.f	ICGFAC	40 ms average filtered phase current angle, C-Phase, Terminal G
METGMMXU1	W.phsA.instCVal.mag.f	PAGFC	40 ms average phase fundamental active power, A-Phase, Terminal G
METGMMXU1	W.phsB.instCVal.mag.f	PBGFC	40 ms average phase fundamental active power, B-Phase, Terminal G
METGMMXU1	W.phsC.instCVal.mag.f	PCGFC	40 ms average phase fundamental active power, C-Phase, Terminal G
METGMMXU1	VAr.phsA.instCVal.mag.f	QAGFC	40 ms average phase fundamental reactive power, A-Phase, Terminal G
METGMMXU1	VAr.phsB.instCVal.mag.f	QBGFC	40 ms average phase fundamental reactive power, B-Phase, Terminal G
METGMMXU1	VAr.phsC.instCVal.mag.f	QCGFC	40 ms average phase fundamental reactive power, C-Phase, Terminal G
METGMMXU1	VA.phsA.instCVal.mag.f	SAGFC	40 ms average phase fundamental apparent power, A-Phase, Terminal G
METGMMXU1	VA.phsB.instCVal.mag.f	SBGFC	40 ms average phase fundamental apparent power, B-Phase, Terminal G
METGMMXU1	VA.phsC.instCVal.mag.f	SCGFC	40 ms average phase fundamental apparent power, C-Phase, Terminal G
METGMMXU1	PF.phsA.instCVal.mag.f	PFAGC	Phase displacement power factor, A-Phase, Terminal G
METGMMXU1	PF.phsB.instCVal.mag.f	PFBGC	Phase displacement power factor, B-Phase, Terminal G
METGMMXU1	PF.phsC.instCVal.mag.f	PFCGC	Phase displacement power factor, C-Phase, Terminal G
METGMMXU1	NeutFund.instCVal.mag.f	VNFMC	40 ms average filtered generator neutral voltage magnitude
METGMMXU1	NeutFund.instCVal.ang.f	VNFAC	40 ms average filtered generator neutral voltage angle
METGMMXU1	Neut3Ha.instCVal.mag.f	VN3FMC	40 ms average filtered generator neutral third-harmonic voltage magnitude
METGMMXU1	Neut3Ha.instCVal.ang.f	VN3FAC	40 ms average filtered generator neutral third-harmonic voltage angle
METGMMXU1	Term3Ha.instCVal.mag.f	3V0Z3MC	40 ms average filtered generator terminal third-harmonic voltage magnitude
METGMMXU1	Term3Ha.instCVal.ang.f	3V0Z3AC	40 ms average filtered generator terminal third-harmonic voltage angle
METGMMXU1	Tot3Ha.instCVal.mag.f	VG3FMC	40 ms average filtered total neutral third-harmonic voltage magnitude
METGMMXU1	Tot3Ha.instCVal.ang.f	VG3FAC	40 ms average filtered total neutral third-harmonic voltage angle
METGMMXU1	StatInsRis.instMag.f	64SIR	64S stator insulation resistance
METGMMXU1	StatInsCapac.instMag.f	64SIC	64S stator insulation capacitance
METGMMXU1	FldInsRis.instMag.f	64FIR	64F field insulation resistance
METGMMXU1	Hz.instMag.f	FREQPG	Generator frequency
METGMMXU1	Fs.instMag.f	FREQPS	System frequency
METSMMXU1	Hz.instMag.f	FREQPG	Generator frequency
METSMMXU1	Fs.instMag.f	FREQPS	System frequency
METSMMXU1	TotW.instMag.f	3PSFC	40 ms average three-phase fundamental active power, Terminal S
METSMMXU1	TotVAr.instMag.f	3QSFC	40 ms average three-phase fundamental reactive power, Terminal S
METSMMXU1	TotVA.instMag.f	3SSFC	40 ms average three-phase fundamental apparent power, Terminal S
METSMMXU1	TotPF.instMag.f	3PFSC	Three-phase displacement power factor, Terminal S
METSMMXU1	A.phsA.instCVal.mag.f	IASFMC	40 ms average filtered phase current magnitude, A-Phase, Terminal S
METSMMXU1	A.phsA.instCVal.ang.f	IASFAC	40 ms average filtered phase current angle, A-Phase, Terminal S
METSMMXU1	A.phsB.instCVal.mag.f	IBSFMC	40 ms average filtered phase current magnitude, B-Phase, Terminal S
METSMMXU1	A.phsB.instCVal.ang.f	IBSFAC	40 ms average filtered phase current angle, B-Phase, Terminal S
METSMMXU1	A.phsC.instCVal.mag.f	ICSFMC	40 ms average filtered phase current magnitude, C-Phase, Terminal S
METSMMXU1	A.phsC.instCVal.ang.f	ICSFAC	40 ms average filtered phase current angle, C-Phase, Terminal S

Table 10.24 Logical Device: MET (Metering) (Sheet 3 of 8)

Logical Node	Attribute	Data Source	Comment
METSMMXU1	W.phsA.instCVal.mag.f	PASFC	40 ms average phase fundamental active power, A-Phase, Terminal S
METSMMXU1	W.phsB.instCVal.mag.f	PBSFC	40 ms average phase fundamental active power, B-Phase, Terminal S
METSMMXU1	W.phsC.instCVal.mag.f	PCSFC	40 ms average phase fundamental active power, C-Phase, Terminal S
METSMMXU1	VAr.phsA.instCVal.mag.f	QASFC	40 ms average phase fundamental reactive power, A-Phase, Terminal S
METSMMXU1	VAr.phsB.instCVal.mag.f	QBSFC	40 ms average phase fundamental reactive power, B-Phase, Terminal S
METSMMXU1	VAr.phsC.instCVal.mag.f	QCSFC	40 ms average phase fundamental reactive power, C-Phase, Terminal S
METSMMXU1	VA.phsA.instCVal.mag.f	SASFC	40 ms average phase fundamental apparent power, A-Phase, Terminal S
METSMMXU1	VA.phsB.instCVal.mag.f	SBSFC	40 ms average phase fundamental apparent power, B-Phase, Terminal S
METSMMXU1	VA.phsC.instCVal.mag.f	SCSFC	40 ms average phase fundamental apparent power, C-Phase, Terminal S
METSMMXU1	PF.phsA.instCVal.mag.f	PFASC	Phase displacement power factor, A-Phase, Terminal S
METSMMXU1	PF.phsB.instCVal.mag.f	PFBSC	Phase displacement power factor, B-Phase, Terminal S
METSMMXU1	PF.phsC.instCVal.mag.f	PFCSC	Phase displacement power factor, C-Phase, Terminal S
METTMMXU1	Hz.instMag.f	FREQPG	Generator frequency
METTMMXU1	Fs.instMag.f	FREQPS	System frequency
METTMMXU1	TotW.instMag.f	3PTFC	40 ms average three-phase fundamental active power, Terminal T
METTMMXU1	TotVAr.instMag.f	3QTFC	40 ms average three-phase fundamental reactive power, Terminal T
METTMMXU1	TotVA.instMag.f	3STFC	40 ms average three-phase fundamental apparent power, Terminal T
METTMMXU1	TotPF.instMag.f	3PFTC	Three-phase displacement power factor, Terminal T
METTMMXU1	A.phsA.instCVal.mag.f	IATFMC	40 ms average filtered phase current magnitude, A-Phase, Terminal T
METTMMXU1	A.phsA.instCVal.ang.f	IATFAC	40 ms average filtered phase current angle, A-Phase, Terminal T
METTMMXU1	A.phsB.instCVal.mag.f	IBTFMC	40 ms average filtered phase current magnitude, B-Phase, Terminal T
METTMMXU1	A.phsB.instCVal.ang.f	IBTFAC	40 ms average filtered phase current angle, B-Phase, Terminal T
METTMMXU1	A.phsC.instCVal.mag.f	ICTFMC	40 ms average filtered phase current magnitude, C-Phase, Terminal T
METTMMXU1	A.phsC.instCVal.ang.f	ICTFAC	40 ms average filtered phase current angle, C-Phase, Terminal T
METTMMXU1	W.phsA.instCVal.mag.f	PATFC	40 ms average phase fundamental active power, A-Phase, Terminal T
METTMMXU1	W.phsB.instCVal.mag.f	PBTFC	40 ms average phase fundamental active power, B-Phase, Terminal T
METTMMXU1	W.phsC.instCVal.mag.f	PCTFC	40 ms average phase fundamental active power, C-Phase, Terminal T
METTMMXU1	VAr.phsA.instCVal.mag.f	QATFC	40 ms average phase fundamental reactive power, A-Phase, Terminal T
METTMMXU1	VAr.phsB.instCVal.mag.f	QBTFC	40 ms average phase fundamental reactive power, B-Phase, Terminal T
METTMMXU1	VAr.phsC.instCVal.mag.f	QCTFC	40 ms average phase fundamental reactive power, C-Phase, Terminal T
METTMMXU1	VA.phsA.instCVal.mag.f	SATFC	40 ms average phase fundamental apparent power, A-Phase, Terminal T
METTMMXU1	VA.phsB.instCVal.mag.f	SBTFC	40 ms average phase fundamental apparent power, B-Phase, Terminal T
METTMMXU1	VA.phsC.instCVal.mag.f	SCTFC	40 ms average phase fundamental apparent power, C-Phase, Terminal T
METTMMXU1	PF.phsA.instCVal.mag.f	PFATC	Phase displacement power factor, A-Phase, Terminal T
METTMMXU1	PF.phsB.instCVal.mag.f	PFBTC	Phase displacement power factor, B-Phase, Terminal T
METTMMXU1	PF.phsC.instCVal.mag.f	PFCTC	Phase displacement power factor, C-Phase, Terminal T
METUMMXU1	Hz.instMag.f	FREQPG	Generator frequency
METUMMXU1	Fs.instMag.f	FREQPS	System frequency
METUMMXU1	TotW.instMag.f	3PUFC	40 ms average three-phase fundamental active power, Terminal U
METUMMXU1	TotVAr.instMag.f	3QUFC	40 ms average three-phase fundamental reactive power, Terminal U
METUMMXU1	TotVA.instMag.f	3SUFC	40 ms average three-phase fundamental apparent power, Terminal U

Table 10.24 Logical Device: MET (Metering) (Sheet 4 of 8)

Logical Node	Attribute	Data Source	Comment
METUMMXU1	TotPF.instMag.f	3PFUC	Three-phase displacement power factor, Terminal U
METUMMXU1	A.phsA.instCVal.mag.f	IAUFMC	40 ms average filtered phase current magnitude, A-Phase, Terminal U
METUMMXU1	A.phsA.instCVal.ang.f	IAUFAC	40 ms average filtered phase current angle, A-Phase, Terminal U
METUMMXU1	A.phsB.instCVal.mag.f	IBUFMC	40 ms average filtered phase current magnitude, B-Phase, Terminal U
METUMMXU1	A.phsB.instCVal.ang.f	IBUFAC	40 ms average filtered phase current angle, B-Phase, Terminal U
METUMMXU1	A.phsC.instCVal.mag.f	ICUFMC	40 ms average filtered phase current magnitude, C-Phase, Terminal U
METUMMXU1	A.phsC.instCVal.ang.f	ICUFAC	40 ms average filtered phase current angle, C-Phase, Terminal U
METUMMXU1	W.phsA.instCVal.mag.f	PAUFC	40 ms average phase fundamental active power, A-Phase, Terminal U
METUMMXU1	W.phsB.instCVal.mag.f	PBUFC	40 ms average phase fundamental active power, B-Phase, Terminal U
METUMMXU1	W.phsC.instCVal.mag.f	PCUFC	40 ms average phase fundamental active power, C-Phase, Terminal U
METUMMXU1	VAr.phsA.instCVal.mag.f	QAUFC	40 ms average phase fundamental reactive power, A-Phase, Terminal U
METUMMXU1	VAr.phsB.instCVal.mag.f	QBUFC	40 ms average phase fundamental reactive power, B-Phase, Terminal U
METUMMXU1	VAr.phsC.instCVal.mag.f	QCUFC	40 ms average phase fundamental reactive power, C-Phase, Terminal U
METUMMXU1	VA.phsA.instCVal.mag.f	SAUFC	40 ms average phase fundamental apparent power, A-Phase, Terminal U
METUMMXU1	VA.phsB.instCVal.mag.f	SBUFC	40 ms average phase fundamental apparent power, B-Phase, Terminal U
METUMMXU1	VA.phsC.instCVal.mag.f	SCUFC	40 ms average phase fundamental apparent power, C-Phase, Terminal U
METUMMXU1	PF.phsA.instCVal.mag.f	PFAUC	Phase displacement power factor, A-Phase, Terminal U
METUMMXU1	PF.phsB.instCVal.mag.f	PFBUC	Phase displacement power factor, B-Phase, Terminal U
METUMMXU1	PF.phsC.instCVal.mag.f	PFCUC	Phase displacement power factor, C-Phase, Terminal U
METVMMXU1	PPV.phsAB.instCVal.mag.f	VABVFMC	40 ms average filtered phase-to-phase voltage magnitude, AB-Phase, Terminal V
METVMMXU1	PPV.phsAB.instCVal.ang.f	VABVFAC	40 ms average filtered phase-to-phase voltage angle, AB-Phase, Terminal V
METVMMXU1	PPV.phsBC.instCVal.mag.f	VBCVFMC	40 ms average filtered phase-to-phase voltage magnitude, BC-Phase, Terminal V
METVMMXU1	PPV.phsBC.instCVal.ang.f	VBCVFAC	40 ms average filtered phase-to-phase voltage angle, BC-Phase, Terminal V
METVMMXU1	PPV.phsCA.instCVal.mag.f	VCAVFMC	40 ms average filtered phase-to-phase voltage magnitude, CA-Phase, Terminal V
METVMMXU1	PPV.phsCA.instCVal.ang.f	VCAVFAC	40 ms average filtered phase-to-phase voltage angle, CA-Phase, Terminal V
METVMMXU1	PhV.phsA.instCVal.mag.f	VAVFMC	40 ms average filtered phase-to-neutral voltage magnitude, A-Phase, Terminal V
METVMMXU1	PhV.phsA.instCVal.ang.f	VAVFAC	40 ms average filtered phase-to-neutral voltage angle, A-Phase, Terminal V
METVMMXU1	PhV.phsB.instCVal.mag.f	VBVFMC	40 ms average filtered phase-to-neutral voltage magnitude, B-Phase, Terminal V
METVMMXU1	PhV.phsB.instCVal.ang.f	VBVFAC	40 ms average filtered phase-to-neutral voltage angle, B-Phase, Terminal V
METVMMXU1	PhV.phsC.instCVal.mag.f	VCVFMC	40 ms average filtered phase-to-neutral voltage magnitude, C-Phase, Terminal V
METVMMXU1	PhV.phsC.instCVal.ang.f	VCVFAC	40 ms average filtered phase-to-neutral voltage angle, C-Phase, Terminal V
METY1MMXN1	Amp.instMag.f	IY1FMC	40 ms average filtered current magnitude, Channel 1, Terminal Y
METY2MMXN1	Amp.instMag.f	IY2FMC	40 ms average filtered current magnitude, Channel 2, Terminal Y

Table 10.24 Logical Device: MET (Metering) (Sheet 5 of 8)

Logical Node	Attribute	Data Source	Comment
METY3MMXN1	Amp.instMag.f	IY3FMC	40 ms average filtered current magnitude, Channel 3, Terminal Y
METYMMXU1	Hz.instMag.f	FREQPG	Generator frequency
METYMMXU1	Fs.instMag.f	FREQPS	System frequency
METYMMXU1	TotW.instMag.f	3PYFC	40 ms average three-phase fundamental active power, Terminal Y
METYMMXU1	TotVAr.instMag.f	3QYFC	40 ms average three-phase fundamental reactive power, Terminal Y
METYMMXU1	TotVA.instMag.f	3SYFC	40 ms average three-phase fundamental apparent power, Terminal Y
METYMMXU1	TotPF.instMag.f	3PFYC	Three-phase displacement power factor, Terminal Y
METYMMXU1	A.phsA.instCVal.mag.f	IAYFMC	40 ms average filtered phase current magnitude, A-Phase, Terminal Y
METYMMXU1	A.phsA.instCVal.ang.f	IAYFAC	40 ms average filtered phase current angle, A-Phase, Terminal Y
METYMMXU1	A.phsB.instCVal.mag.f	IBYFMC	40 ms average filtered phase current magnitude, B-Phase, Terminal Y
METYMMXU1	A.phsB.instCVal.ang.f	IBYFAC	40 ms average filtered phase current angle, B-Phase, Terminal Y
METYMMXU1	A.phsC.instCVal.mag.f	ICYFMC	40 ms average filtered phase current magnitude, C-Phase, Terminal Y
METYMMXU1	A.phsC.instCVal.ang.f	ICYFAC	40 ms average filtered phase current angle, C-Phase, Terminal Y
METYMMXU1	W.phsA.instCVal.mag.f	PAYFC	40 ms average phase fundamental active power, A-Phase, Terminal Y
METYMMXU1	W.phsB.instCVal.mag.f	PBYFC	40 ms average phase fundamental active power, B-Phase, Terminal Y
METYMMXU1	W.phsC.instCVal.mag.f	PCYFC	40 ms average phase fundamental active power, C-Phase, Terminal Y
METYMMXU1	VAr.phsA.instCVal.mag.f	QAYFC	40 ms average phase fundamental reactive power, A-Phase, Terminal Y
METYMMXU1	VAr.phsB.instCVal.mag.f	QBYFC	40 ms average phase fundamental reactive power, B-Phase, Terminal Y
METYMMXU1	VAr.phsC.instCVal.mag.f	QCYFC	40 ms average phase fundamental reactive power, C-Phase, Terminal Y
METYMMXU1	VA.phsA.instCVal.mag.f	SAYFC	40 ms average phase fundamental apparent power, A-Phase, Terminal Y
METYMMXU1	VA.phsB.instCVal.mag.f	SBYFC	40 ms average phase fundamental apparent power, B-Phase, Terminal Y
METYMMXU1	VA.phsC.instCVal.mag.f	SCYFC	40 ms average phase fundamental apparent power, C-Phase, Terminal Y
METYMMXU1	PF.phsA.instCVal.mag.f	PFAYC	Phase displacement power factor, A-Phase, Terminal Y
METYMMXU1	PF.phsB.instCVal.mag.f	PFBYC	Phase displacement power factor, B-Phase, Terminal Y
METYMMXU1	PF.phsC.instCVal.mag.f	PFCYC	Phase displacement power factor, C-Phase, Terminal Y
METZMMXU1	PPV.phsAB.instCVal.mag.f	VABZFMC	40 ms average filtered phase-to-phase voltage magnitude, Phases AB, Terminal Z
METZMMXU1	PPV.phsAB.instCVal.ang.f	VABZFAC	40 ms average filtered phase-to-phase voltage angle, Phases AB, Terminal Z
METZMMXU1	PPV.phsBC.instCVal.mag.f	VBCZFMC	40 ms average filtered phase-to-phase voltage magnitude, Phases BC, Terminal Z
METZMMXU1	PPV.phsBC.instCVal.ang.f	VBCZFAC	40 ms average filtered phase-to-phase voltage angle, Phases BC, Terminal Z
METZMMXU1	PPV.phsCA.instCVal.mag.f	VCAZFMC	40 ms average filtered phase-to-phase voltage magnitude, Phases CA, Terminal Z
METZMMXU1	PPV.phsCA.instCVal.ang.f	VCAZFAC	40 ms average filtered phase-to-phase voltage angle, Phases CA, Terminal Z
METZMMXU1	PhV.phsA.instCVal.mag.f	VAZFMC	40 ms average filtered phase-to-neutral voltage magnitude, A-Phase, Terminal Z
METZMMXU1	PhV.phsA.instCVal.ang.f	VAZFAC	40 ms average filtered phase-to-neutral voltage angle, A-Phase, Terminal Z
METZMMXU1	PhV.phsB.instCVal.mag.f	VBZFMC	40 ms average filtered phase-to-neutral voltage magnitude, B-Phase, Terminal Z

Table 10.24 Logical Device: MET (Metering) (Sheet 6 of 8)

Logical Node	Attribute	Data Source	Comment
METZMMXU1	PhV.phsB.instCVal.ang.f	VBZFAC	40 ms average filtered phase-to-neutral voltage angle, B-Phase, Terminal Z
METZMMXU1	PhV.phsC.instCVal.mag.f	VCZFMC	40 ms average filtered phase-to-neutral voltage magnitude, C-Phase, Terminal Z
METZMMXU1	PhV.phsC.instCVal.ang.f	VCZFAC	40 ms average filtered phase-to-neutral voltage angle, C-Phase, Terminal Z
SEQGMSQI1	SeqA.c1.instCVal.mag.f	I1GMC	40 ms average positive-sequence current magnitude, Terminal G
SEQGMSQI1	SeqA.c1.instCVal.ang.f	I1GAC	40 ms average positive-sequence current angle, Terminal G
SEQGMSQI1	SeqA.c2.instCVal.mag.f	3I2GMC	40 ms average negative-sequence current magnitude, Terminal G
SEQGMSQI1	SeqA.c2.instCVal.ang.f	3I2GAC	40 ms average negative-sequence current angle, Terminal G
SEQGMSQI1	SeqA.c3.instCVal.mag.f	3I0GMC	40 ms average zero-sequence current magnitude, Terminal G
SEQGMSQI1	SeqA.c3.instCVal.ang.f	3I0GAC	40 ms average zero-sequence current angle, Terminal G
SEQSMSQI1	SeqA.c1.instCVal.mag.f	I1SMC	40 ms average positive-sequence current magnitude, Terminal S
SEQSMSQI1	SeqA.c1.instCVal.ang.f	I1SAC	40 ms average positive-sequence current angle, Terminal S
SEQSMSQI1	SeqA.c2.instCVal.mag.f	3I2SMC	40 ms average negative-sequence current magnitude, Terminal S
SEQSMSQI1	SeqA.c2.instCVal.ang.f	3I2SAC	40 ms average negative-sequence current angle, Terminal S
SEQSMSQI1	SeqA.c3.instCVal.mag.f	3I0SMC	40 ms average zero-sequence current magnitude, Terminal S
SEQSMSQI1	SeqA.c3.instCVal.ang.f	3I0SAC	40 ms average zero-sequence current angle, Terminal S
SEQTMSQI1	SeqA.c1.instCVal.mag.f	I1TMC	40 ms average positive-sequence current magnitude, Terminal T
SEQTMSQI1	SeqA.c1.instCVal.ang.f	I1TAC	40 ms average positive-sequence current angle, Terminal T
SEQTMSQI1	SeqA.c2.instCVal.mag.f	3I2TMC	40 ms average negative-sequence current magnitude, Terminal T
SEQTMSQI1	SeqA.c2.instCVal.ang.f	3I2TAC	40 ms average negative-sequence current angle, Terminal T
SEQTMSQI1	SeqA.c3.instCVal.mag.f	3I0TMC	40 ms average zero-sequence current magnitude, Terminal T
SEQTMSQI1	SeqA.c3.instCVal.ang.f	3I0TAC	40 ms average zero-sequence current angle, Terminal T
SEQUMSQI1	SeqA.c1.instCVal.mag.f	I1UMC	40 ms average positive-sequence current magnitude, Terminal U
SEQUMSQI1	SeqA.c1.instCVal.ang.f	I1UAC	40 ms average positive-sequence current angle, Terminal U
SEQUMSQI1	SeqA.c2.instCVal.mag.f	3I2UMC	40 ms average negative-sequence current magnitude, Terminal U
SEQUMSQI1	SeqA.c2.instCVal.ang.f	3I2UAC	40 ms average negative-sequence current angle, Terminal U
SEQUMSQI1	SeqA.c3.instCVal.mag.f	3I0UMC	40 ms average zero-sequence current magnitude, Terminal U
SEQUMSQI1	SeqA.c3.instCVal.ang.f	3I0UAC	40 ms average zero-sequence current angle, Terminal U
SEQVMSQI1	SeqV.c1.instCVal.mag.f	V1VMC	40 ms average positive-sequence voltage magnitude, Terminal V
SEQVMSQI1	SeqV.c1.instCVal.ang.f	V1VAC	40 ms average positive-sequence voltage angle, Terminal V
SEQVMSQI1	SeqV.c2.instCVal.mag.f	3V2VMC	40 ms average negative-sequence voltage magnitude, Terminal V
SEQVMSQI1	SeqV.c2.instCVal.ang.f	3V2VAC	40 ms average negative-sequence voltage angle, Terminal V
SEQVMSQI1	SeqV.c3.instCVal.mag.f	3V0VMC	40 ms average zero-sequence voltage magnitude, Terminal V
SEQVMSQI1	SeqV.c3.instCVal.ang.f	3V0VAC	40 ms average zero-sequence voltage angle, Terminal V
SEQYMSQI1	SeqA.c1.instCVal.mag.f	I1YMC	40 ms average positive-sequence current magnitude, Terminal Y
SEQYMSQI1	SeqA.c1.instCVal.ang.f	I1YAC	40 ms average positive-sequence current angle, Terminal Y
SEQYMSQI1	SeqA.c2.instCVal.mag.f	3I2YMC	40 ms average negative-sequence current magnitude, Terminal Y
SEQYMSQI1	SeqA.c2.instCVal.ang.f	3I2YAC	40 ms average negative-sequence current angle, Terminal Y
SEQYMSQI1	SeqA.c3.instCVal.mag.f	3I0YMC	40 ms average zero-sequence current magnitude, Terminal Y
SEQYMSQI1	SeqA.c3.instCVal.ang.f	3I0YAC	40 ms average zero-sequence current angle, Terminal Y

Table 10.24 Logical Device: MET (Metering) (Sheet 7 of 8)

Logical Node	Attribute	Data Source	Comment
SEQZMSQI1	SeqV.c1.instCVal.mag.f	V1ZMC	40 ms average positive-sequence voltage magnitude, Terminal Z
SEQZMSQI1	SeqV.c1.instCVal.ang.f	V1ZAC	40 ms average positive-sequence voltage angle, Terminal Z
SEQZMSQI1	SeqV.c2.instCVal.mag.f	3V2ZMC	40 ms average negative-sequence voltage magnitude, Terminal Z
SEQZMSQI1	SeqV.c2.instCVal.ang.f	3V2ZAC	40 ms average negative-sequence voltage angle, Terminal Z
SEQZMSQI1	SeqV.c3.instCVal.mag.f	3V0ZMC	40 ms average zero-sequence voltage magnitude, Terminal Z
SEQZMSQI1	SeqV.c3.instCVal.ang.f	3V0ZAC	40 ms average zero-sequence voltage angle, Terminal Z
THERMCMTHR1	Tmp01.instMag.f	RTC01TV	Remote temperature value in °C, RTC01
THERMCMTHR1	Tmp02.instMag.f	RTC02TV	Remote temperature value in °C, RTC02
THERMCMTHR1	Tmp03.instMag.f	RTC03TV	Remote temperature value in °C, RTC03
THERMCMTHR1	Tmp04.instMag.f	RTC04TV	Remote temperature value in °C, RTC04
THERMCMTHR1	Tmp05.instMag.f	RTC05TV	Remote temperature value in °C, RTC05
THERMCMTHR1	Tmp06.instMag.f	RTC06TV	Remote temperature value in °C, RTC06
THERMCMTHR1	Tmp07.instMag.f	RTC07TV	Remote temperature value in °C, RTC07
THERMCMTHR1	Tmp08.instMag.f	RTC08TV	Remote temperature value in °C, RTC08
THERMCMTHR1	Tmp09.instMag.f	RTC09TV	Remote temperature value in °C, RTC09
THERMCMTHR1	Tmp10.instMag.f	RTC10TV	Remote temperature value in °C, RTC10
THERMCMTHR1	Tmp11.instMag.f	RTC11TV	Remote temperature value in °C, RTC11
THERMCMTHR1	Tmp12.instMag.f	RTC12TV	Remote temperature value in °C, RTC12
THERMCMTHR1	Tmp13.instMag.f	RTC13TV	Remote temperature value in °C, RTC13
THERMCMTHR1	Tmp14.instMag.f	RTC14TV	Remote temperature value in °C, RTC14
THERMCMTHR1	Tmp15.instMag.f	RTC15TV	Remote temperature value in °C, RTC15
THERMCMTHR1	Tmp16.instMag.f	RTC16TV	Remote temperature value in °C, RTC16
THERMCMTHR1	Tmp17.instMag.f	RTC17TV	Remote temperature value in °C, RTC17
THERMCMTHR1	Tmp18.instMag.f	RTC18TV	Remote temperature value in °C, RTC18
THERMCMTHR1	Tmp19.instMag.f	RTC19TV	Remote temperature value in °C, RTC19
THERMCMTHR1	Tmp20.instMag.f	RTC20TV	Remote temperature value in °C, RTC20
THERMCMTHR1	Tmp21.instMag.f	RTC21TV	Remote temperature value in °C, RTC21
THERMCMTHR1	Tmp22.instMag.f	RTC22TV	Remote temperature value in °C, RTC22
THERMCMTHR1	Tmp23.instMag.f	RTC23TV	Remote temperature value in °C, RTC23
THERMCMTHR1	Tmp24.instMag.f	RTC24TV	Remote temperature value in °C, RTC24
THERMSMTHR1	Tmp01.instMag.f	RTS01TV	RTD temperature value in °C, RTS01
THERMSMTHR1	Tmp02.instMag.f	RTS02TV	RTD temperature value in °C, RTS02
THERMSMTHR1	Tmp03.instMag.f	RTS03TV	RTD temperature value in °C, RTS03
THERMSMTHR1	Tmp04.instMag.f	RTS04TV	RTD temperature value in °C, RTS04
THERMSMTHR1	Tmp05.instMag.f	RTS05TV	RTD temperature value in °C, RTS05
THERMSMTHR1	Tmp06.instMag.f	RTS06TV	RTD temperature value in °C, RTS06
THERMSMTHR1	Tmp07.instMag.f	RTS07TV	RTD temperature value in °C, RTS07
THERMSMTHR1	Tmp08.instMag.f	RTS08TV	RTD temperature value in °C, RTS08
THERMSMTHR1	Tmp09.instMag.f	RTS09TV	RTD temperature value in °C, RTS09
THERMSMTHR1	Tmp10.instMag.f	RTS10TV	RTD temperature value in °C, RTS10
THERMSMTHR1	Tmp11.instMag.f	RTS11TV	RTD temperature value in °C, RTS11

Table 10.24 Logical Device: MET (Metering) (Sheet 8 of 8)

Logical Node	Attribute	Data Source	Comment
THERMSMTHR1	Tmp12.instMag.f	RTS12TV	RTD temperature value in °C, RTS12
THERMSMTHR1	Tmp13.instMag.f	RTS13TV	RTD temperature value in °C, RTS13
THERMSMTHR1	Tmp14.instMag.f	RTS14TV	RTD temperature value in °C, RTS14
THERMSMTHR1	Tmp15.instMag.f	RTS15TV	RTD temperature value in °C, RTS15
THERMSMTHR1	Tmp16.instMag.f	RTS16TV	RTD temperature value in °C, RTS16
THERMSMTHR1	Tmp17.instMag.f	RTS17TV	RTD temperature value in °C, RTS17
THERMSMTHR1	Tmp18.instMag.f	RTS18TV	RTD temperature value in °C, RTS18
THERMSMTHR1	Tmp19.instMag.f	RTS19TV	RTD temperature value in °C, RTS19
THERMSMTHR1	Tmp20.instMag.f	RTS20TV	RTD temperature value in °C, RTS20
THERMSMTHR1	Tmp21.instMag.f	RTS21TV	RTD temperature value in °C, RTS21
THERMSMTHR1	Tmp22.instMag.f	RTS22TV	RTD temperature value in °C, RTS22
THERMSMTHR1	Tmp23.instMag.f	RTS23TV	RTD temperature value in °C, RTS23
THERMSMTHR1	Tmp24.instMag.f	RTS24TV	RTD temperature value in °C, RTS24
Functional Constraint = DC			
LLN0	NamPlt.swRev	VERFID	Relay FID string
METLPHD1	PhyNam.hwRev	HWREV[c]	Hardware version of the relay mainboard
METLPHD1	PhyNam.serNum	SERNUM	Relay serial number
METLPHD1	PhyNam.model	PARNUM	Relay part number
Functional Constraint = SP			
LLN0	GrRef.setSrcRef	IdName	Functional name
LLN0	MltLev.setVal	MLTLEV	Multi-level control authority

[a] I60MOD is an internal data source derived from the I850MOD analog quantity and it is not available to the user.
[b] If enabled, value = 1. If disabled, value = 3.
[c] HWREV is an internal data source and is not available to the user.

Table 10.25 shows LNs specific to the SEL-400G that are associated with the annunciation element, defined as Logical Device ANN. See *Section 17: IEC 61850 Communication in the SEL-400 Series Relays Instruction Manual* for ANN logical nodes supported by both the SEL-400G and other SEL-400 series relays.

Table 10.25 SEL-400G Specific Logical Device: ANN (Annunciation) (Sheet 1 of 2)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = ST			
INADGGIO1	Ind01.stVal	INADAS	Inadvertent energization element armed, Terminal S
INADGGIO1	Ind02.stVal	INADAT	Inadvertent energization element armed, Terminal T
INADGGIO1	Ind03.stVal	INADAU	Inadvertent energization element armed, Terminal U
INADGGIO1	Ind04.stVal	INADAY	Inadvertent energization element armed, Terminal Y
RTC1GGIO1	Ind01.stVal	RTC01OK	RTC01 healthy
RTC1GGIO1	Ind02.stVal	RTC02OK	RTC02 healthy
RTC1GGIO1	Ind03.stVal	RTC03OK	RTC03 healthy
• • •			
RTS1GGIO1	Ind22.stVal	RTS22OK	RTD22 healthy

Table 10.25 SEL-400G Specific Logical Device: ANN (Annunciation) (Sheet 2 of 2)

Logical Node	Attribute	Data Source	Comment
RTS1GGIO1	Ind23.stVal	RTS23OK	RTD23 healthy
RTS1GGIO1	Ind24.stVal	RTS24OK	RTD24 healthy

Table 10.26 FLTYPE—Fault Type

Value	Fault Type
0	No fault type identified/present

Table 10.27 FLTCAUS—Fault Cause

Value	Fault Cause
0	No fault summary loaded
1	Trigger command
2	Trip element
3	Event report element
6	87 Zone 1 differential trip
7	87 Zone 2 differential trip
8	Restricted earth fault
9	Excitation trip
10	Prime mover trip
11	Auxiliary trip

Synchrophasors

General synchrophasor operation is described in *Section 18: Synchrophasors in the SEL-400 Series Relays Instruction Manual*. This section describes characteristics of synchrophasors that are unique to the SEL-400G.

The SEL-400G complies with IEEE C37.118-2011. The SEL-400G supports the P class. For information on the accuracy classes, refer to the IEEE C37.118.1-2011 standard.

NOTE: To meet P class latency requirements, set PMOTSn = UDP_S, UDP_T, or UDP_U.

The SEL-400G has 18 current channels and 6 voltage channels. Current Terminals S, T, U, W, X, Y, and voltage Terminals V, Z are three-phase channels.

From these 24 channels, the SEL-400G can measure as many as 32 synchrophasors (24 phase synchrophasors and 8 positive-sequence synchrophasors). Synchrophasors are always in primary, so set the CT and PT ratios in the group settings appropriately.

Table 10.28 shows the default voltage synchrophasor name, enable conditions and the PT ratio used to scale to the primary values.

Table 10.28 Voltage Synchrophasor Names (Sheet 1 of 2)

Phasor Name	Phasor Enable Conditions	PT Ratio
V1VPM	PHDV*q* = V1 or ALL AND Terminal V included	PTRV
VAVPM	PHDV*q* = PH or ALL AND Terminal V included	PTRV
VBVPM	PHDV*q* = PH or ALL AND Terminal V included	PTRV

Table 10.28 Voltage Synchrophasor Names (Sheet 2 of 2)

Phasor Name	Phasor Enable Conditions	PT Ratio
VCVPM	PHDV*q* = PH or ALL AND Terminal V included	PTRV
V1ZPM	PHDV*q* = V1 or ALL AND Terminal Z included	PTRZ
VAZPM	PHDV*q* = PH or ALL AND Terminal Z included	PTRZ
VBZPM	PHDV*q* = PH or ALL AND Terminal Z included	PTRZ
VCZPM	PHDV*q* = PH or ALL AND Terminal Z included	PTRZ

Table 10.29 shows the default current synchrophasor names, enable conditions, and the CT ratio used to scale to the primary values.

Table 10.29 Current Synchrophasor Names

Phasor Name	Phasor Enable Conditions	CT Ratio
I1SPM	PHDI*q* = I1 or ALL AND Terminal S included	CTRS
IASPM	PHDI*q* = PH or ALL AND Terminal S included	CTRS
IBSPM	PHDI*q* = PH or ALL AND Terminal S included	CTRS
ICSPM	PHDI*q* = PH or ALL AND Terminal S included	CTRS
I1TPM	PHDI*q* = I1 or ALL AND Terminal T included	CTRT
IATPM	PHDI*q* = PH or ALL AND Terminal T included	CTRT
IBTPM	PHDI*q* = PH or ALL AND Terminal T included	CTRT
ICTPM	PHDI*q* = PH or ALL AND Terminal T included	CTRT
I1UPM	PHDI*q* = I1 or ALL AND Terminal U included	CTRU
IAUPM	PHDI*q* = PH or ALL AND Terminal U included	CTRU
IBUPM	PHDI*q* = PH or ALL AND Terminal U included	CTRU
ICUPM	PHDI*q* = PH or ALL AND Terminal U included	CTRU
I1WPM	PHDI*q* = I1 or ALL AND Terminal W included	CTRW
IAWPM	PHDI*q* = PH or ALL AND Terminal W included	CTRW
IBWPM	PHDI*q* = PH or ALL AND Terminal W included	CTRW
ICWPM	PHDI*q* = PH or ALL AND Terminal W included	CTRW
I1XPM	PHDI*q* = I1 or ALL AND Terminal X included	CTRX
IAXPM	PHDI*q* = PH or ALL AND Terminal X included	CTRX
IBXPM	PHDI*q* = PH or ALL AND Terminal X included	CTRX
ICXPM	PHDI*q* = PH or ALL AND Terminal X included	CTRX
I1YPM	PHDI*q* = I1 or ALL AND Terminal Y included	CTRY[a]
IAYPM	PHDI*q* = PH or ALL AND Terminal Y included	CTRY1[b]
IBYPM	PHDI*q* = PH or ALL AND Terminal Y included	CTRY2[b]
ICYPM	PHDI*q* = PH or ALL AND Terminal Y included	CTRY3[b]

[a] If CTCONY = 1PH, the CT ratio is zero.
[b] If CTCONY = Y, the CT ratio is CTRY.

Accuracy

The SEL-400G has the following phasor measurement accuracy:

TVE (total vector error) ≤1 percent for one or more of the following influence quantities:

- ➤ Voltage magnitude range: 30 V–150 V
- ➤ Current magnitude range: (0.1–2) • I_{NOM} (I_{NOM} = 1 A or 5 A)
- ➤ Phase angle range: –179.99° to 180°
- ➤ Signal frequency range: ±2 Hz of nominal (50 or 60 Hz)
- ➤ Harmonic distortion: ≤1 percent (any harmonic)

It is important to note that the synchrophasors can only be correlated when the PMU is in HIRIG or HPTP timekeeping mode, which can be verified by monitoring the TSOK Relay Word bit. When TSOK = logical 1, the PMU timekeeping is synchronized to the high-accuracy IRIG-B signal or Precision Time Protocol (PTP) time source, and the synchrophasor data are precisely time-stamped. See *Section 11: Time and Date Management in the SEL-400 Series Relays Instruction Manual* for details.

Modbus TCP Communication

Overview

This section describes Modbus TCP communications features supported by the SEL-400G. Complete specifications for the Modbus protocol are available from the Modbus user's group website at modbus.org.

The SEL-400G allows as many as two simultaneous Modbus sessions and allows a Modbus master device to do the following:

- ➤ Acquire metering, monitoring, and event data from the relay
- ➤ Control the SEL-400G breaker, disconnect, and remote bits
- ➤ Read and switch the active setting group
- ➤ Read and set the time and date
- ➤ Reset targets, demand and peak data, energy data, breaker monitor, min/max, and battery monitor data

Enable Modbus TCP sessions with Ethernet port (**PORT 5**) setting EMOD. The master IP address for each session is selected with **PORT 5** settings MODIP1 and MODIP2. Modbus TCP uses the device IP address as the Modbus identifier to access data in the relay using a data map and function codes. If multiple sessions are enabled, all sessions reference the same data map.

Communications Protocol

Modbus TCP Queries

The Modbus request or response is encapsulated when carried on a Modbus TCP/IP network. A dedicated header used on TCP/IP identifies the Modbus Application Data Unit (ADU). The header is called the MBAP (Modbus Application Protocol header), and it contains the following fields shown in *Table 10.30*.

Table 10.30 SEL-400G MBAP Header Fields

Field	Number of Bytes
Transaction Identifier	2 Bytes
Protocol Identifier	2 Bytes (0 = MODBUS protocol)
Length	2 Bytes
Unit Identifier	1 Byte

The Modbus TCP message consists of the MBAP Header, followed by the Modbus function code and the data supporting the function code. The Modbus TCP message does not contain a CRC because error checking is accomplished through TCP.

Modbus Responses

The subordinate device sends a response message after it performs the action the query specifies. If the subordinate cannot execute the query command for any reason, it sends an error response. Otherwise, the subordinate device response is formatted similarly to the query and includes the MBAP header, function code and data (if applicable). Note that because subordinate devices are differentiated using the Unit Identifier field in the MBAP header, there is no need for a subordinate address field like in Modbus RTU.

Supported Modbus Function Codes

The SEL-400G supports the Modbus function codes shown in *Table 10.31*.

Table 10.31 SEL-400G Modbus Function Codes

Codes	Description
01h	Read Discrete Output Coil Status
02h	Read Discrete Input Status
03h	Read Holding Registers
04h	Read Input Registers
05h	Write Single Coil
06h	Preset Single Register
08h	Diagnostic Command
0Fh	Write Multiple Coils
10h	Preset Multiple Registers

Modbus Exception Responses

The SEL-400G sends an exception code under the conditions described in *Table 10.32*.

Table 10.32 SEL-400G Modbus Exception Codes (Sheet 1 of 2)

Exception Code	Error Type	Description
1	Illegal Function Code	The received function code is either undefined or unsupported.
2	Illegal Data Address	The received command contains an unsupported address in the data field.
3	Illegal Data Value	The received command contains a value that is out of range.

Table 10.32 SEL-400G Modbus Exception Codes (Sheet 2 of 2)

Exception Code	Error Type	Description
4	Device Error	The SEL-400G is in the wrong state for the function a query specifies. The relay is unable to perform the action specified by a query (i.e., cannot write to a read-only register, device is disabled, etc.).
6	Busy	The device is unable to process the command at this time because of a busy resource.

In the event that any of the errors listed in *Table 10.32* occur, the relay assembles a response message that includes the exception code in the data field. The relay sets the most significant bit in the function code field to indicate to the master that the data field contains an error code, instead of the required data.

Function Codes

01h Read Discrete Output Coil Status Command

Use function code 01h to read the On/Off status of the selected bits (coils) (see the Output Coils table shown in *Table 10.43*). The SEL-400G coil addresses start at 0000. The coil status is packed one coil per bit of the data field. The Least Significant Bit (LSB) of the first data byte contains the starting coil address in the query. The other coils follow towards the high order end of this byte and from low order to high order in subsequent bytes. The command request and response are shown in *Table 10.33*.

Table 10.33 01h Read Discrete Output Coil Status Command

Bytes	Field
Requests from the master must have the following format:	
1 byte	Function Code (01h)
2 bytes	Address of the first bit
2 bytes	Number of bits to read
A successful response from the subordinate will have the following format:	
1 byte	Function Code (01h)
1 byte	Bytes of data (*n*)
n bytes	Data

To build the response, the SEL-400G calculates the number of bytes required to contain the number of bits requested. If the number of bits requested is not evenly divisible by eight, the device adds one more byte to maintain the balance of bits, padded by zeros to make an even byte. *Table 10.43* includes the coil number and lists all possible coils available in the device.

The relay responses to errors in the query are shown in *Table 10.34*.

Table 10.34 Responses to 01h Read Discrete Output Coil Query Errors

Error	Error Code Returned
Invalid bit to read	Illegal Data Address (02h)
Invalid number of bits to read	Illegal Data Value (03h)
Format error	Illegal Data Value (03h)

02h Read Discrete Input Status Command

Use function code 02h to read the On/Off status of the selected bits (inputs), as shown in *Table 10.36*. Input addresses start at 0000. The input status is packed one input per bit of the data field. The LSB of the first data byte contains the starting input address in the query. The other inputs follow towards the high order end of this byte, and from low order to high order in subsequent bytes. The command request and response are shown in *Table 10.35*.

Table 10.35 02h Read Discrete Input Status Command

Bytes	Field
Requests from the master must have the following format:	
1 byte	Function Code (02h)
2 bytes	Address of the first bit
2 bytes	Number of bits to read
A successful response from the subordinate will have the following format:	
1 byte	Function Code (02h)
1 byte	Bytes of data (*n*)
n bytes	Data

To build the response, the device calculates the number of bytes required to contain the number of bits requested. If the number of bits requested is not evenly divisible by eight, the device adds one more byte to maintain the balance of bits, padded by zeros to make an even byte.

In each row, the input numbers are assigned from the right-most input to the left-most input (i.e., input address 0 is reserved for future use and input address 7 is EN). Input addresses start at 0000. *Table 10.36* includes a sample of input addresses in decimal and hexadecimal for some inputs (Relay Word bits) available in the device.

The Address numbers are assigned from the right-most address to the left-most address in the Relay row, as shown in the following SEL-400G example.

Address 7 = EN
Address 6 = TRIPLED
Address 5 = reserved for future use
Address 4 = reserved for future use
Address 3 = reserved for future use
Address 2 = reserved for future use
Address 1 = reserved for future use
Address 0 = reserved for future use

Address 15 = TLED_1
Address 14 = TLED_2
Address 13 = TLED_3
Address 12 = TLED_4
Address 11 = TLED_5
Address 10 = TLED_6
Address 9 = TLED_7
Address 8 = TLED_8

Table 10.36 02h SEL-400G Inputs[a]

Discrete Input Address in Decimal	Discrete Input Address in Hex	Function Code Supported	Discrete Address Description
0–7	0–7	02	Relay Element Status Row 0
8–15	8–F	02	Relay Element Status Row 1
16–23	10–17	02	Relay Element Status Row 2
…	…	…	….
4336–4343	10F0–10F7	02	Relay Element Status Row 529
4344–4351	10F8–10FF	02	Relay Element Status Row 530
4352–4359	1100–1107	02	Relay Element Status Row 531

[a] See Section 11: Relay Word Bits for relay element row numbers and definitions.

Table 10.37 shows the relay responses to errors in the query.

Table 10.37 Responses to 02h Read Input Query Errors

Error	Error Code Returned
Invalid bit to read	Illegal Data Address (02h)
Invalid number of bits to read	Illegal Data Value (03h)
Format error	Illegal Data Value (03h)

03h Read Holding Register Command

Use function code 03h to read directly from the Modbus Register Map. The default relay map is shown in *Table 10.54*. Use the **SET U** command (see *Configurable Register Mapping on page 10.77*) to configure the map using the register label names shown in *Table 10.53*. You can read a maximum of 125 registers at once with this function code. Most masters use 4X references with this function code. *Table 10.38* shows the command request and response.

Table 10.38 03h Read Holding Register Command

Bytes	Field
Requests from the master must have the following format:	
1 byte	Function Code (03h)
2 bytes	Starting Register Address
2 bytes	Number of Registers to Read
A successful response from the subordinate will have the following format:	
1 byte	Function Code (03h)
1 byte	Bytes of data (*n*)
n bytes	Data (2–250)

The relay responses to errors in the query are shown in *Table 10.39*.

Table 10.39 Responses to 03h Read Holding Register Query Errors

Error	Error Code Returned
Illegal register to read	Illegal Data Address (02h)
Illegal number of registers to read	Illegal Data Value (03h)
Format error	Illegal Data Value (03h)

04h Read Input Register Command

Use function code 04h to read directly from the Modbus Register Map. The default relay map is shown in *Table 10.54*. Use the **SET U** command (see *Configurable Register Mapping on page 10.77*) to configure the map using the register label names shown in *Table 10.53*. You can read a maximum of 125 registers at once with this function code. Most masters use 3X references with this function code. The command request and response are shown in *Table 10.40*.

Table 10.40 04h Read Input Register Command

Bytes	Field
Requests from the master must have the following format:	
1 byte	Function Code (04h)
2 bytes	Starting Register Address
2 bytes	Number of Registers to Read
A successful response from the subordinate will have the following format:	
1 byte	Function Code (04h)
1 byte	Bytes of data (*n*)
n bytes	Data (2–250)

The relay responses to errors in the query are shown in *Table 10.41*.

Table 10.41 Responses to 04h Read Input Register Query Errors

Error	Error Code Returned
Illegal register to read	Illegal Data Address (02h)
Illegal number of registers to read	Illegal Data Value (03h)
Format error	Illegal Data Value (03h)

05h Write Single Coil Command

Use function code 05h to set or clear a coil. The command request is shown in *Table 10.42*.

Table 10.42 05h Write Single Coil Command

Bytes	Field
Requests from the master must have the following format:	
1 byte	Function Code (05h)
2 bytes	Coil Reference
1 byte	Operation Code (FF for bit set, 00 for bit clear)
1 byte	Placeholder (00)

Table 10.43 lists the coil numbers supported by the SEL-400G. A set operation (FF) to decimal address 32–63 has the effect of pulsing the corresponding Remote Bit in the relay. RB*nn*P itself is not a Relay Word bit but an internal label used to differentiate Remote Bit pulsing from the Set/Clear operation of RB*nn*.

Table 10.43 01h, 05h, 0Fh SEL-400G Output Coils (Sheet 1 of 6)

Coil Address in Decimal	Coil Address in Hex	Function Code Supported	Coil Label	Coil Description	Coil Function	Duration
0	0	01, 05, 0F	RB01	Remote Bit 1 Set/Clear	Set/Clear	NA
1	1	01, 05, 0F	RB02	Remote Bit 2 Set/Clear	Set/Clear	NA
2	2	01, 05, 0F	RB03	Remote Bit 3 Set/Clear	Set/Clear	NA
3	3	01, 05, 0F	RB04	Remote Bit 4 Set/Clear	Set/Clear	NA
4	4	01, 05, 0F	RB05	Remote Bit 5 Set/Clear	Set/Clear	NA
5	5	01, 05, 0F	RB06	Remote Bit 6 Set/Clear	Set/Clear	NA
6	6	01, 05, 0F	RB07	Remote Bit 7 Set/Clear	Set/Clear	NA
7	7	01, 05, 0F	RB08	Remote Bit 8 Set/Clear	Set/Clear	NA
8	8	01, 05, 0F	RB09	Remote Bit 9 Set/Clear	Set/Clear	NA
9	9	01, 05, 0F	RB10	Remote Bit 10 Set/Clear	Set/Clear	NA
10	A	01, 05, 0F	RB11	Remote Bit 11 Set/Clear	Set/Clear	NA
11	B	01, 05, 0F	RB12	Remote Bit 12 Set/Clear	Set/Clear	NA
12	C	01, 05, 0F	RB13	Remote Bit 13 Set/Clear	Set/Clear	NA
13	D	01, 05, 0F	RB14	Remote Bit 14 Set/Clear	Set/Clear	NA
14	E	01, 05, 0F	RB15	Remote Bit 15 Set/Clear	Set/Clear	NA
15	F	01, 05, 0F	RB16	Remote Bit 16 Set/Clear	Set/Clear	NA
16	10	01, 05, 0F	RB17	Remote Bit 17 Set/Clear	Set/Clear	NA
17	11	01, 05, 0F	RB18	Remote Bit 18 Set/Clear	Set/Clear	NA
18	12	01, 05, 0F	RB19	Remote Bit 19 Set/Clear	Set/Clear	NA
19	13	01, 05, 0F	RB20	Remote Bit 20 Set/Clear	Set/Clear	NA
20	14	01, 05, 0F	RB21	Remote Bit 21 Set/Clear	Set/Clear	NA
21	15	01, 05, 0F	RB22	Remote Bit 22 Set/Clear	Set/Clear	NA
22	16	01, 05, 0F	RB23	Remote Bit 23 Set/Clear	Set/Clear	NA
23	17	01, 05, 0F	RB24	Remote Bit 24 Set/Clear	Set/Clear	NA
24	18	01, 05, 0F	RB25	Remote Bit 25 Set/Clear	Set/Clear	NA
25	19	01, 05, 0F	RB26	Remote Bit 26 Set/Clear	Set/Clear	NA
26	1A	01, 05, 0F	RB27	Remote Bit 27 Set/Clear	Set/Clear	NA
27	1B	01, 05, 0F	RB28	Remote Bit 28 Set/Clear	Set/Clear	NA
28	1C	01, 05, 0F	RB29	Remote Bit 29 Set/Clear	Set/Clear	NA
29	1D	01, 05, 0F	RB30	Remote Bit 30 Set/Clear	Set/Clear	NA
30	1E	01, 05, 0F	RB31	Remote Bit 31 Set/Clear	Set/Clear	NA
31	1F	01, 05, 0F	RB32	Remote Bit 32 Set/Clear	Set/Clear	NA
32	20	01, 05, 0F	RB01P	Remote Bit 1 Pulse	Pulse[a]	1 SELOGIC processing interval
33	21	01, 05, 0F	RB02P	Remote Bit 2 Pulse	Pulse[a]	1 SELOGIC processing interval
34	22	01, 05, 0F	RB03P	Remote Bit 3 Pulse	Pulse[a]	1 SELOGIC processing interval
35	23	01, 05, 0F	RB04P	Remote Bit 4 Pulse	Pulse[a]	1 SELOGIC processing interval
36	24	01, 05, 0F	RB05P	Remote Bit 5 Pulse	Pulse[a]	1 SELOGIC processing interval

Table 10.43 01h, 05h, 0Fh SEL-400G Output Coils (Sheet 2 of 6)

Coil Address in Decimal	Coil Address in Hex	Function Code Supported	Coil Label	Coil Description	Coil Function	Duration
37	25	01, 05, 0F	RB06P	Remote Bit 6 Pulse	Pulse[a]	1 SELOGIC processing interval
38	26	01, 05, 0F	RB07P	Remote Bit 7 Pulse	Pulse[a]	1 SELOGIC processing interval
39	27	01, 05, 0F	RB08P	Remote Bit 8 Pulse	Pulse[a]	1 SELOGIC processing interval
40	28	01, 05, 0F	RB09P	Remote Bit 9 Pulse	Pulse[a]	1 SELOGIC processing interval
41	29	01, 05, 0F	RB10P	Remote Bit 10 Pulse	Pulse[a]	1 SELOGIC processing interval
42	2A	01, 05, 0F	RB11P	Remote Bit 11 Pulse	Pulse[a]	1 SELOGIC processing interval
43	2B	01, 05, 0F	RB12P	Remote Bit 12 Pulse	Pulse[a]	1 SELOGIC processing interval
44	2C	01, 05, 0F	RB13P	Remote Bit 13 Pulse	Pulse[a]	1 SELOGIC processing interval
45	2D	01, 05, 0F	RB14P	Remote Bit 14 Pulse	Pulse[a]	1 SELOGIC processing interval
46	2E	01, 05, 0F	RB15P	Remote Bit 15 Pulse	Pulse[a]	1 SELOGIC processing interval
47	2F	01, 05, 0F	RB16P	Remote Bit 16 Pulse	Pulse[a]	1 SELOGIC processing interval
48	30	01, 05, 0F	RB17P	Remote Bit 17 Pulse	Pulse[a]	1 SELOGIC processing interval
49	31	01, 05, 0F	RB18P	Remote Bit 18 Pulse	Pulse[a]	1 SELOGIC processing interval
50	32	01, 05, 0F	RB19P	Remote Bit 19 Pulse	Pulse[a]	1 SELOGIC processing interval
51	33	01, 05, 0F	RB20P	Remote Bit 20 Pulse	Pulse[a]	1 SELOGIC processing interval
52	34	01, 05, 0F	RB21P	Remote Bit 21 Pulse	Pulse[a]	1 SELOGIC processing interval
53	35	01, 05, 0F	RB22P	Remote Bit 22 Pulse	Pulse[a]	1 SELOGIC processing interval
54	36	01, 05, 0F	RB23P	Remote Bit 23 Pulse	Pulse[a]	1 SELOGIC processing interval
55	37	01, 05, 0F	RB24P	Remote Bit 24 Pulse	Pulse[a]	1 SELOGIC processing interval
56	38	01, 05, 0F	RB25P	Remote Bit 25 Pulse	Pulse[a]	1 SELOGIC processing interval
57	39	01, 05, 0F	RB26P	Remote Bit 26 Pulse	Pulse[a]	1 SELOGIC processing interval
58	3A	01, 05, 0F	RB27P	Remote Bit 27 Pulse	Pulse[a]	1 SELOGIC processing interval
59	3B	01, 05, 0F	RB28P	Remote Bit 28 Pulse	Pulse[a]	1 SELOGIC processing interval
60	3C	01, 05, 0F	RB29P	Remote Bit 29 Pulse	Pulse[a]	1 SELOGIC processing interval

Table 10.43 01h, 05h, 0Fh SEL-400G Output Coils (Sheet 3 of 6)

Coil Address in Decimal	Coil Address in Hex	Function Code Supported	Coil Label	Coil Description	Coil Function	Duration
61	3D	01, 05, 0F	RB30P	Remote Bit 30 Pulse	Pulse[a]	1 SELOGIC processing interval
62	3E	01, 05, 0F	RB31P	Remote Bit 31 Pulse	Pulse[a]	1 SELOGIC processing interval
63	3F	01, 05, 0F	RB32P	Remote Bit 32 Pulse	Pulse[a]	1 SELOGIC processing interval
64	40	01, 05, 0F	OCS	Breaker Open Command, Terminal S	Set/Clear[b]	NA
65	41	01, 05, 0F	CCS	Breaker Close Command, Terminal S	Set/Clear[b]	NA
66	42	01, 05, 0F	OCT	Breaker Open Command, Terminal T	Set/Clear[b]	NA
67	43	01, 05, 0F	CCT	Breaker Close Command, Terminal T	Set/Clear[b]	NA
68	44	01, 05, 0F	OCU	Breaker Open Command, Terminal U	Set/Clear[b]	NA
69	45	01, 05, 0F	CCU	Breaker Close Command, Terminal U	Set/Clear[b]	NA
70	46	01, 05, 0F	OCY	Breaker Open Command, Terminal Y	Set/Clear[b]	NA
71	47	01, 05, 0F	CCY	Breaker Close Command, Terminal Y	Set/Clear[b]	NA
72	48	01, 05, 0F	89OC01	Open Disconnect Control 1	Set/Clear[b]	NA
73	49	01, 05, 0F	89CC01	Close Disconnect Control 1	Set/Clear[b]	NA
74	4A	01, 05, 0F	89OC02	Open Disconnect Control 2	Set/Clear[b]	NA
75	4B	01, 05, 0F	89CC02	Close Disconnect Control 2	Set/Clear[b]	NA
76	4C	01, 05, 0F	89OC03	Open Disconnect Control 3	Set/Clear[b]	NA
77	4D	01, 05, 0F	89CC03	Close Disconnect Control 3	Set/Clear[b]	NA
78	4E	01, 05, 0F	89OC04	Open Disconnect Control 4	Set/Clear[b]	NA
79	4F	01, 05, 0F	89CC04	Close Disconnect Control 4	Set/Clear[b]	NA
80	50	01, 05, 0F	89OC05	Open Disconnect Control 5	Set/Clear[b]	NA
81	51	01, 05, 0F	89CC05	Close Disconnect Control 5	Set/Clear[b]	NA
82	52	01, 05, 0F	89OC06	Open Disconnect Control 6	Set/Clear[b]	NA
83	53	01, 05, 0F	89CC06	Close Disconnect Control 6	Set/Clear[b]	NA
84	54	01, 05, 0F	89OC07	Open Disconnect Control 7	Set/Clear[b]	NA
85	55	01, 05, 0F	89CC07	Close Disconnect Control 7	Set/Clear[b]	NA
86	56	01, 05, 0F	89OC08	Open Disconnect Control 8	Set/Clear[b]	NA
87	57	01, 05, 0F	89CC08	Close Disconnect Control 8	Set/Clear[b]	NA
88	58	01, 05, 0F	89OC09	Open Disconnect Control 9	Set/Clear[b]	NA
89	59	01, 05, 0F	89CC09	Close Disconnect Control 9	Set/Clear[b]	NA
90	5A	01, 05, 0F	89OC10	Open Disconnect Control 10	Set/Clear[b]	NA
91	5B	01, 05, 0F	89CC10	Close Disconnect Control 10	Set/Clear[b]	NA
92	5C	01, 05, 0F	RST_DEM[c]	Reset Demand Metering	Pulse	Approximately 1 s
93	5D	01, 05, 0F	RST_PDM[c]	Reset Peak Demand Metering	Pulse	Approximately 0.5 s

Table 10.43 01h, 05h, 0Fh SEL-400G Output Coils (Sheet 4 of 6)

Coil Address in Decimal	Coil Address in Hex	Function Code Supported	Coil Label	Coil Description	Coil Function	Duration
94	5E	01, 05, 0F	RST_ENE[c]	Reset Energy Metering	Pulse	Approximately 0.5 s
95	5F	01, 05, 0F	RST_BKS	Reset Breaker S Monitoring	Pulse	Approximately 3 s
96	60	01, 05, 0F	RST_BKT	Reset Breaker T Monitoring	Pulse	Approximately 3 s
97	61	01, 05, 0F	RST_BKU	Reset Breaker U Monitoring	Pulse	Approximately 3 s
98	62	01, 05, 0F	RST_BKY	Reset Breaker Y Monitoring	Pulse	Approximately 3 s
99	63	01, 05, 0F	RST_MM	Reset Min/Max Metering	Pulse	Approximately 10 ms
100	64	01, 05, 0F	RST_BAT[c]	Reset Battery Monitoring	Pulse	Approximately 0.5 s
101	65	01, 05, 0F	RSTTRGT	Reset Front Panel Targets	Pulse	1 SELOGIC processing interval
102	66	01, 05, 0F	RST_HAL	Rest HALARMA	Pulse	Approximately 0.3 s
103	67	01, 05, 0F	RB33	Remote Bit 33 Set/Clear	Set/Clear	NA
104	68	01, 05, 0F	RB34	Remote Bit 34 Set/Clear	Set/Clear	NA
105	69	01, 05, 0F	RB35	Remote Bit 35 Set/Clear	Set/Clear	NA
106	6A	01, 05, 0F	RB36	Remote Bit 36 Set/Clear	Set/Clear	NA
107	6B	01, 05, 0F	RB37	Remote Bit 37 Set/Clear	Set/Clear	NA
108	6C	01, 05, 0F	RB38	Remote Bit 38 Set/Clear	Set/Clear	NA
109	6D	01, 05, 0F	RB39	Remote Bit 39 Set/Clear	Set/Clear	NA
110	6E	01, 05, 0F	RB40	Remote Bit 40 Set/Clear	Set/Clear	NA
111	6F	01, 05, 0F	RB41	Remote Bit 41 Set/Clear	Set/Clear	NA
112	70	01, 05, 0F	RB42	Remote Bit 42 Set/Clear	Set/Clear	NA
113	71	01, 05, 0F	RB43	Remote Bit 43 Set/Clear	Set/Clear	NA
114	72	01, 05, 0F	RB44	Remote Bit 44 Set/Clear	Set/Clear	NA
115	73	01, 05, 0F	RB45	Remote Bit 45 Set/Clear	Set/Clear	NA
116	74	01, 05, 0F	RB46	Remote Bit 46 Set/Clear	Set/Clear	NA
117	75	01, 05, 0F	RB47	Remote Bit 47 Set/Clear	Set/Clear	NA
118	76	01, 05, 0F	RB48	Remote Bit 48 Set/Clear	Set/Clear	NA
119	77	01, 05, 0F	RB49	Remote Bit 49 Set/Clear	Set/Clear	NA
120	78	01, 05, 0F	RB50	Remote Bit 50 Set/Clear	Set/Clear	NA
121	79	01, 05, 0F	RB51	Remote Bit 51 Set/Clear	Set/Clear	NA
122	7A	01, 05, 0F	RB52	Remote Bit 52 Set/Clear	Set/Clear	NA
123	7B	01, 05, 0F	RB53	Remote Bit 53 Set/Clear	Set/Clear	NA
124	7C	01, 05, 0F	RB54	Remote Bit 54 Set/Clear	Set/Clear	NA
125	7D	01, 05, 0F	RB55	Remote Bit 55 Set/Clear	Set/Clear	NA
126	7E	01, 05, 0F	RB56	Remote Bit 56 Set/Clear	Set/Clear	NA
127	7F	01, 05, 0F	RB57	Remote Bit 57 Set/Clear	Set/Clear	NA
128	80	01, 05, 0F	RB58	Remote Bit 58 Set/Clear	Set/Clear	NA
129	81	01, 05, 0F	RB59	Remote Bit 59 Set/Clear	Set/Clear	NA
130	82	01, 05, 0F	RB60	Remote Bit 60 Set/Clear	Set/Clear	NA
131	83	01, 05, 0F	RB61	Remote Bit 61 Set/Clear	Set/Clear	NA
132	84	01, 05, 0F	RB62	Remote Bit 62 Set/Clear	Set/Clear	NA
133	85	01, 05, 0F	RB63	Remote Bit 63 Set/Clear	Set/Clear	NA

Table 10.43 01h, 05h, 0Fh SEL-400G Output Coils (Sheet 5 of 6)

Coil Address in Decimal	Coil Address in Hex	Function Code Supported	Coil Label	Coil Description	Coil Function	Duration
134	86	01, 05, 0F	RB64	Remote Bit 64 Set/Clear	Set/Clear	NA
135	87	01, 05, 0F	RB33P	Remote Bit 33 Pulse	Pulse[a]	1 SELOGIC processing interval
136	88	01, 05, 0F	RB34P	Remote Bit 34 Pulse	Pulse[a]	1 SELOGIC processing interval
137	89	01, 05, 0F	RB35P	Remote Bit 35 Pulse	Pulse[a]	1 SELOGIC processing interval
138	8A	01, 05, 0F	RB36P	Remote Bit 36 Pulse	Pulse[a]	1 SELOGIC processing interval
139	8B	01, 05, 0F	RB37P	Remote Bit 37 Pulse	Pulse[a]	1 SELOGIC processing interval
140	8C	01, 05, 0F	RB38P	Remote Bit 38 Pulse	Pulse[a]	1 SELOGIC processing interval
141	8D	01, 05, 0F	RB39P	Remote Bit 39 Pulse	Pulse[a]	1 SELOGIC processing interval
142	8E	01, 05, 0F	RB40P	Remote Bit 40 Pulse	Pulse[a]	1 SELOGIC processing interval
143	8F	01, 05, 0F	RB41P	Remote Bit 41 Pulse	Pulse[a]	1 SELOGIC processing interval
144	90	01, 05, 0F	RB42P	Remote Bit 42 Pulse	Pulse[a]	1 SELOGIC processing interval
145	91	01, 05, 0F	RB43P	Remote Bit 43 Pulse	Pulse[a]	1 SELOGIC processing interval
146	92	01, 05, 0F	RB44P	Remote Bit 44 Pulse	Pulse[a]	1 SELOGIC processing interval
147	93	01, 05, 0F	RB45P	Remote Bit 45 Pulse	Pulse[a]	1 SELOGIC processing interval
148	94	01, 05, 0F	RB46P	Remote Bit 46 Pulse	Pulse[a]	1 SELOGIC processing interval
149	95	01, 05, 0F	RB47P	Remote Bit 47 Pulse	Pulse[a]	1 SELOGIC processing interval
150	96	01, 05, 0F	RB48P	Remote Bit 48 Pulse	Pulse[a]	1 SELOGIC processing interval
151	97	01, 05, 0F	RB49P	Remote Bit 49 Pulse	Pulse[a]	1 SELOGIC processing interval
152	98	01, 05, 0F	RB50P	Remote Bit 50 Pulse	Pulse[a]	1 SELOGIC processing interval
153	99	01, 05, 0F	RB51P	Remote Bit 51 Pulse	Pulse[a]	1 SELOGIC processing interval
154	9A	01, 05, 0F	RB52P	Remote Bit 52 Pulse	Pulse[a]	1 SELOGIC processing interval
155	9B	01, 05, 0F	RB53P	Remote Bit 53 Pulse	Pulse[a]	1 SELOGIC processing interval
156	9C	01, 05, 0F	RB54P	Remote Bit 54 Pulse	Pulse[a]	1 SELOGIC processing interval
157	9D	01, 05, 0F	RB55P	Remote Bit 55 Pulse	Pulse[a]	1 SELOGIC processing interval
158	9E	01, 05, 0F	RB56P	Remote Bit 56 Pulse	Pulse[a]	1 SELOGIC processing interval

Table 10.43 01h, 05h, 0Fh SEL-400G Output Coils (Sheet 6 of 6)

Coil Address in Decimal	Coil Address in Hex	Function Code Supported	Coil Label	Coil Description	Coil Function	Duration
159	9F	01, 05, 0F	RB57P	Remote Bit 57 Pulse	Pulse[a]	1 SELOGIC processing interval
160	100	01, 05, 0F	RB58P	Remote Bit 58 Pulse	Pulse[a]	1 SELOGIC processing interval
161	101	01, 05, 0F	RB59P	Remote Bit 59 Pulse	Pulse[a]	1 SELOGIC processing interval
162	102	01, 05, 0F	RB60P	Remote Bit 60 Pulse	Pulse[a]	1 SELOGIC processing interval
163	103	01, 05, 0F	RB61P	Remote Bit 61 Pulse	Pulse[a]	1 SELOGIC processing interval
164	104	01, 05, 0F	RB62P	Remote Bit 62 Pulse	Pulse[a]	1 SELOGIC processing interval
165	105	01, 05, 0F	RB63P	Remote Bit 63 Pulse	Pulse[a]	1 SELOGIC processing interval
166	106	01, 05, 0F	RB64P	Remote Bit 64 Pulse	Pulse[a]	1 SELOGIC processing interval

[a] Pulsing a remote bit that is already set will cause the remote bit to be cleared at the end of the pulse.
[b] If the breaker control jumper is removed, the relay returns an error code 06 (Subordinate Device Busy).
[c] Executing multiple reset bits simultaneously may extend the pulse duration of this bit by several seconds.

Coil addresses start at 0000. If the device is disabled, a function code 05h to any coil will result in an Error Code 04 response. The device responses to other errors in the query are shown in *Table 10.44*.

Table 10.44 Responses to 05h Write Single Coil Query Errors

Error	Error Code Returned
Invalid bit (coil)	Illegal Data Address (02h)
Invalid bit state requested	Illegal Data Value (03h)
Format Error	Illegal Data Value (03h)

06h Preset Single Register Command

The SEL-400G uses this function to allow a Modbus master to write directly to a database register. Refer to the Modbus Quantities Table (*Table 10.53*) for a list of registers that can be written by using this function code. The command request is shown in *Table 10.45*.

Table 10.45 06h Preset Single Register Command

Bytes	Field
Requests from the master must have the following format:	
1 byte	Function Code (06h)
2 bytes	Register Address
2 bytes	Data

The relay responses to errors in the query are shown in *Table 10.46*.

Table 10.46 Responses to 06h Preset Single Register Query Errors

Error	Error Code Returned
Illegal register address	Illegal Data Address (02h)
Illegal register value	Illegal Data Value (03h)
Format error	Illegal Data Value (03h)

08h Loopback Diagnostic Command

The SEL-400G uses this function to allow a Modbus master to perform a diagnostic test on the Modbus communications channel and relay. When the subfunction field is 0000h, the relay returns a replica of the received message. The command request and response are shown in *Table 10.47*.

Table 10.47 08h Loopback Diagnostic Command

Bytes	Field
Requests from the master must have the following format:	
1 byte	Function Code (08h)
2 bytes	Subfunction (0000h)
2 bytes	Data Field
A successful response from the subordinate will have the following format:	
1 byte	Function Code (08h)
2 bytes	Subfunction (0000h)
2 bytes	Data Field (identical to data in Master request)

The relay responses to errors in the query are shown in *Table 10.48*.

Table 10.48 Responses to 08h Loopback Diagnostic Query Errors

Error	Error Code Returned
Illegal subfunction code	Illegal Data Value (03h)
Format error	Illegal Data Value (03h)

0Fh Write Multiple Coils Command

This function code works much like code 05h, except that it allows you to write multiple coils at once, to as many as 1968 per operation. The command request and response are shown in *Table 10.49*.

Table 10.49 0Fh Write Multiple Coils Command (Sheet 1 of 2)

Bytes	Field
Requests from the master must have the following format:	
1 byte	Function Code (0Fh)
2 bytes	Starting Address
2 bytes	Number of Coils to Write
1 byte	Number of Bytes of Data (*n*)
n bytes	Data

Table 10.49 0Fh Write Multiple Coils Command (Sheet 2 of 2)

Bytes	Field
A successful response from the subordinate will have the following format:	
1 byte	Function Code (0Fh)
2 bytes	Starting Address
2 bytes	Number of Coils

Table 10.43 lists the coils supported by the SEL-400G.

Coil addresses start at 0000. If the breaker jumper is removed, the device is disabled or any of the individual bit operations fail for any other reason, the device will respond with Error Code 04. The device responses to other errors in the query are shown in *Table 10.50*.

Table 10.50 Responses to 0Fh Write Multiple Coils Query Errors

Error	Error Code Returned
Invalid starting address and/or quantity of coils	Illegal Data Address (02h)
Quantity of coils and byte count (*n*) do not agree with each other	Illegal Data Value (03h)
Format error	Illegal Data Value (03h)

10h Preset Multiple Registers Command

This function code works much like code 06h, except that it allows you to write multiple registers at once, to as many as 100 per operation. The command request and response are shown in *Table 10.51*.

Table 10.51 10h Preset Multiple Registers Command

Bytes	Field
Requests from the master must have the following format:	
1 byte	Function Code (10h)
2 bytes	Starting Address
2 bytes	Number of Registers to Write
1 byte	Number of Bytes of Data (*n*)
n bytes	Data
A successful response from the subordinate will have the following format:	
1 byte	Function Code (10h)
2 bytes	Starting Address
2 bytes	Number of Registers

The relay responses to errors in the query are shown in *Table 10.52*.

Table 10.52 10h Preset Multiple Registers Query Errors

Error	Error Code Returned
Illegal register to set	Illegal Data Address (02h)
Illegal number of registers to set	Illegal Data Value (03h)
Incorrect number of bytes in query data region	Illegal Data Value (03h)
Invalid register data value	Illegal Data Value (03h)

Bit Operations Using Function Codes 06h and 10h

The SEL-400G includes a register for controlling some of the outputs (RSTDAT in *Table 10.53*). Use Modbus function codes 06h or 10h to write appropriate reset data bits.

Remote Bit labels RB0108S, RB0108C, RB0108P, RB0916S, etc., are also bit operations. Only those bit positions containing a 1 will operate when writing to registers containing the Remote Bit labels.

For Set and Clear operations, each single register write operation will be atomic. This means the affected bits will set or clear simultaneously during the same processing interval. For Pulse operations, bits pulsed in a single register write are not guaranteed to be atomic.

In the case of function code 10h Multiple Register write, the order of operation is determined by the order the Remote Bits are received. When multiple registers are written to, the registers with the highest address take priority.

A function code 03h or 04h read of any of the bit operation registers (RSTDAT or Remote Bit Operations) will return a value of 0.

Modbus Documentation

Configurable Register Mapping

The SEL-400G Modbus Register Map defines an area of 1000 contiguous addresses whose contents are defined by user-settable labels. Use the SEL ASCII command **SET U** (or the Modbus User Map settings in SEL Grid Configurator Software) to define the user map addresses. A default map is provided with the relay. If the default Modbus map is not appropriate or more data are desired, edit the map as necessary for your application.

To use the user-defined data region, follow these steps.

Step 1. Define the list of desired quantities (as many as 1000). Arrange the quantities in any order that is convenient for you to use.

Step 2. Refer to *Table 10.53* for a list of the Modbus labels for each quantity.

Step 3. Use the **SET U** command from the command line or Grid Configurator Modbus User Map to map user registers 1 to 1000 (UM1 to UM1000) using the labels in *Table 10.53* and to map scaling values (UMS1 to UMS1000).

Step 4. Use Modbus function code 03h or 04h to read as many as 125 quantities at a time from map indexes 1 through 1000 (decimal). The Modbus addresses begin with zero, which corresponds to Set U setting UM1.

NOTE: If your master uses 5- or 6-digit address references, add the appropriate number to the Modbus Address when configuring your master. For example, if your master uses 5-digit addressing, add 40001 for holding register operations. For input register functions, add 30001. If your master uses 6-digit addressing, add 400001 for holding register operations or 300001 for input register functions. The actual address that appears in the address field for UM1 will be 0000. A master using 6-digit addresses to read a holding register may be configured for address 400001. However, the data address field of the message from the master will contain address 0000.

The relay multiplies the corresponding analog quantity value by this scaling number. Note that the Modbus master should divide by this number to obtain the original analog quantity value. Blank entries are not allowed in the Modbus User Map. If the User Map text file is sent to the relay containing blank entries, the relay will condense the map so that no blank entries exist. To create spacing in the map, enter a value of 0 for each unused line. If 0 is used, the scaling value for that quantity is forced to 1. Some analog quantities having scaling values that are always forced to 1 (see *Table 10.53*).

As each label is entered in a register via the **SET U** command, the relay will increment to the next valid register.

Modbus Quantities Table

The available labels for the user-defined Modbus data region are defined in *Table 10.53*.

Table 10.53 Modbus Analog Quantities Table (Sheet 1 of 17)

Labels	Scaling	Function Code Supported	Description
ACTGRP[a]	1	03, 04, 06, 10	Active Settings Group (1–6)
RA001–RA256	1	03, 04, 06, 10	Remote Analogs 001–256
EVESEL	1	03, 04, 06, 10	Select an event to load into the Historical Fault Summary Registers. Also, use this register to report the serial number selected
RSTDAT	1	03, 04, 06, 10	Reset Data Analog Bit 0 = RST_DEM Bit 1 = RST_PDM Bit 2 = RST_ENE Bit 3 = RST_BKS Bit 4 = RST_BKT Bit 5 = RST_BKU Bit 6 = RST_BKY Bit 7 = RST_MM Bit 8 = RST_BAT Bit 9 = RSTTRGT Bit 10 = RST_HAL Bits 11–15 Reserved
RB0108S	1	03, 04, 06, 10	Set bit position as follows: Bit 0 = RB08 Bit 1 = RB07 Bit 2 = RB06 Bit 3 = RB05 Bit 4 = RB04 Bit 5 = RB03 Bit 6 = RB02 Bit 7 = RB01 Bits 8–15 Reserved

Table 10.53 Modbus Analog Quantities Table (Sheet 2 of 17)

Labels	Scaling	Function Code Supported	Description
RB0916S	1	03, 04, 06, 10	Set bit position as follows: Bit 0 = RB16 Bit 1 = RB15 Bit 2 = RB14 Bit 3 = RB13 Bit 4 = RB12 Bit 5 = RB11 Bit 6 = RB10 Bit 7 = RB09 Bits 8–15 Reserved
RB1724S	1	03, 04, 06, 10	Set bit position as follows: Bit 0 = RB24 Bit 1 = RB23 Bit 2 = RB22 Bit 3 = RB21 Bit 4 = RB20 Bit 5 = RB19 Bit 6 = RB18 Bit 7 = RB17 Bits 8–15 Reserved
RB2532S	1	03, 04, 06, 10	Set bit position as follows: Bit 0 = RB32 Bit 1 = RB31 Bit 2 = RB30 Bit 3 = RB29 Bit 4 = RB28 Bit 5 = RB27 Bit 6 = RB26 Bit 7 = RB25 Bits 8–15 Reserved
RB3340S	1	03, 04, 06, 10	Set bit position as follows: Bit 0 = RB40 Bit 1 = RB39 Bit 2 = RB38 Bit 3 = RB37 Bit 4 = RB36 Bit 5 = RB35 Bit 6 = RB34 Bit 7 = RB33 Bits 8–15 Reserved
RB4148S	1	03, 04, 06, 10	Set bit position as follows: Bit 0 = RB48 Bit 1 = RB47 Bit 2 = RB46 Bit 3 = RB45 Bit 4 = RB44 Bit 5 = RB43 Bit 6 = RB42 Bit 7 = RB41 Bits 8–15 Reserved

Table 10.53 Modbus Analog Quantities Table (Sheet 3 of 17)

Labels	Scaling	Function Code Supported	Description
RB4956S	1	03, 04, 06, 10	Set bit position as follows: Bit 0 = RB56 Bit 1 = RB55 Bit 2 = RB54 Bit 3 = RB53 Bit 4 = RB52 Bit 5 = RB51 Bit 6 = RB50 Bit 7 = RB49 Bits 8–15 Reserved
RB5764S	1	03, 04, 06, 10	Set bit position as follows: Bit 0 = RB64 Bit 1 = RB63 Bit 2 = RB62 Bit 3 = RB61 Bit 4 = RB60 Bit 5 = RB59 Bit 6 = RB58 Bit 7 = RB57 Bits 8–15 Reserved
RB0108C	1	03, 04, 06, 10	Clear bit position as follows: Bit 0 = RB08 Bit 1 = RB07 Bit 2 = RB06 Bit 3 = RB05 Bit 4 = RB04 Bit 5 = RB03 Bit 6 = RB02 Bit 7 = RB01 Bits 8–15 Reserved
RB0916C	1	03, 04, 06, 10	Clear bit position as follows: Bit 0 = RB16 Bit 1 = RB15 Bit 2 = RB14 Bit 3 = RB13 Bit 4 = RB12 Bit 5 = RB11 Bit 6 = RB10 Bit 7 = RB09 Bits 8–15 Reserved
RB1724C	1	03, 04, 06, 10	Clear bit position as follows: Bit 0 = RB24 Bit 1 = RB23 Bit 2 = RB22 Bit 3 = RB21 Bit 4 = RB20 Bit 5 = RB19 Bit 6 = RB18 Bit 7 = RB17 Bits 8–15 Reserved

Table 10.53 Modbus Analog Quantities Table (Sheet 4 of 17)

Labels	Scaling	Function Code Supported	Description
RB2532C	1	03, 04, 06, 10	Clear bit position as follows: Bit 0 = RB32 Bit 1 = RB31 Bit 2 = RB30 Bit 3 = RB29 Bit 4 = RB28 Bit 5 = RB27 Bit 6 = RB26 Bit 7 = RB25 Bits 8–15 Reserved
RB3340C	1	03, 04, 06, 10	Clear bit position as follows: Bit 0 = RB40 Bit 1 = RB39 Bit 2 = RB38 Bit 3 = RB37 Bit 4 = RB36 Bit 5 = RB35 Bit 6 = RB34 Bit 7 = RB33 Bits 8–15 Reserved
RB4148C	1	03, 04, 06, 10	Clear bit position as follows: Bit 0 = RB48 Bit 1 = RB47 Bit 2 = RB46 Bit 3 = RB45 Bit 4 = RB44 Bit 5 = RB43 Bit 6 = RB42 Bit 7 = RB41 Bits 8–15 Reserved
RB4956C	1	03, 04, 06, 10	Clear bit position as follows: Bit 0 = RB56 Bit 1 = RB55 Bit 2 = RB54 Bit 3 = RB53 Bit 4 = RB52 Bit 5 = RB51 Bit 6 = RB50 Bit 7 = RB49 Bits 8–15 Reserved
RB5764C	1	03, 04, 06, 10	Clear bit position as follows: Bit 0 = RB64 Bit 1 = RB63 Bit 2 = RB62 Bit 3 = RB61 Bit 4 = RB60 Bit 5 = RB59 Bit 6 = RB58 Bit 7 = RB57 Bits 8–15 Reserved

Table 10.53 Modbus Analog Quantities Table (Sheet 5 of 17)

Labels	Scaling	Function Code Supported	Description
RB0108P	1	03, 04, 06, 10	Pulse bit position as follows: Bit 0 = RB08 Bit 1 = RB07 Bit 2 = RB06 Bit 3 = RB05 Bit 4 = RB04 Bit 5 = RB03 Bit 6 = RB02 Bit 7 = RB01 Bits 8–15 Reserved
RB0916P	1	03, 04, 06, 10	Pulse bit position as follows: Bit 0 = RB16 Bit 1 = RB15 Bit 2 = RB14 Bit 3 = RB13 Bit 4 = RB12 Bit 5 = RB11 Bit 6 = RB10 Bit 7 = RB09 Bits 8–15 Reserved
RB1724P	1	03, 04, 06, 10	Pulse bit position as follows: Bit 0 = RB24 Bit 1 = RB23 Bit 2 = RB22 Bit 3 = RB21 Bit 4 = RB20 Bit 5 = RB19 Bit 6 = RB18 Bit 7 = RB17 Bits 8–15 Reserved
RB2532P	1	03, 04, 06, 10	Pulse bit position as follows: Bit 0 = RB32 Bit 1 = RB31 Bit 2 = RB30 Bit 3 = RB29 Bit 4 = RB28 Bit 5 = RB27 Bit 6 = RB26 Bit 7 = RB25 Bits 8–15 Reserved
RB3340P	1	03, 04, 06, 10	Pulse bit position as follows: Bit 0 = RB40 Bit 1 = RB39 Bit 2 = RB38 Bit 3 = RB37 Bit 4 = RB36 Bit 5 = RB35 Bit 6 = RB34 Bit 7 = RB33 Bits 8–15 Reserved

Table 10.53 Modbus Analog Quantities Table (Sheet 6 of 17)

Labels	Scaling	Function Code Supported	Description
RB4148P	1	03, 04, 06, 10	Pulse bit position as follows: Bit 0 = RB48 Bit 1 = RB47 Bit 2 = RB46 Bit 3 = RB45 Bit 4 = RB44 Bit 5 = RB43 Bit 6 = RB42 Bit 7 = RB41 Bits 8–15 Reserved
RB4956P	1	03, 04, 06, 10	Pulse bit position as follows: Bit 0 = RB56 Bit 1 = RB55 Bit 2 = RB54 Bit 3 = RB53 Bit 4 = RB52 Bit 5 = RB51 Bit 6 = RB50 Bit 7 = RB49 Bits 8–15 Reserved
RB5764P	1	03, 04, 06, 10	Pulse bit position as follows: Bit 0 = RB64 Bit 1 = RB63 Bit 2 = RB62 Bit 3 = RB61 Bit 4 = RB60 Bit 5 = RB59 Bit 6 = RB58 Bit 7 = RB57 Bits 8–15 Reserved
OPBKRS[b]	1	03, 04, 06, 10	Operate Breaker S
OPBKRT[b]	1	03, 04, 06, 10	Operate Breaker T
OPBKRU[b]	1	03, 04, 06, 10	Operate Breaker U
OPBKRY[b]	1	03, 04, 06, 10	Operate Breaker Y
OP8901[b]	1	03, 04, 06, 10	Operate Disconnect 1
OP8902[b]	1	03, 04, 06, 10	Operate Disconnect 2
OP8903[b]	1	03, 04, 06, 10	Operate Disconnect 3
OP8904[b]	1	03, 04, 06, 10	Operate Disconnect 4
OP8905[b]	1	03, 04, 06, 10	Operate Disconnect 5
OP8906[b]	1	03, 04, 06, 10	Operate Disconnect 6
OP8907[b]	1	03, 04, 06, 10	Operate Disconnect 7
OP8908[b]	1	03, 04, 06, 10	Operate Disconnect 8
OP8909[b]	1	03, 04, 06, 10	Operate Disconnect 9
OP8910[b]	1	03, 04, 06, 10	Operate Disconnect 10
TIME_S	1	03, 04, 06, 10	Set Seconds (0–59)
TIME_M	1	03, 04, 06, 10	Set Minutes (0–59)

Table 10.53 Modbus Analog Quantities Table (Sheet 7 of 17)

Labels	Scaling	Function Code Supported	Description
TIME_H	1	03, 04, 06, 10	Set Hour (0–23)
DATE_D	1	03, 04, 06, 10	Set Day (1–31)
DATE_M	1	03, 04, 06, 10	Set Month (1–12)
DATE_Y	1	03, 04, 06, 10	Set Year (2000–2090)
MAXGRP	1	03, 04	Maximum number of protection groups
LSTEVSN	1	03, 04	Last event serial number
ETYPE[c]	1	03, 04	Event fault type
ETAR1[c]	1	03, 04	Event fault targets (Upper byte is first target row, lower byte is second target row)
ETAR2[c]	1	03, 04	Event fault targets (Upper byte is third target row, lower byte is 0)
EFREQG[c]		03, 04	Event fault generator fault frequency
EFREQS[c]		03, 04	Event fault system fault frequency
EGRP[c]	1	03, 04	Event fault active Settings Group (1–6)
ETIMES[c]	1	03, 04	Event fault time seconds (scaled to milliseconds)
ETIMEM[c]	1	03, 04	Event fault time minutes
ETIMEH[c]	1	03, 04	Event fault time hours
EDATED[c]	1	03, 04	Event fault date day
EDATEM[c]	1	03, 04	Event fault date month
EDATEY[c]	1	03, 04	Event fault date year
ETIMEUS[c]	1	03, 04	Event fault time UTC Seconds (scaled to milliseconds)
ETIMEUM[c]	1	03, 04	Event fault time UTC minutes
ETIMEUH[c]	1	03, 04	Event fault time UTC hours
EDATEUD[c]	1	03, 04	Event fault date UTC day
EDATEUM[c]	1	03, 04	Event fault date UTC month
EDATEUY[c]	1	03, 04	Event fault date UTC year
FWREV	1	03, 04	Relay firmware revision
SNUMBL[d]	1	03, 04	Lowest 4 digits of the relay serial number
SNUMBM[d]	1	03, 04	Middle 4 digits of the relay serial number
SNUMBH[d]	1	03, 04	Highest 4 digits of the relay serial number
ROW_000–ROW_531	1	03, 04	Bitwise representation of Relay Word Row 000–531
BKRSOP		03, 04	Number of Breaker S operations
BKRTOP		03, 04	Number of Breaker T operations
BKRUOP		03, 04	Number of Breaker U operations
BKRYOP		03, 04	Number of Breaker Y operations
RTS01TV–RTS24TV		03, 04	RTD temperature value in °C, RTS 01–24
RTC01TV–RTC24TV		03, 04	Remote temperature value in °C, RTC 01–24
MAMB1		03, 04	Ambient temperature value in °C, Element 1
MAMB2		03, 04	Ambient temperature value in °C, Element 2
MAMB3		03, 04	Ambient temperature value in °C, Element 3
BSBCWPA		03, 04	Breaker S breaker-contact wear for Pole A
BSBCWPB		03, 04	Breaker S breaker-contact wear for Pole B

Table 10.53 Modbus Analog Quantities Table (Sheet 8 of 17)

Labels	Scaling	Function Code Supported	Description
BSBCWPC		03, 04	Breaker S breaker-contact wear for Pole C
BTBCWPA		03, 04	Breaker T breaker-contact wear for Pole A
BTBCWPB		03, 04	Breaker T breaker-contact wear for Pole B
BTBCWPC		03, 04	Breaker T breaker-contact wear for Pole C
BUBCWPA		03, 04	Breaker U breaker-contact wear for Pole A
BUBCWPB		03, 04	Breaker U breaker-contact wear for Pole B
BUBCWPC		03, 04	Breaker U breaker-contact wear for Pole C
BYBCWPA		03, 04	Breaker Y breaker-contact wear for Pole A
BYBCWPB		03, 04	Breaker Y breaker-contact wear for Pole B
BYBCWPC		03, 04	Breaker Y breaker-contact wear for Pole C
FREQPG		03, 04	Generator frequency
FREQPS		03, 04	System frequency
DFREQPG		03, 04	Generator rate-of-change of frequency
DFREQPS		03, 04	System rate-of-change of frequency
VDC		03, 04	Station battery dc voltage
DCPO		03, 04	Average positive-to-ground DC 1 voltage
DCNE		03, 04	Average Negative-to-Ground DC 1 Voltage
DCRI		03, 04	AC ripple of DC 1 voltage
DCMIN		03, 04	Minimum DC 1 voltage
DCMAX		03, 04	Maximum DC 1 voltage
PMV01–PMV64		03, 04	Protection SELOGIC Math Variable 01–64
PCN01CV–PCN32CV		03, 04	Protection SELOGIC Counter 01–32 current value
AMV001–AMV256		03, 04	Automation SELOGIC Math Variable 001–256
ACN01CV–ACN32CV		03, 04	Automation SELOGIC Counter 01–32 current value
TODMS		03, 04	UTC Time of Day in Milliseconds (0–86400000)
THR		03, 04	UTC Time, Hour (0–23)
TMIN		03, 04	UTC Time, Minute (0–59)
TSEC		03, 04	UTC Time, Seconds (0–59)
TMSEC		03, 04	UTC Time, Milliseconds (0–999)
DDOW		03, 04	UTC Date, Day of the week (1-SUN … 7-SAT)
DDOM		03, 04	UTC Date, Day of the month (1–31)
DDOY		03, 04	UTC Date, Day of the year (1–366)
DMON		03, 04	UTC Date, Month (1–12)
DYEAR		03, 04	UTC Date, Year (2000–2200)
TLODMS		03, 04	Local Time of Day in Milliseconds (0–86400000)
TLHR		03, 04	Local Time, Hour (0–23)
TLMIN		03, 04	Local Time, Minute (0–59)
TLSEC		03, 04	Local Time, Seconds (0–59)
TLMSEC		03, 04	Local Time, Milliseconds (0–999)
DLDOW		03, 04	Local Date, Day of the week (1-SUN … 7-SAT)

Table 10.53 Modbus Analog Quantities Table (Sheet 9 of 17)

Labels	Scaling	Function Code Supported	Description
DLDOM		03, 04	Local Date, Day of the month (1–31)
DLDOY		03, 04	Local Date, Day of the year (1–366)
DLMON		03, 04	Local Date, Month (1–12)
DLYEAR		03, 04	Local Date, Year (2000–2200)
TUTC		03, 04	Offset from local time to UTC time
TQUAL		03, 04	Worst case time source clock time error
RLYTEMP		03, 04	Relay temperature (°C temperature of the box)
RAO01– RAO64		03, 04	Remote Analog Output 01–64
25VPFM		03, 04	25 sync-check polarizing voltage magnitude
25VPFA		03, 04	25 sync-check polarizing voltage angle
25VSSFM		03, 04	25 sync-check synchronizing voltage magnitude for Breaker S
25VSTFM		03, 04	25 sync-check synchronizing voltage magnitude for Breaker T
25VSUFM		03, 04	25 sync-check synchronizing voltage magnitude for Breaker U
25VSYFM		03, 04	25 sync-check synchronizing voltage magnitude for Breaker Y
25VSSFA		03, 04	25 sync-check synchronizing voltage angle for Breaker S
25VSTFA		03, 04	25 sync-check synchronizing voltage angle for Breaker T
25VSUFA		03, 04	25 sync-check synchronizing voltage angle for Breaker U
25VSYFA		03, 04	25 sync-check synchronizing voltage angle for Breaker Y
25ANGS		03, 04	25 sync-check angle difference for Breaker S
25ANGT		03, 04	25 sync-check angle difference for Breaker T
25ANGU		03, 04	25 sync-check angle difference for Breaker U
25ANGY		03, 04	25 sync-check angle difference for Breaker Y
25ANGCS		03, 04	25 sync-check compensated angle difference for Breaker S
25ANGCT		03, 04	25 sync-check compensated angle difference for Breaker T
25ANGCU		03, 04	25 sync-check compensated angle difference for Breaker U
25ANGCY		03, 04	25 sync-check compensated angle difference for Breaker Y
25SLIPS		03, 04	25 sync-check slip frequency Breaker S
25SLIPT		03, 04	25 sync-check slip frequency Breaker T
25SLIPU		03, 04	25 sync-check slip frequency Breaker U
25SLIPY		03, 04	25 sync-check slip frequency Breaker Y
25DIFVS		03, 04	25 sync-check voltage difference for Breaker S
25DIFVT		03, 04	25 sync-check voltage difference for Breaker T
25DIFVU		03, 04	25 sync-check voltage difference for Breaker U
25DIFVY		03, 04	25 sync-check voltage difference for Breaker Y
25AFCT		03, 04	25A Autosynchronizer frequency pulse count
25AVCT		03, 04	25A Autosynchronizer voltage pulse count
40PQMX		03, 04	Loss-of-field Zone 3 Maximum Reactive Power
40PPMX		03, 04	Loss-of-field Zone 3 Maximum Active Power
40PQMN		03, 04	Loss-of-field Zone 2 Minimum Reactive Power
40PPLG		03, 04	Loss-of-field Zone 3 Active Power Lag PF Limit

Table 10.53 Modbus Analog Quantities Table (Sheet 10 of 17)

Labels	Scaling	Function Code Supported	Description
40PPLD		03, 04	Loss-of-field Zone 3 Active Power Lead PF Limit
40PPU		03, 04	Loss-of-field Zone 3 Active Power UPF limit
40PQZ2		03, 04	Loss-of-field Zone 2 Reactive Power limit
VAVFMC		03, 04	40 ms average filtered phase-to-neutral voltage magnitude, A-Phase, Terminal V
VBVFMC		03, 04	40 ms average filtered phase-to-neutral voltage magnitude, B-Phase, Terminal V
VCVFMC		03, 04	40 ms average filtered phase-to-neutral voltage magnitude, C-Phase, Terminal V
VAZFMC		03, 04	40 ms average filtered phase-to-neutral voltage magnitude, A-Phase, Terminal Z
VBZFMC		03, 04	40 ms average filtered phase-to-neutral voltage magnitude, B-Phase, Terminal Z
VCZFMC		03, 04	40 ms average filtered phase-to-neutral voltage magnitude, C-Phase, Terminal Z
VAVFAC		03, 04	40 ms average filtered phase-to-neutral voltage angle, A-Phase, Terminal V
VBVFAC		03, 04	40 ms average filtered phase-to-neutral voltage angle, B-Phase, Terminal V
VCVFAC		03, 04	40 ms average filtered phase-to-neutral voltage angle, C-Phase, Terminal V
VAZFAC		03, 04	40 ms average filtered phase-to-neutral voltage angle, A-Phase, Terminal Z
VBZFAC		03, 04	40 ms average filtered phase-to-neutral voltage angle, B-Phase, Terminal Z
VCZFAC		03, 04	40 ms average filtered phase-to-neutral voltage angle, C-Phase, Terminal Z
VABVFMC		03, 04	40 ms average filtered phase-to-phase voltage magnitude, Phases AB, Terminal V
VBCVFMC		03, 04	40 ms average filtered phase-to-phase voltage magnitude, Phases BC, Terminal V
VCAVFMC		03, 04	40 ms average filtered phase-to-phase voltage magnitude, Phases CA, Terminal V
VABZFMC		03, 04	40 ms average filtered phase-to-phase voltage magnitude, Phases AB, Terminal Z
VBCZFMC		03, 04	40 ms average filtered phase-to-phase voltage magnitude, Phases BC, Terminal Z
VCAZFMC		03, 04	40 ms average filtered phase-to-phase voltage magnitude, Phases CA, Terminal Z
VABVFAC		03, 04	40 ms average filtered phase-to-phase voltage angle, Phases AB, Terminal V
VBCVFAC		03, 04	40 ms average filtered phase-to-phase voltage angle, Phases BC, Terminal V
VCAVFAC		03, 04	40 ms average filtered phase-to-phase voltage angle, Phases CA, Terminal V
VABZFAC		03, 04	40 ms average filtered phase-to-phase voltage angle, Phases AB, Terminal Z
VBCZFAC		03, 04	40 ms average filtered phase-to-phase voltage angle, Phases BC, Terminal Z
VCAZFAC		03, 04	40 ms average filtered phase-to-phase voltage angle, Phases CA, Terminal Z
V1VMC		03, 04	40 ms average positive-sequence voltage magnitude, Terminal V
V1ZMC		03, 04	40 ms average positive-sequence voltage magnitude, Terminal Z
V1VAC		03, 04	40 ms average positive-sequence voltage angle, Terminal V
V1ZAC		03, 04	40 ms average positive-sequence voltage angle, Terminal Z
3V2VMC		03, 04	40 ms average negative-sequence voltage magnitude, Terminal V
3V2ZMC		03, 04	40 ms average negative-sequence voltage magnitude, Terminal Z
3V2VAC		03, 04	40 ms average negative-sequence voltage angle, Terminal V
3V2ZAC		03, 04	40 ms average negative-sequence voltage angle, Terminal Z
3V0VMC		03, 04	40 ms average zero-sequence voltage magnitude, Terminal V
3V0ZMC		03, 04	40 ms average zero-sequence voltage magnitude, Terminal Z
3V0VAC		03, 04	40 ms average zero-sequence voltage angle, Terminal V
3V0ZAC		03, 04	40 ms average zero-sequence voltage angle, Terminal Z

Table 10.53 Modbus Analog Quantities Table (Sheet 11 of 17)

Labels	Scaling	Function Code Supported	Description
VN3FMC		03, 04	40 ms average filtered Generator Neutral Third-Harmonic Voltage magnitude
VN3FAC		03, 04	40 ms average filtered Generator Neutral Third-Harmonic Voltage angle
3V0Z3MC		03, 04	40 ms average filtered Generator Terminal Third-Harmonic Voltage magnitude
3V0Z3AC		03, 04	40 ms average filtered Generator Terminal Third-Harmonic Voltage angle
VG3FMC		03, 04	40 ms average filtered Total Neutral Third-Harmonic Voltage magnitude
VG3FAC		03, 04	40 ms average filtered Total Neutral Third-Harmonic Voltage angle
IASFMC		03, 04	40 ms average filtered phase current magnitude, A-Phase, Terminal S
IBSFMC		03, 04	40 ms average filtered phase current magnitude, B-Phase, Terminal S
ICSFMC		03, 04	40 ms average filtered phase current magnitude, C-Phase, Terminal S
IATFMC		03, 04	40 ms average filtered phase current magnitude, A-Phase, Terminal T
IBTFMC		03, 04	40 ms average filtered phase current magnitude, B-Phase, Terminal T
ICTFMC		03, 04	40 ms average filtered phase current magnitude, C-Phase, Terminal T
IAUFMC		03, 04	40 ms average filtered phase current magnitude, A-Phase, Terminal U
IBUFMC		03, 04	40 ms average filtered phase current magnitude, B-Phase, Terminal U
ICUFMC		03, 04	40 ms average filtered phase current magnitude, C-Phase, Terminal U
IAYFMC		03, 04	40 ms average filtered phase current magnitude, A-Phase, Terminal Y
IBYFMC		03, 04	40 ms average filtered phase current magnitude, B-Phase, Terminal Y
ICYFMC		03, 04	40 ms average filtered phase current magnitude, C-Phase, Terminal Y
IAGFMC		03, 04	40 ms average filtered phase current magnitude, A-Phase, Terminal G
IBGFMC		03, 04	40 ms average filtered phase current magnitude, B-Phase, Terminal G
ICGFMC		03, 04	40 ms average filtered phase current magnitude, C-Phase, Terminal G
IASFAC		03, 04	40 ms average filtered phase current angle, A-Phase, Terminal S
IBSFAC		03, 04	40 ms average filtered phase current angle, B-Phase, Terminal S
ICSFAC		03, 04	40 ms average filtered phase current angle, C-Phase, Terminal S
IATFAC		03, 04	40 ms average filtered phase current angle, A-Phase, Terminal T
IBTFAC		03, 04	40 ms average filtered phase current angle, B-Phase, Terminal T
ICTFAC		03, 04	40 ms average filtered phase current angle, C-Phase, Terminal T
IAUFAC		03, 04	40 ms average filtered phase current angle, A-Phase, Terminal U
IBUFAC		03, 04	40 ms average filtered phase current angle, B-Phase, Terminal U
ICUFAC		03, 04	40 ms average filtered phase current angle, C-Phase, Terminal U
IAYFAC		03, 04	40 ms average filtered phase current angle, A-Phase, Terminal Y
IBYFAC		03, 04	40 ms average filtered phase current angle, B-Phase, Terminal Y
ICYFAC		03, 04	40 ms average filtered phase current angle, C-Phase, Terminal Y
IAGFAC		03, 04	40 ms average filtered phase current angle, A-Phase, Terminal G
IBGFAC		03, 04	40 ms average filtered phase current angle, B-Phase, Terminal G
ICGFAC		03, 04	40 ms average filtered phase current angle, C-Phase, Terminal G
IY1FMC		03, 04	40 ms average filtered current magnitude, Channel 1, Terminal Y
IY2FMC		03, 04	40 ms average filtered current magnitude, Channel 2, Terminal Y
IY3FMC		03, 04	40 ms average filtered current magnitude, Channel 3, Terminal Y
IY1FAC		03, 04	40 ms average filtered current angle, Channel 1, Terminal Y

Table 10.53 Modbus Analog Quantities Table (Sheet 12 of 17)

Labels	Scaling	Function Code Supported	Description
IY2FAC		03, 04	40 ms average filtered current angle, Channel 2, Terminal Y
IY3FAC		03, 04	40 ms average filtered current angle, Channel 3, Terminal Y
I1SMC		03, 04	40 ms average positive-sequence current magnitude, Terminal S
I1TMC		03, 04	40 ms average positive-sequence current magnitude, Terminal T
I1UMC		03, 04	40 ms average positive-sequence current magnitude, Terminal U
I1YMC		03, 04	40 ms average positive-sequence current magnitude, Terminal Y
I1GMC		03, 04	40 ms average positive-sequence current magnitude, Terminal G
I1SAC		03, 04	40 ms average positive-sequence current angle, Terminal S
I1TAC		03, 04	40 ms average positive-sequence current angle, Terminal T
I1UAC		03, 04	40 ms average positive-sequence current angle, Terminal U
I1YAC		03, 04	40 ms average positive-sequence current angle, Terminal Y
I1GAC		03, 04	40 ms average positive-sequence current angle, Terminal G
3I2SMC		03, 04	40 ms average negative-sequence current magnitude, Terminal S
3I2TMC		03, 04	40 ms average negative-sequence current magnitude, Terminal T
3I2UMC		03, 04	40 ms average negative-sequence current magnitude, Terminal U
3I2YMC		03, 04	40 ms average negative-sequence current magnitude, Terminal Y
3I2GMC		03, 04	40 ms average negative-sequence current magnitude, Terminal G
3I2SAC		03, 04	40 ms average negative-sequence current angle, Terminal S
3I2TAC		03, 04	40 ms average negative-sequence current angle, Terminal T
3I2UAC		03, 04	40 ms average negative-sequence current angle, Terminal U
3I2YAC		03, 04	40 ms average negative-sequence current angle, Terminal Y
3I2GAC		03, 04	40 ms average negative-sequence current angle, Terminal G
3I0SMC		03, 04	40 ms average zero-sequence current magnitude, Terminal S
3I0TMC		03, 04	40 ms average zero-sequence current magnitude, Terminal T
3I0UMC		03, 04	40 ms average zero-sequence current magnitude, Terminal U
3I0YMC		03, 04	40 ms average zero-sequence current magnitude, Terminal Y
3I0GMC		03, 04	40 ms average zero-sequence current magnitude, Terminal G
3I0SAC		03, 04	40 ms average zero-sequence current angle, Terminal S
3I0TAC		03, 04	40 ms average zero-sequence current angle, Terminal T
3I0UAC		03, 04	40 ms average zero-sequence current angle, Terminal U
3I0YAC		03, 04	40 ms average zero-sequence current angle, Terminal Y
3I0GAC		03, 04	40 ms average zero-sequence current angle, Terminal G
3I2SMS		03, 04	1 s average negative-sequence current magnitude, Terminal S
3I2TMS		03, 04	1 s average negative-sequence current magnitude, Terminal T
3I2UMS		03, 04	1 s average negative-sequence current magnitude, Terminal U
3I2YMS		03, 04	1 s average negative-sequence current magnitude, Terminal Y
3I2GMS		03, 04	1 s average negative-sequence current magnitude, Terminal G
3I0SMS		03, 04	1 s average zero-sequence current magnitude, Terminal S
3I0TMS		03, 04	1 s average zero-sequence current magnitude, Terminal T
3I0UMS		03, 04	1 s average zero-sequence current magnitude, Terminal U

Table 10.53 Modbus Analog Quantities Table (Sheet 13 of 17)

Labels	Scaling	Function Code Supported	Description
3I0YMS		03, 04	1 s average zero-sequence current magnitude, Terminal Y
3I0GMS		03, 04	1 s average zero-sequence current magnitude, Terminal G
PASFC		03, 04	40 ms average phase fundamental active power, A-Phase, Terminal S
PBSFC		03, 04	40 ms average phase fundamental active power, B-Phase, Terminal S
PCSFC		03, 04	40 ms average phase fundamental active power, C-Phase, Terminal S
PATFC		03, 04	40 ms average phase fundamental active power, A-Phase, Terminal T
PBTFC		03, 04	40 ms average phase fundamental active power, B-Phase, Terminal T
PCTFC		03, 04	40 ms average phase fundamental active power, C-Phase, Terminal T
PAUFC		03, 04	40 ms average phase fundamental active power, A-Phase, Terminal U
PBUFC		03, 04	40 ms average phase fundamental active power, B-Phase, Terminal U
PCUFC		03, 04	40 ms average phase fundamental active power, C-Phase, Terminal U
PAYFC		03, 04	40 ms average phase fundamental active power, A-Phase, Terminal Y
PBYFC		03, 04	40 ms average phase fundamental active power, B-Phase, Terminal Y
PCYFC		03, 04	40 ms average phase fundamental active power, C-Phase, Terminal Y
PAGFC		03, 04	40 ms average phase fundamental active power, A-Phase, Terminal G
PBGFC		03, 04	40 ms average phase fundamental active power, B-Phase, Terminal G
PCGFC		03, 04	40 ms average phase fundamental active power, C-Phase, Terminal G
QASFC		03, 04	40 ms average phase fundamental reactive power, A-Phase, Terminal S
QBSFC		03, 04	40 ms average phase fundamental reactive power, B-Phase, Terminal S
QCSFC		03, 04	40 ms average phase fundamental reactive power, C-Phase, Terminal S
QATFC		03, 04	40 ms average phase fundamental reactive power, A-Phase, Terminal T
QBTFC		03, 04	40 ms average phase fundamental reactive power, B-Phase, Terminal T
QCTFC		03, 04	40 ms average phase fundamental reactive power, C-Phase, Terminal T
QAUFC		03, 04	40 ms average phase fundamental reactive power, A-Phase, Terminal U
QBUFC		03, 04	40 ms average phase fundamental reactive power, B-Phase, Terminal U
QCUFC		03, 04	40 ms average phase fundamental reactive power, C-Phase, Terminal U
QAYFC		03, 04	40 ms average phase fundamental reactive power, A-Phase, Terminal Y
QBYFC		03, 04	40 ms average phase fundamental reactive power, B-Phase, Terminal Y
QCYFC		03, 04	40 ms average phase fundamental reactive power, C-Phase, Terminal Y
QAGFC		03, 04	40 ms average phase fundamental reactive power, A-Phase, Terminal G
QBGFC		03, 04	40 ms average phase fundamental reactive power, B-Phase, Terminal G
QCGFC		03, 04	40 ms average phase fundamental reactive power, C-Phase, Terminal G
SASFC		03, 04	40 ms average phase fundamental apparent power, A-Phase, Terminal S
SBSFC		03, 04	40 ms average phase fundamental apparent power, B-Phase, Terminal S
SCSFC		03, 04	40 ms average phase fundamental apparent power, C-Phase, Terminal S
SATFC		03, 04	40 ms average phase fundamental apparent power, A-Phase, Terminal T
SBTFC		03, 04	40 ms average phase fundamental apparent power, B-Phase, Terminal T
SCTFC		03, 04	40 ms average phase fundamental apparent power, C-Phase, Terminal T
SAUFC		03, 04	40 ms average phase fundamental apparent power, A-Phase, Terminal U
SBUFC		03, 04	40 ms average phase fundamental apparent power, B-Phase, Terminal U

Table 10.53 Modbus Analog Quantities Table (Sheet 14 of 17)

Labels	Scaling	Function Code Supported	Description
SCUFC		03, 04	40 ms average phase fundamental apparent power, C-Phase, Terminal U
SAYFC		03, 04	40 ms average phase fundamental apparent power, A-Phase, Terminal Y
SBYFC		03, 04	40 ms average phase fundamental apparent power, B-Phase, Terminal Y
SCYFC		03, 04	40 ms average phase fundamental apparent power, C-Phase, Terminal Y
SAGFC		03, 04	40 ms average phase fundamental apparent power, A-Phase, Terminal G
SBGFC		03, 04	40 ms average phase fundamental apparent power, B-Phase, Terminal G
SCGFC		03, 04	40 ms average phase fundamental apparent power, C-Phase, Terminal G
3PSFC		03, 04	40 ms average three-phase fundamental active power, Terminal S
3PTFC		03, 04	40 ms average three-phase fundamental active power, Terminal T
3PUFC		03, 04	40 ms average three-phase fundamental active power, Terminal U
3PYFC		03, 04	40 ms average three-phase fundamental active power, Terminal Y
3PGFC		03, 04	40 ms average three-phase fundamental active power, Terminal G
3QSFC		03, 04	40 ms average three-phase fundamental reactive power, Terminal S
3QTFC		03, 04	40 ms average three-phase fundamental reactive power, Terminal T
3QUFC		03, 04	40 ms average three-phase fundamental reactive power, Terminal U
3QYFC		03, 04	40 ms average three-phase fundamental reactive power, Terminal Y
3QGFC		03, 04	40 ms average three-phase fundamental reactive power, Terminal G
3SSFC		03, 04	40 ms average three-phase fundamental apparent power, Terminal S
3STFC		03, 04	40 ms average three-phase fundamental apparent power, Terminal T
3SUFC		03, 04	40 ms average three-phase fundamental apparent power, Terminal U
3SYFC		03, 04	40 ms average three-phase fundamental apparent power, Terminal Y
3SGFC		03, 04	40 ms average three-phase fundamental apparent power, Terminal G
3PSFS		03, 04	1 s average three-phase fundamental active power, Terminal S
3PTFS		03, 04	1 s average three-phase fundamental active power, Terminal T
3PUFS		03, 04	1 s average three-phase fundamental active power, Terminal U
3PYFS		03, 04	1 s average three-phase fundamental active power, Terminal Y
3PGFS		03, 04	1 s average three-phase fundamental active power, Terminal G
3QSFS		03, 04	1 s average three-phase fundamental reactive power, Terminal S
3QTFS		03, 04	1 s average three-phase fundamental reactive power, Terminal T
3QUFS		03, 04	1 s average three-phase fundamental reactive power, Terminal U
3QYFS		03, 04	1 s average three-phase fundamental reactive power, Terminal Y
3QGFS		03, 04	1 s average three-phase fundamental reactive power, Terminal G
3SSFS		03, 04	1 s average three-phase fundamental apparent power, Terminal S
3STFS		03, 04	1 s average three-phase fundamental apparent power, Terminal T
3SUFS		03, 04	1 s average three-phase fundamental apparent power, Terminal U
3SYFS		03, 04	1 s average three-phase fundamental apparent power, Terminal Y
3SGFS		03, 04	1 s average three-phase fundamental apparent power, Terminal G
PFASC		03, 04	Phase displacement power factor, A-Phase, Terminal S
PFBSC		03, 04	Phase displacement power factor, B-Phase, Terminal S
PFCSC		03, 04	Phase displacement power factor, C-Phase, Terminal S

Table 10.53 Modbus Analog Quantities Table (Sheet 15 of 17)

Labels	Scaling	Function Code Supported	Description
PFATC		03, 04	Phase displacement power factor, A-Phase, Terminal T
PFBTC		03, 04	Phase displacement power factor, B-Phase, Terminal T
PFCTC		03, 04	Phase displacement power factor, C-Phase, Terminal T
PFAUC		03, 04	Phase displacement power factor, A-Phase, Terminal U
PFBUC		03, 04	Phase displacement power factor, B-Phase, Terminal U
PFCUC		03, 04	Phase displacement power factor, C-Phase, Terminal U
PFAYC		03, 04	Phase displacement power factor, A-Phase, Terminal Y
PFBYC		03, 04	Phase displacement power factor, B-Phase, Terminal Y
PFCYC		03, 04	Phase displacement power factor, C-Phase, Terminal Y
PFAGC		03, 04	Phase displacement power factor, A-Phase, Terminal G
PFBGC		03, 04	Phase displacement power factor, B-Phase, Terminal G
PFCGC		03, 04	Phase displacement power factor, C-Phase, Terminal G
3PFSC		03, 04	Three-phase displacement power factor, Terminal S
3PFTC		03, 04	Three-phase displacement power factor, Terminal T
3PFUC		03, 04	Three-phase displacement power factor, Terminal U
3PFYC		03, 04	Three-phase displacement power factor, Terminal Y
3PFGC		03, 04	Three-phase displacement power factor, Terminal G
VAZRC		03, 04	40 ms average rms phase-to-neutral voltage magnitude, A-Phase, Terminal Z
VBZRC		03, 04	40 ms average rms phase-to-neutral voltage magnitude, B-Phase, Terminal Z
VCZRC		03, 04	40 ms average rms phase-to-neutral voltage magnitude, C-Phase, Terminal Z
VABZRC		03, 04	40 ms average rms phase-to-phase voltage magnitude, Phases AB, Terminal Z
VBCZRC		03, 04	40 ms average rms phase-to-phase voltage magnitude, Phases BC, Terminal Z
VCAZRC		03, 04	40 ms average rms phase-to-phase voltage magnitude, Phases CA, Terminal Z
IAGRC		03, 04	40 ms average rms phase current magnitude, A-Phase, Terminal G
IBGRC		03, 04	40 ms average rms phase current magnitude, B-Phase, Terminal G
ICGRC		03, 04	40 ms average rms phase current magnitude, C-Phase, Terminal G
IAGRS		03, 04	1 s average rms phase current magnitude, A-Phase, Terminal G
IBGRS		03, 04	1 s average rms phase current magnitude, B-Phase, Terminal G
ICGRS		03, 04	1 s average rms phase current magnitude, C-Phase, Terminal G
VNFMC		03, 04	40 ms average filtered generator neutral voltage magnitude
VNFAC		03, 04	40 ms average filtered generator neutral voltage angle
DM01		03, 04	Demand metering value 01
DM02		03, 04	Demand metering value 02
DM03		03, 04	Demand metering value 03
DM04		03, 04	Demand metering value 04
DM05		03, 04	Demand metering value 05
DM06		03, 04	Demand metering value 06
DM07		03, 04	Demand metering value 07
DM08		03, 04	Demand metering value 08
DM09		03, 04	Demand metering value 09

Table 10.53 Modbus Analog Quantities Table (Sheet 16 of 17)

Labels	Scaling	Function Code Supported	Description
DM10		03, 04	Demand metering value 10
DMM01		03, 04	Demand metering maximum value 01
DMM02		03, 04	Demand metering maximum value 02
DMM03		03, 04	Demand metering maximum value 03
DMM04		03, 04	Demand metering maximum value 04
DMM05		03, 04	Demand metering maximum value 05
DMM06		03, 04	Demand metering maximum value 06
DMM07		03, 04	Demand metering maximum value 07
DMM08		03, 04	Demand metering maximum value 08
DMM09		03, 04	Demand metering maximum value 09
DMM10		03, 04	Demand metering maximum value 10
3PSMWHP		03, 04	Three-phase active energy exported, Terminal S
3PTMWHP		03, 04	Three-phase active energy exported, Terminal T
3PUMWHP		03, 04	Three-phase active energy exported, Terminal U
3PYMWHP		03, 04	Three-phase active energy exported, Terminal Y
3PGMWHP		03, 04	Three-phase active energy exported, Terminal G
3QSMVHP		03, 04	Three-phase reactive energy exported, Terminal S
3QTMVHP		03, 04	Three-phase reactive energy exported, Terminal T
3QUMVHP		03, 04	Three-phase reactive energy exported, Terminal U
3QYMVHP		03, 04	Three-phase reactive energy exported, Terminal Y
3QGMVHP		03, 04	Three-phase reactive energy exported, Terminal G
3PSMWHN		03, 04	Three-phase active energy imported, Terminal S
3PTMWHN		03, 04	Three-phase active energy imported, Terminal T
3PUMWHN		03, 04	Three-phase active energy imported, Terminal U
3PYMWHN		03, 04	Three-phase active energy imported, Terminal Y
3PGMWHN		03, 04	Three-phase active energy imported, Terminal G
3QSMVHN		03, 04	Three-phase reactive energy imported, Terminal S
3QTMVHN		03, 04	Three-phase reactive energy imported, Terminal T
3QUMVHN		03, 04	Three-phase reactive energy imported, Terminal U
3QYMVHN		03, 04	Three-phase reactive energy imported, Terminal Y
3QGMVHN		03, 04	Three-phase reactive energy imported, Terminal G
3PSMWHT		03, 04	Total three-phase active energy, Terminal S
3PTMWHT		03, 04	Total three-phase active energy, Terminal T
3PUMWHT		03, 04	Total three-phase active energy, Terminal U
3PYMWHT		03, 04	Total three-phase active energy, Terminal Y
3PGMWHT		03, 04	Total three-phase active energy, Terminal G
3QSMVHT		03, 04	Total three-phase reactive energy, Terminal S
3QTMVHT		03, 04	Total three-phase reactive energy, Terminal T
3QUMVHT		03, 04	Total three-phase reactive energy, Terminal U
3QYMVHT		03, 04	Total three-phase reactive energy, Terminal Y

Table 10.53 Modbus Analog Quantities Table (Sheet 17 of 17)

Labels	Scaling	Function Code Supported	Description
3QGMVHT		03, 04	Total three-phase reactive energy, Terminal G
78GCN		03, 04	Out-of-step generator pole slip count
78SCN		03, 04	Out-of-step system pole slip count
78CN		03, 04	Out-of-step common pole slip count
60LDVM		03, 04	60 LOP Voltage Unbalance Magnitude
81AB1S		03, 04	81A Element Band 1 accumulated time
81AB2S		03, 04	81A Element Band 2 accumulated time
81AB3S		03, 04	81A Element Band 3 accumulated time
81AB4S		03, 04	81A Element Band 4 accumulated time
81AB5S		03, 04	81A Element Band 5 accumulated time
81AB6S		03, 04	81A Element Band 6 accumulated time
81AB7S		03, 04	81A Element Band 7 accumulated time
81AB8S		03, 04	81A Element Band 8 accumulated time
FREQPP		03, 04	Frequency for Synchrophasor Data, P Class
DFDTPP		03, 04	Rate-of-change of Frequency for Synchrophasor Data, P Class
THTCU1		03, 04	IEC Thermal Capacity used, Element 1
THTCU2		03, 04	IEC Thermal Capacity used, Element 2
THTCU3		03, 04	IEC Thermal Capacity used, Element 3
I2GPEQ		03, 04	Generator Negative-sequence Equivalent Harmonic Current
I2GP		03, 04	Generator Fundamental Negative-sequence Current
64SIR		03, 04	64S Stator Insulation Resistance
64SIC		03, 04	64S Stator Insulation capacitance
64FIR		03, 04	64F Field Insulation Resistance
PLLSTA		03, 04	Status register of the PLL
PLLCPP		03, 04	PLL clocks per pulse
I850MOD		03, 04	IEC 61850 Mode/Behavior Status

[a] The active settings group can be modified by writing the desired settings group number to ACTGRP. If any of the SELOGIC Group Switch equations SS1–SS6 are asserted, the write is accepted but the active group will not change.

[b] Breaker and Disconnect Close and Open are mutually exclusive, and the relay asserts neither bit but returns the Exception Response 03 if an attempt is made to write both bits.

[c] An analog associated with Event Fault Summary registers.

[d] The serial number is a string that is converted to a number stored in three registers. The three serial number registers contain the lowest 12 digits (right-most). Because SEL-400 series relay serial numbers are 10 digits long, only the 2 right-most digits of SNUMBH are relevant. If any of the three registers of the serial number cannot be decoded to a number between 0 and 9999, 0 is reported for that register. (This is for the case where an alphanumeric character is entered into the serial number.)

Default Modbus Map and Modbus Addresses

The default user map entries are defined in *Table 10.54*. Use the **SET U** and **SHO U** commands to modify or view these map settings, or use Grid Configurator to manage the Modbus mapping.

Table 10.54 Default Modbus Map (Sheet 1 of 3)

Map Index	Register Address in Decimal	Label	Scale	Description
1	0	IASFMC	1	40 ms average filtered phase current magnitude, A-Phase, Terminal S
2	1	IASFAC	100	40 ms average filtered phase current angle, A-Phase, Terminal S
3	2	IBSFMC	1	40 ms average filtered phase current magnitude, B-Phase, Terminal S
4	3	IBSFAC	100	40 ms average filtered phase current angle, B-Phase, Terminal S
5	4	ICSFMC	1	40 ms average filtered phase current magnitude, C-Phase, Terminal S
6	5	ICSFAC	100	40 ms average filtered phase current angle, C-Phase, Terminal S
7	6	IATFMC	1	40 ms average filtered phase current magnitude, A-Phase, Terminal T
8	7	IATFAC	100	40 ms average filtered phase current angle, A-Phase, Terminal T
9	8	IBTFMC	1	40 ms average filtered phase current magnitude, B-Phase, Terminal T
10	9	IBTFAC	100	40 ms average filtered phase current angle, B-Phase, Terminal T
11	10	ICTFMC	1	40 ms average filtered phase current magnitude, C-Phase, Terminal T
12	11	ICTFAC	100	40 ms average filtered phase current angle, C-Phase, Terminal T
13	12	IAUFMC	1	40 ms average filtered phase current magnitude, A-Phase, Terminal U
14	13	IAUFAC	100	40 ms average filtered phase current angle, A-Phase, Terminal U
15	14	IBUFMC	1	40 ms average filtered phase current magnitude, B-Phase, Terminal U
16	15	IBUFAC	100	40 ms average filtered phase current angle, B-Phase, Terminal U
17	16	ICUFMC	1	40 ms average filtered phase current magnitude, C-Phase, Terminal U
18	17	ICUFAC	100	40 ms average filtered phase current angle, C-Phase, Terminal U
19	18	IAYFMC	1	40 ms average filtered phase current magnitude, A-Phase, Terminal Y
20	19	IAYFAC	100	40 ms average filtered phase current angle, A-Phase, Terminal Y
21	20	IBYFMC	1	40 ms average filtered phase current magnitude, B-Phase, Terminal Y
22	21	IBYFAC	100	40 ms average filtered phase current angle, B-Phase, Terminal Y
23	22	ICYFMC	1	40 ms average filtered phase current magnitude, C-Phase, Terminal Y
24	23	ICYFAC	100	40 ms average filtered phase current angle, C-Phase, Terminal Y
25	24	IAGFMC	1	40 ms average filtered phase current magnitude, A-Phase, Terminal G
26	25	IAGFAC	100	40 ms average filtered phase current angle, A-Phase, Terminal G
27	26	IBGFMC	1	40 ms average filtered phase current magnitude, B-Phase, Terminal G
28	27	IBGFAC	100	40 ms average filtered phase current angle, B-Phase, Terminal G
29	28	ICGFMC	1	40 ms average filtered phase current magnitude, C-Phase, Terminal G
30	29	ICGFAC	100	40 ms average filtered phase current angle, C-Phase, Terminal G
31	30	VAVFMC	1	40 ms average filtered phase-to-neutral voltage magnitude, A-Phase, Terminal V
32	31	VAVFAC	100	40 ms average filtered phase-to-neutral voltage angle, A-Phase, Terminal V
33	32	VBVFMC	1	40 ms average filtered phase-to-neutral voltage magnitude, B-Phase, Terminal V
34	33	VBVFAC	100	40 ms average filtered phase-to-neutral voltage angle, B-Phase, Terminal V
35	34	VCVFMC	1	40 ms average filtered phase-to-neutral voltage magnitude, C-Phase, Terminal V
36	35	VCVFAC	100	40 ms average filtered phase-to-neutral voltage angle, C-Phase, Terminal V
37	36	VAZFMC	1	40 ms average filtered phase-to-neutral voltage magnitude, A-Phase, Terminal Z
38	37	VAZFAC	100	40 ms average filtered phase-to-neutral voltage angle, A-Phase, Terminal Z
39	38	VBZFMC	1	40 ms average filtered phase-to-neutral voltage magnitude, B-Phase, Terminal Z

Table 10.54 Default Modbus Map (Sheet 2 of 3)

Map Index	Register Address in Decimal	Label	Scale	Description
40	39	VBZFAC	100	40 ms average filtered phase-to-neutral voltage angle, B-Phase, Terminal Z
41	40	VCZFMC	1	40 ms average filtered phase-to-neutral voltage magnitude, C-Phase, Terminal Z
42	41	VCZFAC	100	40 ms average filtered phase-to-neutral voltage angle, C-Phase, Terminal Z
43	42	PASFC	1	40 ms average phase fundamental active power, A-Phase, Terminal S
44	43	PBSFC	1	40 ms average phase fundamental active power, B-Phase, Terminal S
45	44	PCSFC	1	40 ms average phase fundamental active power, C-Phase, Terminal S
46	45	PATFC	1	40 ms average phase fundamental active power, A-Phase, Terminal T
47	46	PBTFC	1	40 ms average phase fundamental active power, B-Phase, Terminal T
48	47	PCTFC	1	40 ms average phase fundamental active power, C-Phase, Terminal T
49	48	PAUFC	1	40 ms average phase fundamental active power, A-Phase, Terminal U
50	49	PBUFC	1	40 ms average phase fundamental active power, B-Phase, Terminal U
51	50	PCUFC	1	40 ms average phase fundamental active power, C-Phase, Terminal U
52	51	PAYFC	1	40 ms average phase fundamental active power, A-Phase, Terminal Y
53	52	PBYFC	1	40 ms average phase fundamental active power, B-Phase, Terminal Y
54	53	PCYFC	1	40 ms average phase fundamental active power, C-Phase, Terminal Y
55	54	PAGFC	1	40 ms average phase fundamental active power, A-Phase, Terminal G
56	55	PBGFC	1	40 ms average phase fundamental active power, B-Phase, Terminal G
57	56	PCGFC	1	40 ms average phase fundamental active power, C-Phase, Terminal G
58	57	QASFC	1	40 ms average phase fundamental reactive power, A-Phase, Terminal S
59	58	QBSFC	1	40 ms average phase fundamental reactive power, B-Phase, Terminal S
60	59	QCSFC	1	40 ms average phase fundamental reactive power, C-Phase, Terminal S
61	60	QATFC	1	40 ms average phase fundamental reactive power, A-Phase, Terminal T
62	61	QBTFC	1	40 ms average phase fundamental reactive power, B-Phase, Terminal T
63	62	QCTFC	1	40 ms average phase fundamental reactive power, C-Phase, Terminal T
64	63	QAUFC	1	40 ms average phase fundamental reactive power, A-Phase, Terminal U
65	64	QBUFC	1	40 ms average phase fundamental reactive power, B-Phase, Terminal U
66	65	QCUFC	1	40 ms average phase fundamental reactive power, C-Phase, Terminal U
67	66	QAYFC	1	40 ms average phase fundamental reactive power, A-Phase, Terminal Y
68	67	QBYFC	1	40 ms average phase fundamental reactive power, B-Phase, Terminal Y
69	68	QCYFC	1	40 ms average phase fundamental reactive power, C-Phase, Terminal Y
70	69	QAGFC	1	40 ms average phase fundamental reactive power, A-Phase, Terminal G
71	70	QBGFC	1	40 ms average phase fundamental reactive power, B-Phase, Terminal G
72	71	QCGFC	1	40 ms average phase fundamental reactive power, C-Phase, Terminal G
73	72	ACTGRP	1	Active Settings Group (1–6)
74	73	RLYTEMP	100	Relay temperature (°C temperature of the box)
75	74	FREQPG	100	Generator frequency
76	75	FREQPS	100	System frequency
77	76	VDC	10	Station battery dc voltage
78	77	LSTEVSN	1	Last event serial number
79	78	EVESEL	1	Event number to select

Table 10.54 Default Modbus Map (Sheet 3 of 3)

Map Index	Register Address in Decimal	Label	Scale	Description
80	79	ETYPE	1	Event fault type
81	80	ETAR1	1	Event fault targets (Upper byte is first target row, lower byte is second target row)
82	81	ETAR2	1	Event fault targets (Upper byte is third target row, lower byte is 0)
83	82	EFREQG	100	Event fault Generator fault frequency
84	83	EFREQS	100	Event fault System fault frequency
85	84	EGRP	1	Event fault active settings group (1–6)
86	85	ETIMEUS	1	Event fault Time UTC Seconds (scaled to milliseconds)
87	86	ETIMEUM	1	Event fault Time UTC Minutes
88	87	ETIMEUH	1	Event fault Time UTC Hours
89	88	EDATEUD	1	Event fault Date UTC Day
90	89	EDATEUM	1	Event fault Date UTC Month
91	90	EDATEUY	1	Event fault Date UTC Year
92–1000	91–999	Not Assigned	Not Assigned	Not Assigned
1001–1020	1000–1019	RID	NA	Relay Identifier character data, two ASCII characters per register, left to right[a]
1021–1040	1020–1039	SID	NA	Station Identifier character data, two ASCII characters per register, left to right[a]
1041–1064	1040–1063	FID	NA	Firmware Identifier character data, two ASCII characters per register, left to right[a]

[a] Modbus addresses 1000–1063 contain fixed relay information map data as strings. The strings are packed two characters per register, with the most significant bit containing the character closest to the beginning of the string.

Reading Event Data Using Modbus

The SEL-400G provides a feature that allows relay event summary data to be retrieved via Modbus. The Event Fault Summary registers are listed and footnoted in *Table 10.53*. To read the event summary data, set the Modbus Map to contain the EVESEL label, along with the other Event Fault Summary related labels. *Figure 10.2* shows some of the available event summary labels in the Modbus map.

```
=>>SHO U <Enter>

UM1 = LSTEVSN
UM2 = EVESEL
UM3 = ETIMES
UM4 = ETIMEM
UM5 = ETIMEH
UM6 = EDATED
UM7 = EDATEM
UM8 = EDATEY
UM9 = EFREQG
UM10 = EFREQS
UM11 = EGRP
UM12 = ETYPE
```

Figure 10.2 Modbus Event Summary Labels Example

Use Modbus function code 03 or 04 to read the Modbus registers. The LSTEVSN label will contain the most recent event serial number. To read relay event summary data for a particular event using Modbus, use function code 06 to write the event number to the Modbus register containing the EVESEL label. The SEL-400G will populate the other event related registers with the data related to the event number specified in the EVESEL label address. Issue a Modbus function code 03 or 04 command to read the registers containing the history data.

For example, issue the **HIS** command to view stored events in the relay, as shown in *Figure 10.3*.

```
=>>HIS <Enter>

Relay 1                                     Date: 10/06/2019  Time: 19:43:37.109
Station A                                   Serial Number: 1153550843

#       DATE        TIME       EVENT   GRP  TARGETS
10003 10/06/2019 19:43:23.374 ER        1
10002 10/06/2019 19:43:12.424 ER        1
10001 10/06/2019 19:42:42.599 TRIP      1
10000 10/06/2019 19:42:20.732 ER        1

=>>
```

Figure 10.3 History Command Example

NOTE: The Modbus Map is indexed beginning with 1, which corresponds to register address 0 in Modbus.

In this example, retrieve the event summary data for the trip event by setting register address 0001 to the value of 3 (the third oldest event) using a function code 06 command. If a value is written to the EVESEL register for an event that does not currently exist in the history data, the SEL-400G will respond with an exception code 03.

Following the function code 06 command, issue a function code 03 or 04 command to read Registers 0–11. The data returned in Registers 2–11 contain the event time, event date, generator frequency, system frequency, active settings group, and event type associated with the third oldest event.

The relay also returns the event summary data if the unique event serial number is written to the EVESEL register as long as that event is currently in the history data. So, repeating the previous example, the same trip event can be retrieved by loading the Event Serial Number of 10001 into EVESEL.

When the history data are cleared in the relay, either from the **HIS C** command or from a remote control point, the LSTEVSN register will contain the value of 0, indicating there are no events that can be read using Modbus. The Modbus event summary data registers may contain data from a past event, until a new valid event number is written to the EVESEL register.

SECTION 11

Relay Word Bits

This section contains tables of the Relay Word bits available within the SEL-400G Advanced Generator Protection System. *Table 11.1* lists the Relay Word bits in alphabetic order; *Table 11.2* lists every Relay Word bit row and the bits contained within each row.

Alphabetical List

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 1 of 90)

Name	Bit Description	Row
21PAB1P	Zone 1 backup phase distance for AB loop picked up	456
21PAB1T	Zone 1 backup phase distance for AB loop timed out	456
21PAB2P	Zone 2 backup phase distance for AB loop picked up	456
21PAB2T	Zone 2 backup phase distance for AB loop timed out	457
21PBC1P	Zone 1 backup phase distance for BC loop picked up	456
21PBC1T	Zone 1 backup phase distance for BC loop timed out	456
21PBC2P	Zone 2 backup phase distance for BC loop picked up	456
21PBC2T	Zone 2 backup phase distance for BC loop timed out	457
21PCA1P	Zone 1 backup phase distance for CA loop picked up	456
21PCA1T	Zone 1 backup phase distance for CA loop timed out	457
21PCA2P	Zone 2 backup phase distance for CA loop picked up	456
21PCA2T	Zone 2 backup phase distance for CA loop timed out	457
21PRAB1	Zone 1 backup phase distance for AB loop is within resistive blinder	457
21PRAB2	Zone 2 backup phase distance for AB loop is within resistive blinder	457
21PRBC1	Zone 1 backup phase distance for BC loop is within resistive blinder	457
21PRBC2	Zone 2 backup phase distance for BC loop is within resistive blinder	458
21PRCA1	Zone 1 backup phase distance for CA loop is within resistive blinder	457
21PRCA2	Zone 2 backup phase distance for CA loop is within resistive blinder	458
21PZ1T	Zone 1 backup phase distance timed out	458
21PZ1TC	Zone 1 backup phase distance torque control	458
21PZ2T	Zone 2 backup phase distance timed out	458
21PZ2TC	Zone 2 backup phase distance torque control	458
24D11	Volts per hertz Element 1 Level 1 asserted	95
24D121	Volts per hertz Element 1 Level 2 pickup 1 asserted	98
24D122	Volts per hertz Element 1 Level 2 pickup 2 asserted	98
24D1R2	Volts per hertz Element 1 Level 2 reset	95
24D1R21	Definite-time Element 1 Level 1 reset	95

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 2 of 90)

Name	Bit Description	Row
24D1R22	Definite-time Element 1 Level 2 reset	96
24D1T1	Volts per hertz Element 1 Level 1 timed out	95
24D1T2	Volts per hertz Element 1 Level 2 timed out	95
24D1T21	Definite-time Element 1 Level 1 timed out	95
24D1T22	Definite-time Element 1 Level 2 timed out	95
24D21	Volts per hertz Element 2 Level 1 asserted	96
24D221	Volts per hertz Element 2 Level 2 pickup 1 asserted	99
24D222	Volts per hertz Element 2 Level 2 pickup 2 asserted	99
24D2R2	Volts per hertz Element 2 Level 2 reset	97
24D2R21	Definite-time Element 2 Level 1 reset	97
24D2R22	Definite-time Element 2 Level 2 reset	97
24D2T1	Volts per hertz Element 2 Level 1 timed out	97
24D2T2	Volts per hertz Element 2 Level 2 timed out	97
24D2T21	Definite-time Element 2 Level 1 timed out	97
24D2T22	Definite-time Element 2 Level 2 timed out	97
24TC1	Volts per hertz predefined Element 1, torque control	95
24TC2	Volts per hertz predefined Element 2, torque control	97
24U1R1	User-defined volts per hertz Curve 1 Element 1 reset	96
24U1R2	User-defined volts per hertz Curve 2 Element 1 reset	96
24U1T1	User-defined volts per hertz Curve 1 Element 1 timed out	96
24U1T2	User-defined volts per hertz Curve 2 Element 1 timed out	96
24U1TC1	User-defined volts per hertz Curve 1 Element 1, torque control	96
24U1TC2	User-defined volts per hertz Curve 2 Element 1, torque control	96
24U2R1	User-defined volts per hertz Curve 1 Element 2 reset	98
24U2R2	User-defined volts per hertz Curve 2 Element 2 reset	98
24U2T1	User-defined volts per hertz Curve 1 Element 2 timed out	98
24U2T2	User-defined volts per hertz Curve 2 Element 2 timed out	98
24U2TC1	User-defined volts per hertz Curve 1 Element 2, torque control	98
24U2TC2	User-defined volts per hertz Curve 2 Element 2, torque control	98
25AACT	Autosynchronizer active	509
25ACNS	Breaker S autosynchronizer cancel	508
25ACNT	Breaker T autosynchronizer cancel	508
25ACNU	Breaker U autosynchronizer cancel	508
25ACNY	Breaker Y autosynchronizer cancel	508
25AFL	Frequency lower command	509
25AFR	Frequency raise command	509
25AS	Breaker S voltage within sync angle window uncompensated	430
25ASACT	Breaker S autosynchronizer active	510
25ASTO	Breaker S autosynchronizer timed out	510
25ASTS	Breaker S autosynchronizer start	508
25ASTT	Breaker T autosynchronizer start	508

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 3 of 90)

Name	Bit Description	Row
25ASTU	Breaker U autosynchronizer start	508
25ASTY	Breaker Y autosynchronizer start	508
25AT	Breaker T voltage within sync angle window uncompensated	430
25ATACT	Breaker T autosynchronizer active	510
25ATTO	Breaker T autosynchronizer timed out	510
25AU	Breaker U voltage within sync angle window uncompensated	430
25AUACT	Breaker U autosynchronizer active	510
25AUTO	Breaker U autosynchronizer timed out	510
25AVL	Voltage lower command	509
25AVR	Voltage raise command	509
25AY	Breaker Y voltage within sync angle window uncompensated	430
25AYACT	Breaker Y autosynchronizer active	510
25AYTO	Breaker Y autosynchronizer timed out	510
25BFSPS	Breaker S closed indication for breaker failure	436
25BFSPT	Breaker T closed indication for breaker failure	436
25BFSPU	Breaker U closed indication for breaker failure	436
25BFSPY	Breaker Y closed indication for breaker failure	436
25CS	Breaker S voltages within sync angle window compensated	431
25CT	Breaker T voltages within sync angle window compensated	431
25CU	Breaker U voltages within sync angle window compensated	431
25CY	Breaker Y voltages within sync angle window compensated	431
25ENBKS	Breaker S synchronism check enabled	433
25ENBKT	Breaker T synchronism check enabled	433
25ENBKU	Breaker U synchronism check enabled	433
25ENBKY	Breaker W synchronism check enabled	433
25PHOK	Autosynchronizer phasing check is OK	509
25VDIFS	Breaker S voltage difference is within acceptable window	435
25VDIFT	Breaker T voltage difference is within acceptable window	435
25VDIFU	Breaker U voltage difference is within acceptable window	435
25VDIFY	Breaker Y voltage difference is within acceptable window	435
25WCS	Breaker S voltages within sync angle window compensated and unsupervised	430
25WCT	Breaker T voltages within sync angle window compensated and unsupervised	430
25WCU	Breaker U voltages within sync angle window compensated and unsupervised	430
25WCY	Breaker Y voltages within sync angle window compensated and unsupervised	430
271P1	Undervoltage Element 1, Level 1 asserted	33
271P1T	Undervoltage Element 1, Level 1 timed out	33
271P2	Undervoltage Element 1, Level 2 asserted	33
271P2T	Undervoltage Element 1, Level 2 timed out	33
272P1	Undervoltage Element 2, Level 1 asserted	33
272P1T	Undervoltage Element 2, Level 1 timed out	33
272P2	Undervoltage Element 2, Level 2 asserted	33

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 4 of 90)

Name	Bit Description	Row
272P2T	Undervoltage Element 2, Level 2 timed out	34
273P1	Undervoltage Element 3, Level 1 asserted	34
273P1T	Undervoltage Element 3, Level 1 timed out	34
273P2	Undervoltage Element 3, Level 2 asserted	34
273P2T	Undervoltage Element 3, Level 2 timed out	34
274P1	Undervoltage Element 4, Level 1 asserted	34
274P1T	Undervoltage Element 4, Level 1 timed out	35
274P2	Undervoltage Element 4, Level 2 asserted	35
274P2T	Undervoltage Element 4, Level 2 timed out	35
275P1	Undervoltage Element 5, Level 1 asserted	35
275P1T	Undervoltage Element 5, Level 1 timed out	35
275P2	Undervoltage Element 5, Level 2 asserted	35
275P2T	Undervoltage Element 5, Level 2 timed out	35
276P1	Undervoltage Element 6, Level 1 asserted	36
276P1T	Undervoltage Element 6, Level 1 timed out	36
276P2	Undervoltage Element 6, Level 2 asserted	36
276P2T	Undervoltage Element 6, Level 2 timed out	36
27B81G	Undervoltage supervision for generator frequency elements	44
27B81RG	Undervoltage supervision for generator rate-of-change-of-frequency elements	51
27B81RS	Undervoltage supervision for system rate-of-change-of-frequency elements	51
27B81S	Undervoltage supervision for system frequency elements	44
27TC1	Undervoltage Element 1, torque control	33
27TC2	Undervoltage Element 2, torque control	34
27TC3	Undervoltage Element 3, torque control	34
27TC4	Undervoltage Element 4, torque control	35
27TC5	Undervoltage Element 5, torque control	36
27TC6	Undervoltage Element 6, torque control	36
32BIA01	Directional power Element 1 bias	105
32BIA02	Directional power Element 2 bias	105
32BIA03	Directional power Element 3 bias	105
32BIA04	Directional power Element 4 bias	105
32P01	Directional power Element 1 asserted	104
32P02	Directional power Element 2 asserted	104
32P03	Directional power Element 3 asserted	104
32P04	Directional power Element 4 asserted	105
32T01	Directional power Element 1 timed out	104
32T02	Directional power Element 2 timed out	104
32T03	Directional power Element 3 timed out	104
32T04	Directional power Element 4 timed out	105
32TC01	Directional power Element 1 torque control	104
32TC02	Directional power Element 2 torque control	104

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 5 of 90)

Name	Bit Description	Row
32TC03	Directional power Element 3 torque control	105
32TC04	Directional power Element 4 torque control	105
3PORS	Terminal S three-pole open asserted raw	60
3PORT	Terminal T three-pole open asserted raw	60
3PORU	Terminal U three-pole open asserted raw	60
3PORY	Terminal Y three-pole open asserted raw	60
3POS	Terminal S three-pole open asserted	60
3POT	Terminal T three-pole open asserted	60
3POU	Terminal U three-pole open asserted	60
3POY	Terminal Y three-pole open asserted	60
40P1	Loss-of-field PQ Zone 1 picked up	460
40P1T	Loss-of-field PQ Zone 1 timed out	460
40P1TC	Loss-of-field PQ Zone 1 torque control	460
40P2	Loss-of-field PQ Zone 2 picked up	460
40P2T	Loss-of-field PQ Zone 2 timed out	460
40P2TC	Loss-of-field PQ Zone 2 torque control	460
40P3	Steady-state stability limit Zone 3 picked up	461
40P3T	Steady-state stability limit Zone 3 timed out	461
40P3TC	Steady-state stability limit Zone 3 torque control	462
40P4	Capability curve limit Zone 4 picked up	460
40P4OE	Capability curve limit Zone 4 overexcitation segment picked up	461
40P4PLD	Capability curve limit Zone 4 over power lead PF segment picked up	461
40P4PLG	Capability curve limit Zone 4 over power lag PF segment picked up	461
40P4T	Capability curve limit Zone 4 timed out	461
40P4TC	Capability curve limit Zone 4 torque control	461
40P4UE	Capability curve limit Zone 4 underexcitation segment picked up	461
40PAT	Loss-of-field undervoltage acceleration timed out	462
40PDAQ	40P dynamic zone analog quality	462
40PUV	Loss-of-field PQ zone undervoltage element picked up	460
40Z1	Loss-of-field Zone 1 picked up	62
40Z1T	Loss-of-field Zone 1 timed out	62
40Z1TC	Loss-of-field Zone 1 torque control	62
40Z2	Loss-of-field Zone 2 picked up	62
40Z2T	Loss-of-field Zone 2 timed out	62
40Z2TC	Loss-of-field Zone 2 torque control	62
40ZSUP	Loss-of-field supervision picked up	62
46Q11	Generator current unbalance Element 1 Level 1 picked up	512
46Q12	Generator current unbalance Element 1 Level 2 picked up	512
46Q1R2	Generator current unbalance Element 1 Level 2 reset	513
46Q1T1	Generator current unbalance Element 1 Level 1 timed out	512
46Q1T2	Generator current unbalance Element 1 Level 2 timed out	512

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 6 of 90)

Name	Bit Description	Row
46Q1TC	Generator current unbalance Element 1 torque control	512
46Q21	Generator current unbalance Element 2 Level 1 picked up	512
46Q22	Generator current unbalance Element 2 Level 2 picked up	512
46Q2R2	Generator current unbalance Element 2 Level 2 reset	513
46Q2T1	Generator current unbalance Element 2 Level 1 timed out	513
46Q2T2	Generator current unbalance Element 2 Level 2 timed out	513
46Q2TC	Generator current unbalance Element 2 torque control	512
49R01S1	RTD Element 01 Level 1 asserted	490
49R01S2	RTD Element 01 Level 2 asserted	488
49R02S1	RTD Element 02 Level 1 asserted	490
49R02S2	RTD Element 02 Level 2 asserted	488
49R03S1	RTD Element 03 Level 1 asserted	490
49R03S2	RTD Element 03 Level 2 asserted	488
49R04S1	RTD Element 04 Level 1 asserted	490
49R04S2	RTD Element 04 Level 2 asserted	488
49R05S1	RTD Element 05 Level 1 asserted	490
49R05S2	RTD Element 05 Level 2 asserted	488
49R06S1	RTD Element 06 Level 1 asserted	490
49R06S2	RTD Element 06 Level 2 asserted	488
49R07S1	RTD Element 07 Level 1 asserted	490
49R07S2	RTD Element 07 Level 2 asserted	488
49R08S1	RTD Element 08 Level 1 asserted	490
49R08S2	RTD Element 08 Level 2 asserted	488
49R09S1	RTD Element 09 Level 1 asserted	491
49R09S2	RTD Element 09 Level 2 asserted	489
49R10S1	RTD Element 10 Level 1 asserted	491
49R10S2	RTD Element 10 Level 2 asserted	489
49R11S1	RTD Element 11 Level 1 asserted	491
49R11S2	RTD Element 11 Level 2 asserted	489
49R12S1	RTD Element 12 Level 1 asserted	491
49R12S2	RTD Element 12 Level 2 asserted	489
49RLV1P	RTD Element Location 1 voted trip asserted	492
49RLV2P	RTD Element Location 2 voted trip asserted	492
49RLV3P	RTD Element Location 3 voted trip asserted	492
49RLV4P	RTD Element Location 4 voted trip asserted	492
50FS	Phase or neutral current above pickup, Terminal S	122
50FT	Phase or neutral current above pickup, Terminal T	124
50FU	Phase or neutral current above pickup, Terminal U	126
50FY	Phase or neutral current above pickup, Terminal Y	128
50SG1	Residual definite-time Element 1, Terminal S asserted	9
50SG2	Residual definite-time Element 2, Terminal S asserted	9

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 7 of 90)

Name	Bit Description	Row
50SG3	Residual definite-time Element 3, Terminal S asserted	10
50SP1	Phase definite-time Element 1, Terminal S asserted	6
50SP2	Phase definite-time Element 2, Terminal S asserted	6
50SP3	Phase definite-time Element 3, Terminal S asserted	7
50SQ1	Negative-sequence definite-time Element 1, Terminal S asserted	7
50SQ2	Negative-sequence definite-time Element 2, Terminal S asserted	8
50SQ3	Negative-sequence definite-time Element 3, Terminal S asserted	8
50TG1	Residual definite-time Element 1, Terminal T asserted	13
50TG2	Residual definite-time Element 2, Terminal T asserted	14
50TG3	Residual definite-time Element 3, Terminal T asserted	14
50TP1	Phase definite-time Element 1, Terminal T asserted	10
50TP2	Phase definite-time Element 2, Terminal T asserted	11
50TP3	Phase definite-time Element 3, Terminal T asserted	11
50TQ1	Negative-sequence definite-time Element 1, Terminal T asserted	12
50TQ2	Negative-sequence definite-time Element 2, Terminal T asserted	12
50TQ3	Negative-sequence definite-time Element 3, Terminal T asserted	13
50UG1	Residual definite-time Element 1, Terminal U asserted	18
50UG2	Residual definite-time Element 2, Terminal U asserted	18
50UG3	Residual definite-time Element 3, Terminal U asserted	19
50UP1	Phase definite-time Element 1, Terminal U asserted	15
50UP2	Phase definite-time Element 2, Terminal U asserted	15
50UP3	Phase definite-time Element 3, Terminal U asserted	16
50UQ1	Negative-sequence definite-time Element 1, Terminal U asserted	16
50UQ2	Negative-sequence definite-time Element 2, Terminal U asserted	17
50UQ3	Negative-sequence definite-time Element 3, Terminal U asserted	17
50YG1	Residual definite-time Element 1, Terminal Y asserted	22
50YG2	Residual definite-time Element 2, Terminal Y asserted	23
50YG3	Residual definite-time Element 3, Terminal Y asserted	23
50YP1	Phase definite-time Element 1, Terminal Y asserted	19
50YP2	Phase definite-time Element 2, Terminal Y asserted	20
50YP3	Phase definite-time Element 3, Terminal Y asserted	20
50YQ1	Negative-sequence definite-time Element 1, Terminal Y asserted	21
50YQ2	Negative-sequence definite-time Element 2, Terminal Y asserted	21
50YQ3	Negative-sequence definite-time Element 3, Terminal Y asserted	22
51C	Voltage-controlled instantaneous OC picked up	114
51CA	A-Phase, voltage-controlled instantaneous OC picked up	114
51CAR	A-Phase, voltage-controlled OC reset	115
51CAT	A-Phase, voltage-controlled OC timed out	114
51CB	B-Phase, voltage-controlled instantaneous OC picked up	114
51CBR	B-Phase, voltage-controlled OC reset	115
51CBT	B-Phase, voltage-controlled OC timed out	114

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 8 of 90)

Name	Bit Description	Row
51CC	C-Phase, voltage-controlled instantaneous OC picked up	114
51CCR	C-Phase, voltage-controlled OC reset	115
51CCT	C-Phase, voltage-controlled OC timed out	114
51CR	Voltage-controlled OC reset	115
51CT	Voltage-controlled OC timed out	114
51CTC	Voltage-controlled OC torque control asserted	115
51MM01	Inverse-time Element 01 pickup setting outside of specified limits	24
51MM02	Inverse-time Element 02 pickup setting outside of specified limits	25
51MM03	Inverse-time Element 03 pickup setting outside of specified limits	26
51MM04	Inverse-time Element 04 pickup setting outside of specified limits	26
51MM05	Inverse-time Element 05 pickup setting outside of specified limits	27
51MM06	Inverse-time Element 06 pickup setting outside of specified limits	28
51MM07	Inverse-time Element 07 pickup setting outside of specified limits	29
51MM08	Inverse-time Element 08 pickup setting outside of specified limits	29
51MM09	Inverse-time Element 09 pickup setting outside of specified limits	30
51MM10	Inverse-time Element 10 pickup setting outside of specified limits	31
51MM11	Inverse-time Element 11 pickup setting outside of specified limits	32
51MM12	Inverse-time Element 12 pickup setting outside of specified limits	32
51R01	Inverse-time Element 01 reset	24
51R02	Inverse-time Element 02 reset	25
51R03	Inverse-time Element 03 reset	25
51R04	Inverse-time Element 04 reset	26
51R05	Inverse-time Element 05 reset	27
51R06	Inverse-time Element 06 reset	28
51R07	Inverse-time Element 07 reset	28
51R08	Inverse-time Element 08 reset	29
51R09	Inverse-time Element 09 reset	30
51R10	Inverse-time Element 10 reset	31
51R11	Inverse-time Element 11 reset	31
51R12	Inverse-time Element 12 reset	32
51S01	Inverse-time Element 01 picked up	24
51S02	Inverse-time Element 02 picked up	24
51S03	Inverse-time Element 03 picked up	25
51S04	Inverse-time Element 04 picked up	26
51S05	Inverse-time Element 05 picked up	27
51S06	Inverse-time Element 06 picked up	27
51S07	Inverse-time Element 07 picked up	28
51S08	Inverse-time Element 08 picked up	29
51S09	Inverse-time Element 09 picked up	30
51S10	Inverse-time Element 10 picked up	30
51S11	Inverse-time Element 11 picked up	31

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 9 of 90)

Name	Bit Description	Row
51S12	Inverse-time Element 12 picked up	32
51T01	Inverse-time Element 01 timed out	24
51T02	Inverse-time Element 02 timed out	25
51T03	Inverse-time Element 03 timed out	25
51T04	Inverse-time Element 04 timed out	26
51T05	Inverse-time Element 05 timed out	27
51T06	Inverse-time Element 06 timed out	28
51T07	Inverse-time Element 07 timed out	28
51T08	Inverse-time Element 08 timed out	29
51T09	Inverse-time Element 09 timed out	30
51T10	Inverse-time Element 10 timed out	31
51T11	Inverse-time Element 11 timed out	31
51T12	Inverse-time Element 12 timed out	32
51TC01	Inverse-time Element 01 enabled	24
51TC02	Inverse-time Element 02 enabled	24
51TC03	Inverse-time Element 03 enabled	25
51TC04	Inverse-time Element 04 enabled	26
51TC05	Inverse-time Element 05 enabled	27
51TC06	Inverse-time Element 06 enabled	27
51TC07	Inverse-time Element 07 enabled	28
51TC08	Inverse-time Element 08 enabled	29
51TC09	Inverse-time Element 09 enabled	30
51TC10	Inverse-time Element 10 enabled	30
51TC11	Inverse-time Element 11 enabled	31
51TC12	Inverse-time Element 12 enabled	32
51TM01	Inverse-time Element 01 time-dial setting outside of specified limits	24
51TM02	Inverse-time Element 02 time-dial setting outside of specified limits	25
51TM03	Inverse-time Element 03 time-dial setting outside of specified limits	26
51TM04	Inverse-time Element 04 time-dial setting outside of specified limits	26
51TM05	Inverse-time Element 05 time-dial setting outside of specified limits	27
51TM06	Inverse-time Element 06 time-dial setting outside of specified limits	28
51TM07	Inverse-time Element 07 time-dial setting outside of specified limits	29
51TM08	Inverse-time Element 08 time-dial setting outside of specified limits	29
51TM09	Inverse-time Element 09 time-dial setting outside of specified limits	30
51TM10	Inverse-time Element 10 time-dial setting outside of specified limits	31
51TM11	Inverse-time Element 11 time-dial setting outside of specified limits	32
51TM12	Inverse-time Element 12 time-dial setting outside of specified limits	32
51V	Voltage-restrained instantaneous OC picked up	112
51VA	A-Phase, voltage-restrained instantaneous OC picked up	112
51VAR	A-Phase, voltage-restrained OC reset	113
51VAT	A-Phase, voltage-restrained OC timed out	112

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 10 of 90)

Name	Bit Description	Row
51VB	B-Phase, voltage-restrained instantaneous OC picked up	112
51VBR	B-Phase, voltage-restrained OC reset	113
51VBT	B-Phase, voltage-restrained OC timed out	112
51VC	C-Phase, voltage-restrained instantaneous OC picked up	112
51VCR	C-Phase, voltage-restrained OC reset	113
51VCT	C-Phase, voltage-restrained OC timed out	112
51VR	Voltage-restrained OC reset	113
51VT	Voltage-restrained OC timed out	112
51VTC	Voltage-restrained OC torque-control asserted	113
52A_S	Breaker S normally open status	133
52A_T	Breaker T normally open status	133
52A_U	Breaker U normally open status	133
52A_Y	Breaker Y normally open status	133
52ALS	Breaker alarm, Terminal S	132
52ALT	Breaker alarm, Terminal T	132
52ALU	Breaker alarm, Terminal U	132
52ALY	Breaker alarm, Terminal Y	132
52B_S	Breaker S normally closed status	133
52B_T	Breaker T normally closed status	133
52B_U	Breaker U normally closed status	133
52B_Y	Breaker Y normally closed status	133
52CLS	Breaker closed, Terminal S	132
52CLT	Breaker closed, Terminal T	132
52CLU	Breaker closed, Terminal U	132
52CLY	Breaker closed, Terminal Y	132
52SRACK	Breaker S rack position	500
52STEST	Breaker S test position	500
52TRACK	Breaker T rack position	500
52TTEST	Breaker T test position	500
52URACK	Breaker U rack position	500
52UTEST	Breaker U test position	500
52YRACK	Breaker Y rack position	500
52YTEST	Breaker Y test position	500
591P1	Overvoltage Element 1, Level 1 asserted	37
591P1T	Overvoltage Element 1, Level 1 timed out	37
591P2	Overvoltage Element 1, Level 2 asserted	37
591P2T	Overvoltage Element 1, Level 2 timed out	37
592P1	Overvoltage Element 2, Level 1 asserted	37
592P1T	Overvoltage Element 2, Level 1 timed out	37
592P2	Overvoltage Element 2, Level 2 asserted	37
592P2T	Overvoltage Element 2, Level 2 timed out	38

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 11 of 90)

Name	Bit Description	Row
593P1	Overvoltage Element 3, Level 1 asserted	38
593P1T	Overvoltage Element 3, Level 1 timed out	38
593P2	Overvoltage Element 3, Level 2 asserted	38
593P2T	Overvoltage Element 3, Level 2 timed out	38
594P1	Overvoltage Element 4, Level 1 asserted	38
594P1T	Overvoltage Element 4, Level 1 timed out	39
594P2	Overvoltage Element 4, Level 2 asserted	39
594P2T	Overvoltage Element 4, Level 2 timed out	39
595P1	Overvoltage Element 5, Level 1 asserted	39
595P1T	Overvoltage Element 5, Level 1 timed out	39
595P2	Overvoltage Element 5, Level 2 asserted	39
595P2T	Overvoltage Element 5, Level 2 timed out	39
596P1	Overvoltage Element 6, Level 1 asserted	40
596P1T	Overvoltage Element 6, Level 1 timed out	40
596P2	Overvoltage Element 6, Level 2 asserted	40
596P2T	Overvoltage Element 6, Level 2 timed out	40
59TC1	Overvoltage Element 1, torque control	37
59TC2	Overvoltage Element 2, torque control	38
59TC3	Overvoltage Element 3, torque control	38
59TC4	Overvoltage Element 4, torque control	39
59TC5	Overvoltage Element 5, torque control	40
59TC6	Overvoltage Element 6, torque control	40
59VPS	Breaker S polarizing voltage within healthy voltage window	432
59VPT	Breaker T polarizing voltage within healthy voltage window	432
59VPU	Breaker U polarizing voltage within healthy voltage window	432
59VPY	Breaker Y polarizing voltage within healthy voltage window	432
59VSS	Breaker S synchronizing voltage within healthy voltage window	432
59VST	Breaker T synchronizing voltage within healthy voltage window	432
59VSU	Breaker U synchronizing voltage within healthy voltage window	432
59VSY	Breaker Y synchronizing voltage within healthy voltage window	432
60LOPV	60 loss-of-potential element voltage unbalance logic picked up, Terminal V	464
60LOPZ	60 loss-of-potential element voltage unbalance logic picked up, Terminal Z	465
60NHS	Highset level picked up	544
60NHSS	Highset level switched to secure	544
60NHT	Highset level picked up with timer	544
60NHTC	60N highset level torque control picked up	545
60NLR	Lowset reset picked up	545
60NLS	Lowset level picked up	544
60NLSS	Lowset level switched to secure	544
60NLT	Lowset level picked up with timer	544
60NLTC	60N lowset level torque control picked up	545

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 12 of 90)

Name	Bit Description	Row
60NS	60N picked up	544
60NT	60N picked up with timer	544
60PAHS	A-Phase highset level picked up	540
60PAHSS	A-Phase highset level switched to secure	542
60PAHT	A-Phase highset level picked up with timer	540
60PALS	A-Phase lowset level picked up	541
60PALSS	A-Phase lowset level switched to secure	542
60PALT	A-Phase lowset level picked up with timer	541
60PBHS	B-Phase highset level picked up	540
60PBHSS	B-Phase highset level switched to secure	542
60PBHT	B-Phase highset level picked up with timer	540
60PBLS	B-Phase lowset level picked up	541
60PBLSS	B-Phase lowset level switched to secure	542
60PBLT	B-Phase lowset level picked up with timer	541
60PCHS	C-Phase highset level picked up	540
60PCHSS	C-Phase highset level switched to secure	542
60PCHT	C-Phase highset level picked up with timer	540
60PCLS	C-Phase lowset level picked up	541
60PCLSS	C-Phase lowset level switched to secure	542
60PCLT	C-Phase lowset level picked up with timer	541
60PHS	Highset level picked up	540
60PHT	Highset level picked up with timer	540
60PHTC	60P highset level torque control picked up	543
60PLR	Lowset reset picked up	543
60PLS	Lowset level picked up	541
60PLT	Lowset level picked up with timer	541
60PLTC	60P lowset level torque control picked up	543
60PS	60P picked up	542
60PT	60P picked up with timer	542
64F1	64F instantaneous Level 1 pickup	518
64F1T	64F time-delayed Level 1 pickup	518
64F1TC	64F torque-controlled Element 1 picked up	518
64F2	64F instantaneous Level 2 pickup	518
64F2T	64F time-delayed Level 2 pickup	518
64F2TC	64F torque-controlled Element 2 picked up	518
64FIQ	64F remote insulation measurement quality bit	518
64FFLT	64F indicate a non-functional SEL-2664 or communication failure	519
64FCF	64F indicate SEL-2664 communication failure	519
64FDF	64F indicate SEL-2664 status failure	519
64G1	64G Element 1 pickup	520
64G11	64G Element 1 Level 1 pickup	520

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 13 of 90)

Name	Bit Description	Row
64G12	64G Element 1 Level 2 pickup	520
64G1T	64G Element 1 delayed pickup	520
64G1T1	64G Element 1 Level 1 delayed pickup	520
64G1T2	64G Element 1 Level 2 delayed pickup	520
64G1TC1	64G Element 1 Level 1 fundamental neutral overvoltage torque control	520
64G1TC2	64G Element 1 Level 2 fundamental neutral overvoltage torque control	520
64G2	64G Element 2 pickup	521
64G2DEN	64G Element 2 third-harmonic differential internal enable	521
64G2DIF	64G Element 2 third-harmonic differential asserted	521
64G2T	64G Element 2 delayed pickup	521
64G2TC	64G Element 2 third-harmonic differential undervoltage torque control	521
64G2UEN	64G Element 2 undervoltage internal enable	521
64G2UV	64G Element 2 undervoltage asserted	521
64G3	64G Element 3 pickup	522
64G3EN	64G Element 3 enable	522
64G3T	64G Element 3 delayed pickup	522
64G3TC	64G Element 3 third-harmonic ratio torque control	522
64GAIN	64G accelerated input asserted	522
64GALT	64G alternative setting selected	521
64GAOK	64G third-harmonic angle check OK	523
64GATC	64G accelerated torque control	522
64GT	64G stator ground trip pickup	522
64GTIN	64G normal trip input asserted	522
64S1	64S instantaneous Level 1 pickup	516
64S1T	64S time-delayed Level 1 pickup	516
64S1TC	64S torque-controlled Element 1 picked up	516
64S2	64S instantaneous Level 2 pickup	516
64S2T	64S time-delayed Level 2 pickup	516
64S2TC	64S torque-controlled Element 2 picked up	516
64SIQ	64S remote insulation measurement quality bit	516
67SG1	Residual-directional/torque-controlled Element 1, Terminal S picked up	9
67SG1T	Residual-directional/torque-controlled Element 1, Terminal S timed out	9
67SG1TC	Residual-directional/torque-control enable definite-time Element 1, Terminal S	9
67SG2	Residual-directional/torque-controlled Element 2, Terminal S picked up	9
67SG2T	Residual-directional/torque-controlled Element 2, Terminal S timed out	9
67SG2TC	Residual-directional/torque-control enable definite-time Element 2, Terminal S	9
67SG3	Residual-directional/torque-controlled Element 3, Terminal S picked up	10
67SG3T	Residual-directional/torque-controlled Element 3, Terminal S timed out	10
67SG3TC	Residual-directional/torque-control enable definite-time Element 3, Terminal S	10
67SP1	Phase-directional/torque-controlled Element 1, Terminal S picked up	6
67SP1T	Phase-directional/torque-controlled Element 1, Terminal S timed out	6

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 14 of 90)

Name	Bit Description	Row
67SP1TC	Phase-directional/torque-control enable definite-time Element 1, Terminal S	6
67SP2	Phase-directional/torque-controlled Element 2, Terminal S picked up	6
67SP2T	Phase-directional/torque-controlled Element 2, Terminal S timed out.	6
67SP2TC	Phase-directional/torque-control enable definite-time Element 2, Terminal S	6
67SP3	Phase-directional/torque-controlled Element 3, Terminal S picked up	7
67SP3T	Phase-directional/torque-controlled Element 3, Terminal S timed out	7
67SP3TC	Phase-directional/torque-control enable definite-time Element 3, Terminal S	7
67SQ1	Negative-sequence directional/torque-controlled Element 1, Terminal S picked up	7
67SQ1T	Negative-sequence directional/torque-controlled Element 1, Terminal S timed out	7
67SQ1TC	Negative-sequence directional/torque-control enable definite-time Element 1, Terminal S	7
67SQ2	Negative-sequence directional/torque-controlled Element 2, Terminal S picked up	8
67SQ2T	Negative-sequence directional/torque-controlled Element 2, Terminal S timed out	8
67SQ2TC	Negative-sequence directional/torque-control enable definite-time Element 2, Terminal S	8
67SQ3	Negative-sequence directional/torque-controlled Element 3, Terminal S picked up	8
67SQ3T	Negative-sequence directional/torque-controlled Element 3, Terminal S timed out	8
67SQ3TC	Negative-sequence directional/torque-control enable definite-time Element 3, Terminal S	8
67TG1	Residual-directional/torque-controlled Element 1, Terminal T picked up	13
67TG1T	Residual-directional/torque-controlled Element 1, Terminal T timed out	13
67TG1TC	Residual-directional/torque-control enable definite-time Element 1, Terminal T	13
67TG2	Residual-directional/torque-controlled Element 2, Terminal T picked up	14
67TG2T	Residual-directional/torque-controlled Element 2, Terminal T timed out	14
67TG2TC	Residual-directional/torque-control enable definite-time Element 2, Terminal T	14
67TG3	Residual-directional/torque-controlled Element 3, Terminal T picked up	14
67TG3T	Residual-directional/torque-controlled Element 3, Terminal T timed out	14
67TG3TC	Residual-directional/torque-control enable definite-time Element 3, Terminal T	14
67TP1	Phase-directional/torque-controlled Element 1, Terminal T picked up	10
67TP1T	Phase-directional/torque-controlled Element 1, Terminal T timed out	10
67TP1TC	Phase-directional/torque-control enable definite-time Element 1, Terminal T	10
67TP2	Phase-directional/torque-controlled Element 2, Terminal T picked up	11
67TP2T	Phase-directional/torque-controlled Element 2, Terminal T timed out	11
67TP2TC	Phase-directional/torque-control enable definite-time Element 2, Terminal T	11
67TP3	Phase-directional/torque-controlled Element 3, Terminal T picked up	11
67TP3T	Phase-directional/torque-controlled Element 3, Terminal T timed out	11
67TP3TC	Phase-directional/torque-control enable definite-time Element 3, Terminal T	11
67TQ1	Negative-sequence directional/torque-controlled Element 1, Terminal T picked up	12
67TQ1T	Negative-sequence directional/torque-controlled Element 1, Terminal T timed out	12
67TQ1TC	Negative-sequence directional/torque-control enable definite-time Element 1, Terminal T	12
67TQ2	Negative-sequence directional/torque-controlled Element 2, Terminal T picked up	12
67TQ2T	Negative-sequence directional/torque-controlled Element 2, Terminal T timed out	12
67TQ2TC	Negative-sequence directional/torque-control enable definite-time Element 2, Terminal T	12
67TQ3	Negative-sequence directional/torque-controlled Element 3, Terminal T picked up	13

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 15 of 90)

Name	Bit Description	Row
67TQ3T	Negative-sequence directional/torque-controlled Element 3, Terminal T timed out	13
67TQ3TC	Negative-sequence directional/torque-control enable definite-time Element 3, Terminal T	13
67UG1	Residual-directional/torque-controlled Element 1, Terminal U picked up	18
67UG1T	Residual-directional/torque-controlled Element 1, Terminal U timed out	18
67UG1TC	Residual-directional/torque-control enable definite-time Element 1, Terminal U	18
67UG2	Residual-directional/torque-controlled Element 2, Terminal U picked up	18
67UG2T	Residual-directional/torque-controlled Element 2, Terminal U timed out	18
67UG2TC	Residual-directional/torque-control enable definite-time Element 2, Terminal U	18
67UG3	Residual-directional/torque-controlled Element 3, Terminal U picked up	19
67UG3T	Residual-directional/torque-controlled Element 3, Terminal U timed out	19
67UG3TC	Residual-directional/torque-control enable definite-time Element 3, Terminal U	19
67UP1	Phase-directional/torque-controlled Element 1, Terminal U picked up	15
67UP1T	Phase-directional/torque-controlled Element 1, Terminal U timed out	15
67UP1TC	Phase-directional/torque-control enable definite-time Element 1, Terminal U	15
67UP2	Phase-directional/torque-controlled Element 2, Terminal U picked up	15
67UP2T	Phase-directional/torque-controlled Element 2, Terminal U timed out	15
67UP2TC	Phase-directional/torque-control enable definite-time Element 2, Terminal U	15
67UP3	Phase-directional/torque-controlled Element 3, Terminal U picked up	16
67UP3T	Phase-directional/torque-controlled Element 3, Terminal U timed out	16
67UP3TC	Phase-directional/torque-control enable definite-time Element 3, Terminal U	16
67UQ1	Negative-sequence directional/torque-controlled Element 1, Terminal U picked up	16
67UQ1T	Negative-sequence directional/torque-controlled Element 1, Terminal U timed out	16
67UQ1TC	Negative-sequence directional/torque-control enable definite-time Element 1, Terminal U	16
67UQ2	Negative-sequence directional/torque-controlled Element 2, Terminal U picked up	17
67UQ2T	Negative-sequence directional/torque-controlled Element 2, Terminal U timed out	17
67UQ2TC	Negative-sequence directional/torque control enable definite-time Element 2, Terminal U	17
67UQ3	Negative-sequence directional/torque-controlled Element 3, Terminal U picked up	17
67UQ3T	Negative-sequence directional/torque-controlled Element 3, Terminal U timed out	17
67UQ3TC	Negative-sequence directional/torque control enable definite-time Element 3, Terminal U	17
67YG1	Residual-directional/torque-controlled Element 1, Terminal Y picked up	22
67YG1T	Residual-directional/torque-controlled Element 1, Terminal Y timed out	22
67YG1TC	Residual-directional/torque-control enable definite-time Element 1, Terminal Y	22
67YG2	Residual-directional/torque-controlled Element 2, Terminal Y picked up	23
67YG2T	Residual-directional/torque-controlled Element 2, Terminal Y timed out	23
67YG2TC	Residual-directional/torque-control enable definite-time Element 2, Terminal Y	23
67YG3	Residual-directional/torque-controlled Element 3, Terminal Y picked up	23
67YG3T	Residual-directional/torque-controlled Element 3, Terminal Y timed out	23
67YG3TC	Residual-directional/torque-control enable definite-time Element 3, Terminal Y	23
67YP1	Phase-directional/torque-controlled Element 1, Terminal Y picked up	19
67YP1T	Phase-directional/torque-controlled Element 1, Terminal Y timed out	19
67YP1TC	Phase-directional/torque-control enable definite-time Element 1, Terminal Y	19

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 16 of 90)

Name	Bit Description	Row
67YP2	Phase-directional/torque-controlled Element 2, Terminal Y picked up	20
67YP2T	Phase-directional/torque-controlled Element 2, Terminal Y timed out	20
67YP2TC	Phase-directional/torque-control enable definite-time Element 2, Terminal Y	20
67YP3	Phase-directional/torque-controlled Element 3, Terminal Y picked up	20
67YP3T	Phase-directional/torque-controlled Element 3, Terminal Y timed out	20
67YP3TC	Phase-directional/torque-control enable definite-time Element 3, Terminal Y	20
67YQ1	Negative-sequence directional/torque-controlled Element 1, Terminal Y picked up	21
67YQ1T	Negative-sequence directional/torque-controlled Element 1, Terminal Y timed out	21
67YQ1TC	Negative-sequence directional/torque-control enable definite-time Element 1, Terminal Y	21
67YQ2	Negative-sequence directional/torque-controlled Element 2, Terminal Y picked up	21
67YQ2T	Negative-sequence directional/torque-controlled Element 2, Terminal Y timed out	21
67YQ2TC	Negative-sequence directional/torque-control enable definite-time Element 2, Terminal Y	21
67YQ3	Negative-sequence directional/torque-controlled Element 3, Terminal Y picked up	22
67YQ3T	Negative-sequence directional/torque-controlled Element 3, Terminal Y timed out	22
67YQ3TC	Negative-sequence directional/torque-control enable definite-time Element 3, Terminal Y	22
78CNT	Out-of-step slips equal to count	467
78GCNT	Out-of-step generator slips equal to count	466
78OOS	Out-of-step protection picked up	466
78OST	Out-of-step protection timed out	466
78OSTR	Out-of-step protection trip raw	466
78R1	Out-of-step Blinder 1 picked up	466
78R2	Out-of-step Blinder 2 picked up	466
78SCNT	Out-of-step system slips equal to count	467
78SWNG	Out-of-step swing detected	466
78TC	Out-of-step torque control	467
78Z1	Out-of-step positive-sequence impedance inside the characteristic	466
81AB1	81A Element Band 1 pickup	484
81AB1T	81A Element Band 1 delayed pickup	485
81AB2	81A Element Band 2 pickup	484
81AB2T	81A Element Band 2 delayed pickup	485
81AB3	81A Element Band 3 pickup	484
81AB3T	81A Element Band 3 delayed pickup	485
81AB4	81A Element Band 4 pickup	484
81AB4T	81A Element Band 4 delayed pickup	485
81AB5	81A Element Band 5 pickup	484
81AB5T	81A Element Band 5 delayed pickup	485
81AB6	81A Element Band 6 pickup	484
81AB6T	81A Element Band 6 delayed pickup	485
81AB7	81A Element Band 7 pickup	484
81AB7T	81A Element Band 7 delayed pickup	485
81AB8	81A Element Band 8 pickup	484

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 17 of 90)

Name	Bit Description	Row
81AB8T	81A Element Band 8 delayed pickup	485
81AC	81A Element pickup	486
81AT	81A Element delayed pickup	486
81ATC	81A Element torque control	486
81D1	Definite-time frequency element picked up, Level 1	41
81D1OVR	Definite-time overfrequency Level 1	41
81D1T	Definite-time over-/underfrequency element delay for Level 1	41
81D1TC	Definite-time frequency Element 1, torque control	41
81D1UDR	Definite-time underfrequency Level 1	41
81D2	Definite-time frequency element picked up, Level 2	42
81D2OVR	Definite-time overfrequency Level 2	41
81D2T	Definite-time over-/underfrequency element delay for Level 2	41
81D2TC	Definite-time frequency Element 2, torque control	42
81D2UDR	Definite-time underfrequency Level 2	41
81D3	Definite-time frequency element picked up, Level 3	42
81D3OVR	Definite-time overfrequency Level 3	42
81D3T	Definite-time over-/underfrequency element delay for Level 3	42
81D3TC	Definite-time frequency Element 3, torque control	42
81D3UDR	Definite-time underfrequency Level 3	42
81D4	Definite-time frequency element picked up, Level 4	43
81D4OVR	Definite-time overfrequency Level 4	42
81D4T	Definite-time over-/underfrequency element delay for Level 4	43
81D4TC	Definite-time frequency Element 4, torque control	43
81D4UDR	Definite-time underfrequency Level 4	43
81D5	Definite-time frequency element picked up, Level 5	43
81D5OVR	Definite-time overfrequency Level 5	43
81D5T	Definite-time over-/underfrequency element delay for Level 5	43
81D5TC	Definite-time frequency Element 5, torque control	44
81D5UDR	Definite-time underfrequency Level 5	43
81D6	Definite-time frequency element picked up, Level 6	44
81D6OVR	Definite-time overfrequency Level 6	44
81D6T	Definite-time over-/underfrequency element delay for Level 6	44
81D6TC	Definite-time frequency Element 6, torque control	44
81D6UDR	Definite-time underfrequency Level 6	44
81R1	Definite-time rate-of-change-of-frequency element picked up, Level 1	48
81R1OVR	Definite-time over rate-of-change-of-frequency Level 1	48
81R1T	Definite-time over-/under rate-of-change-of-frequency element delay for Level 1	48
81R1TC	Definite-time rate-of-change-of-frequency Element 1, torque control	48
81R1UDR	Definite-time under rate-of-change-of-frequency Level 1	48
81R2	Definite-time rate-of-change-of-frequency element picked up, Level 2	49
81R2OVR	Definite-time over rate-of-change-of-frequency Level 2	48

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 18 of 90)

Name	Bit Description	Row
81R2T	Definite-time over-/under rate-of-change-of-frequency element delay for Level 2	48
81R2TC	Definite-time rate-of-change-of-frequency Element 2, torque control	49
81R2UDR	Definite-time under rate-of-change-of-frequency Level 2	48
81R3	Definite-time rate-of-change-of-frequency element picked up, Level 3	49
81R3OVR	Definite-time over rate-of-change-of-frequency Level 3	49
81R3T	Definite-time over-/under rate-of-change-of-frequency element delay for Level 3	49
81R3TC	Definite-time rate-of-change-of-frequency Element 3, torque control	49
81R3UDR	Definite-time under rate-of-change-of-frequency Level 3	49
81R4	Definite-time rate-of-change-of-frequency element picked up, Level 4	50
81R4OVR	Definite-time over rate-of-change-of-frequency Level 4	49
81R4T	Definite-time over-/under rate-of-change-of-frequency element delay for Level 4	50
81R4TC	Definite-time rate-of-change-of-frequency Element 4, torque control	50
81R4UDR	Definite-time under rate-of-change-of-frequency Level 4	50
81R5	Definite-time rate-of-change-of-frequency element picked up, Level 5	50
81R5OVR	Definite-time over rate-of-change-of-frequency Level 5	50
81R5T	Definite-time over-/under rate-of-change-of-frequency element delay for Level 5	50
81R5TC	Definite-time rate-of-change-of-frequency Element 5, torque control	51
81R5UDR	Definite-time under rate-of-change-of-frequency Level 5	50
81R6	Definite-time rate-of-change-of-frequency element picked up, Level 6	51
81R6OVR	Definite-time over rate-of-change-of-frequency Level 6	51
81R6T	Definite-time over-/under rate-of-change-of-frequency element delay for Level 6	51
81R6TC	Definite-time rate-of-change-of-frequency Element 6, torque control	51
81R6UDR	Definite-time under rate-of-change-of-frequency Level 6	51
87AAP51	5th harmonic alarm picked up, A-Phase, Element 1	73
87AAP52	5th harmonic alarm picked up, A-Phase, Element 2	83
87AB21	A-Phase Element 1 2nd harmonic blocking picked up	74
87AB22	A-Phase Element 2 2nd harmonic blocking picked up	84
87AB241	A-Phase Element 1 2nd or 4th harmonic blocking picked up	68
87AB242	A-Phase Element 2 2nd or 4th harmonic blocking picked up	79
87AB51	A-Phase Element 1 5th harmonic blocking picked up	68
87AB52	A-Phase Element 2 5th harmonic blocking picked up	79
87AD51	5th Harmonic delayed alarm picked up, Element 1	73
87AD52	5th Harmonic delayed alarm picked up, Element 2	84
87AHB1	A-Phase Element 1 harmonic blocking picked up	67
87AHB2	A-Phase Element 2 harmonic blocking picked up	78
87AHR1	A-Phase Element 1 harmonic restraint picked up	67
87AHR2	A-Phase Element 2 harmonic restraint picked up	78
87AP51	5th Harmonic alarm picked up, Element 1	73
87AP52	5th Harmonic alarm picked up, Element 2	84
87AR1	A-Phase restrained differential Element 1 picked up	65
87AR2	A-Phase restrained differential Element 2 picked up	75

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 19 of 90)

Name	Bit Description	Row
87ARHB1	A-Phase restrained differential Element 1 picked up through harmonic blocking	66
87ARHB2	A-Phase restrained differential Element 2 picked up through harmonic blocking	77
87ARHR1	A-Phase restrained differential Element 1 picked up through harmonic restraint	67
87ARHR2	A-Phase restrained differential Element 2 picked up through harmonic restraint	77
87ARMS1	A-Phase rms differential Element 1 picked up	66
87ARMS2	A-Phase rms differential Element 2 picked up	77
87ASEC1	Differential Element 1 A-Phase, switch to secure	69
87ASEC2	Differential Element 2 A-Phase, switch to secure	79
87AUF1	A-Phase filtered unrestrained differential Element 1 picked up	65
87AUF2	A-Phase filtered unrestrained differential Element 2 picked up	76
87AUR1	A-Phase raw unrestrained differential Element 1 picked up	66
87AUR2	A-Phase raw unrestrained differential Element 2 picked up	76
87B21	Element 1 2nd harmonic blocking picked up	74
87B22	Element 2 2nd harmonic blocking picked up	85
87B51	Element 1 5th harmonic blocking picked up	74
87B52	Element 2 5th harmonic blocking picked up	85
87BAP51	5th Harmonic alarm picked up, B-Phase, Element 1	73
87BAP52	5th Harmonic alarm picked up, B-Phase, Element 2	83
87BB21	B-Phase Element 1 2nd harmonic blocking picked up	74
87BB22	B-Phase Element 2 2nd harmonic blocking picked up	84
87BB241	B-Phase Element 1 2nd or 4th harmonic blocking picked up	68
87BB242	B-Phase Element 2 2nd or 4th harmonic blocking picked up	79
87BB51	B-Phase Element 1 5th harmonic blocking picked up	68
87BB52	B-Phase Element 2 5th harmonic blocking picked up	79
87BHB1	B-Phase Element 1 harmonic blocking picked up	67
87BHB2	B-Phase Element 2 harmonic blocking picked up	78
87BHCA1	HIGH bipolar, level low supervision, A-Phase, Element 1	88
87BHCA2	HIGH bipolar, level low supervision, A-Phase, Element 2	92
87BHCB1	HIGH bipolar, level low supervision, B-Phase, Element 1	88
87BHCB2	HIGH bipolar, level low supervision, B-Phase, Element 2	93
87BHCC1	HIGH bipolar, level low supervision, C-Phase, Element 1	88
87BHCC2	HIGH bipolar, level low supervision, C-Phase, Element 2	93
87BHR1	B-Phase Element 1 harmonic restraint picked up	68
87BHR2	B-Phase Element 2 harmonic restraint picked up	78
87BLCA1	LOW bipolar, level low supervision, A-Phase, Element 1	88
87BLCA2	LOW bipolar, level low supervision, A-Phase, Element 2	92
87BLCB1	LOW bipolar, level low supervision, B-Phase, Element 1	88
87BLCB2	LOW bipolar, level low supervision, B-Phase, Element 2	92
87BLCC1	LOW bipolar, level low supervision, C-Phase, Element 1	88
87BLCC2	LOW bipolar, level low supervision, C-Phase, Element 2	92
87BPH1	HIGH bipolar signature identified, Element 1	89

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 20 of 90)

Name	Bit Description	Row
87BPH2	HIGH bipolar signature identified, Element 2	93
87BPHA1	HIGH bipolar signature identified, A-Phase, Element 1	89
87BPHA2	HIGH bipolar signature identified, A-Phase, Element 2	93
87BPHB1	HIGH bipolar signature identified, B-Phase, Element 1	89
87BPHB2	HIGH bipolar signature identified, B-Phase, Element 2	94
87BPHC1	HIGH bipolar signature identified, C-Phase, Element 1	89
87BPHC2	HIGH bipolar signature identified, C-Phase, Element 2	94
87BPL1	LOW bipolar signature identified, Element 1	88
87BPL2	LOW bipolar signature identified, Element 2	93
87BPLA1	LOW bipolar signature identified, A-Phase, Element 1	88
87BPLA2	LOW bipolar signature identified, A-Phase, Element 2	93
87BPLB1	LOW bipolar signature identified, B-Phase, Element 1	89
87BPLB2	LOW bipolar signature identified, B-Phase, Element 2	93
87BPLC1	LOW bipolar signature identified, C-Phase, Element 1	89
87BPLC2	LOW bipolar signature identified, C-Phase, Element 2	93
87BR1	B-Phase restrained differential Element 1 picked up	65
87BR2	B-Phase restrained differential Element 2 picked up	75
87BRHB1	B-Phase restrained differential Element 1 picked up through harmonic blocking	66
87BRHB2	B-Phase restrained differential Element 2 picked up through harmonic blocking	77
87BRHR1	B-Phase restrained differential Element 1 picked up through harmonic restraint	67
87BRHR2	B-Phase restrained differential Element 2 picked up through harmonic restraint	77
87BRMS1	B-Phase rms differential Element 1 picked up	66
87BRMS2	B-Phase rms differential Element 2 picked up	77
87BSEC1	Differential Element 1 B-Phase, switch to secure	69
87BSEC2	Differential Element 2 B-Phase, switch to secure	79
87BUF1	B-Phase filtered unrestrained differential Element 1 picked up	65
87BUF2	B-Phase filtered unrestrained differential Element 2 picked up	76
87BUR1	B-Phase raw unrestrained differential Element 1 picked up	66
87BUR2	B-Phase raw unrestrained differential Element 2 picked up	76
87CAP51	5th harmonic alarm picked up, C-Phase, Element 1	73
87CAP52	5th harmonic alarm picked up, C-Phase, Element 2	83
87CB21	C-Phase Element 1 2nd harmonic blocking picked up	74
87CB22	C-Phase Element 2 2nd harmonic blocking picked up	84
87CB241	C-Phase Element 1 2nd or 4th harmonic blocking picked up	68
87CB242	C-Phase Element 2 2nd or 4th harmonic blocking picked up	79
87CB51	C-Phase Element 1 5th harmonic blocking picked up	69
87CB52	C-Phase Element 2 5th harmonic blocking picked up	79
87CHB1	C-Phase Element 1 harmonic blocking picked up	67
87CHB2	C-Phase Element 2 harmonic blocking picked up	78
87CHR1	C-Phase Element 1 harmonic restraint picked up	68
87CHR2	C-Phase Element 2 harmonic restraint picked up	78

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 21 of 90)

Name	Bit Description	Row
87CR1	C-Phase restrained differential Element 1 picked up	65
87CR2	C-Phase restrained differential Element 2 picked up	75
87CRHB1	C-Phase restrained differential Element 1 picked up through harmonic blocking	67
87CRHB2	C-Phase restrained differential Element 2 picked up through harmonic blocking	77
87CRHR1	C-Phase restrained differential Element 1 picked up through harmonic restraint	67
87CRHR2	C-Phase restrained differential Element 2 picked up through harmonic restraint	78
87CRMS1	C-Phase rms differential Element 1 picked up	66
87CRMS2	C-Phase rms differential Element 2 picked up	77
87CSEC1	Differential Element 1 C-Phase, switch to secure	69
87CSEC2	Differential Element 2 C-Phase, switch to secure	80
87CUF1	C-Phase filtered unrestrained differential Element 1 picked up	65
87CUF2	C-Phase filtered unrestrained differential Element 2 picked up	76
87CUR1	C-Phase raw unrestrained differential Element 1 picked up	66
87CUR2	C-Phase raw unrestrained differential Element 2 picked up	76
87Q1	Negative-sequence differential Element 1 asserted (interturn fault detected)	100
87Q2	Negative-sequence differential Element 2 asserted (interturn fault detected)	100
87QB1	Negative-sequence differential blocking Element 1 asserted	100
87QB2	Negative-sequence differential blocking Element 2 asserted	100
87QTC1	Negative-sequence differential Element 1, torque control	100
87QTC2	Negative-sequence differential Element 2, torque control	100
87R1	Restrained differential Element 1 picked up	64
87R2	Restrained differential Element 2 picked up	74
87RMS1	RMS differential Element 1 picked up	64
87RMS2	RMS differential Element 2 picked up	75
87RMTC1	RMS differential Element 1 torque control	64
87RMTC2	RMS differential Element 2 torque control	75
87RTC1	Restrained differential Element 1 torque control	64
87RTC2	Restrained differential Element 2 torque control	75
87TBHA1	HIGH bipolar unsupervised signature identified, A-Phase, Element 1	87
87TBHA2	HIGH bipolar unsupervised signature identified, A-Phase, Element 2	91
87TBHB1	HIGH bipolar unsupervised signature identified, B-Phase, Element 1	87
87TBHB2	HIGH bipolar unsupervised signature identified, B-Phase, Element 2	91
87TBHC1	HIGH bipolar unsupervised signature identified, C-Phase, Element 1	87
87TBHC2	HIGH bipolar unsupervised signature identified, C-Phase, Element 2	91
87TBLA1	LOW bipolar unsupervised signature identified, A-Phase, Element 1	86
87TBLA2	LOW bipolar unsupervised signature identified, A-Phase, Element 2	91
87TBLB1	LOW bipolar unsupervised signature identified, B-Phase, Element 1	86
87TBLB2	LOW bipolar unsupervised signature identified, B-Phase, Element 2	91
87TBLC1	LOW bipolar unsupervised signature identified, C-Phase, Element 1	87
87TBLC2	LOW bipolar unsupervised signature identified, C-Phase, Element 2	91
87TM1	Fundamental operate current picked up for three-legged core, Element 1	85

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 22 of 90)

Name	Bit Description	Row
87TM2	Fundamental operate current picked up for three-legged core, Element 2	89
87TMA1	Fundamental operate current picked up for single core, A-Phase, Element 1	85
87TMA2	Fundamental operate current picked up for single core, A-Phase, Element 2	89
87TMB1	Fundamental operate current picked up for single core, B-Phase, Element 1	85
87TMB2	Fundamental operate current picked up for single core, B-Phase, Element 2	90
87TMC1	Fundamental operate current picked up for single core, C-Phase, Element 1	85
87TMC2	Fundamental operate current picked up for single core, C-Phase, Element 2	90
87TS1	Small and flat periods identified in the operate current for three-legged core, Element 1	85
87TS2	Small and flat periods identified in the operate current for three-legged core, Element 2	90
87TSA1	Small and flat periods identified in the operate current for single core, A-Phase, Element 1	85
87TSA2	Small and flat periods identified in the operate current for single core, A-Phase, Element 2	90
87TSB1	Small and flat periods identified in the operate current for single core, B-Phase, Element 1	86
87TSB2	Small and flat periods identified in the operate current for single core, B-Phase, Element 2	90
87TSC1	Small and flat periods identified in the operate current for single core, C-Phase, Element 1	86
87TSC2	Small and flat periods identified in the operate current for single core, C-Phase, Element 2	90
87U1	Unrestrained differential Element 1 picked up	64
87U2	Unrestrained differential Element 2 picked up	74
87UBL1	Bipolar unblocking identified, Element 1	87
87UBL2	Bipolar unblocking identified, Element 2	92
87UBLA1	Bipolar unblocking identified, A-Phase, Element 1	87
87UBLA2	Bipolar unblocking identified, A-Phase, Element 2	92
87UBLB1	Bipolar unblocking identified, B-Phase, Element 1	87
87UBLB2	Bipolar unblocking identified, B-Phase, Element 2	92
87UBLC1	Bipolar unblocking identified, C-Phase, Element 1	87
87UBLC2	Bipolar unblocking identified, C-Phase, Element 2	92
87UF1	Filtered unrestrained differential Element 1 picked up	65
87UF2	Filtered unrestrained differential Element 2 picked up	76
87UR1	Raw unrestrained differential Element 1 picked up	65
87UR2	Raw unrestrained differential Element 2 picked up	76
87UTC1	Unrestrained differential Element 1 Torque Control	64
87UTC2	Unrestrained differential Element 2 Torque Control	75
87WB1	87 waveshape inrush blocking logic asserted, Element 1	86
87WB2	87 waveshape inrush blocking logic asserted, Element 2	91
87WBA1	87 waveshape inrush blocking logic asserted, A-Phase, Element 1	86
87WBA2	87 waveshape inrush blocking logic asserted, A-Phase, Element 2	90
87WBB1	87 waveshape inrush blocking logic asserted, B-Phase, Element 1	86
87WBB2	87 waveshape inrush blocking logic asserted, B-Phase, Element 2	90
87WBC1	87 waveshape inrush blocking logic asserted, C-Phase, Element 1	86
87WBC2	87 waveshape inrush blocking logic asserted, C-Phase, Element 2	91
87XB21	Element 1 harmonic cross blocking picked up	68
87XB22	Element 2 harmonic cross blocking picked up	78

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 23 of 90)

Name	Bit Description	Row
87Z1	Differential Element 1 picked up	64
87Z2	Differential Element 2 picked up	74
89AL	Any disconnect alarm	134
89AL01	Disconnect 1 alarm	134
89AL02	Disconnect 2 alarm	135
89AL03	Disconnect 3 alarm	136
89AL04	Disconnect 4 alarm	137
89AL05	Disconnect 5 alarm	138
89AL06	Disconnect 6 alarm	139
89AL07	Disconnect 7 alarm	140
89AL08	Disconnect 8 alarm	141
89AL09	Disconnect 9 alarm	142
89AL10	Disconnect 10 alarm	143
89AM01	Disconnect 1 N/O auxiliary contact	134
89AM02	Disconnect 2 N/O auxiliary contact	135
89AM03	Disconnect 3 N/O auxiliary contact	136
89AM04	Disconnect 4 N/O auxiliary contact	137
89AM05	Disconnect 5 N/O auxiliary contact	138
89AM06	Disconnect 6 N/O auxiliary contact	139
89AM07	Disconnect 7 N/O auxiliary contact	140
89AM08	Disconnect 8 N/O auxiliary contact	141
89AM09	Disconnect 9 N/O auxiliary contact	142
89AM10	Disconnect 10 N/O auxiliary contact	143
89BM01	Disconnect 1 N/C auxiliary contact	134
89BM02	Disconnect 2 N/C auxiliary contact	135
89BM03	Disconnect 3 N/C auxiliary contact	136
89BM04	Disconnect 4 N/C auxiliary contact	137
89BM05	Disconnect 5 N/C auxiliary contact	138
89BM06	Disconnect 6 N/C auxiliary contact	139
89BM07	Disconnect 7 N/C auxiliary contact	140
89BM08	Disconnect 8 N/C auxiliary contact	141
89BM09	Disconnect 9 N/C auxiliary contact	142
89BM10	Disconnect 10 N/C auxiliary contact	143
89CBL01	Disconnect 01 close block	160
89CBL02	Disconnect 02 close block	162
89CBL03	Disconnect 03 close block	163
89CBL04	Disconnect 04 close block	165
89CBL05	Disconnect 05 close block	166
89CBL06	Disconnect 06 close block	168
89CBL07	Disconnect 07 close block	169
89CBL08	Disconnect 08 close block	171

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 24 of 90)

Name	Bit Description	Row
89CBL09	Disconnect 09 close block	172
89CBL10	Disconnect 10 close block	174
89CC01	ASCII close Disconnect 1 command	149
89CC02	ASCII close Disconnect 2 command	150
89CC03	ASCII close Disconnect 3 command	151
89CC04	ASCII close Disconnect 4 command	152
89CC05	ASCII close Disconnect 5 command	153
89CC06	ASCII close Disconnect 6 command	154
89CC07	ASCII close Disconnect 7 command	155
89CC08	ASCII close Disconnect 8 command	156
89CC09	ASCII close Disconnect 9 command	157
89CC10	ASCII close Disconnect 10 command	158
89CCM01	Mimic Disconnect 1 close control	149
89CCM02	Mimic Disconnect 2 close control	150
89CCM03	Mimic Disconnect 3 close control	151
89CCM04	Mimic Disconnect 4 close control	152
89CCM05	Mimic Disconnect 5 close control	153
89CCM06	Mimic Disconnect 6 close control	154
89CCM07	Mimic Disconnect 7 close control	155
89CCM08	Mimic Disconnect 8 close control	156
89CCM09	Mimic Disconnect 9 close control	157
89CCM10	Mimic Disconnect 10 close control	158
89CCN01	Close Disconnect 1	149
89CCN02	Close Disconnect 2	150
89CCN03	Close Disconnect 3	151
89CCN04	Close Disconnect 4	152
89CCN05	Close Disconnect 5	153
89CCN06	Close Disconnect 6	154
89CCN07	Close Disconnect 7	155
89CCN08	Close Disconnect 8	156
89CCN09	Close Disconnect 9	157
89CCN10	Close Disconnect 10	158
89CIM01	Disconnect 01 close immobility timer timed out	161
89CIM02	Disconnect 02 close immobility timer timed out	163
89CIM03	Disconnect 03 close immobility timer timed out	164
89CIM04	Disconnect 04 close immobility timer timed out	166
89CIM05	Disconnect 05 close immobility timer timed out	167
89CIM06	Disconnect 06 close immobility timer timed out	169
89CIM07	Disconnect 07 close immobility timer timed out	170
89CIM08	Disconnect 08 close immobility timer timed out	172
89CIM09	Disconnect 09 close immobility timer timed out	173

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 25 of 90)

Name	Bit Description	Row
89CIM10	Disconnect 10 close immobility timer timed out	175
89CIR01	Disconnect 01 close immobility timer reset	160
89CIR02	Disconnect 02 close immobility timer reset	162
89CIR03	Disconnect 03 close immobility timer reset	164
89CIR04	Disconnect 04 close immobility timer reset	165
89CIR05	Disconnect 05 close immobility timer reset	167
89CIR06	Disconnect 06 close immobility timer reset	168
89CIR07	Disconnect 07 close immobility timer reset	170
89CIR08	Disconnect 08 close immobility timer reset	171
89CIR09	Disconnect 09 close immobility timer reset	173
89CIR10	Disconnect 10 close immobility timer reset	174
89CL01	Disconnect 1 closed	134
89CL02	Disconnect 2 closed	135
89CL03	Disconnect 3 closed	136
89CL04	Disconnect 4 closed	137
89CL05	Disconnect 5 closed	138
89CL06	Disconnect 6 closed	139
89CL07	Disconnect 7 closed	140
89CL08	Disconnect 8 closed	141
89CL09	Disconnect 9 closed	142
89CL10	Disconnect 10 closed	143
89CLB01	Disconnect 1 bus zone protection	146
89CLB02	Disconnect 2 bus zone protection	146
89CLB03	Disconnect 3 bus zone protection	146
89CLB04	Disconnect 4 bus zone protection	146
89CLB05	Disconnect 5 bus zone protection	146
89CLB06	Disconnect 6 bus zone protection	146
89CLB07	Disconnect 7 bus zone protection	146
89CLB08	Disconnect 8 bus zone protection	146
89CLB09	Disconnect 9 bus zone protection	147
89CLB10	Disconnect 10 bus zone protection	147
89CLS01	Disconnect Close 1 output	149
89CLS02	Disconnect Close 2 output	150
89CLS03	Disconnect Close 3 output	151
89CLS04	Disconnect Close 4 output	152
89CLS05	Disconnect Close 5 output	153
89CLS06	Disconnect Close 6 output	154
89CLS07	Disconnect Close 7 output	155
89CLS08	Disconnect Close 8 output	156
89CLS09	Disconnect Close 9 output	157
89CLS10	Disconnect Close 10 output	158

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 26 of 90)

Name	Bit Description	Row
89CRS01	Disconnect 01 close reset	160
89CRS02	Disconnect 02 close reset	162
89CRS03	Disconnect 03 close reset	164
89CRS04	Disconnect 04 close reset	165
89CRS05	Disconnect 05 close reset	167
89CRS06	Disconnect 06 close reset	168
89CRS07	Disconnect 07 close reset	170
89CRS08	Disconnect 08 close reset	171
89CRS09	Disconnect 09 close reset	173
89CRS10	Disconnect 10 close reset	174
89CSI01	Disconnect 01 close seal-in timer timed out	160
89CSI02	Disconnect 02 close seal-in timer timed out	162
89CSI03	Disconnect 03 close seal-in timer timed out	163
89CSI04	Disconnect 04 close seal-in timer timed out	165
89CSI05	Disconnect 05 close seal-in timer timed out	166
89CSI06	Disconnect 06 close seal-in timer timed out	168
89CSI07	Disconnect 07 close seal-in timer timed out	169
89CSI08	Disconnect 08 close seal-in timer timed out	171
89CSI09	Disconnect 09 close seal-in timer timed out	172
89CSI10	Disconnect 10 close seal-in timer timed out	174
89CTL01	Disconnect 1 control status	134
89CTL02	Disconnect 2 control status	135
89CTL03	Disconnect 3 control status	136
89CTL04	Disconnect 4 control status	137
89CTL05	Disconnect 5 control status	138
89CTL06	Disconnect 6 control status	139
89CTL07	Disconnect 7 control status	140
89CTL08	Disconnect 8 control status	141
89CTL09	Disconnect 9 control status	142
89CTL10	Disconnect 10 control status	143
89ENC01	Disconnect 1 close control operation enabled	572
89ENC02	Disconnect 2 close control operation enabled	572
89ENC03	Disconnect 3 close control operation enabled	572
89ENC04	Disconnect 4 close control operation enabled	572
89ENC05	Disconnect 5 close control operation enabled	573
89ENC06	Disconnect 6 close control operation enabled	573
89ENC07	Disconnect 7 close control operation enabled	573
89ENC08	Disconnect 8 close control operation enabled	573
89ENC09	Disconnect 9 close control operation enabled	574
89ENC10	Disconnect 10 close control operation enabled	574
89ENO01	Disconnect 1 open control operation enabled	572

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 27 of 90)

Name	Bit Description	Row
89ENO02	Disconnect 2 open control operation enabled	572
89ENO03	Disconnect 3 open control operation enabled	572
89ENO04	Disconnect 4 open control operation enabled	572
89ENO05	Disconnect 5 open control operation enabled	573
89ENO06	Disconnect 6 open control operation enabled	573
89ENO07	Disconnect 7 open control operation enabled	573
89ENO08	Disconnect 8 open control operation enabled	573
89ENO09	Disconnect 9 open control operation enabled	574
89ENO10	Disconnect 10 open control operation enabled	574
89OBL01	Disconnect 01 open block	160
89OBL02	Disconnect 02 open block	162
89OBL03	Disconnect 03 open block	164
89OBL04	Disconnect 04 open block	165
89OBL05	Disconnect 05 open block	167
89OBL06	Disconnect 06 open block	168
89OBL07	Disconnect 07 open block	170
89OBL08	Disconnect 08 open block	171
89OBL09	Disconnect 09 open block	173
89OBL10	Disconnect 10 open block	174
89OC01	ASCII open Disconnect 1 command	149
89OC02	ASCII open Disconnect 2 command	150
89OC03	ASCII open Disconnect 3 command	151
89OC04	ASCII open Disconnect 4 command	152
89OC05	ASCII open Disconnect 5 command	153
89OC06	ASCII open Disconnect 6 command	154
89OC07	ASCII open Disconnect 7 command	155
89OC08	ASCII open Disconnect 8 command	156
89OC09	ASCII open Disconnect 9 command	157
89OC10	ASCII open Disconnect 10 command	158
89OCM01	Mimic Disconnect 1 open control	149
89OCM02	Mimic Disconnect 2 open control	150
89OCM03	Mimic Disconnect 3 open control	151
89OCM04	Mimic Disconnect 4 open control	152
89OCM05	Mimic Disconnect 5 open control	153
89OCM06	Mimic Disconnect 6 open control	154
89OCM07	Mimic Disconnect 7 open control	155
89OCM08	Mimic Disconnect 8 open control	156
89OCM09	Mimic Disconnect 9 open control	157
89OCM10	Mimic Disconnect 10 open control	158
89OCN01	Open Disconnect 1	149
89OCN02	Open Disconnect 2	150

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 28 of 90)

Name	Bit Description	Row
89OCN03	Open Disconnect 3	151
89OCN04	Open Disconnect 4	152
89OCN05	Open Disconnect 5	153
89OCN06	Open Disconnect 6	154
89OCN07	Open Disconnect 7	155
89OCN08	Open Disconnect 8	156
89OCN09	Open Disconnect 9	157
89OCN10	Open Disconnect 10	158
89OIM01	Disconnect 01 open immobility timer timed out	161
89OIM02	Disconnect 02 open immobility timer timed out	163
89OIM03	Disconnect 03 open immobility timer timed out	164
89OIM04	Disconnect 04 open immobility timer timed out	166
89OIM05	Disconnect 05 open immobility timer timed out	167
89OIM06	Disconnect 06 open immobility timer timed out	169
89OIM07	Disconnect 07 open immobility timer timed out	170
89OIM08	Disconnect 08 open immobility timer timed out	172
89OIM09	Disconnect 09 open immobility timer timed out	173
89OIM10	Disconnect 10 open immobility timer timed out	175
89OIP	Any disconnect operation in progress	135
89OIP01	Disconnect 1 operation in progress	134
89OIP02	Disconnect 2 operation in progress	135
89OIP03	Disconnect 3 operation in progress	136
89OIP04	Disconnect 4 operation in progress	137
89OIP05	Disconnect 5 operation in progress	138
89OIP06	Disconnect 6 operation in progress	139
89OIP07	Disconnect 7 operation in progress	140
89OIP08	Disconnect 8 operation in progress	141
89OIP09	Disconnect 9 operation in progress	142
89OIP10	Disconnect 10 operation in progress	143
89OIR01	Disconnect 01 open immobility timer reset	160
89OIR02	Disconnect 02 open immobility timer reset	162
89OIR03	Disconnect 03 open immobility timer reset	163
89OIR04	Disconnect 04 open immobility timer reset	165
89OIR05	Disconnect 05 open immobility timer reset	166
89OIR06	Disconnect 06 open immobility timer reset	168
89OIR07	Disconnect 07 open immobility timer reset	169
89OIR08	Disconnect 08 open immobility timer reset	171
89OIR09	Disconnect 09 open immobility timer reset	172
89OIR10	Disconnect 10 open immobility timer reset	174
89OPE01	Disconnect Open 1 output	149
89OPE02	Disconnect Open 2 output	150

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 29 of 90)

Name	Bit Description	Row
89OPE03	Disconnect Open 3 output	151
89OPE04	Disconnect Open 4 output	152
89OPE05	Disconnect Open 5 output	153
89OPE06	Disconnect Open 6 output	154
89OPE07	Disconnect Open 7 output	155
89OPE08	Disconnect Open 8 output	156
89OPE09	Disconnect Open 9 output	157
89OPE10	Disconnect Open 10 output	158
89OPN01	Disconnect 1 open	134
89OPN02	Disconnect 2 open	135
89OPN03	Disconnect 3 open	136
89OPN04	Disconnect 4 open	137
89OPN05	Disconnect 5 open	138
89OPN06	Disconnect 6 open	139
89OPN07	Disconnect 7 open	140
89OPN08	Disconnect 8 open	141
89OPN09	Disconnect 9 open	142
89OPN10	Disconnect 10 open	143
89ORS01	Disconnect 01 open reset	160
89ORS02	Disconnect 02 open reset	162
89ORS03	Disconnect 03 open reset	164
89ORS04	Disconnect 04 open reset	165
89ORS05	Disconnect 05 open reset	167
89ORS06	Disconnect 06 open reset	168
89ORS07	Disconnect 07 open reset	170
89ORS08	Disconnect 08 open reset	171
89ORS09	Disconnect 09 open reset	173
89ORS10	Disconnect 10 open reset	174
89OSI01	Disconnect 01 open seal-in timer timed out	160
89OSI02	Disconnect 02 open seal-in timer timed out	162
89OSI03	Disconnect 03 open seal-in timer timed out	163
89OSI04	Disconnect 04 open seal-in timer timed out	165
89OSI05	Disconnect 05 open seal-in timer timed out	166
89OSI06	Disconnect 06 open seal-in timer timed out	168
89OSI07	Disconnect 07 open seal-in timer timed out	169
89OSI08	Disconnect 08 open seal-in timer timed out	171
89OSI09	Disconnect 09 open seal-in timer timed out	172
89OSI10	Disconnect 10 open seal-in timer timed out	174
ABFITS	Alternative breaker failure, Terminal S	123
ABFITT	Alternative breaker failure, Terminal T	125
ABFITU	Alternative breaker failure, Terminal U	127

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 30 of 90)

Name	Bit Description	Row
ABFITY	Alternative breaker failure, Terminal Y	129
ACCESS	A user is logged in at Access Level B or higher	318
ACCESSP	Pulsed alarm for logins to Access Level B or higher	318
ACN01Q	Automation SELOGIC Counter 01 asserted	308
ACN01R	Automation SELOGIC Counter 01 reset	312
ACN02Q	Automation SELOGIC Counter 02 asserted	308
ACN02R	Automation SELOGIC Counter 02 reset	312
ACN03Q	Automation SELOGIC Counter 03 asserted	308
ACN03R	Automation SELOGIC Counter 03 reset	312
ACN04Q	Automation SELOGIC Counter 04 asserted	308
ACN04R	Automation SELOGIC Counter 04 reset	312
ACN05Q	Automation SELOGIC Counter 05 asserted	308
ACN05R	Automation SELOGIC Counter 05 reset	312
ACN06Q	Automation SELOGIC Counter 06 asserted	308
ACN06R	Automation SELOGIC Counter 06 reset	312
ACN07Q	Automation SELOGIC Counter 07 asserted	308
ACN07R	Automation SELOGIC Counter 07 reset	312
ACN08Q	Automation SELOGIC Counter 08 asserted	308
ACN08R	Automation SELOGIC Counter 08 reset	312
ACN09Q	Automation SELOGIC Counter 09 asserted	309
ACN09R	Automation SELOGIC Counter 09 reset	313
ACN10Q	Automation SELOGIC Counter 10 asserted	309
ACN10R	Automation SELOGIC Counter 10 reset	313
ACN11Q	Automation SELOGIC Counter 11 asserted	309
ACN11R	Automation SELOGIC Counter 11 reset	313
ACN12Q	Automation SELOGIC Counter 12 asserted	309
ACN12R	Automation SELOGIC Counter 12 reset	313
ACN13Q	Automation SELOGIC Counter 13 asserted	309
ACN13R	Automation SELOGIC Counter 13 reset	313
ACN14Q	Automation SELOGIC Counter 14 asserted	309
ACN14R	Automation SELOGIC Counter 14 reset	313
ACN15Q	Automation SELOGIC Counter 15 asserted	309
ACN15R	Automation SELOGIC Counter 15 reset	313
ACN16Q	Automation SELOGIC Counter 16 asserted	309
ACN16R	Automation SELOGIC Counter 16 reset	313
ACN17Q	Automation SELOGIC Counter 17 asserted	310
ACN17R	Automation SELOGIC Counter 17 reset	314
ACN18Q	Automation SELOGIC Counter 18 asserted	310
ACN18R	Automation SELOGIC Counter 18 reset	314
ACN19Q	Automation SELOGIC Counter 19 asserted	310
ACN19R	Automation SELOGIC Counter 19 reset	314

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 31 of 90)

Name	Bit Description	Row
ACN20Q	Automation SELOGIC Counter 20 asserted	310
ACN20R	Automation SELOGIC Counter 20 reset	314
ACN21Q	Automation SELOGIC Counter 21 asserted	310
ACN21R	Automation SELOGIC Counter 21 reset	314
ACN22Q	Automation SELOGIC Counter 22 asserted	310
ACN22R	Automation SELOGIC Counter 22 reset	314
ACN23Q	Automation SELOGIC Counter 23 asserted	310
ACN23R	Automation SELOGIC Counter 23 reset	314
ACN24Q	Automation SELOGIC Counter 24 asserted	310
ACN24R	Automation SELOGIC Counter 24 reset	314
ACN25Q	Automation SELOGIC Counter 25 asserted	311
ACN25R	Automation SELOGIC Counter 25 reset	315
ACN26Q	Automation SELOGIC Counter 26 asserted	311
ACN26R	Automation SELOGIC Counter 26 reset	315
ACN27Q	Automation SELOGIC Counter 27 asserted	311
ACN27R	Automation SELOGIC Counter 27 reset	315
ACN28Q	Automation SELOGIC Counter 28 asserted	311
ACN28R	Automation SELOGIC Counter 28 reset	315
ACN29Q	Automation SELOGIC Counter 29 asserted	311
ACN29R	Automation SELOGIC Counter 29 reset	315
ACN30Q	Automation SELOGIC Counter 30 asserted	311
ACN30R	Automation SELOGIC Counter 30 reset	315
ACN31Q	Automation SELOGIC Counter 31 asserted	311
ACN31R	Automation SELOGIC Counter 31 reset	315
ACN32Q	Automation SELOGIC Counter 32 asserted	311
ACN32R	Automation SELOGIC Counter 32 reset	315
ACT01Q	Automation SELOGIC Conditioning Timer 01 asserted	552
ACT02Q	Automation SELOGIC Conditioning Timer 02 asserted	552
ACT03Q	Automation SELOGIC Conditioning Timer 03 asserted	552
ACT04Q	Automation SELOGIC Conditioning Timer 04 asserted	552
ACT05Q	Automation SELOGIC Conditioning Timer 05 asserted	552
ACT06Q	Automation SELOGIC Conditioning Timer 06 asserted	552
ACT07Q	Automation SELOGIC Conditioning Timer 07 asserted	552
ACT08Q	Automation SELOGIC Conditioning Timer 08 asserted	552
ACT09Q	Automation SELOGIC Conditioning Timer 09 asserted	553
ACT10Q	Automation SELOGIC Conditioning Timer 10 asserted	553
ACT11Q	Automation SELOGIC Conditioning Timer 11 asserted	553
ACT12Q	Automation SELOGIC Conditioning Timer 12 asserted	553
ACT13Q	Automation SELOGIC Conditioning Timer 13 asserted	553
ACT14Q	Automation SELOGIC Conditioning Timer 14 asserted	553
ACT15Q	Automation SELOGIC Conditioning Timer 15 asserted	553

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 32 of 90)

Name	Bit Description	Row
ACT16Q	Automation SELOGIC Conditioning Timer 16 asserted	553
ACT17Q	Automation SELOGIC Conditioning Timer 17 asserted	554
ACT18Q	Automation SELOGIC Conditioning Timer 18 asserted	554
ACT19Q	Automation SELOGIC Conditioning Timer 19 asserted	554
ACT20Q	Automation SELOGIC Conditioning Timer 20 asserted	554
ACT21Q	Automation SELOGIC Conditioning Timer 21 asserted	554
ACT22Q	Automation SELOGIC Conditioning Timer 22 asserted	554
ACT23Q	Automation SELOGIC Conditioning Timer 23 asserted	554
ACT24Q	Automation SELOGIC Conditioning Timer 24 asserted	554
ACT25Q	Automation SELOGIC Conditioning Timer 25 asserted	555
ACT26Q	Automation SELOGIC Conditioning Timer 26 asserted	555
ACT27Q	Automation SELOGIC Conditioning Timer 27 asserted	555
ACT28Q	Automation SELOGIC Conditioning Timer 28 asserted	555
ACT29Q	Automation SELOGIC Conditioning Timer 29 asserted	555
ACT30Q	Automation SELOGIC Conditioning Timer 30 asserted	555
ACT31Q	Automation SELOGIC Conditioning Timer 31 asserted	555
ACT32Q	Automation SELOGIC Conditioning Timer 32 asserted	555
AFRTEXA	Automation SELOGIC control equation first execution after automation settings change	316
AFRTEXP	Automation SELOGIC control equation first execution after protection settings change	316
ALT01	Automation SELOGIC Latch 01 asserted	296
ALT02	Automation SELOGIC Latch 02 asserted	296
ALT03	Automation SELOGIC Latch 03 asserted	296
ALT04	Automation SELOGIC Latch 04 asserted	296
ALT05	Automation SELOGIC Latch 05 asserted	296
ALT06	Automation SELOGIC Latch 06 asserted	296
ALT07	Automation SELOGIC Latch 07 asserted	296
ALT08	Automation SELOGIC Latch 08 asserted	296
ALT09	Automation SELOGIC Latch 09 asserted	297
ALT10	Automation SELOGIC Latch 10 asserted	297
ALT11	Automation SELOGIC Latch 11 asserted	297
ALT12	Automation SELOGIC Latch 12 asserted	297
ALT13	Automation SELOGIC Latch 13 asserted	297
ALT14	Automation SELOGIC Latch 14 asserted	297
ALT15	Automation SELOGIC Latch 15 asserted	297
ALT16	Automation SELOGIC Latch 16 asserted	297
ALT17	Automation SELOGIC Latch 17 asserted	298
ALT18	Automation SELOGIC Latch 18 asserted	298
ALT19	Automation SELOGIC Latch 19 asserted	298
ALT20	Automation SELOGIC Latch 20 asserted	298
ALT21	Automation SELOGIC Latch 21 asserted	298
ALT22	Automation SELOGIC Latch 22 asserted	298

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 33 of 90)

Name	Bit Description	Row
ALT23	Automation SELOGIC Latch 23 asserted	298
ALT24	Automation SELOGIC Latch 24 asserted	298
ALT25	Automation SELOGIC Latch 25 asserted	299
ALT26	Automation SELOGIC Latch 26 asserted	299
ALT27	Automation SELOGIC Latch 27 asserted	299
ALT28	Automation SELOGIC Latch 28 asserted	299
ALT29	Automation SELOGIC Latch 29 asserted	299
ALT30	Automation SELOGIC Latch 30 asserted	299
ALT31	Automation SELOGIC Latch 31 asserted	299
ALT32	Automation SELOGIC Latch 32 asserted	299
AMB_F	Ambient temperature fault condition	447
ANOKA	Analog transfer on Mirrored Bit Channel A	352
ANOKB	Analog transfer on Mirrored Bit Channel B	353
AO201CH	AO201 is clamped to AO201H setting value	528
AO201CL	AO201 is clamped to AO201L setting value	528
AO201FL	AO201 loop is faulted	528
AO202CH	AO202 is clamped to AO202H setting value	528
AO202CL	AO202 is clamped to AO202L setting value	528
AO202FL	AO202 loop is faulted	528
AST01Q	Automation SELOGIC Sequencing Timer 01 asserted	300
AST01R	Automation SELOGIC Sequencing Timer 01 reset	304
AST02Q	Automation SELOGIC Sequencing Timer 02 asserted	300
AST02R	Automation SELOGIC Sequencing Timer 02 reset	304
AST03Q	Automation SELOGIC Sequencing Timer 03 asserted	300
AST03R	Automation SELOGIC Sequencing Timer 03 reset	304
AST04Q	Automation SELOGIC Sequencing Timer 04 asserted	300
AST04R	Automation SELOGIC Sequencing Timer 04 reset	304
AST05Q	Automation SELOGIC Sequencing Timer 05 asserted	300
AST05R	Automation SELOGIC Sequencing Timer 05 reset	304
AST06Q	Automation SELOGIC Sequencing Timer 06 asserted	300
AST06R	Automation SELOGIC Sequencing Timer 06 reset	304
AST07Q	Automation SELOGIC Sequencing Timer 07 asserted	300
AST07R	Automation SELOGIC Sequencing Timer 07 reset	304
AST08Q	Automation SELOGIC Sequencing Timer 08 asserted	300
AST08R	Automation SELOGIC Sequencing Timer 08 reset	304
AST09Q	Automation SELOGIC Sequencing Timer 09 asserted	301
AST09R	Automation SELOGIC Sequencing Timer 09 reset	305
AST10Q	Automation SELOGIC Sequencing Timer 10 asserted	301
AST10R	Automation SELOGIC Sequencing Timer 10 reset	305
AST11Q	Automation SELOGIC Sequencing Timer 11 asserted	301
AST11R	Automation SELOGIC Sequencing Timer 11 reset	305

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 34 of 90)

Name	Bit Description	Row
AST12Q	Automation SELOGIC Sequencing Timer 12 asserted	301
AST12R	Automation SELOGIC Sequencing Timer 12 reset	305
AST13Q	Automation SELOGIC Sequencing Timer 13 asserted	301
AST13R	Automation SELOGIC Sequencing Timer 13 reset	305
AST14Q	Automation SELOGIC Sequencing Timer 14 asserted	301
AST14R	Automation SELOGIC Sequencing Timer 14 reset	305
AST15Q	Automation SELOGIC Sequencing Timer 15 asserted	301
AST15R	Automation SELOGIC Sequencing Timer 15 reset	305
AST16Q	Automation SELOGIC Sequencing Timer 16 asserted	301
AST16R	Automation SELOGIC Sequencing Timer 16 reset	305
AST17Q	Automation SELOGIC Sequencing Timer 17 asserted	302
AST17R	Automation SELOGIC Sequencing Timer 17 reset	306
AST18Q	Automation SELOGIC Sequencing Timer 18 asserted	302
AST18R	Automation SELOGIC Sequencing Timer 18 reset	306
AST19Q	Automation SELOGIC Sequencing Timer 19 asserted	302
AST19R	Automation SELOGIC Sequencing Timer 19 reset	306
AST20Q	Automation SELOGIC Sequencing Timer 20 asserted	302
AST20R	Automation SELOGIC Sequencing Timer 20 reset	306
AST21Q	Automation SELOGIC Sequencing Timer 21 asserted	302
AST21R	Automation SELOGIC Sequencing Timer 21 reset	306
AST22Q	Automation SELOGIC Sequencing Timer 22 asserted	302
AST22R	Automation SELOGIC Sequencing Timer 22 reset	306
AST23Q	Automation SELOGIC Sequencing Timer 23 asserted	302
AST23R	Automation SELOGIC Sequencing Timer 23 reset	306
AST24Q	Automation SELOGIC Sequencing Timer 24 asserted	302
AST24R	Automation SELOGIC Sequencing Timer 24 reset	306
AST25Q	Automation SELOGIC Sequencing Timer 25 asserted	303
AST25R	Automation SELOGIC Sequencing Timer 25 reset	307
AST26Q	Automation SELOGIC Sequencing Timer 26 asserted	303
AST26R	Automation SELOGIC Sequencing Timer 26 reset	307
AST27Q	Automation SELOGIC Sequencing Timer 27 asserted	303
AST27R	Automation SELOGIC Sequencing Timer 27 reset	307
AST28Q	Automation SELOGIC Sequencing Timer 28 asserted	303
AST28R	Automation SELOGIC Sequencing Timer 28 reset	307
AST29Q	Automation SELOGIC Sequencing Timer 29 asserted	303
AST29R	Automation SELOGIC Sequencing Timer 29 reset	307
AST30Q	Automation SELOGIC Sequencing Timer 30 asserted	303
AST30R	Automation SELOGIC Sequencing Timer 30 reset	307
AST31Q	Automation SELOGIC Sequencing Timer 31 asserted	303
AST31R	Automation SELOGIC Sequencing Timer 31 reset	307
AST32Q	Automation SELOGIC Sequencing Timer 32 asserted	303

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 35 of 90)

Name	Bit Description	Row
AST32R	Automation SELOGIC Sequencing Timer 32 reset	307
ASV001	Automation SELOGIC Variable 001 asserted	264
ASV002	Automation SELOGIC Variable 002 asserted	264
ASV003	Automation SELOGIC Variable 003 asserted	264
ASV004	Automation SELOGIC Variable 004 asserted	264
ASV005	Automation SELOGIC Variable 005 asserted	264
ASV006	Automation SELOGIC Variable 006 asserted	264
ASV007	Automation SELOGIC Variable 007 asserted	264
ASV008	Automation SELOGIC Variable 008 asserted	264
ASV009	Automation SELOGIC Variable 009 asserted	265
ASV010	Automation SELOGIC Variable 010 asserted	265
ASV011	Automation SELOGIC Variable 011 asserted	265
ASV012	Automation SELOGIC Variable 012 asserted	265
ASV013	Automation SELOGIC Variable 013 asserted	265
ASV014	Automation SELOGIC Variable 014 asserted	265
ASV015	Automation SELOGIC Variable 015 asserted	265
ASV016	Automation SELOGIC Variable 016 asserted	265
ASV017	Automation SELOGIC Variable 017 asserted	266
ASV018	Automation SELOGIC Variable 018 asserted	266
ASV019	Automation SELOGIC Variable 019 asserted	266
ASV020	Automation SELOGIC Variable 020 asserted	266
ASV021	Automation SELOGIC Variable 021 asserted	266
ASV022	Automation SELOGIC Variable 022 asserted	266
ASV023	Automation SELOGIC Variable 023 asserted	266
ASV024	Automation SELOGIC Variable 024 asserted	266
ASV025	Automation SELOGIC Variable 025 asserted	267
ASV026	Automation SELOGIC Variable 026 asserted	267
ASV027	Automation SELOGIC Variable 027 asserted	267
ASV028	Automation SELOGIC Variable 028 asserted	267
ASV029	Automation SELOGIC Variable 029 asserted	267
ASV030	Automation SELOGIC Variable 030 asserted	267
ASV031	Automation SELOGIC Variable 031 asserted	267
ASV032	Automation SELOGIC Variable 032 asserted	267
ASV033	Automation SELOGIC Variable 033 asserted	268
ASV034	Automation SELOGIC Variable 034 asserted	268
ASV035	Automation SELOGIC Variable 035 asserted	268
ASV036	Automation SELOGIC Variable 036 asserted	268
ASV037	Automation SELOGIC Variable 037 asserted	268
ASV038	Automation SELOGIC Variable 038 asserted	268
ASV039	Automation SELOGIC Variable 039 asserted	268
ASV040	Automation SELOGIC Variable 040 asserted	268

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Name	Bit Description	Row
ASV041	Automation SELOGIC Variable 041 asserted	269
ASV042	Automation SELOGIC Variable 042 asserted	269
ASV043	Automation SELOGIC Variable 043 asserted	269
ASV044	Automation SELOGIC Variable 044 asserted	269
ASV045	Automation SELOGIC Variable 045 asserted	269
ASV046	Automation SELOGIC Variable 046 asserted	269
ASV047	Automation SELOGIC Variable 047 asserted	269
ASV048	Automation SELOGIC Variable 048 asserted	269
ASV049	Automation SELOGIC Variable 049 asserted	270
ASV050	Automation SELOGIC Variable 050 asserted	270
ASV051	Automation SELOGIC Variable 051 asserted	270
ASV052	Automation SELOGIC Variable 052 asserted	270
ASV053	Automation SELOGIC Variable 053 asserted	270
ASV054	Automation SELOGIC Variable 054 asserted	270
ASV055	Automation SELOGIC Variable 055 asserted	270
ASV056	Automation SELOGIC Variable 056 asserted	270
ASV057	Automation SELOGIC Variable 057 asserted	271
ASV058	Automation SELOGIC Variable 058 asserted	271
ASV059	Automation SELOGIC Variable 059 asserted	271
ASV060	Automation SELOGIC Variable 060 asserted	271
ASV061	Automation SELOGIC Variable 061 asserted	271
ASV062	Automation SELOGIC Variable 062 asserted	271
ASV063	Automation SELOGIC Variable 063 asserted	271
ASV064	Automation SELOGIC Variable 064 asserted	271
ASV065	Automation SELOGIC Variable 065 asserted	272
ASV066	Automation SELOGIC Variable 066 asserted	272
ASV067	Automation SELOGIC Variable 067 asserted	272
ASV068	Automation SELOGIC Variable 068 asserted	272
ASV069	Automation SELOGIC Variable 069 asserted	272
ASV070	Automation SELOGIC Variable 070 asserted	272
ASV071	Automation SELOGIC Variable 071 asserted	272
ASV072	Automation SELOGIC Variable 072 asserted	272
ASV073	Automation SELOGIC Variable 073 asserted	273
ASV074	Automation SELOGIC Variable 074 asserted	273
ASV075	Automation SELOGIC Variable 075 asserted	273
ASV076	Automation SELOGIC Variable 076 asserted	273
ASV077	Automation SELOGIC Variable 077 asserted	273
ASV078	Automation SELOGIC Variable 078 asserted	273
ASV079	Automation SELOGIC Variable 079 asserted	273
ASV080	Automation SELOGIC Variable 080 asserted	273
ASV081	Automation SELOGIC Variable 081 asserted	274

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Name	Bit Description	Row
ASV082	Automation SELOGIC Variable 082 asserted	274
ASV083	Automation SELOGIC Variable 083 asserted	274
ASV084	Automation SELOGIC Variable 084 asserted	274
ASV085	Automation SELOGIC Variable 085 asserted	274
ASV086	Automation SELOGIC Variable 086 asserted	274
ASV087	Automation SELOGIC Variable 087 asserted	274
ASV088	Automation SELOGIC Variable 088 asserted	274
ASV089	Automation SELOGIC Variable 089 asserted	275
ASV090	Automation SELOGIC Variable 090 asserted	275
ASV091	Automation SELOGIC Variable 091 asserted	275
ASV092	Automation SELOGIC Variable 092 asserted	275
ASV093	Automation SELOGIC Variable 093 asserted	275
ASV094	Automation SELOGIC Variable 094 asserted	275
ASV095	Automation SELOGIC Variable 095 asserted	275
ASV096	Automation SELOGIC Variable 096 asserted	275
ASV097	Automation SELOGIC Variable 097 asserted	276
ASV098	Automation SELOGIC Variable 098 asserted	276
ASV099	Automation SELOGIC Variable 099 asserted	276
ASV100	Automation SELOGIC Variable 100 asserted	276
ASV101	Automation SELOGIC Variable 101 asserted	276
ASV102	Automation SELOGIC Variable 102 asserted	276
ASV103	Automation SELOGIC Variable 103 asserted	276
ASV104	Automation SELOGIC Variable 104 asserted	276
ASV105	Automation SELOGIC Variable 105 asserted	277
ASV106	Automation SELOGIC Variable 106 asserted	277
ASV107	Automation SELOGIC Variable 107 asserted	277
ASV108	Automation SELOGIC Variable 108 asserted	277
ASV109	Automation SELOGIC Variable 109 asserted	277
ASV110	Automation SELOGIC Variable 110 asserted	277
ASV111	Automation SELOGIC Variable 111 asserted	277
ASV112	Automation SELOGIC Variable 112 asserted	277
ASV113	Automation SELOGIC Variable 113 asserted	278
ASV114	Automation SELOGIC Variable 114 asserted	278
ASV115	Automation SELOGIC Variable 115 asserted	278
ASV116	Automation SELOGIC Variable 116 asserted	278
ASV117	Automation SELOGIC Variable 117 asserted	278
ASV118	Automation SELOGIC Variable 118 asserted	278
ASV119	Automation SELOGIC Variable 119 asserted	278
ASV120	Automation SELOGIC Variable 120 asserted	278
ASV121	Automation SELOGIC Variable 121 asserted	279
ASV122	Automation SELOGIC Variable 122 asserted	279

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Name	Bit Description	Row
ASV123	Automation SELOGIC Variable 123 asserted	279
ASV124	Automation SELOGIC Variable 124 asserted	279
ASV125	Automation SELOGIC Variable 125 asserted	279
ASV126	Automation SELOGIC Variable 126 asserted	279
ASV127	Automation SELOGIC Variable 127 asserted	279
ASV128	Automation SELOGIC Variable 128 asserted	279
ASV129	Automation SELOGIC Variable 129 asserted	280
ASV130	Automation SELOGIC Variable 130 asserted	280
ASV131	Automation SELOGIC Variable 131 asserted	280
ASV132	Automation SELOGIC Variable 132 asserted	280
ASV133	Automation SELOGIC Variable 133 asserted	280
ASV134	Automation SELOGIC Variable 134 asserted	280
ASV135	Automation SELOGIC Variable 135 asserted	280
ASV136	Automation SELOGIC Variable 136 asserted	280
ASV137	Automation SELOGIC Variable 137 asserted	281
ASV138	Automation SELOGIC Variable 138 asserted	281
ASV139	Automation SELOGIC Variable 139 asserted	281
ASV140	Automation SELOGIC Variable 140 asserted	281
ASV141	Automation SELOGIC Variable 141 asserted	281
ASV142	Automation SELOGIC Variable 142 asserted	281
ASV143	Automation SELOGIC Variable 143 asserted	281
ASV144	Automation SELOGIC Variable 144 asserted	281
ASV145	Automation SELOGIC Variable 145 asserted	282
ASV146	Automation SELOGIC Variable 146 asserted	282
ASV147	Automation SELOGIC Variable 147 asserted	282
ASV148	Automation SELOGIC Variable 148 asserted	282
ASV149	Automation SELOGIC Variable 149 asserted	282
ASV150	Automation SELOGIC Variable 150 asserted	282
ASV151	Automation SELOGIC Variable 151 asserted	282
ASV152	Automation SELOGIC Variable 152 asserted	282
ASV153	Automation SELOGIC Variable 153 asserted	283
ASV154	Automation SELOGIC Variable 154 asserted	283
ASV155	Automation SELOGIC Variable 155 asserted	283
ASV156	Automation SELOGIC Variable 156 asserted	283
ASV157	Automation SELOGIC Variable 157 asserted	283
ASV158	Automation SELOGIC Variable 158 asserted	283
ASV159	Automation SELOGIC Variable 159 asserted	283
ASV160	Automation SELOGIC Variable 160 asserted	283
ASV161	Automation SELOGIC Variable 161 asserted	284
ASV162	Automation SELOGIC Variable 162 asserted	284
ASV163	Automation SELOGIC Variable 163 asserted	284

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Name	Bit Description	Row
ASV164	Automation SELOGIC Variable 164 asserted	284
ASV165	Automation SELOGIC Variable 165 asserted	284
ASV166	Automation SELOGIC Variable 166 asserted	284
ASV167	Automation SELOGIC Variable 167 asserted	284
ASV168	Automation SELOGIC Variable 168 asserted	284
ASV169	Automation SELOGIC Variable 169 asserted	285
ASV170	Automation SELOGIC Variable 170 asserted	285
ASV171	Automation SELOGIC Variable 171 asserted	285
ASV172	Automation SELOGIC Variable 172 asserted	285
ASV173	Automation SELOGIC Variable 173 asserted	285
ASV174	Automation SELOGIC Variable 174 asserted	285
ASV175	Automation SELOGIC Variable 175 asserted	285
ASV176	Automation SELOGIC Variable 176 asserted	285
ASV177	Automation SELOGIC Variable 177 asserted	286
ASV178	Automation SELOGIC Variable 178 asserted	286
ASV179	Automation SELOGIC Variable 179 asserted	286
ASV180	Automation SELOGIC Variable 180 asserted	286
ASV181	Automation SELOGIC Variable 181 asserted	286
ASV182	Automation SELOGIC Variable 182 asserted	286
ASV183	Automation SELOGIC Variable 183 asserted	286
ASV184	Automation SELOGIC Variable 184 asserted	286
ASV185	Automation SELOGIC Variable 185 asserted	287
ASV186	Automation SELOGIC Variable 186 asserted	287
ASV187	Automation SELOGIC Variable 187 asserted	287
ASV188	Automation SELOGIC Variable 188 asserted	287
ASV189	Automation SELOGIC Variable 189 asserted	287
ASV190	Automation SELOGIC Variable 190 asserted	287
ASV191	Automation SELOGIC Variable 191 asserted	287
ASV192	Automation SELOGIC Variable 192 asserted	287
ASV193	Automation SELOGIC Variable 193 asserted	288
ASV194	Automation SELOGIC Variable 194 asserted	288
ASV195	Automation SELOGIC Variable 195 asserted	288
ASV196	Automation SELOGIC Variable 196 asserted	288
ASV197	Automation SELOGIC Variable 197 asserted	288
ASV198	Automation SELOGIC Variable 198 asserted	288
ASV199	Automation SELOGIC Variable 199 asserted	288
ASV200	Automation SELOGIC Variable 200 asserted	288
ASV201	Automation SELOGIC Variable 201 asserted	289
ASV202	Automation SELOGIC Variable 202 asserted	289
ASV203	Automation SELOGIC Variable 203 asserted	289
ASV204	Automation SELOGIC Variable 204 asserted	289

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Name	Bit Description	Row
ASV205	Automation SELOGIC Variable 205 asserted	289
ASV206	Automation SELOGIC Variable 206 asserted	289
ASV207	Automation SELOGIC Variable 207 asserted	289
ASV208	Automation SELOGIC Variable 208 asserted	289
ASV209	Automation SELOGIC Variable 209 asserted	290
ASV210	Automation SELOGIC Variable 210 asserted	290
ASV211	Automation SELOGIC Variable 211 asserted	290
ASV212	Automation SELOGIC Variable 212 asserted	290
ASV213	Automation SELOGIC Variable 213 asserted	290
ASV214	Automation SELOGIC Variable 214 asserted	290
ASV215	Automation SELOGIC Variable 215 asserted	290
ASV216	Automation SELOGIC Variable 216 asserted	290
ASV217	Automation SELOGIC Variable 217 asserted	291
ASV218	Automation SELOGIC Variable 218 asserted	291
ASV219	Automation SELOGIC Variable 219 asserted	291
ASV220	Automation SELOGIC Variable 220 asserted	291
ASV221	Automation SELOGIC Variable 221 asserted	291
ASV222	Automation SELOGIC Variable 222 asserted	291
ASV223	Automation SELOGIC Variable 223 asserted	291
ASV224	Automation SELOGIC Variable 224 asserted	291
ASV225	Automation SELOGIC Variable 225 asserted	292
ASV226	Automation SELOGIC Variable 226 asserted	292
ASV227	Automation SELOGIC Variable 227 asserted	292
ASV228	Automation SELOGIC Variable 228 asserted	292
ASV229	Automation SELOGIC Variable 229 asserted	292
ASV230	Automation SELOGIC Variable 230 asserted	292
ASV231	Automation SELOGIC Variable 231 asserted	292
ASV232	Automation SELOGIC Variable 232 asserted	292
ASV233	Automation SELOGIC Variable 233 asserted	293
ASV234	Automation SELOGIC Variable 234 asserted	293
ASV235	Automation SELOGIC Variable 235 asserted	293
ASV236	Automation SELOGIC Variable 236 asserted	293
ASV237	Automation SELOGIC Variable 237 asserted	293
ASV238	Automation SELOGIC Variable 238 asserted	293
ASV239	Automation SELOGIC Variable 239 asserted	293
ASV240	Automation SELOGIC Variable 240 asserted	293
ASV241	Automation SELOGIC Variable 241 asserted	294
ASV242	Automation SELOGIC Variable 242 asserted	294
ASV243	Automation SELOGIC Variable 243 asserted	294
ASV244	Automation SELOGIC Variable 244 asserted	294
ASV245	Automation SELOGIC Variable 245 asserted	294

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Name	Bit Description	Row
ASV246	Automation SELOGIC Variable 246 asserted	294
ASV247	Automation SELOGIC Variable 247 asserted	294
ASV248	Automation SELOGIC Variable 248 asserted	294
ASV249	Automation SELOGIC Variable 249 asserted	295
ASV250	Automation SELOGIC Variable 250 asserted	295
ASV251	Automation SELOGIC Variable 251 asserted	295
ASV252	Automation SELOGIC Variable 252 asserted	295
ASV253	Automation SELOGIC Variable 253 asserted	295
ASV254	Automation SELOGIC Variable 254 asserted	295
ASV255	Automation SELOGIC Variable 255 asserted	295
ASV256	Automation SELOGIC Variable 256 asserted	295
ATBFIS	Alternative breaker failure initiated, Terminal S	122
ATBFIT	Alternative breaker failure initiated, Terminal T	124
ATBFIU	Alternative breaker failure initiated, Terminal U	126
ATBFIY	Alternative breaker failure initiated, Terminal Y	128
ATBFTS	Alternative breaker failure timer timed out, Terminal S	122
ATBFTT	Alternative breaker failure timer timed out, Terminal T	124
ATBFTU	Alternative breaker failure timer timed out, Terminal U	126
ATBFTY	Alternative breaker failure timer timed out, Terminal Y	128
AUNRLBL	Automation SELOGIC control equation unresolved label	316
BADPASS	Invalid password attempt alarm	317
BFIS	Circuit Breaker S breaker failure initiate SELOGIC control equation	122
BFISPTS	Breaker failure seal-in timer timed out, Terminal S	123
BFISPTT	Breaker failure seal-in timer timed out, Terminal T	125
BFISPTU	Breaker failure seal-in timer timed out, Terminal U	127
BFISPTY	Breaker failure seal-in timer timed out, Terminal Y	129
BFIT	Circuit Breaker T breaker failure initiate SELOGIC control equation	124
BFITS	Breaker failure timer timed out, Terminal S	122
BFITT	Breaker failure timer timed out, Terminal T	124
BFITU	Breaker failure timer timed out, Terminal U	126
BFITY	Breaker failure timer timed out, Terminal Y	128
BFIU	Circuit Breaker U breaker failure initiate SELOGIC control equation	126
BFIY	Circuit Breaker Y breaker failure initiate SELOGIC control equation	128
BKENCS	Circuit Breaker S close control operation enabled	576
BKENCT	Circuit Breaker T close control operation enabled	576
BKENCU	Circuit Breaker U close control operation enabled	576
BKENCY	Circuit Breaker Y close control operation enabled	576
BKENOS	Circuit Breaker S open control operation enabled	576
BKENOT	Circuit Breaker T open control operation enabled	576
BKENOU	Circuit Breaker U open control operation enabled	576
BKENOY	Circuit Breaker Y open control operation enabled	576

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Name	Bit Description	Row
BLKFOS	Breaker S flashover logic blocked	121
BLKFOT	Breaker T flashover logic blocked	121
BLKFOU	Breaker U flashover logic blocked	121
BLKFOY	Breaker Y flashover logic blocked	121
BLKLPTS	Block low-priority source from updating relay time	322
BNC_BNP	Bad jitter on BNC port and the IRIG-B signal is lost afterwards	440
BNC_OK	IRIG-B signal from BNC port is available and has sufficient quality	440
BNC_RST	Disqualify BNC IRIG-B time source	440
BNC_SET	Qualify BNC IRIG-B time source	440
BNC_TIM	A valid IRIG-B time source is detected on BNC port	441
BNCSYNC	Synchronized to a high-quality BNC IRIG source	442
BRKENAB	Breaker control enable jumper is installed	318
BSBCWAL	Breaker contact wear alarm, Breaker S	176
BSBITAL	Inactivity time alarm, Breaker S	176
BSESOAL	Slow electrical operate alarm, Breaker S	176
BSKAIAL	Interrupted rms current alarm, Breaker S	176
BSMRTAL	Motor run time alarm, Breaker S	176
BSMSOAL	Mechanical slow operation alarm, Breaker S	176
BSYNBKS	Breaker S synchronism check blocked	433
BSYNBKT	Breaker T synchronism check blocked	433
BSYNBKU	Breaker U synchronism check blocked	433
BSYNBKY	Breaker Y synchronism check blocked	433
BTBCWAL	Breaker contact wear alarm, Breaker T	177
BTBITAL	Inactivity time alarm, Breaker T	177
BTESOAL	Slow electrical operation alarm, Breaker T	177
BTKAIAL	Interrupted rms current alarm, Breaker T	177
BTMRTAL	Motor run time alarm, Breaker T	177
BTMSOAL	Mechanical slow operation alarm, Breaker T	177
BUBCWAL	Breaker contact wear alarm, Breaker U	178
BUBITAL	Inactivity time alarm, Breaker U	178
BUESOAL	Slow electrical operation alarm, Breaker U	178
BUKAIAL	Interrupted rms current alarm, Breaker U	178
BUMRTAL	Motor run time alarm, Breaker U	178
BUMSOAL	Mechanical slow operation alarm, Breaker U	178
BYBCWAL	Breaker contact wear alarm, Breaker Y	179
BYBITAL	Inactivity time alarm, Breaker Y	179
BYESOAL	Slow electrical operation alarm, Breaker Y	179
BYKAIAL	Interrupted rms current alarm, Breaker Y	179
BYMRTAL	Motor run time alarm, Breaker Y	179
BYMSOAL	Mechanical slow operation alarm, Breaker Y	179
CBADA	Unavailability threshold exceeded for normal Mirrored Bit communication, Channel A	352

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Name	Bit Description	Row
CBADB	Unavailability threshold exceeded for normal Mirrored Bit communication, Channel B	353
CCS	Breaker close command, Terminal S	188
CCT	Breaker close command, Terminal T	188
CCU	Breaker close command, Terminal U	188
CCY	Breaker close command, Terminal Y	188
CFAS	Breaker S close fail angle alarm	436
CFAT	Breaker T close fail angle alarm	436
CFAU	Breaker U close fail angle alarm	436
CFAY	Breaker Y close fail angle alarm	436
CFS	Close logic timer timed out, Terminal S	210
CFT	Close logic timer timed out, Terminal T	210
CFU	Close logic timer timed out, Terminal U	210
CFY	Close logic timer timed out, Terminal Y	210
CHSG	Settings Group changed	208
CLS	Close SELOGIC, Terminal S	209
CLSS	Close Breaker S asserted	210
CLST	Close Breaker T asserted	210
CLSU	Close Breaker U asserted	210
CLSY	Close Breaker Y asserted	210
CLT	Close SELOGIC, Terminal T	209
CLU	Close SELOGIC, Terminal U	209
CLY	Close SELOGIC, Terminal Y	209
CON1	External fault detected, Element 1	64
CON2	External fault detected, Element 2	75
CONA1	External fault detected A-Phase, Element 1	70
CONA2	External fault detected A-Phase, Element 2	81
CONAAC1	AC external fault detected A-Phase, Element 1	70
CONAAC2	AC external fault detected A-Phase, Element 2	81
CONAC1	AC external fault detected, Element 1	71
CONAC2	AC external fault detected, Element 2	81
CONADC1	DC external fault detected A-Phase, Element 1	71
CONADC2	DC external fault detected A-Phase, Element 2	81
CONB1	External fault detected B-Phase, Element 1	70
CONB2	External fault detected B-Phase, Element 2	81
CONBAC1	AC external fault detected B-Phase, Element 1	70
CONBAC2	AC external fault detected B-Phase, Element 2	81
CONBDC1	DC external fault detected B-Phase, Element 1	71
CONBDC2	DC external fault detected B-Phase, Element 2	82
CONC1	External fault detected C-Phase, Element 1	70
CONC2	External fault detected C-Phase, Element 2	81
CONCAC1	AC external fault detected C-Phase, Element 1	71

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Name	Bit Description	Row
CONCAC2	AC external fault detected C-Phase, Element 2	81
CONCDC1	DC external fault detected C-Phase, Element 1	71
CONCDC2	DC external fault detected C-Phase, Element 2	82
CONDC1	DC external fault detected, Element 1	71
CONDC2	DC external fault detected, Element 2	82
CTUA1	CT unsaturated A-Phase, Element 1	72
CTUA2	CT unsaturated A-Phase, Element 2	83
CTUB1	CT unsaturated B-Phase, Element 1	72
CTUB2	CT unsaturated B-Phase, Element 2	83
CTUC1	CT unsaturated C-Phase, Element 1	72
CTUC2	CT unsaturated C-Phase, Element 2	83
DC1F	DC Channel 1 failed	184
DC1G	DC Channel 1 ground fault detected	184
DC1R	DC Channel 1 excess ripples detected	184
DC1W	DC Channel 1 warning	184
DCA1	DC component in Element 1 A-Phase	70
DCA2	DC component in Element 2 A-Phase	80
DCB1	DC component in Element 1 B-Phase	70
DCB2	DC component in Element 2 B-Phase	80
DCC1	DC component in Element 1 C-Phase	70
DCC2	DC component in Element 2 C-Phase	80
DIRBLKS	Terminal S directional element block SELOGIC control equation	532
DIRBLKT	Terminal T directional element block SELOGIC control equation	532
DIRBLKU	Terminal U directional element block SELOGIC control equation	532
DIRBLKY	Terminal Y directional element block SELOGIC control equation	532
DMP01	Demand metering Element 01 asserted	185
DMP02	Demand metering Element 02 asserted	185
DMP03	Demand metering Element 03 asserted	185
DMP04	Demand metering Element 04 asserted	185
DMP05	Demand metering Element 05 asserted	186
DMP06	Demand metering Element 06 asserted	186
DMP07	Demand metering Element 07 asserted	186
DMP08	Demand metering Element 08 asserted	186
DMP09	Demand metering Element 09 asserted	187
DMP10	Demand metering Element 10 asserted	187
DOKA	Mirrored Bit Channel A in normal mode	352
DOKB	Mirrored Bit Channel B in normal mode	353
DRTRIG	Disturbance Recording Event Triggered	346
DST	Daylight-saving time	398
DSTP	IRIG-B daylight-saving time pending	398
DUMMY		399

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Name	Bit Description	Row
E2AC	Enable Levels 1–2 access (SELOGIC control equation)	318
EACC	Enable Level 1 access (SELOGIC control equation)	318
EBFITS	Externally initiated breaker failure timer timed out, Terminal S	122
EBFITT	Externally initiated breaker failure timer timed out, Terminal T	124
EBFITU	Externally initiated breaker failure timer timed out, Terminal U	126
EBFITY	Externally initiated breaker failure timer timed out, Terminal Y	128
EBSMON	Breaker monitoring Terminal S enabled	176
EBTMON	Breaker monitoring Terminal T enabled	177
EBUMON	Breaker monitoring Terminal U enabled	178
EBYMON	Breaker monitoring Terminal Y enabled	179
EDM01	Demand metering Element 01 enabled	185
EDM02	Demand metering Element 02 enabled	185
EDM03	Demand metering Element 03 enabled	185
EDM04	Demand metering Element 04 enabled	185
EDM05	Demand metering Element 05 enabled	186
EDM06	Demand metering Element 06 enabled	186
EDM07	Demand metering Element 07 enabled	186
EDM08	Demand metering Element 08 enabled	186
EDM09	Demand metering Element 09 enabled	187
EDM10	Demand metering Element 10 enabled	187
EN	Enable LED on relay front panel	0
ENINBFS	Neutral/residual breaker failure function enabled, Terminal S	123
ENINBFT	Neutral/residual breaker failure function enabled, Terminal T	125
ENINBFU	Neutral/residual breaker failure function enabled, Terminal U	127
ENINBFY	Neutral/residual breaker failure function enabled, Terminal Y	129
ER	Event report triggered	346
EVELOCK	Lock DNP events	403
EXBFS	External breaker failure input initiated, Terminal S	122
EXBFSPS	External breaker failure supervisor, Terminal S	130
EXBFSPT	External breaker failure supervisor, Terminal T	130
EXBFSPU	External breaker failure supervisor, Terminal U	130
EXBFSPY	External breaker failure supervisor, Terminal Y	130
EXBFT	External breaker failure input initiated, Terminal T	124
EXBFU	External breaker failure input initiated, Terminal U	126
EXBFY	External breaker failure input initiated, Terminal Y	128
FASTS	Polarizing voltage slipping faster than Breaker S synchronizing voltage	428
FASTT	Polarizing voltage slipping faster than Breaker T synchronizing voltage	428
FASTU	Polarizing voltage slipping faster than Breaker U synchronizing voltage	428
FASTY	Polarizing voltage slipping faster than Breaker Y synchronizing voltage	428
FAULT	Fault detected	346
FBFS	Circuit Breaker S failure	123

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Name	Bit Description	Row
FBFT	Circuit Breaker T failure	125
FBFU	Circuit Breaker U failure	127
FBFY	Circuit Breaker Y failure	129
FLDENRG	Generator field energized	45
FOBFS	Breaker S breaker flashover asserted	121
FOBFT	Breaker T breaker flashover asserted	121
FOBFU	Breaker U breaker flashover asserted	121
FOBFY	Breaker Y breaker flashover asserted	121
FOP1_01	PORT 1 Fast Operate transmit Bit 1	408
FOP1_02	PORT 1 Fast Operate transmit Bit 2	408
FOP1_03	PORT 1 Fast Operate transmit Bit 3	408
FOP1_04	PORT 1 Fast Operate transmit Bit 4	408
FOP1_05	PORT 1 Fast Operate transmit Bit 5	408
FOP1_06	PORT 1 Fast Operate transmit Bit 6	408
FOP1_07	PORT 1 Fast Operate transmit Bit 7	408
FOP1_08	PORT 1 Fast Operate transmit Bit 8	408
FOP1_09	PORT 1 Fast Operate transmit Bit 9	409
FOP1_10	PORT 1 Fast Operate transmit Bit 10	409
FOP1_11	PORT 1 Fast Operate transmit Bit 11	409
FOP1_12	PORT 1 Fast Operate transmit Bit 12	409
FOP1_13	PORT 1 Fast Operate transmit Bit 13	409
FOP1_14	PORT 1 Fast Operate transmit Bit 14	409
FOP1_15	PORT 1 Fast Operate transmit Bit 15	409
FOP1_16	PORT 1 Fast Operate transmit Bit 16	409
FOP1_17	PORT 1 Fast Operate transmit Bit 17	410
FOP1_18	PORT 1 Fast Operate transmit Bit 18	410
FOP1_19	PORT 1 Fast Operate transmit Bit 19	410
FOP1_20	PORT 1 Fast Operate transmit Bit 20	410
FOP1_21	PORT 1 Fast Operate transmit Bit 21	410
FOP1_22	PORT 1 Fast Operate transmit Bit 22	410
FOP1_23	PORT 1 Fast Operate transmit Bit 23	410
FOP1_24	PORT 1 Fast Operate transmit Bit 24	410
FOP1_25	PORT 1 Fast Operate transmit Bit 25	411
FOP1_26	PORT 1 Fast Operate transmit Bit 26	411
FOP1_27	PORT 1 Fast Operate transmit Bit 27	411
FOP1_28	PORT 1 Fast Operate transmit Bit 28	411
FOP1_29	PORT 1 Fast Operate transmit Bit 29	411
FOP1_30	PORT 1 Fast Operate transmit Bit 30	411
FOP1_31	PORT 1 Fast Operate transmit Bit 31	411
FOP1_32	PORT 1 Fast Operate transmit Bit 32	411
FOP2_01	PORT 2 Fast Operate transmit Bit 1	412

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 47 of 90)

Name	Bit Description	Row
FOP2_02	PORT 2 Fast Operate transmit Bit 2	412
FOP2_03	PORT 2 Fast Operate transmit Bit 3	412
FOP2_04	PORT 2 Fast Operate transmit Bit 4	412
FOP2_05	PORT 2 Fast Operate transmit Bit 5	412
FOP2_06	PORT 2 Fast Operate transmit Bit 6	412
FOP2_07	PORT 2 Fast Operate transmit Bit 7	412
FOP2_08	PORT 2 Fast Operate transmit Bit 8	412
FOP2_09	PORT 2 Fast Operate transmit Bit 9	413
FOP2_10	PORT 2 Fast Operate transmit Bit 10	413
FOP2_11	PORT 2 Fast Operate transmit Bit 11	413
FOP2_12	PORT 2 Fast Operate transmit Bit 12	413
FOP2_13	PORT 2 Fast Operate transmit Bit 13	413
FOP2_14	PORT 2 Fast Operate transmit Bit 14	413
FOP2_15	PORT 2 Fast Operate transmit Bit 15	413
FOP2_16	PORT 2 Fast Operate transmit Bit 16	413
FOP2_17	PORT 2 Fast Operate transmit Bit 17	414
FOP2_18	PORT 2 Fast Operate transmit Bit 18	414
FOP2_19	PORT 2 Fast Operate transmit Bit 19	414
FOP2_20	PORT 2 Fast Operate transmit Bit 20	414
FOP2_21	PORT 2 Fast Operate transmit Bit 21	414
FOP2_22	PORT 2 Fast Operate transmit Bit 22	414
FOP2_23	PORT 2 Fast Operate transmit Bit 23	414
FOP2_24	PORT 2 Fast Operate transmit Bit 24	414
FOP2_25	PORT 2 Fast Operate transmit Bit 25	415
FOP2_26	PORT 2 Fast Operate transmit Bit 26	415
FOP2_27	PORT 2 Fast Operate transmit Bit 27	415
FOP2_28	PORT 2 Fast Operate transmit Bit 28	415
FOP2_29	PORT 2 Fast Operate transmit Bit 29	415
FOP2_30	PORT 2 Fast Operate transmit Bit 30	415
FOP2_31	PORT 2 Fast Operate transmit Bit 31	415
FOP2_32	PORT 2 Fast Operate transmit Bit 32	415
FOP3_01	PORT 3 Fast Operate transmit Bit 1	416
FOP3_02	PORT 3 Fast Operate transmit Bit 2	416
FOP3_03	PORT 3 Fast Operate transmit Bit 3	416
FOP3_04	PORT 3 Fast Operate transmit Bit 4	416
FOP3_05	PORT 3 Fast Operate transmit Bit 5	416
FOP3_06	PORT 3 Fast Operate transmit Bit 6	416
FOP3_07	PORT 3 Fast Operate transmit Bit 7	416
FOP3_08	PORT 3 Fast Operate transmit Bit 8	416
FOP3_09	PORT 3 Fast Operate transmit Bit 9	417
FOP3_10	PORT 3 Fast Operate transmit Bit 10	417

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 48 of 90)

Name	Bit Description	Row
FOP3_11	PORT 3 Fast Operate transmit Bit 11	417
FOP3_12	PORT 3 Fast Operate transmit Bit 12	417
FOP3_13	PORT 3 Fast Operate transmit Bit 13	417
FOP3_14	PORT 3 Fast Operate transmit Bit 14	417
FOP3_15	PORT 3 Fast Operate transmit Bit 15	417
FOP3_16	PORT 3 Fast Operate transmit Bit 16	417
FOP3_17	PORT 3 Fast Operate transmit Bit 17	418
FOP3_18	PORT 3 Fast Operate transmit Bit 18	418
FOP3_19	PORT 3 Fast Operate transmit Bit 19	418
FOP3_20	PORT 3 Fast Operate transmit Bit 20	418
FOP3_21	PORT 3 Fast Operate transmit Bit 21	418
FOP3_22	PORT 3 Fast Operate transmit Bit 22	418
FOP3_23	PORT 3 Fast Operate transmit Bit 23	418
FOP3_24	PORT 3 Fast Operate transmit Bit 24	418
FOP3_25	PORT 3 Fast Operate transmit Bit 25	419
FOP3_26	PORT 3 Fast Operate transmit Bit 26	419
FOP3_27	PORT 3 Fast Operate transmit Bit 27	419
FOP3_28	PORT 3 Fast Operate transmit Bit 28	419
FOP3_29	PORT 3 Fast Operate transmit Bit 29	419
FOP3_30	PORT 3 Fast Operate transmit Bit 30	419
FOP3_31	PORT 3 Fast Operate transmit Bit 31	419
FOP3_32	PORT 3 Fast Operate transmit Bit 32	419
FOPF_01	Port Front Fast Operate transmit Bit 1	404
FOPF_02	Port Front Fast Operate transmit Bit 2	404
FOPF_03	Port Front Fast Operate transmit Bit 3	404
FOPF_04	Port Front Fast Operate transmit Bit 4	404
FOPF_05	Port Front Fast Operate transmit Bit 5	404
FOPF_06	Port Front Fast Operate transmit Bit 6	404
FOPF_07	Port Front Fast Operate transmit Bit 7	404
FOPF_08	Port Front Fast Operate transmit Bit 8	404
FOPF_09	Port Front Fast Operate transmit Bit 9	405
FOPF_10	Port Front Fast Operate transmit Bit 10	405
FOPF_11	Port Front Fast Operate transmit Bit 11	405
FOPF_12	Port Front Fast Operate transmit Bit 12	405
FOPF_13	Port Front Fast Operate transmit Bit 13	405
FOPF_14	Port Front Fast Operate transmit Bit 14	405
FOPF_15	Port Front Fast Operate transmit Bit 15	405
FOPF_16	Port Front Fast Operate transmit Bit 16	405
FOPF_17	Port Front Fast Operate transmit Bit 17	406
FOPF_18	Port Front Fast Operate transmit Bit 18	406
FOPF_19	Port Front Fast Operate transmit Bit 19	406

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 49 of 90)

Name	Bit Description	Row
FOPF_20	Port Front Fast Operate transmit Bit 20	406
FOPF_21	Port Front Fast Operate transmit Bit 21	406
FOPF_22	Port Front Fast Operate transmit Bit 22	406
FOPF_23	Port Front Fast Operate transmit Bit 23	406
FOPF_24	Port Front Fast Operate transmit Bit 24	406
FOPF_25	Port Front Fast Operate transmit Bit 25	407
FOPF_26	Port Front Fast Operate transmit Bit 26	407
FOPF_27	Port Front Fast Operate transmit Bit 27	407
FOPF_28	Port Front Fast Operate transmit Bit 28	407
FOPF_29	Port Front Fast Operate transmit Bit 29	407
FOPF_30	Port Front Fast Operate transmit Bit 30	407
FOPF_31	Port Front Fast Operate transmit Bit 31	407
FOPF_32	Port Front Fast Operate transmit Bit 32	407
FREQFZG	Generator frequency estimation frozen	5
FREQFZS	System frequency estimation frozen	5
FREQOKG	Generator frequency estimation OK	5
FREQOKS	System frequency estimation OK	5
FROKPM	Synchrophasor frequency measurement OK	389
FSERP1	Fast SER enabled for **PORT 1**	388
FSERP2	Fast SER enabled for **PORT 2**	388
FSERP3	Fast SER enabled for **PORT 3**	388
FSERP5	Fast SER enabled for network port	388
FSERPF	Fast SER enabled for front port	388
FTSSV1	Terminal V1 selected for system frequency tracking source	47
FTSSV2	Terminal V2 selected for system frequency tracking source	47
FTSSV3	Terminal V3 selected for system frequency tracking source	47
GENVHIS	Generator voltage is higher than Breaker S system voltage	434
GENVHIT	Generator voltage is higher than Breaker T system voltage	434
GENVHIU	Generator voltage is higher than Breaker U system voltage	434
GENVHIY	Generator voltage is higher than Breaker Y system voltage	434
GENVLOS	Generator voltage is lower than Breaker S system voltage	434
GENVLOT	Generator voltage is lower than Breaker T system voltage	434
GENVLOU	Generator voltage is lower than Breaker U system voltage	434
GENVLOY	Generator voltage is lower than Breaker Y system voltage	434
GFLTA1	Internal fault detected A-Phase, Element 1	73
GFLTA2	Internal fault detected A-Phase, Element 2	84
GFLTB1	Internal fault detected B-Phase, Element 1	73
GFLTB2	Internal fault detected B-Phase, Element 2	84
GFLTC1	Internal fault detected C-Phase, Element 1	73
GFLTC2	Internal fault detected C-Phase, Element 2	84
GRPSW	Pulsed alarm for group switches	317

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 50 of 90)

Name	Bit Description	Row
HALARM	Hardware alarm	317
HALARMA	Pulse stream for unacknowledged diagnostic warnings	317
HALARML	Latched alarm for diagnostic failures	317
HALARMP	Pulsed alarm for diagnostic warnings	317
HSRAOK	HSR Port 5A status	582
HSRBOK	HSR Port 5B status	582
HSRCOK	HSR Port 5C status	582
HSRDOK	HSR Port 5D status	582
IASBF	A-Phase current above threshold, Terminal S	123
IATBF	A-Phase current above threshold, Terminal T	125
IAUBF	A-Phase current above threshold, Terminal U	127
IAYBF	A-Phase current above threshold, Terminal Y	129
IBSBF	B-Phase current above threshold, Terminal S	123
IBTBF	B-Phase current above threshold, Terminal T	125
IBUBF	B-Phase current above threshold, Terminal U	127
IBYBF	B-Phase current above threshold, Terminal Y	129
ICSBF	C-Phase current above threshold, Terminal S	123
ICTBF	C-Phase current above threshold, Terminal T	125
ICUBF	C-Phase current above threshold, Terminal U	127
ICYBF	C-Phase current above threshold, Terminal Y	129
IFLT1	Internal fault detected, Element 1	72
IFLT2	Internal fault detected, Element 2	82
IFLTA1	Internal fault detected A-Phase, Element 1	71
IFLTA2	Internal fault detected A-Phase, Element 2	82
IFLTB1	Internal fault detected B-Phase, Element 1	71
IFLTB2	Internal fault detected B-Phase, Element 2	82
IFLTC1	Internal fault detected C-Phase, Element 1	72
IFLTC2	Internal fault detected C-Phase, Element 2	82
IN101	Input 101 asserted	212
IN102	Input 102 asserted	212
IN103	Input 103 asserted	212
IN104	Input 104 asserted	212
IN105	Input 105 asserted	212
IN106	Input 106 asserted	212
IN107	Input 107 asserted	212
IN201	Input 201 asserted	216
IN202	Input 202 asserted	216
IN203	Input 203 asserted	216
IN204	Input 204 asserted	216
IN205	Input 205 asserted	216
IN206	Input 206 asserted	216

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 51 of 90)

Name	Bit Description	Row
IN207	Input 207 asserted	216
IN208	Input 208 asserted	216
IN209	Input 209 asserted	217
IN210	Input 210 asserted	217
IN211	Input 211 asserted	217
IN212	Input 212 asserted	217
IN213	Input 213 asserted	217
IN214	Input 214 asserted	217
IN215	Input 215 asserted	217
IN216	Input 216 asserted	217
IN217	Input 217 asserted	218
IN218	Input 218 asserted	218
IN219	Input 219 asserted	218
IN220	Input 220 asserted	218
IN221	Input 221 asserted	218
IN222	Input 222 asserted	218
IN223	Input 223 asserted	218
IN224	Input 224 asserted	218
IN301	Input 301 asserted	220
IN302	Input 302 asserted	220
IN303	Input 303 asserted	220
IN304	Input 304 asserted	220
IN305	Input 305 asserted	220
IN306	Input 306 asserted	220
IN307	Input 307 asserted	220
IN308	Input 308 asserted	220
IN309	Input 309 asserted	221
IN310	Input 310 asserted	221
IN311	Input 311 asserted	221
IN312	Input 312 asserted	221
IN313	Input 313 asserted	221
IN314	Input 314 asserted	221
IN315	Input 315 asserted	221
IN316	Input 316 asserted	221
IN317	Input 317 asserted	222
IN318	Input 318 asserted	222
IN319	Input 319 asserted	222
IN320	Input 320 asserted	222
IN321	Input 321 asserted	222
IN322	Input 322 asserted	222
IN323	Input 323 asserted	222

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 52 of 90)

Name	Bit Description	Row
IN324	Input 324 asserted	222
IN401	Input 401 asserted	224
IN402	Input 402 asserted	224
IN403	Input 403 asserted	224
IN404	Input 404 asserted	224
IN405	Input 405 asserted	224
IN406	Input 406 asserted	224
IN407	Input 407 asserted	224
IN408	Input 408 asserted	224
IN409	Input 409 asserted	225
IN410	Input 410 asserted	225
IN411	Input 411 asserted	225
IN412	Input 412 asserted	225
IN413	Input 413 asserted	225
IN414	Input 414 asserted	225
IN415	Input 415 asserted	225
IN416	Input 416 asserted	225
IN417	Input 417 asserted	226
IN418	Input 418 asserted	226
IN419	Input 419 asserted	226
IN420	Input 420 asserted	226
IN421	Input 421 asserted	226
IN422	Input 422 asserted	226
IN423	Input 423 asserted	226
IN424	Input 424 asserted	226
IN501	Input 501 asserted	228
IN502	Input 502 asserted	228
IN503	Input 503 asserted	228
IN504	Input 504 asserted	228
IN505	Input 505 asserted	228
IN506	Input 506 asserted	228
IN507	Input 507 asserted	228
IN508	Input 508 asserted	228
IN509	Input 509 asserted	229
IN510	Input 510 asserted	229
IN511	Input 511 asserted	229
IN512	Input 512 asserted	229
IN513	Input 513 asserted	229
IN514	Input 514 asserted	229
IN515	Input 515 asserted	229
IN516	Input 516 asserted	229

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 53 of 90)

Name	Bit Description	Row
IN517	Input 517 asserted	230
IN518	Input 518 asserted	230
IN519	Input 519 asserted	230
IN520	Input 520 asserted	230
IN521	Input 521 asserted	230
IN522	Input 522 asserted	230
IN523	Input 523 asserted	230
IN524	Input 524 asserted	230
INADAS	Inadvertent energization element armed, Terminal S	53
INADAT	Inadvertent energization element armed, Terminal T	53
INADAU	Inadvertent energization element armed, Terminal U	53
INADAY	Inadvertent energization element armed, Terminal Y	53
INADS	Inadvertent energization element picked up, Terminal S	53
INADT	Inadvertent energization element picked up, Terminal T	53
INADTCS	Inadvertent energization delayed element torque control, Terminal S	54
INADTCT	Inadvertent energization delayed element torque control, Terminal T	54
INADTCU	Inadvertent energization delayed element torque control, Terminal U	54
INADTCY	Inadvertent energization delayed element torque control, Terminal Y	54
INADTS	Inadvertent energization delayed element picked up, Terminal S	54
INADTT	Inadvertent energization delayed element picked up, Terminal T	54
INADTU	Inadvertent energization delayed element picked up, Terminal U	54
INADTY	Inadvertent energization delayed element picked up, Terminal Y	54
INADU	Inadvertent energization Element picked up, Terminal U	53
INADY	Inadvertent energization Element picked up, Terminal Y	53
INR1	Inrush in Element 1	69
INR2	Inrush in Element 2	80
INRA1	Inrush in A-Phase, Element 1	69
INRA2	Inrush in A-Phase, Element 2	80
INRB1	Inrush in B-Phase, Element 1	69
INRB2	Inrush in B-Phase, Element 2	80
INRC1	Inrush in C-Phase, Element 1	69
INRC2	Inrush in C-Phase, Element 2	80
INSBF	Neutral current above threshold, Terminal S	123
INTBF	Neutral/residual current exceeds pickup threshold, Terminal T	125
INUBF	Neutral/residual current exceeds pickup threshold, Terminal U	127
INYBF	Neutral/residual current exceeds pickup threshold, Terminal Y	129
IO300OK	Communication status of Interface Board 300 when installed/commissioned	439
IO400OK	Communication status of Interface Board 400 when installed/commissioned	439
IO500OK	Communication status of Interface Board 500 when installed/commissioned	439
LB_DP01	Local Bit 01 status display enabled	199
LB_DP02	Local Bit 02 status display enabled	199

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 54 of 90)

Name	Bit Description	Row
LB_DP03	Local Bit 03 status display enabled	199
LB_DP04	Local Bit 04 status display enabled	199
LB_DP05	Local Bit 05 status display enabled	199
LB_DP06	Local Bit 06 status display enabled	199
LB_DP07	Local Bit 07 status display enabled	199
LB_DP08	Local Bit 08 status display enabled	199
LB_DP09	Local Bit 09 status display enabled	200
LB_DP10	Local Bit 10 status display enabled	200
LB_DP11	Local Bit 11 status display enabled	200
LB_DP12	Local Bit 12 status display enabled	200
LB_DP13	Local Bit 13 status display enabled	200
LB_DP14	Local Bit 14 status display enabled	200
LB_DP15	Local Bit 15 status display enabled	200
LB_DP16	Local Bit 16 status display enabled	200
LB_DP17	Local Bit 17 status display enabled	201
LB_DP18	Local Bit 18 status display enabled	201
LB_DP19	Local Bit 19 status display enabled	201
LB_DP20	Local Bit 20 status display enabled	201
LB_DP21	Local Bit 21 status display enabled	201
LB_DP22	Local Bit 22 status display enabled	201
LB_DP23	Local Bit 23 status display enabled	201
LB_DP24	Local Bit 24 status display enabled	201
LB_DP25	Local Bit 25 status display enabled	202
LB_DP26	Local Bit 26 status display enabled	202
LB_DP27	Local Bit 27 status display enabled	202
LB_DP28	Local Bit 28 status display enabled	202
LB_DP29	Local Bit 29 status display enabled	202
LB_DP30	Local Bit 30 status display enabled	202
LB_DP31	Local Bit 31 status display enabled	202
LB_DP32	Local Bit 32 status display enabled	202
LB_DP33	Local Bit 33 status display enabled	564
LB_DP34	Local Bit 34 status display enabled	564
LB_DP35	Local Bit 35 status display enabled	564
LB_DP36	Local Bit 36 status display enabled	564
LB_DP37	Local Bit 37 status display enabled	564
LB_DP38	Local Bit 38 status display enabled	564
LB_DP39	Local Bit 39 status display enabled	564
LB_DP40	Local Bit 40 status display enabled	564
LB_DP41	Local Bit 41 status display enabled	565
LB_DP42	Local Bit 42 status display enabled	565
LB_DP43	Local Bit 43 status display enabled	565

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Name	Bit Description	Row
LB_DP44	Local Bit 44 status display enabled	565
LB_DP45	Local Bit 45 status display enabled	565
LB_DP46	Local Bit 46 status display enabled	565
LB_DP47	Local Bit 47 status display enabled	565
LB_DP48	Local Bit 48 status display enabled	565
LB_DP49	Local Bit 49 status display enabled	566
LB_DP50	Local Bit 50 status display enabled	566
LB_DP51	Local Bit 51 status display enabled	566
LB_DP52	Local Bit 52 status display enabled	566
LB_DP53	Local Bit 53 status display enabled	566
LB_DP54	Local Bit 54 status display enabled	566
LB_DP55	Local Bit 55 status display enabled	566
LB_DP56	Local Bit 56 status display enabled	566
LB_DP57	Local Bit 57 status display enabled	567
LB_DP58	Local Bit 58 status display enabled	567
LB_DP259	Local Bit 59 status display enabled	567
LB_DP60	Local Bit 60 status display enabled	567
LB_DP61	Local Bit 61 status display enabled	567
LB_DP62	Local Bit 62 status display enabled	567
LB_DP63	Local Bit 63 status display enabled	567
LB_DP64	Local Bit 64 status display enabled	567
LB_SP01	Local Bit 01 supervision enabled	195
LB_SP02	Local Bit 02 supervision enabled	195
LB_SP03	Local Bit 03 supervision enabled	195
LB_SP04	Local Bit 04 supervision enabled	195
LB_SP05	Local Bit 05 supervision enabled	195
LB_SP06	Local Bit 06 supervision enabled	195
LB_SP07	Local Bit 07 supervision enabled	195
LB_SP08	Local Bit 08 supervision enabled	195
LB_SP09	Local Bit 09 supervision enabled	196
LB_SP10	Local Bit 10 supervision enabled	196
LB_SP11	Local Bit 11 supervision enabled	196
LB_SP12	Local Bit 12 supervision enabled	196
LB_SP13	Local Bit 13 supervision enabled	196
LB_SP14	Local Bit 14 supervision enabled	196
LB_SP15	Local Bit 15 supervision enabled	196
LB_SP16	Local Bit 16 supervision enabled	196
LB_SP17	Local Bit 17 supervision enabled	197
LB_SP18	Local Bit 18 supervision enabled	197
LB_SP19	Local Bit 19 supervision enabled	197
LB_SP20	Local Bit 20 supervision enabled	197

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 56 of 90)

Name	Bit Description	Row
LB_SP21	Local Bit 21 supervision enabled	197
LB_SP22	Local Bit 22 supervision enabled	197
LB_SP23	Local Bit 23 supervision enabled	197
LB_SP24	Local Bit 24 supervision enabled	197
LB_SP25	Local Bit 25 supervision enabled	198
LB_SP26	Local Bit 26 supervision enabled	198
LB_SP27	Local Bit 27 supervision enabled	198
LB_SP28	Local Bit 28 supervision enabled	198
LB_SP29	Local Bit 29 supervision enabled	198
LB_SP30	Local Bit 30 supervision enabled	198
LB_SP31	Local Bit 31 supervision enabled	198
LB_SP32	Local Bit 32 supervision enabled	198
LB_SP33	Local Bit 33 supervision enabled	560
LB_SP34	Local Bit 34 supervision enabled	560
LB_SP35	Local Bit 35 supervision enabled	560
LB_SP36	Local Bit 36 supervision enabled	560
LB_SP37	Local Bit 37 supervision enabled	560
LB_SP38	Local Bit 38 supervision enabled	560
LB_SP39	Local Bit 39 supervision enabled	560
LB_SP40	Local Bit 40 supervision enabled	560
LB_SP41	Local Bit 41 supervision enabled	561
LB_SP42	Local Bit 42 supervision enabled	561
LB_SP43	Local Bit 43 supervision enabled	561
LB_SP44	Local Bit 44 supervision enabled	561
LB_SP45	Local Bit 45 supervision enabled	561
LB_SP46	Local Bit 46 supervision enabled	561
LB_SP47	Local Bit 47 supervision enabled	561
LB_SP48	Local Bit 48 supervision enabled	561
LB_SP49	Local Bit 49 supervision enabled	562
LB_SP50	Local Bit 50 supervision enabled	562
LB_SP51	Local Bit 51 supervision enabled	562
LB_SP52	Local Bit 52 supervision enabled	562
LB_SP53	Local Bit 53 supervision enabled	562
LB_SP54	Local Bit 54 supervision enabled	562
LB_SP55	Local Bit 55 supervision enabled	562
LB_SP56	Local Bit 56 supervision enabled	562
LB_SP57	Local Bit 57 supervision enabled	563
LB_SP58	Local Bit 58 supervision enabled	563
LB_SP59	Local Bit 59 supervision enabled	563
LB_SP60	Local Bit 60 supervision enabled	563
LB_SP61	Local Bit 61 supervision enabled	563

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Name	Bit Description	Row
LB_SP62	Local Bit 62 supervision enabled	563
LB_SP63	Local Bit 63 supervision enabled	563
LB_SP64	Local Bit 64 supervision enabled	563
LB01	Local Bit 01 asserted	191
LB02	Local Bit 02 asserted	191
LB03	Local Bit 03 asserted	191
LB04	Local Bit 04 asserted	191
LB05	Local Bit 05 asserted	191
LB06	Local Bit 06 asserted	191
LB07	Local Bit 07 asserted	191
LB08	Local Bit 08 asserted	191
LB09	Local Bit 09 asserted	192
LB10	Local Bit 10 asserted	192
LB11	Local Bit 11 asserted	192
LB12	Local Bit 12 asserted	192
LB13	Local Bit 13 asserted	192
LB14	Local Bit 14 asserted	192
LB15	Local Bit 15 asserted	192
LB16	Local Bit 16 asserted	192
LB17	Local Bit 17 asserted	193
LB18	Local Bit 18 asserted	193
LB19	Local Bit 19 asserted	193
LB20	Local Bit 20 asserted	193
LB21	Local Bit 21 asserted	193
LB22	Local Bit 22 asserted	193
LB23	Local Bit 23 asserted	193
LB24	Local Bit 24 asserted	193
LB25	Local Bit 25 asserted	194
LB26	Local Bit 26 asserted	194
LB27	Local Bit 27 asserted	194
LB28	Local Bit 28 asserted	194
LB29	Local Bit 29 asserted	194
LB30	Local Bit 30 asserted	194
LB31	Local Bit 31 asserted	194
LB32	Local Bit 32 asserted	194
LB33	Local Bit 33 asserted	556
LB34	Local Bit 34 asserted	556
LB35	Local Bit 35 asserted	556
LB36	Local Bit 36 asserted	556
LB37	Local Bit 37 asserted	556
LB38	Local Bit 38 asserted	556

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Name	Bit Description	Row
LB39	Local Bit 39 asserted	556
LB40	Local Bit 40 asserted	556
LB41	Local Bit 41 asserted	557
LB42	Local Bit 42 asserted	557
LB43	Local Bit 43 asserted	557
LB44	Local Bit 44 asserted	557
LB45	Local Bit 45 asserted	557
LB46	Local Bit 46 asserted	557
LB47	Local Bit 47 asserted	557
LB48	Local Bit 48 asserted	557
LB49	Local Bit 49 asserted	558
LB50	Local Bit 50 asserted	558
LB51	Local Bit 51 asserted	558
LB52	Local Bit 52 asserted	558
LB53	Local Bit 53 asserted	558
LB54	Local Bit 54 asserted	558
LB55	Local Bit 55 asserted	558
LB56	Local Bit 56 asserted	558
LB57	Local Bit 57 asserted	559
LB58	Local Bit 58 asserted	559
LB59	Local Bit 59 asserted	559
LB60	Local Bit 60 asserted	559
LB61	Local Bit 61 asserted	559
LB62	Local Bit 62 asserted	559
LB63	Local Bit 63 asserted	559
LB64	Local Bit 64 asserted	559
LBOKA	Mirrored Bit channel in loopback mode, Channel A	352
LBOKB	Mirrored Bit channel in loopback mode, Channel B	353
LDAGPF	Leading power factor, A-Phase, generator	424
LDASPF	Leading power factor, A-Phase, Terminal S	420
LDATPF	Leading power factor, A-Phase, Terminal T	421
LDAUPF	Leading power factor, A-Phase, Terminal U	422
LDAYPF	Leading power factor, A-Phase, Terminal Y	423
LDBGPF	Leading power factor, B-Phase, generator	424
LDBSPF	Leading power factor, B-Phase, Terminal S	420
LDBTPF	Leading power factor, B-Phase, Terminal T	421
LDBUPF	Leading power factor, B-Phase, Terminal U	422
LDBYPF	Leading power factor, B-Phase, Terminal Y	423
LDCGPF	Leading power factor, C-Phase, generator	424
LDCSPF	Leading power factor, C-Phase, Terminal S	420
LDCTPF	Leading power factor, C-Phase, Terminal T	421

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 59 of 90)

Name	Bit Description	Row
LDCUPF	Leading power factor, C-Phase, Terminal U	422
LDCYPF	Leading power factor, C-Phase, Terminal Y	423
LDG3PF	Leading three-phase power factor, generator	424
LDS3PF	Leading three-phase power factor, Terminal S	420
LDT3PF	Leading three-phase power factor, Terminal T	421
LDU3PF	Leading three-phase power factor, Terminal U	422
LDY3PF	Leading three-phase power factor, Terminal Y	423
LGAGPF	Lagging power factor, A-Phase, generator	424
LGASPF	Lagging power factor, A-Phase, Terminal S	420
LGATPF	Lagging power factor, A-Phase, Terminal T	421
LGAUPF	Lagging power factor, A-Phase, Terminal U	422
LGAYPF	Lagging power factor, A-Phase, Terminal Y	423
LGBGPF	Lagging power factor, B-Phase, generator	424
LGBSPF	Lagging power factor, B-Phase, Terminal S	420
LGBTPF	Lagging power factor, B-Phase, Terminal T	421
LGBUPF	Lagging power factor, B-Phase, Terminal U	422
LGBYPF	Lagging power factor, B-Phase, Terminal Y	423
LGCGPF	Lagging power factor, C-Phase, generator	424
LGCSPF	Lagging power factor, C-Phase, Terminal S	420
LGCTPF	Lagging power factor, C-Phase, Terminal T	421
LGCUPF	Lagging power factor, C-Phase, Terminal U	422
LGCYPF	Lagging power factor, C-Phase, Terminal Y	423
LGG3PF	Lagging three-phase power factor, generator	424
LGS3PF	Lagging three-phase power factor, Terminal S	420
LGT3PF	Lagging three-phase power factor, Terminal T	421
LGU3PF	Lagging three-phase power factor, Terminal U	422
LGY3PF	Lagging three-phase power factor, Terminal Y	423
LINK5A	Link status of the PORT 5A connection	400
LINK5B	Link status of the PORT 5B connection	400
LINK5C	Link status of the PORT 5C connection	400
LINK5D	Link status of the PORT 5D connection	400
LINK5E	Link status of the PORT 5E connection	400
LNKFAIL	Link status of the active station bus port	400
LNKFL2	Link status of the active process bus port	400
LOC	Control authority at local (bay) level	548
LOCAL	Local front-panel control	136
LOCSTA	Control authority at station level	548
LOP3PHV	Loss-of-potential three-phase element picked up, Terminal V	465
LOP3PHZ	Loss-of-potential three-phase element picked up, Terminal Z	465
LOPDIV	Loss-of-potential element current disturbance picked up, Terminal V	463
LOPDIZ	Loss-of-potential element current disturbance picked up, Terminal Z	464

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 60 of 90)

Name	Bit Description	Row
LOPDVV	Loss-of-potential element incremental voltage picked up, Terminal V	463
LOPDVZ	Loss-of-potential element incremental voltage picked up, Terminal Z	464
LOPIV	Loss-of-potential element incremental voltage logic picked up, Terminal V	463
LOPIZ	Loss-of-potential element incremental voltage logic picked up, Terminal Z	465
LOPQV	Loss-of-potential element negative-sequence voltage logic picked up, Terminal V	464
LOPQZ	Loss-of-potential element negative-sequence voltage logic picked up, Terminal Z	465
LOPRSV	Loss-of-potential element voltage reset logic picked up, Terminal V	463
LOPRSZ	Loss-of-potential element voltage reset logic picked up, Terminal Z	465
LOPRV	Loss-of-potential element reset logic picked up, Terminal V	463
LOPRZ	Loss-of-potential element reset logic picked up, Terminal Z	464
LOPSV	Loss-of-potential element set logic picked up, Terminal V	463
LOPSZ	Loss-of-potential element set logic picked up, Terminal Z	464
LOPTCV	Loss-of-potential element torque control, Terminal V	463
LOPTCZ	Loss-of-potential element torque control, Terminal Z	464
LOPV	Loss-of-potential Terminal V	463
LOPZ	Loss-of-potential Terminal Z	464
LPHDSIM	IEC 61850 logical node for physical device simulation	354
LPSEC	Leap second is added	398
LPSECP	Leap second pending	398
MAMBOK1	Element 1, ambient temperature source healthy	447
MAMBOK2	Element 2, ambient temperature source healthy	447
MAMBOK3	Element 3, ambient temperature source healthy	447
MATHERR	SELOGIC control equation Math error	316
MLTLEV	Multi-level control authority	548
NDREF1	Nondirectional REF Element 1 enabled	55
NDREF2	Nondirectional REF Element 2 enabled	56
NDREF3	Nondirectional REF Element 3 enabled	57
OCS	Breaker Open command, Terminal S	188
OCT	Breaker Open command, Terminal T	188
OCU	Breaker Open command, Terminal U	188
OCY	Breaker Open command, Terminal Y	188
ONLINE	Generator online logic	45
OPHAS	A-Phase, Terminal S open	118
OPHAT	A-Phase, Terminal T open	118
OPHAU	A-Phase, Terminal U open	119
OPHAY	A-Phase, Terminal Y open	119
OPHBS	B-Phase, Terminal S open	118
OPHBT	B-Phase, Terminal T open	118
OPHBU	B-Phase, Terminal U open	119
OPHBY	B-Phase, Terminal Y open	119
OPHCS	C-Phase, Terminal S open	118

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 61 of 90)

Name	Bit Description	Row
OPHCT	C-Phase, Terminal T open	118
OPHCU	C-Phase, Terminal U open	119
OPHCY	C-Phase, Terminal Y open	119
OPHS	Terminal S open	118
OPHT	Terminal T open	118
OPHU	Terminal U open	119
OPHY	Terminal Y open	119
OUT201	Output 201 asserted	328
OUT2011	Aurora timer for OUT201 Binary 1	524
OUT2012	Aurora timer for OUT201 Binary 2	524
OUT201T	Aurora timer for OUT201 is timing	524
OUT202	Output 202 asserted	328
OUT2021	Aurora timer for OUT202 Binary 1	524
OUT2022	Aurora timer for OUT202 Binary 2	524
OUT202T	Aurora timer for OUT202 is timing	524
OUT203	Output 203 asserted	328
OUT204	Output 204 asserted	328
OUT205	Output 205 asserted	328
OUT206	Output 206 asserted	328
OUT207	Output 207 asserted	328
OUT208	Output 208 asserted	328
OUT209	Output 209 asserted	329
OUT210	Output 210 asserted	329
OUT211	Output 211 asserted	329
OUT212	Output 212 asserted	329
OUT213	Output 213 asserted	329
OUT214	Output 214 asserted	329
OUT215	Output 215 asserted	329
OUT216	Output 216 asserted	329
OUT301	Output 301 asserted	330
OUT302	Output 302 asserted	330
OUT303	Output 303 asserted	330
OUT304	Output 304 asserted	330
OUT305	Output 305 asserted	330
OUT306	Output 306 asserted	330
OUT307	Output 307 asserted	330
OUT308	Output 308 asserted	330
OUT309	Output 309 asserted	331
OUT310	Output 310 asserted	331
OUT311	Output 311 asserted	331
OUT312	Output 312 asserted	331

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 62 of 90)

Name	Bit Description	Row
OUT313	Output 313 asserted	331
OUT314	Output 314 asserted	331
OUT315	Output 315 asserted	331
OUT316	Output 316 asserted	331
OUT401	Output 401 asserted	332
OUT402	Output 402 asserted	332
OUT403	Output 403 asserted	332
OUT404	Output 404 asserted	332
OUT405	Output 405 asserted	332
OUT406	Output 406 asserted	332
OUT407	Output 407 asserted	332
OUT408	Output 408 asserted	332
OUT409	Output 409 asserted	333
OUT410	Output 410 asserted	333
OUT411	Output 411 asserted	333
OUT412	Output 412 asserted	333
OUT413	Output 413 asserted	333
OUT414	Output 414 asserted	333
OUT415	Output 415 asserted	333
OUT416	Output 416 asserted	333
OUT501	Output 501 asserted	334
OUT502	Output 502 asserted	334
OUT503	Output 503 asserted	334
OUT504	Output 504 asserted	334
OUT505	Output 505 asserted	334
OUT506	Output 506 asserted	334
OUT507	Output 507 asserted	334
OUT508	Output 508 asserted	334
OUT509	Output 509 asserted	335
OUT510	Output 510 asserted	335
OUT511	Output 511 asserted	335
OUT512	Output 512 asserted	335
OUT513	Output 513 asserted	335
OUT514	Output 514 asserted	335
OUT515	Output 515 asserted	335
OUT516	Output 516 asserted	335
P5ABSW	**PORT 5A** or **5B** has just become active	442
P5ASEL	**PORT 5A** active/inactive	401
P5BSEL	**PORT 5B** active/inactive	401
P5CDSW	**PORT 5C** or **5D** has just become active	442
P5CSEL	**PORT 5C** active/inactive	401

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 63 of 90)

Name	Bit Description	Row
P5DSEL	PORT 5D active/inactive	401
P5ESEL	PORT 5E active/inactive	401
PASSDIS	Password disable jumper is installed	318
PB1	Pushbutton 01 asserted	336
PB1_LED	PB01_ LED illuminated	340
PB1_PUL	Pushbutton 01 pulsed for 1 processing interval	338
PB2	Pushbutton 02 asserted	336
PB2_LED	PB02_ LED illuminated	340
PB2_PUL	Pushbutton 02 pulsed for 1 processing interval	338
PB3	Pushbutton 03 asserted	336
PB3_LED	PB03_ LED illuminated	340
PB3_PUL	Pushbutton 03 pulsed for 1 processing interval	338
PB4	Pushbutton 04 asserted	336
PB4_LED	PB04_ LED illuminated	340
PB4_PUL	Pushbutton 04 pulsed for 1 processing interval	338
PB5	Pushbutton 05 asserted	336
PB5_LED	PB05_ LED illuminated	340
PB5_PUL	Pushbutton 05 pulsed for 1 processing interval	338
PB6	Pushbutton 06 asserted	336
PB6_LED	PB06_ LED illuminated	340
PB6_PUL	Pushbutton 06 pulsed for 1 processing interval	338
PB7	Pushbutton 07 asserted	336
PB7_LED	PB07_ LED illuminated	340
PB7_PUL	Pushbutton 07 pulsed for 1 processing interval	338
PB8	Pushbutton 08 asserted	336
PB8_LED	PB08_ LED illuminated	340
PB8_PUL	Pushbutton 08 pulsed for 1 processing interval	338
PB9	Pushbutton 09 asserted	337
PB9_LED	PB09_ LED illuminated	341
PB9_PUL	Pushbutton 09 pulsed for 1 processing interval	339
PB10	Pushbutton 10 asserted	337
PB10LED	PB10LED illuminated	314
PB10PUL	Pushbutton 10 pulsed for 1 processing interval	339
PB11	Pushbutton 11 asserted	337
PB11LED	PB11LED illuminated	341
PB11PUL	Pushbutton 11 pulsed for 1 processing interval	339
PB12	Pushbutton 12 asserted	337
PB12LED	PB12LED illuminated	341
PB12PUL	Pushbutton 12 pulsed for 1 processing interval	339
PCN01Q	Protection SELOGIC Counter 01 asserted	256
PCN01R	Protection SELOGIC Counter 01 reset	260

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 64 of 90)

Name	Bit Description	Row
PCN02Q	Protection SELOGIC Counter 02 asserted	256
PCN02R	Protection SELOGIC Counter 02 reset	260
PCN03Q	Protection SELOGIC Counter 03 asserted	256
PCN03R	Protection SELOGIC Counter 03 reset	260
PCN04Q	Protection SELOGIC Counter 04 asserted	256
PCN04R	Protection SELOGIC Counter 04 reset	260
PCN05Q	Protection SELOGIC Counter 05 asserted	256
PCN05R	Protection SELOGIC Counter 05 reset	260
PCN06Q	Protection SELOGIC Counter 06 asserted	256
PCN06R	Protection SELOGIC Counter 06 reset	260
PCN07Q	Protection SELOGIC Counter 07 asserted	256
PCN07R	Protection SELOGIC Counter 07 reset	260
PCN08Q	Protection SELOGIC Counter 08 asserted	256
PCN08R	Protection SELOGIC Counter 08 reset	260
PCN09Q	Protection SELOGIC Counter 09 asserted	257
PCN09R	Protection SELOGIC Counter 09 reset	261
PCN10Q	Protection SELOGIC Counter 10 asserted	257
PCN10R	Protection SELOGIC Counter 10 reset	261
PCN11Q	Protection SELOGIC Counter 11 asserted	257
PCN11R	Protection SELOGIC Counter 11 reset	261
PCN12Q	Protection SELOGIC Counter 12 asserted	257
PCN12R	Protection SELOGIC Counter 12 reset	261
PCN13Q	Protection SELOGIC Counter 13 asserted	257
PCN13R	Protection SELOGIC Counter 13 reset	261
PCN14Q	Protection SELOGIC Counter 14 asserted	257
PCN14R	Protection SELOGIC Counter 14 reset	261
PCN15Q	Protection SELOGIC Counter 15 asserted	257
PCN15R	Protection SELOGIC Counter 15 reset	261
PCN16Q	Protection SELOGIC Counter 16 asserted	257
PCN16R	Protection SELOGIC Counter 16 reset	261
PCN17Q	Protection SELOGIC Counter 17 asserted	258
PCN17R	Protection SELOGIC Counter 17 reset	262
PCN18Q	Protection SELOGIC Counter 18 asserted	258
PCN18R	Protection SELOGIC Counter 18 reset	262
PCN19Q	Protection SELOGIC Counter 19 asserted	258
PCN19R	Protection SELOGIC Counter 19 reset	262
PCN20Q	Protection SELOGIC Counter 20 asserted	258
PCN20R	Protection SELOGIC Counter 20 reset	262
PCN21Q	Protection SELOGIC Counter 21 asserted	258
PCN21R	Protection SELOGIC Counter 21 reset	262
PCN22Q	Protection SELOGIC Counter 22 asserted	258

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 65 of 90)

Name	Bit Description	Row
PCN22R	Protection SELOGIC Counter 22 reset	262
PCN23Q	Protection SELOGIC Counter 23 asserted	258
PCN23R	Protection SELOGIC Counter 23 reset	262
PCN24Q	Protection SELOGIC Counter 24 asserted	258
PCN24R	Protection SELOGIC Counter 24 reset	262
PCN25Q	Protection SELOGIC Counter 25 asserted	259
PCN25R	Protection SELOGIC Counter 25 reset	263
PCN26Q	Protection SELOGIC Counter 26 asserted	259
PCN26R	Protection SELOGIC Counter 26 reset	263
PCN27Q	Protection SELOGIC Counter 27 asserted	259
PCN27R	Protection SELOGIC Counter 27 reset	263
PCN28Q	Protection SELOGIC Counter 28 asserted	259
PCN28R	Protection SELOGIC Counter 28 reset	263
PCN29Q	Protection SELOGIC Counter 29 asserted	259
PCN29R	Protection SELOGIC Counter 29 reset	263
PCN30Q	Protection SELOGIC Counter 30 asserted	259
PCN30R	Protection SELOGIC Counter 30 reset	263
PCN31Q	Protection SELOGIC Counter 31 asserted	259
PCN31R	Protection SELOGIC Counter 31 reset	263
PCN32Q	Protection SELOGIC Counter 32 asserted	259
PCN32R	Protection SELOGIC Counter 32 reset	263
PCT01Q	Protection SELOGIC Conditioning Timer 01 asserted	244
PCT02Q	Protection SELOGIC Conditioning Timer 02 asserted	244
PCT03Q	Protection SELOGIC Conditioning Timer 03 asserted	244
PCT04Q	Protection SELOGIC Conditioning Timer 04 asserted	244
PCT05Q	Protection SELOGIC Conditioning Timer 05 asserted	244
PCT06Q	Protection SELOGIC Conditioning Timer 06 asserted	244
PCT07Q	Protection SELOGIC Conditioning Timer 07 asserted	244
PCT08Q	Protection SELOGIC Conditioning Timer 08 asserted	244
PCT09Q	Protection SELOGIC Conditioning Timer 09 asserted	245
PCT10Q	Protection SELOGIC Conditioning Timer 10 asserted	245
PCT11Q	Protection SELOGIC Conditioning Timer 11 asserted	245
PCT12Q	Protection SELOGIC Conditioning Timer 12 asserted	245
PCT13Q	Protection SELOGIC Conditioning Timer 13 asserted	245
PCT14Q	Protection SELOGIC Conditioning Timer 14 asserted	245
PCT15Q	Protection SELOGIC Conditioning Timer 15 asserted	245
PCT16Q	Protection SELOGIC Conditioning Timer 16 asserted	245
PCT17Q	Protection SELOGIC Conditioning Timer 17 asserted	246
PCT18Q	Protection SELOGIC Conditioning Timer 18 asserted	246
PCT19Q	Protection SELOGIC Conditioning Timer 19 asserted	246
PCT20Q	Protection SELOGIC Conditioning Timer 20 asserted	246

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 66 of 90)

Name	Bit Description	Row
PCT21Q	Protection SELOGIC Conditioning Timer 21 asserted	246
PCT22Q	Protection SELOGIC Conditioning Timer 22 asserted	246
PCT23Q	Protection SELOGIC Conditioning Timer 23 asserted	246
PCT24Q	Protection SELOGIC Conditioning Timer 24 asserted	246
PCT25Q	Protection SELOGIC Conditioning Timer 25 asserted	247
PCT26Q	Protection SELOGIC Conditioning Timer 26 asserted	247
PCT27Q	Protection SELOGIC Conditioning Timer 27 asserted	247
PCT28Q	Protection SELOGIC Conditioning Timer 28 asserted	247
PCT29Q	Protection SELOGIC Conditioning Timer 29 asserted	247
PCT30Q	Protection SELOGIC Conditioning Timer 30 asserted	247
PCT31Q	Protection SELOGIC Conditioning Timer 31 asserted	247
PCT32Q	Protection SELOGIC Conditioning Timer 32 asserted	247
PFRTEX	Protection SELOGIC control equation first execution	316
PLT01	Protection SELOGIC Latch 01 asserted	240
PLT02	Protection SELOGIC Latch 02 asserted	240
PLT03	Protection SELOGIC Latch 03 asserted	240
PLT04	Protection SELOGIC Latch 04 asserted	240
PLT05	Protection SELOGIC Latch 05 asserted	240
PLT06	Protection SELOGIC Latch 06 asserted	240
PLT07	Protection SELOGIC Latch 07 asserted	240
PLT08	Protection SELOGIC Latch 08 asserted	240
PLT09	Protection SELOGIC Latch 09 asserted	241
PLT10	Protection SELOGIC Latch 10 asserted	241
PLT11	Protection SELOGIC Latch 11 asserted	241
PLT12	Protection SELOGIC Latch 12 asserted	241
PLT13	Protection SELOGIC Latch 13 asserted	241
PLT14	Protection SELOGIC Latch 14 asserted	241
PLT15	Protection SELOGIC Latch 15 asserted	241
PLT16	Protection SELOGIC Latch 16 asserted	241
PLT17	Protection SELOGIC Latch 17 asserted	242
PLT18	Protection SELOGIC Latch 18 asserted	242
PLT19	Protection SELOGIC Latch 19 asserted	242
PLT20	Protection SELOGIC Latch 20 asserted	242
PLT21	Protection SELOGIC Latch 21 asserted	242
PLT22	Protection SELOGIC Latch 22 asserted	242
PLT23	Protection SELOGIC Latch 23 asserted	242
PLT24	Protection SELOGIC Latch 24 asserted	242
PLT25	Protection SELOGIC Latch 25 asserted	243
PLT26	Protection SELOGIC Latch 26 asserted	243
PLT27	Protection SELOGIC Latch 27 asserted	243
PLT28	Protection SELOGIC Latch 28 asserted	243

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 67 of 90)

Name	Bit Description	Row
PLT29	Protection SELOGIC Latch 29 asserted	243
PLT30	Protection SELOGIC Latch 30 asserted	243
PLT31	Protection SELOGIC Latch 31 asserted	243
PLT32	Protection SELOGIC Latch 32 asserted	243
PMDOK	Assert if data acquisition system is operating correctly	321
PMTEST	Synchrophasor Test Mode	389
PMTRIG	Synchrophasor SELOGIC control equation trigger	389
PRPAGOK	PRP PORT 5A GOOSE status	580
PRPASOK	PRP PORT 5A SV status	580
PRPBGOK	PRP PORT 5B GOOSE status	580
PRPBSOK	PRP PORT 5B SV status	580
PRPCGOK	PRP PORT 5C GOOSE status	580
PRPDGOK	PRP PORT 5D GOOSE status	580
PSMODE	Generator in Pumped-Storage Mode	4
PST01Q	Protection SELOGIC Sequencing Timer 01 asserted	248
PST01R	Protection SELOGIC Sequencing Timer 01 reset	252
PST02Q	Protection SELOGIC Sequencing Timer 02 asserted	248
PST02R	Protection SELOGIC Sequencing Timer 02 reset	252
PST03Q	Protection SELOGIC Sequencing Timer 03 asserted	248
PST03R	Protection SELOGIC Sequencing Timer 03 reset	252
PST04Q	Protection SELOGIC Sequencing Timer 04 asserted	248
PST04R	Protection SELOGIC Sequencing Timer 04 reset	252
PST05Q	Protection SELOGIC Sequencing Timer 05 asserted	248
PST05R	Protection SELOGIC Sequencing Timer 05 reset	252
PST06Q	Protection SELOGIC Sequencing Timer 06 asserted	248
PST06R	Protection SELOGIC Sequencing Timer 06 reset	252
PST07Q	Protection SELOGIC Sequencing Timer 07 asserted	248
PST07R	Protection SELOGIC Sequencing Timer 07 reset	252
PST08Q	Protection SELOGIC Sequencing Timer 08 asserted	248
PST08R	Protection SELOGIC Sequencing Timer 08 reset	252
PST09Q	Protection SELOGIC Sequencing Timer 09 asserted	249
PST09R	Protection SELOGIC Sequencing Timer 09 reset	253
PST10Q	Protection SELOGIC Sequencing Timer 10 asserted	249
PST10R	Protection SELOGIC Sequencing Timer 10 reset	253
PST11Q	Protection SELOGIC Sequencing Timer 11 asserted	249
PST11R	Protection SELOGIC Sequencing Timer 11 reset	253
PST12Q	Protection SELOGIC Sequencing Timer 12 asserted	249
PST12R	Protection SELOGIC Sequencing Timer 12 reset	253
PST13Q	Protection SELOGIC Sequencing Timer 13 asserted	249
PST13R	Protection SELOGIC Sequencing Timer 13 reset	253
PST14Q	Protection SELOGIC Sequencing Timer 14 asserted	249

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 68 of 90)

Name	Bit Description	Row
PST14R	Protection SELOGIC Sequencing Timer 14 reset	253
PST15Q	Protection SELOGIC Sequencing Timer 15 asserted	249
PST15R	Protection SELOGIC Sequencing Timer 15 reset	253
PST16Q	Protection SELOGIC Sequencing Timer 16 asserted	249
PST16R	Protection SELOGIC Sequencing Timer 16 reset	253
PST17Q	Protection SELOGIC Sequencing Timer 17 asserted	250
PST17R	Protection SELOGIC Sequencing Timer 17 reset	254
PST18Q	Protection SELOGIC Sequencing Timer 18 asserted	250
PST18R	Protection SELOGIC Sequencing Timer 18 reset	254
PST19Q	Protection SELOGIC Sequencing Timer 19 asserted	250
PST19R	Protection SELOGIC Sequencing Timer 19 reset	254
PST20Q	Protection SELOGIC Sequencing Timer 20 asserted	250
PST20R	Protection SELOGIC Sequencing Timer 20 reset	254
PST21Q	Protection SELOGIC Sequencing Timer 21 asserted	250
PST21R	Protection SELOGIC Sequencing Timer 21 reset	254
PST22Q	Protection SELOGIC Sequencing Timer 22 asserted	250
PST22R	Protection SELOGIC Sequencing Timer 22 reset	254
PST23Q	Protection SELOGIC Sequencing Timer 23 asserted	250
PST23R	Protection SELOGIC Sequencing Timer 23 reset	254
PST24Q	Protection SELOGIC Sequencing Timer 24 asserted	250
PST24R	Protection SELOGIC Sequencing Timer 24 reset	254
PST25Q	Protection SELOGIC Sequencing Timer 25 asserted	251
PST25R	Protection SELOGIC Sequencing Timer 25 reset	255
PST26Q	Protection SELOGIC Sequencing Timer 26 asserted	251
PST26R	Protection SELOGIC Sequencing Timer 26 reset	255
PST27Q	Protection SELOGIC Sequencing Timer 27 asserted	251
PST27R	Protection SELOGIC Sequencing Timer 27 reset	255
PST28Q	Protection SELOGIC Sequencing Timer 28 asserted	251
PST28R	Protection SELOGIC Sequencing Timer 28 reset	255
PST29Q	Protection SELOGIC Sequencing Timer 29 asserted	251
PST29R	Protection SELOGIC Sequencing Timer 29 reset	255
PST30Q	Protection SELOGIC Sequencing Timer 30 asserted	251
PST30R	Protection SELOGIC Sequencing Timer 30 reset	255
PST31Q	Protection SELOGIC Sequencing Timer 31 asserted	251
PST31R	Protection SELOGIC Sequencing Timer 31 reset	255
PST32Q	Protection SELOGIC Sequencing Timer 32 asserted	251
PST32R	Protection SELOGIC Sequencing Timer 32 reset	255
PSV01	Protection SELOGIC Variable 01 asserted	232
PSV02	Protection SELOGIC Variable 02 asserted	232
PSV03	Protection SELOGIC Variable 03 asserted	232
PSV04	Protection SELOGIC Variable 04 asserted	232

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 69 of 90)

Name	Bit Description	Row
PSV05	Protection SELOGIC Variable 05 asserted	232
PSV06	Protection SELOGIC Variable 06 asserted	232
PSV07	Protection SELOGIC Variable 07 asserted	232
PSV08	Protection SELOGIC Variable 08 asserted	232
PSV09	Protection SELOGIC Variable 09 asserted	233
PSV10	Protection SELOGIC Variable 10 asserted	233
PSV11	Protection SELOGIC Variable 11 asserted	233
PSV12	Protection SELOGIC Variable 12 asserted	233
PSV13	Protection SELOGIC Variable 13 asserted	233
PSV14	Protection SELOGIC Variable 14 asserted	233
PSV15	Protection SELOGIC Variable 15 asserted	233
PSV16	Protection SELOGIC Variable 16 asserted	233
PSV17	Protection SELOGIC Variable 17 asserted	234
PSV18	Protection SELOGIC Variable 18 asserted	234
PSV19	Protection SELOGIC Variable 19 asserted	234
PSV20	Protection SELOGIC Variable 20 asserted	234
PSV21	Protection SELOGIC Variable 21 asserted	234
PSV22	Protection SELOGIC Variable 22 asserted	234
PSV23	Protection SELOGIC Variable 23 asserted	234
PSV24	Protection SELOGIC Variable 24 asserted	234
PSV25	Protection SELOGIC Variable 25 asserted	235
PSV26	Protection SELOGIC Variable 26 asserted	235
PSV27	Protection SELOGIC Variable 27 asserted	235
PSV28	Protection SELOGIC Variable 28 asserted	235
PSV29	Protection SELOGIC Variable 29 asserted	235
PSV30	Protection SELOGIC Variable 30 asserted	235
PSV31	Protection SELOGIC Variable 31 asserted	235
PSV32	Protection SELOGIC Variable 32 asserted	235
PSV33	Protection SELOGIC Variable 33 asserted	236
PSV34	Protection SELOGIC Variable 34 asserted	236
PSV35	Protection SELOGIC Variable 35 asserted	236
PSV36	Protection SELOGIC Variable 36 asserted	236
PSV37	Protection SELOGIC Variable 37 asserted	236
PSV38	Protection SELOGIC Variable 38 asserted	236
PSV39	Protection SELOGIC Variable 39 asserted	236
PSV40	Protection SELOGIC Variable 40 asserted	236
PSV41	Protection SELOGIC Variable 41 asserted	237
PSV42	Protection SELOGIC Variable 42 asserted	237
PSV43	Protection SELOGIC Variable 43 asserted	237
PSV44	Protection SELOGIC Variable 44 asserted	237
PSV45	Protection SELOGIC Variable 45 asserted	237

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 70 of 90)

Name	Bit Description	Row
PSV46	Protection SELOGIC Variable 46 asserted	237
PSV47	Protection SELOGIC Variable 47 asserted	237
PSV48	Protection SELOGIC Variable 48 asserted	237
PSV49	Protection SELOGIC Variable 49 asserted	238
PSV50	Protection SELOGIC Variable 50 asserted	238
PSV51	Protection SELOGIC Variable 51 asserted	238
PSV52	Protection SELOGIC Variable 52 asserted	238
PSV53	Protection SELOGIC Variable 53 asserted	238
PSV54	Protection SELOGIC Variable 54 asserted	238
PSV55	Protection SELOGIC Variable 55 asserted	238
PSV56	Protection SELOGIC Variable 56 asserted	238
PSV57	Protection SELOGIC Variable 57 asserted	239
PSV58	Protection SELOGIC Variable 58 asserted	239
PSV59	Protection SELOGIC Variable 59 asserted	239
PSV60	Protection SELOGIC Variable 60 asserted	239
PSV61	Protection SELOGIC Variable 61 asserted	239
PSV62	Protection SELOGIC Variable 62 asserted	239
PSV63	Protection SELOGIC Variable 63 asserted	239
PSV64	Protection SELOGIC Variable 64 asserted	239
PTP_BNP	Bad jitter on PTP signals and the PTP signal is lost afterwards	442
PTP_OK	PTP is available and has sufficient quality	441
PTP_RST	Disqualify PTP time source	441
PTP_SET	Qualify PTP time source	441
PTP_TIM	A valid PTP time source is detected	441
PTPSYNC	Synchronized to a high-quality PTP source	441
PUNRLBL	Protection SELOGIC control equation unresolved label	316
RB01	Remote Bit 01 asserted	207
RB02	Remote Bit 02 asserted	207
RB03	Remote Bit 03 asserted	207
RB04	Remote Bit 04 asserted	207
RB05	Remote Bit 05 asserted	207
RB06	Remote Bit 06 asserted	207
RB07	Remote Bit 07 asserted	207
RB08	Remote Bit 08 asserted	207
RB09	Remote Bit 09 asserted	206
RB10	Remote Bit 10 asserted	206
RB11	Remote Bit 11 asserted	206
RB12	Remote Bit 12 asserted	206
RB13	Remote Bit 13 asserted	206
RB14	Remote Bit 14 asserted	206
RB15	Remote Bit 15 asserted	206

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 71 of 90)

Name	Bit Description	Row
RB16	Remote Bit 16 asserted	206
RB17	Remote Bit 17 asserted	205
RB18	Remote Bit 18 asserted	205
RB19	Remote Bit 19 asserted	205
RB20	Remote Bit 20 asserted	205
RB21	Remote Bit 21 asserted	205
RB22	Remote Bit 22 asserted	205
RB23	Remote Bit 23 asserted	205
RB24	Remote Bit 24 asserted	205
RB25	Remote Bit 25 asserted	204
RB26	Remote Bit 26 asserted	204
RB27	Remote Bit 27 asserted	204
RB28	Remote Bit 28 asserted	204
RB29	Remote Bit 29 asserted	204
RB30	Remote Bit 30 asserted	204
RB31	Remote Bit 31 asserted	204
RB32	Remote Bit 32 asserted	204
RB33	Remote Bit 33 asserted	571
RB34	Remote Bit 34 asserted	571
RB35	Remote Bit 35 asserted	571
RB36	Remote Bit 36 asserted	571
RB37	Remote Bit 37 asserted	571
RB38	Remote Bit 38 asserted	571
RB39	Remote Bit 39 asserted	571
RB40	Remote Bit 40 asserted	571
RB41	Remote Bit 41 asserted	570
RB42	Remote Bit 42 asserted	570
RB43	Remote Bit 43 asserted	570
RB44	Remote Bit 44 asserted	570
RB45	Remote Bit 45 asserted	570
RB46	Remote Bit 46 asserted	570
RB47	Remote Bit 47 asserted	570
RB48	Remote Bit 48 asserted	570
RB49	Remote Bit 49 asserted	569
RB50	Remote Bit 50 asserted	569
RB51	Remote Bit 51 asserted	569
RB52	Remote Bit 52 asserted	569
RB53	Remote Bit 53 asserted	569
RB54	Remote Bit 54 asserted	569
RB55	Remote Bit 55 asserted	569
RB56	Remote Bit 56 asserted	569

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 72 of 90)

Name	Bit Description	Row
RB57	Remote Bit 57 asserted	568
RB58	Remote Bit 58 asserted	568
RB59	Remote Bit 59 asserted	568
RB60	Remote Bit 60 asserted	568
RB61	Remote Bit 61 asserted	568
RB62	Remote Bit 62 asserted	568
RB63	Remote Bit 63 asserted	568
RB64	Remote Bit 64 asserted	568
RBADA	Outage too large for normal Mirrored Bit communication, Channel A	352
RBADB	Outage too large for normal Mirrored Bit communication, Channel B	353
REF	Earth fault inside REF Element 1, 2, or 3 Zones	59
REF501	Neutral instantaneous overcurrent Element 1 picked up	55
REF502	Neutral instantaneous overcurrent Element 2 picked up	56
REF503	Neutral instantaneous overcurrent Element 3 picked up	58
REF50T1	Neutral instantaneous overcurrent Element 1 timed out	55
REF50T2	Neutral instantaneous overcurrent Element 2 timed out	57
REF50T3	Neutral instantaneous overcurrent Element 3 timed out	58
REF511	REF Element 1 TOC element picked up	56
REF512	REF Element 2 TOC element picked up	57
REF513	REF Element 3 TOC element picked up	58
REF51R1	REF Element 1 TOC element reset	56
REF51R2	REF Element 2 TOC element reset	57
REF51R3	REF Element 3 TOC element reset	58
REF51T1	REF Element 1 TOC element timed out	55
REF51T2	REF Element 2 TOC element timed out	57
REF51T3	REF Element 3 TOC element timed out	58
REFF1	Earth fault inside restricted Zone 1	55
REFF2	Earth fault inside restricted Zone 2	56
REFF3	Earth fault inside restricted Zone 3	58
REFR1	Earth fault outside restricted Zone 1	55
REFR2	Earth fault outside restricted Zone 2	56
REFR3	Earth fault outside restricted Zone 3	58
REFBLK1	REF Element 1 phase fault or external ground fault detected	59
REFBLK2	REF Element 2 phase fault or external ground fault detected	59
REFBLK3	REF Element 3 phase fault or external ground fault detected	59
REFOCT1	REF Element 1 open CT, wiring, or setting error detected	59
REFOCT2	REF Element 2 open CT, wiring, or setting error detected	59
REFOCT3	REF Element 3 open CT, wiring, or setting error detected	59
RF50TC1	Neutral instantaneous overcurrent Element 1 enabled	56
RF50TC2	Neutral instantaneous overcurrent Element 2 enabled	57
RF50TC3	Neutral instantaneous overcurrent Element 3 enabled	59

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 73 of 90)

Name	Bit Description	Row
RF51TC1	Inverse-time neutral overcurrent Element 1 enabled	55
RF51TC2	Inverse-time neutral overcurrent Element 2 enabled	57
RF51TC3	Inverse-time neutral overcurrent Element 3 enabled	58
RMB1A	Received Mirrored Bit 1, Channel A	348
RMB1B	Received Mirrored Bit 1, Channel B	350
RMB2A	Received Mirrored Bit 2, Channel A	348
RMB2B	Received Mirrored Bit 2, Channel B	350
RMB3A	Received Mirrored Bit 3, Channel A	348
RMB3B	Received Mirrored Bit 3, Channel B	350
RMB4A	Received Mirrored Bit 4, Channel A	348
RMB4B	Received Mirrored Bit 4, Channel B	350
RMB5A	Received Mirrored Bit 5, Channel A	348
RMB5B	Received Mirrored Bit 5, Channel B	350
RMB6A	Received Mirrored Bit 6, Channel A	348
RMB6B	Received Mirrored Bit 6, Channel B	350
RMB7A	Received Mirrored Bit 7, Channel A	348
RMB7B	Received Mirrored Bit 7, Channel B	350
RMB8A	Received Mirrored Bit 8, Channel A	348
RMB8B	Received Mirrored Bit 8, Channel B	350
ROKA	Mirrored Bit Channel A normal status in non loopback mode	352
ROKB	Mirrored Bit Channel B normal status in non loopback mode	353
RST_BAT	Reset battery monitoring	345
RST_BKS	Reset Breaker S monitoring	344
RST_BKT	Reset Breaker T monitoring	344
RST_BKU	Reset Breaker U monitoring	344
RST_BKY	Reset Breaker Y monitoring	344
RST_DEM	Reset demand metering	344
RST_ENE	Reset energy metering	344
RST_HAL	Reset HALARMA	345
RST_MM	Reset min/max metering	344
RST_PDM	Reset peak demand metering	344
RSTDNPE	Reset DNP fault summary data	345
RSTTRGT	Reset front-panel targets	345
RTC01OC	RTC01 open circuited	476
RTC01OK	RTC01 healthy	468
RTC01Q	RTC01 quality healthy	480
RTC01SC	RTC01 short circuited	472
RTC02OC	RTC02 open circuited	476
RTC02OK	RTC02 healthy	468
RTC02Q	RTC02 quality healthy	480
RTC02SC	RTC02 short circuited	472

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 74 of 90)

Name	Bit Description	Row
RTC03OC	RTC03 open circuited	476
RTC03OK	RTC03 healthy	468
RTC03Q	RTC03 quality healthy	480
RTC03SC	RTC03 short circuited	472
RTC04OC	RTC04 open circuited	476
RTC04OK	RTC04 healthy	468
RTC04Q	RTC04 quality healthy	480
RTC04SC	RTC04 short circuited	472
RTC05OC	RTC05 open circuited	476
RTC05OK	RTC05 healthy	468
RTC05Q	RTC05 quality healthy	480
RTC05SC	RTC05 short circuited	472
RTC06OC	RTC06 open circuited	476
RTC06OK	RTC06 healthy	468
RTC06Q	RTC06 quality healthy	480
RTC06SC	RTC06 short circuited	472
RTC07OC	RTC07 open circuited	476
RTC07OK	RTC07 healthy	468
RTC07Q	RTC07 quality healthy	480
RTC07SC	RTC07 short circuited	472
RTC08OC	RTC08 open circuited	476
RTC08OK	RTC08 healthy	468
RTC08Q	RTC08 quality healthy	480
RTC08SC	RTC08 short circuited	472
RTC09OC	RTC09 open circuited	477
RTC09OK	RTC09 healthy	469
RTC09Q	RTC09 quality healthy	481
RTC09SC	RTC09 short circuited	473
RTC10OC	RTC10 open circuited	477
RTC10OK	RTC10 healthy	469
RTC10Q	RTC10 quality healthy	481
RTC10SC	RTC10 short circuited	473
RTC11OC	RTC11 open circuited	477
RTC11OK	RTC11 healthy	469
RTC11Q	RTC11 quality healthy	481
RTC11SC	RTC11 short circuited	473
RTC12OC	RTC12 open circuited	477
RTC12OK	RTC12 healthy	469
RTC12Q	RTC12 quality healthy	481
RTC12SC	RTC12 short circuited	473
RTC13OC	RTC13 open circuited	477

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 75 of 90)

Name	Bit Description	Row
RTC13OK	RTC13 healthy	469
RTC13Q	RTC13 quality healthy	481
RTC13SC	RTC13 short circuited	473
RTC14OC	RTC14 open circuited	477
RTC14OK	RTC14 healthy	469
RTC14Q	RTC14 quality healthy	481
RTC14SC	RTC14 short circuited	473
RTC15OC	RTC15 open circuited	477
RTC15OK	RTC15 healthy	469
RTC15Q	RTC15 quality healthy	481
RTC15SC	RTC15 short circuited	473
RTC16OC	RTC16 open circuited	477
RTC16OK	RTC16 healthy	469
RTC16Q	RTC16 quality healthy	481
RTC16SC	RTC16 short circuited	473
RTC17OC	RTC17 open circuited	478
RTC17OK	RTC17 healthy	470
RTC17Q	RTC17 quality healthy	482
RTC17SC	RTC17 short circuited	474
RTC18OC	RTC18 open circuited	478
RTC18OK	RTC18 healthy	470
RTC18Q	RTC18 quality healthy	482
RTC18SC	RTC18 short circuited	474
RTC19OC	RTC19 open circuited	478
RTC19OK	RTC19 healthy	470
RTC19Q	RTC19 quality healthy	482
RTC19SC	RTC19 short circuited	474
RTC20OC	RTC20 open circuited	478
RTC20OK	RTC20 healthy	470
RTC20Q	RTC20 quality healthy	482
RTC20SC	RTC20 short circuited	474
RTC21OC	RTC21 open circuited	478
RTC21OK	RTC21 healthy	470
RTC21Q	RTC21 quality healthy	482
RTC21SC	RTC21 short circuited	474
RTC22OC	RTC22 open circuited	478
RTC22OK	RTC22 healthy	470
RTC22Q	RTC22 quality healthy	482
RTC22SC	RTC22 short circuited	474
RTC23OC	RTC23 open circuited	478
RTC23OK	RTC23 healthy	470

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 76 of 90)

Name	Bit Description	Row
RTC23Q	RTC23 quality healthy	482
RTC23SC	RTC23 short circuited	474
RTC24OC	RTC24 open circuited	478
RTC24OK	RTC24 healthy	470
RTC24Q	RTC24 quality healthy	482
RTC24SC	RTC24 short circuited	474
RTCAD01	RTC Channel A remote date Bit 01	392
RTCAD02	RTC Channel A remote date Bit 02	392
RTCAD03	RTC Channel A remote date Bit 03	392
RTCAD04	RTC Channel A remote date Bit 04	392
RTCAD05	RTC Channel A remote date Bit 05	392
RTCAD06	RTC Channel A remote date Bit 06	392
RTCAD07	RTC Channel A remote date Bit 07	392
RTCAD08	RTC Channel A remote date Bit 08	392
RTCAD09	RTC Channel A remote date Bit 09	393
RTCAD10	RTC Channel A remote date Bit 10	393
RTCAD11	RTC Channel A remote date Bit 11	393
RTCAD12	RTC Channel A remote date Bit 12	393
RTCAD13	RTC Channel A remote date Bit 13	393
RTCAD14	RTC Channel A remote date Bit 14	393
RTCAD15	RTC Channel A remote date Bit 15	393
RTCAD16	RTC Channel A remote date Bit 16	393
RTCBD01	RTC Channel B remote date Bit 01	394
RTCBD02	RTC Channel B remote date Bit 02	394
RTCBD03	RTC Channel B remote date Bit 03	394
RTCBD04	RTC Channel B remote date Bit 04	394
RTCBD05	RTC Channel B remote date Bit 05	394
RTCBD06	RTC Channel B remote date Bit 06	394
RTCBD07	RTC Channel B remote date Bit 07	394
RTCBD08	RTC Channel B remote date Bit 08	394
RTCBD09	RTC Channel B remote date Bit 09	395
RTCBD10	RTC Channel B remote date Bit 10	395
RTCBD11	RTC Channel B remote date Bit 11	395
RTCBD12	RTC Channel B remote date Bit 12	395
RTCBD13	RTC Channel B remote date Bit 13	395
RTCBD14	RTC Channel B remote date Bit 14	395
RTCBD15	RTC Channel B remote date Bit 15	395
RTCBD16	RTC Channel B remote date Bit 16	395
RTCCFGA	RTC Channel A configuration complete	390
RTCCFGB	RTC Channel B configuration complete	390
RTCDLYA	Max RTC delay exceeded for Channel A	390

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 77 of 90)

Name	Bit Description	Row
RTCDLYB	Max RTC delay exceeded for Channel B	390
RTCENA	Valid remote synchrophasors received on Channel A	391
RTCENB	Valid remote synchrophasors received on Channel B	391
RTCROK	Valid aligned RTC data available on all enabled channels	390
RTCROKA	Valid aligned RTC data available on Channel A	391
RTCROKB	Valid aligned RTC data available on Channel B	391
RTCSEQA	RTC Channel A data in sequence	390
RTCSEQB	RTC Channel B data in sequence	390
RTS	Circuit Breaker S retrip	122
RTS01OC	RTD01 open circuited	452
RTS01OK	RTD01 healthy	444
RTS01SC	RTD01 short circuited	448
RTS02OC	RTD02 open circuited	452
RTS02OK	RTD02 healthy	444
RTS02SC	RTD02 short circuited	448
RTS03OC	RTD03 open circuited	452
RTS03OK	RTD03 healthy	444
RTS03SC	RTD03 short circuited	448
RTS04OC	RTD04 open circuited	452
RTS04OK	RTD04 healthy	444
RTS04SC	RTD04 short circuited	448
RTS05OC	RTD05 open circuited	452
RTS05OK	RTD05 healthy	444
RTS05SC	RTD05 short circuited	448
RTS06OC	RTD06 open circuited	452
RTS06OK	RTD06 healthy	444
RTS06SC	RTD06 short circuited	448
RTS07OC	RTD07 open circuited	452
RTS07OK	RTD07 healthy	444
RTS07SC	RTD07 short circuited	448
RTS08OC	RTD08 open circuited	452
RTS08OK	RTD08 healthy	444
RTS08SC	RTD08 short circuited	448
RTS09OC	RTD09 open circuited	453
RTS09OK	RTD09 healthy	445
RTS09SC	RTD09 short circuited	449
RTS10OC	RTD10 open circuited	453
RTS10OK	RTD10 healthy	445
RTS10SC	RTD10 short circuited	449
RTS11OC	RTD11 open circuited	453
RTS11OK	RTD11 healthy	445

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 78 of 90)

Name	Bit Description	Row
RTS11SC	RTD11 short circuited	449
RTS12OC	RTD12 open circuited	453
RTS12OK	RTD12 healthy	445
RTS12SC	RTD12 short circuited	449
RTS13OC	RTD13 open circuited	453
RTS13OK	RTD13 healthy	445
RTS13SC	RTD13 short circuited	449
RTS14OC	RTD14 open circuited	453
RTS14OK	RTD14 healthy	445
RTS14SC	RTD14 short circuited	449
RTS15OC	RTD15 open circuited	453
RTS15OK	RTD15 healthy	445
RTS15SC	RTD15 short circuited	449
RTS16OC	RTD16 open circuited	453
RTS16OK	RTD16 healthy	445
RTS16SC	RTD16 short circuited	449
RTS17OC	RTD17 open circuited	454
RTS17OK	RTD17 healthy	446
RTS17SC	RTD17 short circuited	450
RTS18OC	RTD18 open circuited	454
RTS18OK	RTD18 healthy	446
RTS18SC	RTD18 short circuited	450
RTS19OC	RTD19 open circuited	454
RTS19OK	RTD19 healthy	446
RTS19SC	RTD19 short circuited	450
RTS20OC	RTD20 open circuited	454
RTS20OK	RTD20 healthy	446
RTS20SC	RTD20 short circuited	450
RTS21OC	RTD21 open circuited	454
RTS21OK	RTD21 healthy	446
RTS21SC	RTD21 short circuited	450
RTS22OC	RTD22 open circuited	454
RTS22OK	RTD22 healthy	446
RTS22SC	RTD22 short circuited	450
RTS23OC	RTD23 open circuited	454
RTS23OK	RTD23 healthy	446
RTS23SC	RTD23 short circuited	450
RTS24OC	RTD24 open circuited	454
RTS24OK	RTD24 healthy	446
RTS24SC	RTD24 short circuited	450
RTSCFA	SEL-2600 communication failure (RTDA)	447

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 79 of 90)

Name	Bit Description	Row
RTSCFB	SEL-2600 communication failure (RTDB)	447
RTSFLA	SEL-2600 RAM failure (RTDA)	447
RTSFLB	SEL-2600 RAM failure (RTDB)	447
RTT	Circuit Breaker T retrip	124
RTU	Circuit Breaker U retrip	126
RTY	Circuit Breaker Y retrip	128
S32F3P	Terminal S forward three-phase directional picked up	621
S32GE	Terminal S ground-directional calculation enabled	536
S32PE	Terminal S phase-directional calculation enabled	533
S32QE	Terminal S neg. seq directional calculation enabled	533
SALARM	Software alarm	317
SC850BM	SELOGIC control for IEC 61850 blocked mode	496
SC850LS	SELOGIC control for control authority at station level	548
SC850SM	SELOGIC control for IEC 61850 simulation mode	496
SC850TM	SELOGIC control for IEC 61850 test mode	496
SCBKSBC	SELOGIC control for IEC 61850 close block equation for Circuit Breaker S	577
SCBKSBO	SELOGIC control for IEC 61850 open block equation for Circuit Breaker S	577
SCBKTBC	SELOGIC control for IEC 61850 close block equation for Circuit Breaker T	577
SCBKTBO	SELOGIC control for IEC 61850 open block equation for Circuit Breaker T	577
SCBKUBC	SELOGIC control for IEC 61850 close block equation for Circuit Breaker U	577
SCBKUBO	SELOGIC control for IEC 61850 open block equation for Circuit Breaker U	577
SCBKYBC	SELOGIC control for IEC 61850 close block equation for Circuit Breaker Y	577
SCBKYBO	SELOGIC control for IEC 61850 open block equation for Circuit Breaker Y	577
SER_BNP	Bad jitter on serial port and the IRIG-B signal is lost afterwards	441
SER_OK	IRIG-B signal from serial PORT 1 is available and has sufficient quality	440
SER_RST	Disqualify serial IRIG-B time source	440
SER_SET	Qualify serial IRIG-B time source	440
SER_TIM	A valid IRIG-B time source is detected on serial port	441
SERSYNC	Synchronized to a high-quality serial IRIG source	442
SETCHG	Pulsed alarm for settings changes	317
SF32G	Terminal S forward ground directional declared	537
SF32P	Terminal S forward phase directional picked up	535
SF32Q	Terminal S forward negative-sequence directional picked up	534
SFBKS	Breaker S slip frequency is within acceptable slip frequency window	429
SFBKT	Breaker T slip frequency is within acceptable slip frequency window	429
SFBKU	Breaker U slip frequency is within acceptable slip frequency window	429
SFBKY	Breaker Y slip frequency is within acceptable slip frequency window	429
SFZBKS	Breaker S slip frequency is less than 5 mHz	429
SFZBKT	Breaker T slip frequency is less than 5 mHz	429
SFZBKU	Breaker U slip frequency is less than 5 mHz	429
SFZBKY	Breaker Y slip frequency is less than 5 mHz	429

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 80 of 90)

Name	Bit Description	Row
SG1	Setting Group 1 is active	208
SG2	Setting Group 2 is active	208
SG3	Setting Group 3 is active	208
SG4	Setting Group 4 is active	208
SG5	Setting Group 5 is active	208
SG6	Setting Group 6 is active	208
SLOWS	Polarizing voltage slipping slower than Breaker S synchronizing voltage	428
SLOWT	Polarizing voltage slipping slower than Breaker T synchronizing voltage	428
SLOWU	Polarizing voltage slipping slower than Breaker U synchronizing voltage	428
SLOWY	Polarizing voltage slipping slower than Breaker Y synchronizing voltage	428
SPCER1	Synchrophasor configuration error on PORT 1	319
SPCER2	Synchrophasor configuration error on PORT 2	319
SPCER3	Synchrophasor configuration error on PORT 3	319
SPCERF	Synchrophasor configuration error on PORT F	319
SPEN	Signal profiling enabled	402
SR32G	Terminal S reverse ground directional declared	537
SR32P	Terminal S reverse phase directional picked up	535
SR32PD	Terminal S reverse phase directional detected	619
SR32Q	Terminal S reverse negative-sequence directional picked up	534
T32GE	Terminal T ground directional calculation enabled	536
T32PE	Terminal T phase-directional calculation enabled	533
T32QE	Terminal T negative-sequence directional calculation enabled	533
TBNC	The active relay time source is BNC IRIG	321
TCREF1	REF Element 1 enabled	55
TCREF2	REF Element 2 enabled	56
TCREF3	REF Element 3 enabled	57
TESTDB	Database test bit	354
TESTDB2	Enhanced label based test bit	354
TESTFM	Fast Meter test bit	354
TESTPUL	Pulse test bit	354
TF32G	Terminal T forward ground directional declared	537
TF32P	Terminal T forward phase directional picked up	535
TF32PD	Terminal T forward phase directional detected	619
TF32Q	Terminal T forward negative-sequence directional picked up	534
TGLOBAL	Relay calendar clock and ADC sampling synchronized to a high-priority Global time source	322
THLSW1	Element 1 thermal level switch	505
THLSW2	Element 2 thermal level switch	505
THLSW3	Element 3 thermal level switch	505
THRLA1	Element 1 thermal level alarm	504
THRLA2	Element 2 thermal level alarm	504
THRLA3	Element 3 thermal level alarm	504

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Name	Bit Description	Row
THRLT1	Element 1 thermal level trip	504
THRLT2	Element 2 thermal level trip	504
THRLT3	Element 3 thermal level trip	504
TIRIG	Assert while time is based on IRIG for both mark and value	321
TLED_1	Target LED 1 on relay front panel	1
TLED_2	Target LED 2 on relay front panel	1
TLED_3	Target LED 3 on relay front panel	1
TLED_4	Target LED 4 on relay front panel	1
TLED_5	Target LED 5 on relay front panel	1
TLED_6	Target LED 6 on relay front panel	1
TLED_7	Target LED 7 on relay front panel	1
TLED_8	Target LED 8 on relay front panel	1
TLED_9	Target LED 9 on relay front panel	2
TLED_10	Target LED 10 on relay front panel	2
TLED_11	Target LED 11 on relay front panel	2
TLED_12	Target LED 12 on relay front panel	2
TLED_13	Target LED 13 on relay front panel	2
TLED_14	Target LED 14 on relay front panel	2
TLED_15	Target LED 15 on relay front panel	2
TLED_16	Target LED 16 on relay front panel	2
TLED_17	Target LED 17 on relay front panel	3
TLED_18	Target LED 18 on relay front panel	3
TLED_19	Target LED 19 on relay front panel	3
TLED_20	Target LED 20 on relay front panel	3
TLED_21	Target LED 21 on relay front panel	3
TLED_22	Target LED 22 on relay front panel	3
TLED_23	Target LED 23 on relay front panel	3
TLED_24	Target LED 24 on relay front panel	3
TLOCAL	Relay calendar clock and ADC sampling synchronized to a high-priority local time source	322
TMB1A	Transmitted Mirrored Bit 1, Channel A	349
TMB1B	Transmitted Mirrored Bit 1, Channel B	351
TMB2A	Transmitted Mirrored Bit 2, Channel A	349
TMB2B	Transmitted Mirrored Bit 2, Channel B	351
TMB3A	Transmitted Mirrored Bit 3, Channel A	349
TMB3B	Transmitted Mirrored Bit 3, Channel B	351
TMB4A	Transmitted Mirrored Bit 4, Channel A	349
TMB4B	Transmitted Mirrored Bit 4, Channel B	351
TMB5A	Transmitted Mirrored Bit 5, Channel A	349
TMB5B	Transmitted Mirrored Bit 5, Channel B	351
TMB6A	Transmitted Mirrored Bit 6, Channel A	349
TMB6B	Transmitted Mirrored Bit 6, Channel B	351

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Name	Bit Description	Row
TMB7A	Transmitted Mirrored Bit 7, Channel A	349
TMB7B	Transmitted Mirrored Bit 7, Channel B	351
TMB8A	Transmitted Mirrored Bit 8, Channel A	349
TMB8B	Transmitted Mirrored Bit 8, Channel B	351
TPLLEXT	Update PLL using external signal	322
TPTP	The active relay time source is PTP	323
TQUAL1	Time quality, binary, add 1 when asserted	398
TQUAL2	Time quality, binary, add 2 when asserted	398
TQUAL4	Time quality, binary, add 4 when asserted	398
TQUAL8	Time quality, binary, add 8 when asserted	398
TR01	Trip Element 01 SELOGIC control equation asserted	108
TR02	Trip Element 02 SELOGIC control equation asserted	108
TR03	Trip Element 03 SELOGIC control equation asserted	108
TR04	Trip Element 04 SELOGIC control equation asserted	108
TR05	Trip Element 05 SELOGIC control equation asserted	108
TR06	Trip Element 06 SELOGIC control equation asserted	108
TR07	Trip Element 07 SELOGIC control equation asserted	108
TR08	Trip Element 08 SELOGIC control equation asserted	108
TR32G	Terminal T reverse ground directional declared	537
TR32P	Terminal T reverse phase directional picked up	535
TR32Q	Terminal T reverse negative-sequence directional picked up	534
TREA1	Synchrophasor SELOGIC control equation trigger Reason 1	389
TREA2	Synchrophasor SELOGIC control equation trigger Reason 2	389
TREA3	Synchrophasor SELOGIC control equation trigger Reason 3	389
TREA4	Synchrophasor SELOGIC control equation trigger Reason 4	389
TRGTR	Target reset	346
TRIP	General trip asserted	111
TRIP01	Trip Element 01 asserted	110
TRIP02	Trip Element 02 asserted	110
TRIP03	Trip Element 03 asserted	110
TRIP04	Trip Element 04 asserted	110
TRIP05	Trip Element 05 asserted	110
TRIP06	Trip Element 06 asserted	110
TRIP07	Trip Element 07 asserted	110
TRIP08	Trip Element 08 asserted	110
TRIPAUX	Trip generator auxiliary asserted	111
TRIPEX	Trip generator exciter asserted	111
TRIPLED	Trip LED on front of relay front panel	0
TRIPPM	Trip generator prime mover asserted	111
TRIPS	Trip Breaker S asserted	111
TRIPT	Trip Breaker T asserted	111

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Name	Bit Description	Row
TRIPU	Trip Breaker U asserted	111
TRIPY	Trip Breaker Y asserted	111
TSER	The active relay time source is serial IRIG	321
TSNTPB	Asserts if time was synchronized with backup NTP server before SNTP time-out period expired	322
TSNTPP	Asserts if time was synchronized with primary NTP server before SNTP time-out period expired	322
TSOK	Assert if current time source accuracy is sufficient for synchronized phasor measurements	321
TSSW	High-priority time source switching	322
TSYNC	Assert when ADC sampling is synchronized to a valid high-priority time source	321
TSYNCA	Assert while the time mark from time source or fixed internal source is not synchronized	321
TUPDH	Assert if update source is high-priority time source	321
TUTC1	IRIG-B offset hours from UTC time, binary, add 1 if asserted	397
TUTC2	IRIG-B offset hours from UTC time, binary, add 2 if asserted	397
TUTC4	IRIG-B offset hours from UTC time, binary, add 4 if asserted	397
TUTC8	IRIG-B offset hours from UTC time, binary, add 8 if asserted	397
TUTCH	IRIG-B offset half-hour from UTC time, binary, add 0.5 if asserted	397
TUTCS	IRIG-B offset hours sign from UTC time, subtract the UTC offset if TUTCS is asserted, add otherwise	397
U32F3P	Terminal U forward three-phase directional picked up	621
U32GE	Terminal U ground-directional calculation enabled	536
U32PE	Terminal U phase-directional calculation enabled	533
U32QE	Terminal U negative-sequence directional calculation enabled	533
UF32G	Terminal U forward ground directional declared	537
UF32P	Terminal U forward phase directional picked up	535
UF32Q	Terminal U forward negative-sequence directional picked up	534
ULCLS	Unlatch close SELOGIC element asserted, Terminal S	209
ULCLT	Unlatch close SELOGIC element asserted, Terminal T	209
ULCLU	Unlatch close SELOGIC element asserted, Terminal U	209
ULCLY	Unlatch close SELOGIC element asserted, Terminal Y	209
ULTR01	Unlatch trip Element 01 SELOGIC control equation asserted	109
ULTR02	Unlatch trip Element 02 SELOGIC control equation asserted	109
ULTR03	Unlatch trip Element 03 SELOGIC control equation asserted	109
ULTR04	Unlatch trip Element 04 SELOGIC control equation asserted	109
ULTR05	Unlatch trip Element 05 SELOGIC control equation asserted	109
ULTR06	Unlatch trip Element 06 SELOGIC control equation asserted	109
ULTR07	Unlatch trip Element 07 SELOGIC control equation asserted	109
ULTR08	Unlatch trip Element 08 SELOGIC control equation asserted	109
UPD_BLK	Block updating internal clock period and master time	440
UPD_EN	Enable updating internal clock with selected external time source	322
UR32G	Terminal U reverse ground directional declared	537
UR32P	Terminal U reverse phase directional picked up	535
UR32Q	Terminal U reverse negative-sequence directional picked up	534
VB001	Virtual Bit 001	387

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 84 of 90)

Name	Bit Description	Row
VB002	Virtual Bit 002	387
VB003	Virtual Bit 003	387
VB004	Virtual Bit 004	387
VB005	Virtual Bit 005	387
VB006	Virtual Bit 006	387
VB007	Virtual Bit 007	387
VB008	Virtual Bit 008	387
VB009	Virtual Bit 009	386
VB010	Virtual Bit 010	386
VB011	Virtual Bit 011	386
VB012	Virtual Bit 012	386
VB013	Virtual Bit 013	386
VB014	Virtual Bit 014	386
VB015	Virtual Bit 015	386
VB016	Virtual Bit 016	386
VB017	Virtual Bit 017	385
VB018	Virtual Bit 018	385
VB019	Virtual Bit 019	385
VB020	Virtual Bit 020	385
VB021	Virtual Bit 021	385
VB022	Virtual Bit 022	385
VB023	Virtual Bit 023	385
VB024	Virtual Bit 024	385
VB025	Virtual Bit 025	384
VB026	Virtual Bit 026	384
VB027	Virtual Bit 027	384
VB028	Virtual Bit 028	384
VB029	Virtual Bit 029	384
VB030	Virtual Bit 030	384
VB031	Virtual Bit 031	384
VB032	Virtual Bit 032	384
VB033	Virtual Bit 033	383
VB034	Virtual Bit 034	383
VB035	Virtual Bit 035	383
VB036	Virtual Bit 036	383
VB037	Virtual Bit 037	383
VB038	Virtual Bit 038	383
VB039	Virtual Bit 039	383
VB040	Virtual Bit 040	383
VB041	Virtual Bit 041	382
VB042	Virtual Bit 042	382

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 85 of 90)

Name	Bit Description	Row
VB043	Virtual Bit 043	382
VB044	Virtual Bit 044	382
VB045	Virtual Bit 045	382
VB046	Virtual Bit 046	382
VB047	Virtual Bit 047	382
VB048	Virtual Bit 048	382
VB049	Virtual Bit 049	381
VB050	Virtual Bit 050	381
VB051	Virtual Bit 051	381
VB052	Virtual Bit 052	381
VB053	Virtual Bit 053	381
VB054	Virtual Bit 054	381
VB055	Virtual Bit 055	381
VB056	Virtual Bit 056	381
VB057	Virtual Bit 057	380
VB058	Virtual Bit 058	380
VB059	Virtual Bit 059	380
VB060	Virtual Bit 060	380
VB061	Virtual Bit 061	380
VB062	Virtual Bit 062	380
VB063	Virtual Bit 063	380
VB064	Virtual Bit 064	380
VB065	Virtual Bit 065	379
VB066	Virtual Bit 066	379
VB067	Virtual Bit 067	379
VB068	Virtual Bit 068	379
VB069	Virtual Bit 069	379
VB070	Virtual Bit 070	379
VB071	Virtual Bit 071	379
VB072	Virtual Bit 072	379
VB073	Virtual Bit 073	378
VB074	Virtual Bit 074	378
VB075	Virtual Bit 075	378
VB076	Virtual Bit 076	378
VB077	Virtual Bit 077	378
VB078	Virtual Bit 078	378
VB079	Virtual Bit 079	378
VB080	Virtual Bit 080	378
VB081	Virtual Bit 081	377
VB082	Virtual Bit 082	377
VB083	Virtual Bit 083	377

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 86 of 90)

Name	Bit Description	Row
VB084	Virtual Bit 084	377
VB085	Virtual Bit 085	377
VB086	Virtual Bit 086	377
VB087	Virtual Bit 087	377
VB088	Virtual Bit 088	377
VB089	Virtual Bit 089	376
VB090	Virtual Bit 090	376
VB091	Virtual Bit 091	376
VB092	Virtual Bit 092	376
VB093	Virtual Bit 093	376
VB094	Virtual Bit 094	376
VB095	Virtual Bit 095	376
VB096	Virtual Bit 096	376
VB097	Virtual Bit 097	375
VB098	Virtual Bit 098	375
VB099	Virtual Bit 099	375
VB100	Virtual Bit 100	375
VB101	Virtual Bit 101	375
VB102	Virtual Bit 102	375
VB103	Virtual Bit 103	375
VB104	Virtual Bit 104	375
VB105	Virtual Bit 105	374
VB106	Virtual Bit 106	374
VB107	Virtual Bit 107	374
VB108	Virtual Bit 108	374
VB109	Virtual Bit 109	374
VB110	Virtual Bit 110	374
VB111	Virtual Bit 111	374
VB112	Virtual Bit 112	374
VB113	Virtual Bit 113	373
VB114	Virtual Bit 114	373
VB115	Virtual Bit 115	373
VB116	Virtual Bit 116	373
VB117	Virtual Bit 117	373
VB118	Virtual Bit 118	373
VB119	Virtual Bit 119	373
VB120	Virtual Bit 120	373
VB121	Virtual Bit 121	372
VB122	Virtual Bit 122	372
VB123	Virtual Bit 123	372
VB124	Virtual Bit 124	372

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 87 of 90)

Name	Bit Description	Row
VB125	Virtual Bit 125	372
VB126	Virtual Bit 126	372
VB127	Virtual Bit 127	372
VB128	Virtual Bit 128	372
VB129	Virtual Bit 129	371
VB130	Virtual Bit 130	371
VB131	Virtual Bit 131	371
VB132	Virtual Bit 132	371
VB133	Virtual Bit 133	371
VB134	Virtual Bit 134	371
VB135	Virtual Bit 135	371
VB136	Virtual Bit 136	371
VB137	Virtual Bit 137	370
VB138	Virtual Bit 138	370
VB139	Virtual Bit 139	370
VB140	Virtual Bit 140	370
VB141	Virtual Bit 141	370
VB142	Virtual Bit 142	370
VB143	Virtual Bit 143	370
VB144	Virtual Bit 144	370
VB145	Virtual Bit 145	369
VB146	Virtual Bit 146	369
VB147	Virtual Bit 147	369
VB148	Virtual Bit 148	369
VB149	Virtual Bit 149	369
VB150	Virtual Bit 150	369
VB151	Virtual Bit 151	369
VB152	Virtual Bit 152	369
VB153	Virtual Bit 153	368
VB154	Virtual Bit 154	368
VB155	Virtual Bit 155	368
VB156	Virtual Bit 156	368
VB157	Virtual Bit 157	368
VB158	Virtual Bit 158	368
VB159	Virtual Bit 159	368
VB160	Virtual Bit 160	368
VB161	Virtual Bit 161	367
VB162	Virtual Bit 162	367
VB163	Virtual Bit 163	367
VB164	Virtual Bit 164	367
VB165	Virtual Bit 165	367

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 88 of 90)

Name	Bit Description	Row
VB166	Virtual Bit 166	367
VB167	Virtual Bit 167	367
VB168	Virtual Bit 168	367
VB169	Virtual Bit 169	366
VB170	Virtual Bit 170	366
VB171	Virtual Bit 171	366
VB172	Virtual Bit 172	366
VB173	Virtual Bit 173	366
VB174	Virtual Bit 174	366
VB175	Virtual Bit 175	366
VB176	Virtual Bit 176	366
VB177	Virtual Bit 177	365
VB178	Virtual Bit 178	365
VB179	Virtual Bit 179	365
VB180	Virtual Bit 180	365
VB181	Virtual Bit 181	365
VB182	Virtual Bit 182	365
VB183	Virtual Bit 183	365
VB184	Virtual Bit 184	365
VB185	Virtual Bit 185	364
VB186	Virtual Bit 186	364
VB187	Virtual Bit 187	364
VB188	Virtual Bit 188	364
VB189	Virtual Bit 189	364
VB190	Virtual Bit 190	364
VB191	Virtual Bit 191	364
VB192	Virtual Bit 192	364
VB193	Virtual Bit 193	363
VB194	Virtual Bit 194	363
VB195	Virtual Bit 195	363
VB196	Virtual Bit 196	363
VB197	Virtual Bit 197	363
VB198	Virtual Bit 198	363
VB199	Virtual Bit 199	363
VB200	Virtual Bit 200	363
VB201	Virtual Bit 201	362
VB202	Virtual Bit 202	362
VB203	Virtual Bit 203	362
VB204	Virtual Bit 204	362
VB205	Virtual Bit 205	362
VB206	Virtual Bit 206	362

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 89 of 90)

Name	Bit Description	Row
VB207	Virtual Bit 207	362
VB208	Virtual Bit 208	362
VB209	Virtual Bit 209	361
VB210	Virtual Bit 210	361
VB211	Virtual Bit 211	361
VB212	Virtual Bit 212	361
VB213	Virtual Bit 213	361
VB214	Virtual Bit 214	361
VB215	Virtual Bit 215	361
VB216	Virtual Bit 216	361
VB217	Virtual Bit 217	360
VB218	Virtual Bit 218	360
VB219	Virtual Bit 219	360
VB220	Virtual Bit 220	360
VB221	Virtual Bit 221	360
VB222	Virtual Bit 222	360
VB223	Virtual Bit 223	360
VB224	Virtual Bit 224	360
VB225	Virtual Bit 225	359
VB226	Virtual Bit 226	359
VB227	Virtual Bit 227	359
VB228	Virtual Bit 228	359
VB229	Virtual Bit 229	359
VB230	Virtual Bit 230	359
VB231	Virtual Bit 231	359
VB232	Virtual Bit 232	359
VB233	Virtual Bit 233	358
VB234	Virtual Bit 234	358
VB235	Virtual Bit 235	358
VB236	Virtual Bit 236	358
VB237	Virtual Bit 237	358
VB238	Virtual Bit 238	358
VB239	Virtual Bit 239	358
VB240	Virtual Bit 240	358
VB241	Virtual Bit 241	357
VB242	Virtual Bit 242	357
VB243	Virtual Bit 243	357
VB244	Virtual Bit 244	357
VB245	Virtual Bit 245	357
VB246	Virtual Bit 246	357
VB247	Virtual Bit 247	357

Table 11.1 Alphabetical List of Relay Word Bits (Sheet 90 of 90)

Name	Bit Description	Row
VB248	Virtual Bit 248	357
VB249	Virtual Bit 249	356
VB250	Virtual Bit 250	356
VB251	Virtual Bit 251	356
VB252	Virtual Bit 252	356
VB253	Virtual Bit 253	356
VB254	Virtual Bit 254	356
VB255	Virtual Bit 255	356
VB256	Virtual Bit 256	356
VTHROKG	Generator voltage magnitude OK for frequency tracking	5
VTHROKS	System voltage magnitude OK for frequency tracking	5
WFLTA1	Windowed internal fault detected A-Phase, Element 1	72
WFLTA2	Windowed internal fault detected A-Phase, Element 2	82
WFLTB1	Windowed internal fault detected B-Phase, Element 1	72
WFLTB2	Windowed internal fault detected B-Phase, Element 2	83
WFLTC1	Windowed internal fault detected C-Phase, Element 1	72
WFLTC2	Windowed internal fault detected C-Phase, Element 2	83
Y32GE	Terminal Y ground directional calculation enabled	536
Y32PE	Terminal Y phase-directional calculation enabled	533
Y32QE	Terminal Y negative-sequence directional calculation enabled	533
YEAR1	IRIG-B year information, (add 1 year if bit asserted)	396
YEAR10	IRIG-B year information, (add 10 years if bit asserted)	396
YEAR2	IRIG-B year information, (add 2 years if bit asserted)	396
YEAR20	IRIG-B year information, (add 20 years if bit asserted)	396
YEAR4	IRIG-B year information, (add 4 years if bit asserted)	396
YEAR40	IRIG-B year information, (add 40 years if bit asserted)	396
YEAR8	IRIG-B year information, (add 8 years if bit asserted)	396
YEAR80	IRIG-B year information, (add 80 years if bit asserted)	396
YF32G	Terminal Y forward ground directional declared	537
YF32P	Terminal Y forward phase directional picked up	535
YF32Q	Terminal Y forward negative-sequence directional picked up	534
YR32G	Terminal Y reverse ground directional declared	537
YR32P	Terminal Y reverse phase directional picked up	535
YR32Q	Terminal Y reverse negative-sequence directional picked up	534
ZERO_CG	Generator zero crossing	5
ZERO_CS	System zero crossing	5
ZLIN	Load encroachment load-in element	61
ZLOAD	Load-in or load-out element picked up (ZLOUT + ZLIN)	61
ZLOUT	Load encroachment load-out element	61

Row List

Table 11.2 Row List of Relay Word Bits (Sheet 1 of 32)

Name	Bit Description	Row
Enable and Tripping Bits		
EN	Enable LED on relay front panel	0
TRIPLED	Trip LED on front of relay front panel	0
*	Reserved	0
TLED_*xx*	Target LED (01–24) on relay front panel	1–3
Pumped Storage		
*	Reserved	4
PSMODE	Generator in Pumped-Storage mode	4
Frequency Estimation		
ZERO_CS	System zero crossing	5
ZERO_CG	Generator zero crossing	5
VTHROKS	System voltage magnitude OK for frequency tracking	5
VTHROKG	Generator voltage magnitude OK for frequency tracking	5
FREQFZS	System frequency estimation frozen	5
FREQFZG	Generator frequency estimation frozen	5
FREQOKS	System frequency estimation OK	5
FREQOKG	Generator frequency estimation OK	5
Definite and Directional Overcurrent Elements		
50*v*P*x*[a, b]	Phase definite-time Element *x*, Terminal *v* asserted	6, 7, 10, 11, 15, 16, 19, 20
67*v*P*x*TC[a, b]	Phase-directional/torque-control enable definite-time Element *x*, Terminal *v*	6, 7, 10, 11, 15, 16, 19, 20
67*v*P*x*[a, b]	Phase-directional/torque-controlled Element *x*, Terminal *v* picked up	6, 7, 10, 11, 15, 16, 19, 20
67*v*P*x*T[a, b]	Phase-directional/torque-controlled Element *x*, Terminal *v* timed out	6, 7, 10, 11, 15, 16, 19, 20
50*v*Q*x*[a, b]	Negative-sequence definite-time Element *x*, Terminal *v* asserted	7, 8, 12, 13, 16, 17, 21, 22
67*v*Q*x*TC[a, b]	Negative-sequence directional/torque-control enable definite-time Element *x*, Terminal *v*	7, 8, 12, 13, 16, 17, 21, 22
67*v*Q*x*[a, b]	Negative-sequence directional/torque-controlled Element *x*, Terminal *v* picked up	7, 8, 12, 13, 16, 17, 21, 22
67*v*Q*x*T[a, b]	Negative-sequence directional/torque-controlled Element *x*, Terminal *v* timed out	7, 8, 12, 13, 16, 17, 21, 22
50*v*G*x*[a, b]	Residual definite-time Element *x*, Terminal *v* asserted	9, 10, 13, 14, 18, 19, 22, 23
67*v*G*x*TC[a, b]	Residual-directional/torque control enable definite-time Element *x*, Terminal *v*	9, 10, 13, 14, 18, 19, 22, 23
67*v*G*x*[a, b]	Residual-directional/torque-controlled Element *x*, Terminal *v* picked up	9, 10, 13, 14, 18, 19, 22, 23
67*v*G*x*T[a, b]	Residual-directional/torque-controlled Element *x*, Terminal *v* timed out	9, 10, 13, 14, 18, 19, 22, 23

Table 11.2 Row List of Relay Word Bits (Sheet 2 of 32)

Name	Bit Description	Row
Inverse-Time Overcurrent Elements		
51MM*xx*	Inverse-time Element (01–12) pickup setting outside of specified limits	24–32
51R*xx*	Inverse-time Element (01–12) reset	24–32
51S*xx*	Inverse-time Element (01–12) picked up	24–32
51T*xx*	Inverse-time Element (01–12) timed out	24–32
51TC*xx*	Inverse-time Element (01–12) enabled	24–32
51TM*xx*	Inverse-time Element (01–12) time-dial setting outside of specified limits	24–32
Under- and Overvoltage Elements		
27*n*P1[c]	Undervoltage Element *n*, Level 1 asserted	33–36
27*n*P1T[c]	Undervoltage Element *n*, Level 1 timed out	33–36
27*n*P2[c]	Undervoltage Element *n*, Level 2 asserted	33–36
27*n*P2T[c]	Undervoltage Element *n*, Level 2 timed out	33–36
27TC*n*[c]	Undervoltage Element *n*, torque control	33–36
*	Reserved	36
59*n*P1[c]	Overvoltage Element *n*, Level 1 asserted	37–40
59*n*P1T[c]	Overvoltage Element *n*, Level 1 timed out	37–40
59*n*P2[c]	Overvoltage Element *n*, Level 2 asserted	37–40
59*n*P2T[c]	Overvoltage Element *n*, Level 2 timed out	37–40
59TC*n*[c]	Overvoltage Element *n*, torque control	37–40
*	Reserved	40
Frequency Elements		
81D*n*[c]	Definite-time frequency element picked up, Level *n*	41–44
81D*n*OVR[c]	Definite-time overfrequency Level *n*	41–44
81D*n*T[c]	Definite-time under- and overfrequency element delay for Level *n*	41–44
81D*n*UDR[c]	Definite-time underfrequency Level *n*	41–44
81D*n*TC[c]	Definite-time frequency Element *n*, torque control	41–44
27B81G	Undervoltage supervision for generator frequency elements	44
27B81S	Undervoltage supervision for system frequency elements	44
Generator Monitoring Logic		
*	Reserved	45
FLDENRG	Generator field energized	45
ONLINE	Generator online logic	45
Reserved		
*	Reserved	46
Frequency Estimation Elements		
FTSSV1	Terminal V1 selected for system frequency tracking source	47
FTSSV2	Terminal V2 selected for system frequency tracking source	47
FTSSV3	Terminal V3 selected for system frequency tracking source	47
Rate-of-Change-of-Frequency Elements		
81R*n*OVR[c]	Definite-time over rate-of-change-of-frequency Level *n*	48, 49, 50, 51
81R*n*T	Definite-time over/under rate-of-change-of-frequency element delay for Level *n*	48, 49, 50, 51

Table 11.2 Row List of Relay Word Bits (Sheet 3 of 32)

Name	Bit Description	Row
81R*n*UDR	Definite-time under rate-of-change-of-frequency Level *n*	48, 49, 50, 51
81R*n*	Definite-time rate-of-change-of-frequency element picked up, Level *n*	48, 49, 50, 51
81R*n*TC	Definite-time rate-of-change-of-frequency Element *n*, torque control	48, 49, 50, 51
27B81RG	Undervoltage supervision for generator rate-of-change-of-frequency elements	51
27B81RS	Undervoltage supervision for system rate-of-change-of-frequency elements	51
Reserved		
*	Reserved	52
Inadvertent Energization Elements		
INADA*v*[a]	Inadvertent energization element armed, Terminal *v*	53
INAD*v*[a]	Inadvertent energization element picked up, Terminal *v*	54
INADT*v*[a]	Inadvertent energization delayed element picked up, Terminal *v*	55
INADTC*v*[a]	Inadvertent energization delayed element torque control, Terminal *v*	55
Restricted Earth Fault Elements		
TCREF*x*[b]	REF element *x* enabled	55, 56, 57
NDREF*x*[b]	Nondirectional REF Element *x* enabled	55, 56, 57
REFF*x*[b]	Earth fault inside restricted Zone *x*	55, 56, 58
REFR*x*[b]	Earth fault outside restricted Zone *x*	55, 56, 58
REF50*x*[b]	Neutral (operating current) instantaneous overcurrent Element *x* picked up	55, 56, 58
REF50T*x*[b]	Neutral instantaneous overcurrent Element *x* timed out	55, 57, 58
RF51TC*x*[b]	Inverse-time neutral overcurrent Element *x* enabled	55, 57, 58
REF51T*x*[b]	REF Element *x* TOC element timed out	55, 57, 58
REF51R*x*[b]	REF Element *x* TOC element reset	56, 57, 58
REF51*x*[b]	REF Element *x* TOC element picked up	56, 57, 58
RF50TC*x*[b]	Neutral instantaneous overcurrent Element *x* enabled	56, 57, 59
REF	Earth fault inside REF Element 1, 2, or 3 zones	59
REFBLK1	REF Element 1 phase fault or external ground fault detected	59
REFBLK2	REF Element 2 phase fault or external ground fault detected	59
REFBLK3	REF Element 3 phase fault or external ground fault detected	59
REFOCT1	REF Element 1 open CT, wiring, or setting error detected	59
REFOCT2	REF Element 2 open CT, wiring, or setting error detected	59
REFOCT3	REF Element 3 open CT, wiring, or setting error detected	59
Pole Open Logic		
3POS	Terminal S three-pole open asserted	60
3POT	Terminal T three-pole open asserted	60
3POU	Terminal U three-pole open asserted	60
3POY	Terminal Y three-pole open asserted	60
3PORS	Terminal S three-pole open asserted raw	60
3PORT	Terminal T three-pole open asserted raw	60
3PORU	Terminal U three-pole open asserted raw	60
3PORY	Terminal Y three-pole open asserted raw	60

Table 11.2 Row List of Relay Word Bits (Sheet 4 of 32)

Name	Bit Description	Row
Load Encroachment Element		
ZLOAD	Load-in or load-out element picked up (ZLOUT + ZLIN)	61
ZLIN	Load encroachment load-in element	61
ZLOUT	Load encroachment load-out element	61
*	Reserved	61
Impedance-Based Loss-of-Field Element		
40Z1	Loss-of-field Zone 1 picked up	62
40Z1T	Loss-of-field Zone 1 timed out	62
40Z2	Loss-of-field Zone 2 picked up	62
40Z2T	Loss-of-field Zone 2 timed out	62
40ZSUP	Loss-of-field supervision picked up	62
40Z1TC	Loss-of-field Zone 1 torque control	62
40Z2TC	Loss-of-field Zone 2 torque control	62
*	Reserved	62
Reserved		
*	Reserved	63
Phase Differential Elements		
87Z1	Differential Element 1 picked up	64
87R1	Restrained Differential Element 1 picked up	64
87U1	Unrestrained Differential Element 1 picked up	64
87RMS1	RMS Differential Element 1 picked up	64
87RTC1	Restrained Differential Element 1 Torque Control	64
87UTC1	Unrestrained Differential Element 1 Torque Control	64
87RMTC1	RMS Differential Element 1 Torque Control	64
CON1	External fault detected, Element 1	64
87*m*R1[d]	Phase *m* Restrained Differential Element 1 picked up	65
87UF1	Filtered Unrestrained Differential Element 1 picked up	65
87*m*UF1[d]	Phase *m* Filtered Unrestrained Differential Element 1 picked up	65
87UR1	Raw Unrestrained Differential Element 1 picked up	65
87*m*UR1[d]	Phase *m* Raw Unrestrained Differential Element 1 picked up	66
87*m*RMS1[d]	Phase *m* rms Differential Element 1 picked up	66
87*m*RHB1[d]	Phase *m* Restrained Differential Element 1 picked up through harmonic blocking	66–67
87*m*RHR1[d]	Phase *m* Restrained Differential Element 1 picked up through harmonic restraint	67
87*m*HB1[d]	Phase *m* Element 1 harmonic blocking picked up	67
87*m*HR1[d]	Phase *m* Element 1 harmonic restraint picked up	67–68
87XB21	Element 1 harmonic cross blocking picked up	68
87*m*B241[d]	Phase *m* Element 1 2nd or 4th harmonic blocking picked up	68
87*m*B51[d]	Phase *m* Element 1 5th harmonic blocking picked up	68–69
87*m*SEC1[d]	Differential Element 1 A-Phase, switch to secure	69
INR*m*1[d]	Inrush in Phase *m*, Element 1	69
INR1	Inrush in Element 1	69

Table 11.2 Row List of Relay Word Bits (Sheet 5 of 32)

Name	Bit Description	Row
DC*m*1[d]	DC component in Element 1 Phase *m*	70
CON*m*1[d]	External fault detected Phase *m*, Element 1	70
CON*m*AC1[d]	AC external fault detected Phase *m*, Element 1	70–71
CONAC1	AC external fault detected, Element 1	71
CON*m*DC1[d]	DC external fault detected Phase *m*, Element 1	71
CONDC1	DC external fault detected, Element 1	71
IFLT*m*1[d]	Internal fault detected Phase *m*, Element 1	71–72
IFLT1	Internal fault detected, Element 1	72
WFLT*m*1[d]	Windowed internal fault detected Phase *m*, Element 1	72
CTU*m*1[d]	CT unsaturated Phase *m*, Element 1	72
87*m*AP51[d]	5th harmonic alarm picked up, Phase *m*, Element 1	73
87AP51	5th harmonic alarm picked up, Element 1	73
87AD51	5th harmonic delayed alarm picked up, Element 1	73
GFLT*m*1[d]	Internal fault detected phase *m*, Element 1	73
87*m*B21[d]	Phase *m* Element 1 2nd harmonic blocking picked up	74
87B21	Element 1 2nd harmonic blocking picked up	74
87B51	Element 1 5th harmonic blocking picked up	74
87Z2	Differential Element 2 picked up	74
87R2	Restrained differential Element 2 picked up	74
87U2	Unrestrained differential Element 2 picked up	74
87RMS2	RMS differential Element 2 picked up	75
87RTC2	Restrained differential Element 2 Torque Control	75
87UTC2	Unrestrained differential Element 2 Torque Control	75
87RMTC2	RMS differential Element 2 Torque Control	75
CON2	External fault detected, element 2	75
87*m*R2[d]	Phase *m* restrained differential Element 2 picked up	75
87UF2	Filtered unrestrained differential Element 2 picked up	76
87*m*UF2[d]	Phase *m* filtered unrestrained differential Element 2 picked up	76
87UR2	Raw unrestrained differential Element 2 picked up	76
87*m*UR2[d]	Phase *m* raw unrestrained differential Element 2 picked up	76
87*m*RMS2[d]	Phase *m* rms differential Element 2 picked up	77
87*m*RHB2[d]	Phase *m* restrained differential Element 2 picked up through harmonic blocking	77
87*m*RHR2[d]	Phase *m* restrained differential Element 2 picked up through harmonic restraint	77–78
87*m*HB2[d]	Phase *m* Element 2 harmonic blocking picked up	78
87*m*HR2[d]	Phase *m* Element 2 harmonic restraint picked up	78
87XB22	Element 2 harmonic cross blocking picked up	78
87*m*B242[d]	Phase *m* Element 2 2nd or 4th harmonic blocking picked up	79
87*m*B52[d]	Phase *m* Element 2 5th harmonic blocking picked up	79
87*m*SEC2[d]	Differential Element 2 Phase *m*, switch to secure	79–80
INR*m*2[d]	Inrush in Phase *m*, Element 2	80
INR2	Inrush in Element 2	80

Table 11.2 Row List of Relay Word Bits (Sheet 6 of 32)

Name	Bit Description	Row
DC*m*2[d]	DC Component in Element 2 Phase *m*	80
CON*m*2[d]	External fault detected Phase *m*, Element 2	81
CON*m*AC2[d]	AC External fault detected Phase *m*, Element 2	81
CONAC2	AC External fault detected, Element 2	81
CON*m*DC2[d]	DC external fault detected A-Phase, Element 2	81–82
CONDC2	DC external fault detected, Element 2	82
IFLT*m*2[d]	Internal fault detected Phase *m*, Element 2	82
IFLT2	Internal fault detected, Element 2	82
WFLT*m*2[d]	Windowed internal fault detected Phase *m*, Element 2	82
CTU*m*2[d]	CT unsaturated Phase *m*, Element 2	83
87*m*AP52	5th harmonic alarm picked up, Phase *m*, Element 2	83
87AP52	5th harmonic alarm picked up, Element 2	84
87AD52	5th harmonic delayed alarm picked up, Element 2	84
GFLT*m*2[d]	Internal fault detected Phase *m*, Element 2	84
87*m*B22	Phase *m* Element 2 2nd harmonic blocking picked up[d]	84
87B22	Element 2 2nd harmonic blocking picked up	85
87B52	Element 2 5th harmonic blocking picked up	85
87TM1	Fundamental operate current picked up for three-legged core, Element 1	85
87TM*m*1[d]	Fundamental operate current picked up for single core, Phase *m*, Element 1	85
87TS1	Small and flat periods identified in the operate current for three-legged core, Element 1	85
87TS*m*1[d]	Small and flat periods identified in the operate current for single core, Phase *m*, Element 1	85–86
87WB*m*1[d]	87 Waveshape Inrush blocking logic asserted, Phase *m*, Element 1	86
87WB1	87 Waveshape Inrush blocking logic asserted, Element 1	86
87TBL*m*1[d]	LOW bipolar unsupervised signature identified, Phase *m*, Element 1	86–87
87TBH*m*1[d]	HIGH bipolar unsupervised signature identified, Phase *m*, Element 1	87
87UBL1	Bipolar unblocking identified, Element 1	87
87UBL*m*1[d]	Bipolar unblocking identified, phase *m*, Element 1	87
87BLC*m*1[d]	LOW bipolar, level low supervision, Phase *m*, Element 1	88
87BHC*m*1[d]	HIGH bipolar, level low supervision, Phase *m*, Element 1	88
87BPL1	LOW bipolar signature identified, Element 1	88
87BPL*m*1[d]	LOW bipolar signature identified, Phase *m*, Element 1	88–89
87BPH1	HIGH bipolar signature identified, Element 1	89
87BPH*m*1[d]	HIGH bipolar signature identified, Phase *m*, Element 1	89
87TM2	Fundamental operate current picked up for three-legged core, Element 2	89
87TM*m*2[d]	Fundamental operate current picked up for single core, Phase *m*, Element 2	89–90
87TS2	Small and flat periods identified in the operate current for three-legged core, Element 2	90
87TS*m*2[d]	Small and flat periods identified in the operate current for single core, Phase *m*, Element 2	90
87WB*m*2[d]	87 waveshape inrush blocking logic asserted, Phase *m*, Element 2	90–91
87WB2	87 waveshape inrush blocking logic asserted, Element 2	91
87TBL*m*2[d]	LOW bipolar unsupervised signature identified, Phase *m*, Element 2	91
87TBH*m*2[d]	HIGH bipolar unsupervised signature identified, Phase *m*, Element 2	91

Table 11.2 Row List of Relay Word Bits (Sheet 7 of 32)

Name	Bit Description	Row
87UBL2	Bipolar unblocking identified, Element 2	92
87UBL*m*2[d]	Bipolar unblocking identified, Phase *m*, Element 2	92
87BLC*m*2[d]	LOW bipolar, level low supervision, Phase *m*, Element 2	92
87BHC*m*2[d]	HIGH bipolar, level low supervision, Phase *m*, Element 2	92–93
87BPL2	LOW bipolar signature identified, Element 2	93
87BPL*m*2[d]	LOW bipolar signature identified, Phase *m*, Element 2	93
87BPH2	HIGH bipolar signature identified, Element 2	93
87BPH*m*2[d]	HIGH bipolar signature identified, Phase *m*, Element 2	93–94
Volts Per Hertz		
24D*k*1[e]	Volts-per-hertz Element *k* Level 1 asserted	95
24D*k*T1[e]	Volts-per-hertz Element *k* Level 1 timed out	95
24D*k*T2[e]	Volts-per-hertz Element *k* Level 2 timed out	95
24D*k*R2[e]	Volts-per-hertz Element *k* Level 2 reset	95
24TC*k*[e]	Volts-per-hertz predefined Element *k*, torque control	95
24D*k*T21[e]	Definite-time Element *k* Level 1 timed out	95
24D*k*R21[e]	Definite-time Element *k* Level 1 reset	95
24D*k*T22[e]	Definite-time Element *k* Level 2 timed out	95
24D*k*R22[e]	Definite-time Element *k* Level 2 reset	95
24U*k*R[e]	User-defined volts-per-hertz Curve *k* reset	99
24U*k*T[e]	User-defined volts-per-hertz Curve *k* timed out	99
24U*k*TC[e]	User-defined volts-per-hertz Curve *k*, torque control	99
Reserved		
*	Reserved	99
Negative-Sequence Differential Elements		
87Q1	Negative-sequence differential Element 1 asserted (interturn fault detected)	100
87QB1	Negative-sequence differential blocking Element 1 asserted	100
87QTC1	Negative-sequence differential Element 1, torque control	100
87Q2	Negative-sequence differential Element 2 asserted (interturn fault detected)	100
87QB2	Negative-sequence differential blocking Element 2 asserted	100
87QTC2	Negative-sequence differential Element 2, torque control	100
Reserved		
*	Reserved	100–103
Directional Power Elements		
32P01	Directional power Element 1 asserted	104
32T01	Directional power Element 1 timed out	104
32TC01	Directional power Element 1 torque control	104
32P02	Directional power Element 2 asserted	104
32T02	Directional power Element 2 timed out	104
32TC02	Directional power Element 2 torque control	104
32P03	Directional power Element 3 asserted	104
32T03	Directional power Element 3 timed out	104

Table 11.2 Row List of Relay Word Bits (Sheet 8 of 32)

Name	Bit Description	Row
32TC03	Directional power Element 3 torque control	105
32P04	Directional power Element 4 asserted	105
32T04	Directional power Element 4 timed out	105
32TC04	Directional power Element 4 torque control	105
32BIA01	Directional power Element 1 Bias	105
32BIA02	Directional power Element 2 Bias	105
32BIA03	Directional power Element 3 Bias	105
32BIA04	Directional power Element 4 Bias	105
Reserved		
*	Reserved	106–107
Breaker Trip Logic Elements		
TR*p*[f]	Terminal Element *p* SELOGIC control equation asserted	108
ULTR*p*[f]	Unlatch trip Element *p* SELOGIC control equation asserted	109
TRIP*p*[f]	Trip Element *p* asserted	110
TRIP*v*[a]	Trip Breaker *v* asserted	111
TRIPAUX	Trip generator auxiliary asserted	111
TRIP	Generator trip asserted	111
TRIPEX	Trip generator excited asserted	111
TRIPPM	Trip generator prime mover asserted	111
51 Voltage-Restrained Inverse-Time Overcurrent Element		
51V*m*[d]	Phase *m*, voltage-restrained instantaneous OC picked up	112
51V	Voltage-restrained instantaneous OC picked up	112
51V*m*T[d]	Phase *m*, voltage-restrained OC timed out	112
51VT	Voltage-restrained OC timed out	112
51V*m*R[d]	Phase *m*, voltage-restrained OC reset	113
51VR	Voltage-restrained OC reset	113
51VTC	Voltage-restrained OC torque control asserted	113
Reserved		
*	Reserved	113
51 Voltage-Controlled Inverse Time-Overcurrent Element		
51C*m*[d]	Phase *m*, voltage-controlled instantaneous OC picked up	114
51C	Voltage-controlled instantaneous OC picked up	114
51C*m*T[d]	Phase *m*, voltage-controlled OC timed out	114
51CT	Voltage-controlled OC timed out	114
51C*m*R[d]	Phase *m*, voltage-controlled OC reset	115
51CR	Voltage-controlled OC reset	115
51CTC	Voltage-controlled OC torque control asserted	115
Reserved		
*	Reserved	115–117

Table 11.2 Row List of Relay Word Bits (Sheet 9 of 32)

Name	Bit Description	Row
Open-Phase Detector		
OPH*m*S[d]	*m*-Phase, Terminal S open	118
OPHS	Terminal S open	118
OPH*m*T[d]	*m*-Phase, Terminal T open	118
OPHT	Terminal T open	118
OPH*m*U[d]	*m*-Phase, Terminal U open	119
OPHU	Terminal U open	119
OPH*m*Y[d]	*m*-Phase, Terminal Y open	119
OPHY	Terminal Y open	119
Reserved		
*	Reserved	120
Breaker Flashover		
FOBF*v*[a]	Breaker *v* breaker flashover asserted	121
BLKFO*v*[a]	Breaker *v* flashover logic blocked	121
Breaker Failure		
50F*v*[a]	Phase or neutral current above pickup, Terminal *v*	122, 124, 126, 128
BFIT*v*[a]	Breaker failure timer timed out, Terminal *v*	122, 124, 126, 128
RT*v*[a]	Retrip timer timed out/retrip command issued, Terminal *v*	122, 124, 126, 128
EBFIT*v*[a]	Externally initiated breaker failure timer timed out, Terminal *v*	122, 124, 126, 128
BFI*v*[a]	Breaker failure initiated, Terminal *v*	122, 124, 126, 128
EXBF*v*[a]	External breaker failure input initiated, Terminal *v*	122, 124, 126, 128
ATBFI*v*[a]	Alternative breaker failure initiated, Terminal *v*	122, 124, 126, 128
ATBFT*v*[a]	Alternative breaker failure timer timed out, Terminal *v*	122, 124, 126, 128
BFISPT*v*[a]	Breaker failure seal-in timer timed out, Terminal *v*	123, 125, 127, 129
ABFIT*v*[a]	Alternative breaker failure, Terminal *v*	123, 125, 127, 129
ENINBF*v*[a]	Neutral/residual breaker failure function enabled, Terminal *v*	123, 125, 127, 129
IA*v*BF[a]	A-Phase current above threshold, Terminal *v*	123, 125, 127, 129
IB*v*BF[a]	B-Phase current above threshold, Terminal *v*	123, 125, 127, 129
IC*v*BF[a]	C-Phase current above threshold, Terminal *v*	123, 125, 127, 129
IN*v*BF[a]	Neutral current above threshold, Terminal *v*	123, 125, 127, 129
FBF*v*[a]	Breaker failure asserted/initiated, Terminal *v*	123, 125, 127, 129
EXBFSP*v*[a]	External breaker failure supervisor, Terminal *v*	130
Reserved		
*	Reserved	131
52 Status		
52CL*v*[a]	Breaker closed, Terminal *v*	132
52AL*v*[a]	Breaker alarm, Terminal *v*	132
52A_*v*[a]	Breaker *v* normally open status	133
52B_*v*[a]	Breaker *v* normally closed status	133

Table 11.2 Row List of Relay Word Bits (Sheet 10 of 32)

Name	Bit Description	Row
89 Disconnect Switch Status		
89AM*xx*[g]	Disconnect *xx* N/O auxiliary contact	134, 135, 136, 137, 138, 139, 140, 141, 142, 143
89BM*xx*[g]	Disconnect *xx* N/C auxiliary contact	134, 135, 136, 137, 138, 139, 140, 141, 142, 143
89CL*xx*[g]	Disconnect *xx* closed	134, 135, 136, 137, 138, 139, 140, 141, 142, 143
89OPN*xx*[g]	Disconnect *xx* open	134, 135, 136, 137, 138, 139, 140, 141, 142, 143
89OIP*xx*[g]	Disconnect *xx* operation in progress	134, 135, 136, 137, 138, 139, 140, 141, 142, 143
89AL*xx*[g]	Disconnect *xx* alarm	134, 135, 136, 137, 138, 139, 140, 141, 142, 143
89CTL*xx*[g]	Disconnect *xx* control status	134, 135, 136, 137, 138, 139, 140, 141, 142, 143
89AL	Any disconnect alarm	134
89OIP	Any disconnect operation in progress	135
LOCAL	Local front panel control	136
*	Reserved	137, 138, 139, 140,141, 142
*	Reserved	143–145
89CLB*xx*[g]	Disconnect *xx* bus zone protection	146–147
*	Reserved	147–148
Bay Control Disconnect Control		
89OC*xx*[g]	ASCII open Disconnect *xx* command	149, 150, 151, 152, 153, 154, 155, 156, 157, 158
89CC*xx*[g]	ASCII close Disconnect *xx* command	149, 150, 151, 152, 153, 154, 155, 156, 157, 158
89OCM*xx*[g]	Mimic Disconnect *xx* open control	149, 150, 151, 152, 153, 154, 155, 156, 157, 158
89CCM*xx*[g]	Mimic Disconnect *xx* close control	149, 150, 151, 152, 153, 154, 155, 156, 157, 158
89OPE*xx*[g]	Disconnect open *xx* output	149, 150, 151, 152, 153, 154, 155, 156, 157, 158
89CLS*xx*[g]	Disconnect close *xx* output	149, 150, 151, 152, 153, 154, 155, 156, 157, 158

Table 11.2 Row List of Relay Word Bits (Sheet 11 of 32)

Name	Bit Description	Row
89OCN*xx*[g]	Open Disconnect *xx*	149, 150, 151, 152, 153, 154, 155, 156, 157, 158
89CCN*xx*[g]	Close Disconnect *xx*	149, 150, 151, 152, 153, 154, 155, 156, 157, 158
Reserved		
*	Reserved	159
Bay Control Disconnect Timers and Breaker Status		
89CBL*xx*[g]	Disconnect *xx* close block	160, 162, 163, 165, 166, 168, 169, 171, 172, 174
89OSI*xx*[g]	Disconnect *xx* open seal-in timer timed out	160, 162, 163, 165, 166, 168, 169, 171, 172, 174
89CSI*xx*[g]	Disconnect *xx* close seal-in timer timed out	160, 162, 163, 165, 166, 168, 169, 171, 172, 174
89OIR*xx*[g]	Disconnect *xx* open immobility timer reset	160, 162, 163, 165, 166, 168, 169, 171, 172, 174
89CIR*xx*[g]	Disconnect *xx* close immobility timer reset	160, 162, 164, 165, 167, 168, 170, 171, 173, 174
89OBL*xx*[g]	Disconnect *xx* open block	160, 162, 164, 165, 167, 168, 170, 171, 173, 174
89ORS*xx*[g]	Disconnect *xx* open reset	160, 162, 164, 165, 167, 168, 170, 171, 173, 174
89CRS*xx*[g]	Disconnect *xx* close reset	160, 162, 164, 165, 167, 168, 170, 171, 173, 174
89OIM*xx*[g]	Disconnect *xx* open immobility timer timed out	161, 163, 164, 166, 167, 169, 170, 172, 173, 175
89CIM*xx*[g]	Disconnect *xx* close immobility timer timed out	161, 163, 164, 166, 167, 169, 170, 172, 173, 175
*	Reserved	175
Breaker Monitor		
EB*v*MON[a]	Breaker monitoring Terminal *v* enabled	176, 177, 178, 179
B*v*BCWAL[a]	Breaker contact wear alarm, Breaker *v*	176, 177, 178, 179
B*v*ESOAL[a]	Slow electrical operate alarm, Breaker *v*	176, 177, 178, 179
B*v*BITAL[a]	Inactivity time alarm, Breaker *v*	176, 177, 178, 179
B*v*KAIAL[a]	Interrupted rms current alarm, Breaker *v*	176, 177, 178, 179
B*v*MSOAL[a]	Mechanical slow operation alarm, Breaker *v*	176, 177, 178, 179
B*v*MRTAL[a]	Motor run time alarm, Breaker *v*	176, 177, 178, 179
*	Reserved	176, 177, 178, 179

Table 11.2 Row List of Relay Word Bits (Sheet 12 of 32)

Name	Bit Description	Row
Reserved		
*	Reserved	180–183
Battery Monitor		
DC1F	DC Channel 1 failed	184
DC1W	DC Channel 1 warning	184
DC1G	DC Channel 1 ground fault detected	184
DC1R	DC Channel 1 excess ripples detected	184
Demand Metering		
EDM*xx*[g]	Demand metering Element *xx* enabled	185–187
DMP*xx*[g]	Demand metering Element *xx* enabled	185–187
*	Reserved	187
52 Open and Close		
CC*v*[a]	Breaker close command, Terminal *v*	188
OC*v*[a]	Breaker open command, Terminal *v*	188
Reserved		
*	Reserved	189–190
Local Bits		
LB*yy*[h]	Local Bit *yy* asserted	191–194
Local Control		
LB_SP*yy*[h]	Local Bit *yy* supervision enabled	195–198
LB_DP*yy*[h]	Local Bit *yy* status display enabled	199–202
Reserved		
*	Reserved	203
Remote Bits		
RB*yy*[h]	Remote Bit *yy* asserted	204–207
Setting Group Bits		
SG*n*[c]	Setting Group *n* is active	208
CHSG	Settings group changed	208
Breaker Close Logic Elements		
CL*v*[a]	Close SELOGIC, Terminal *v*	209
ULCL*v*[a]	Unlatch close SELOGIC element asserted, Terminal *v*	209
CLS*v*[a]	Close Breaker *v* asserted	210
CF*v*[a]	Close logic timer timed out, Terminal *v*	210
Reserved		
*	Reserved	211
Inputs		
*	Reserved	212–215
IN201–IN208	Input 201–208 asserted	216
IN209–IN216	Input 209–216 asserted	217
IN217–IN224	Input 217–224 asserted	218
*	Reserved	219

Table 11.2 Row List of Relay Word Bits (Sheet 13 of 32)

Name	Bit Description	Row
IN301–IN308	Input 301–308 asserted	220
IN309–IN316	Input 309–316 asserted	221
IN317–IN324	Input 317–324 asserted	222
*	Reserved	223
IN401–IN408	Input 401–408 asserted	224
IN409–IN416	Input 409–416 asserted	225
IN417–IN424	Input 417–424 asserted	226
*	Reserved	227
IN501–IN508	Input 501–508 asserted	228
IN509–IN516	Input 509–516 asserted	229
IN517–IN524	Input 517–524 asserted	230
*	Reserved	231
Protection SELOGIC (Variables)		
PSV01–PSV64	Protection SELOGIC Variable 01–64 asserted	232–239
Protection SELOGIC (Latches)		
PLT01–PLT32	Protection SELOGIC Latch 01–32 asserted	240–243
Protection SELOGIC (Conditioning Timers)		
PCT01Q–PCT32Q	Protection SELOGIC Conditioning Timer 01–32 asserted	244–247
Protection SELOGIC (Sequencing Timers)		
PST01Q–PST32Q	Protection SELOGIC Sequencing Timer 01–32 asserted	248–251
PST01R–PST32R	Protection SELOGIC Sequencing Timer 01–32 reset	252–255
Protection SELOGIC (Counters)		
PCN01Q–PCN32Q	Protection SELOGIC Counter 01–32 asserted	256–259
PCN01R–PCN32R	Protection SELOGIC Counter 01–32 reset	260–263
Automation SELOGIC (Variables)		
ASV001–ASV256	Automation SELOGIC Variable 001–256 asserted	264–295
Automation SELOGIC (Latches)		
ALT01–ALT32	Automation SELOGIC Latch 01–32 asserted	296–299
Automation SELOGIC (Sequencing Timers)		
AST01Q–AST32Q	Automation SELOGIC Sequencing Timer 01–32 asserted	300–303
AST01R–AST32R	Automation SELOGIC Sequencing Timer 01–32 reset	304–307
Automation SELOGIC (Counters)		
ACN01Q–ACN32Q	Automation SELOGIC Counter 01–32 asserted	308–311
ACN01R–ACN32R	Automation SELOGIC Counter 01–32 reset	312–315

Table 11.2 Row List of Relay Word Bits (Sheet 14 of 32)

Name	Bit Description	Row
SELOGIC Error and Status Reporting		
PUNRLBL	Protection SELOGIC control equation unresolved label	316
PFRTEX	Protection SELOGIC control equation first execution	316
MATHERR	SELOGIC control equation math error	316
AUNRLBL	Automation SELOGIC control equation unresolved label	316
AFRTEXP	Automation SELOGIC control equation first execution after protection settings change	316
AFRTEXA	Automation SELOGIC control equation first execution after automation settings change	316
*	Reserved	316
Alarms		
SALARM	Software alarm	317
HALARM	Hardware alarm	317
BADPASS	Invalid password attempt alarm	317
HALARML	Latched alarm for diagnostic failures	317
HALARMP	Pulsed alarm for diagnostic warnings	317
HALARMA	Pulse stream for unacknowledged diagnostic warnings	317
SETCHG	Pulsed alarm for settings changes	317
GRPSW	Pulsed alarm for group switches	317
ACCESS	A user is logged in at Access Level B or above	318
ACCESSP	Pulsed alarm for logins to Access Level B or above	318
EACC	Enable Level 1 access (SELOGIC control equation)	318
2AC	Enable Levels 1–2 access (SELOGIC control equation)	318
PASSDIS	Password disable jumper is installed	318
BRKENAB	Breaker control enable jumper is installed	318
Synchrophasor Configuration Error		
SPCER1	Synchrophasor configuration error on PORT 1	319
SPCER2	Synchrophasor configuration error on PORT 2	319
SPCER3	Synchrophasor configuration error on PORT 3	319
SPCERF	Synchrophasor configuration error on PORT F	319
Time and Date Management		
TIRIG	Assert while time is based on IRIG for both mark and value	321
TUPDH	Assert if update source is high-priority time source	321
TSYNCA	Assert while the time mark from time source or fixed internal source is not synchronized	321
TSOK	Assert if current time source accuracy is sufficient for synchronized phasor measurements	321
PMDOK	Assert if data acquisition system is operating correctly	321
TSYNC	Assert when ADC sampling is synchronized to a valid high-priority time source	321
TBNC	The active relay time source is BNC IRIG	321
TSER	The active relay time source is serial IRIG	321
BLKLPTS	Block low-priority source from updating relay time	322
UPD_EN	Enable updating internal clock with selected external time source	322
TLOCAL	Relay calendar clock and ADC sampling synchronized to a high-priority local time source	322
TPLLEXT	Update PLL using external signal	322

Table 11.2 Row List of Relay Word Bits (Sheet 15 of 32)

Name	Bit Description	Row
TSSW	High-priority time source switching	322
TGLOBAL	Relay calendar clock and ADC sampling synchronized to a high-priority Global time source	322
TSNTPP	Asserts if time was synchronized with primary NTP server before SNTP time-out period expired	322
TSNTPB	Asserts if time was synchronized with backup NTP server before SNTP time-out period expired	322
TPTP	The active relay time source is PTP	323
Outputs		
*	Reserved	324–327
OUT201–OUT208	Output 201–208 asserted	328
OUT209–OUT216	Output 209–216 asserted	329
OUT301–OUT308	Output 301–308 asserted	330
OUT309–OUT316	Output 309–316 asserted	331
OUT401–OUT408	Output 401–408 asserted	332
OUT409–OUT416	Output 409–416 asserted	333
OUT501–OUT508	Output 501–508 asserted	334
OUT509–OUT516	Output 509–516 asserted	335
Pushbuttons		
PB1–PB8	Pushbutton 01–08 asserted	336
PB9–PB12	Pushbutton 09–12 asserted	337
*	Reserved	337
PB1_PUL–PB8_PUL	Pushbutton 01–08 pulsed for 1 processing interval	338
PB9_PUL–PB12PUL	Pushbutton 09–12 pulsed for 1 processing interval	339
*	Reserved	339
Pushbutton LED Bits		
PB1_LED–PB8_LED	PB01_ LED–PB08_LED illuminated	340
PB9_LED–PB12LED	PB09_ LED–PB12LED illuminated	341
*	Reserved	341
*	Reserved	342–343
Data Reset Bits		
RST_DEM	Reset demand metering	344
RST_PDM	Reset peak demand metering	344
RST_ENE	Reset energy metering	344
RST_BKS	Reset Breaker S monitoring	344

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Name	Bit Description	Row
RST_BKT	Reset Breaker T monitoring	344
RST_BKU	Reset Breaker U monitoring	344
RST_BKY	Reset Breaker Y monitoring	344
RST_MM	Reset min/max metering	344
RST_BAT	Reset battery monitoring	345
RSTTRGT	Reset front-panel targets	345
RSTDNPE	Reset DNP fault summary data	345
RST_HAL	Reset HALARMA	345
*	Reserved	345
Target Logic Bits		
TRGTR	Target reset	346
*	Reserved	346
DRTRIG	Disturbance recording event triggered	346
ER	Event report triggered	346
FAULT	Fault detected	346
*	Reserved	347
MIRRORED BITS		
RMB1A–RMB8A	Received Mirrored Bit 1–8, Channel A	348
TMB1A–TMB8A	Transmitted Mirrored Bit 1–8, Channel A	349
RMB1B–RMB8B	Received Mirrored Bit 1–8, Channel B	350
TMB1B–TMB8B	Transmitted Mirrored Bit 1–8, Channel B	351
ROKA	MIRRORED BITS Channel A normal status in nonloopback mode	352
RBADA	Outage to large for normal MIRRORED BITS communications, Channel A	352
CBADA	Unavailability threshold exceeded for normal MIRRORED BITS communications, Channel A	352
LBOKA	MIRRORED BITS channel in loopback mode, Channel A	352
ANOKA	Analog transfer on MIRRORED BITS Channel A	352
DOKA	MIRRORED BITS Channel A in normal mode	352
*	Reserved	352
ROKB	MIRRORED BITS Channel B normal status in non loopback mode	353
RBADB	Outage to large for normal MIRRORED BITS communications, Channel B	353
CBADB	Unavailability threshold exceeded for normal MIRRORED BITS communications, Channel B	353
LBOKB	MIRRORED BITS channel in loopback mode, Channel B	353
ANOKB	Analog transfer on MIRRORED BITS Channel B	353
DOKB	MIRRORED BITS Channel B in normal mode	353
*	Reserved	353
Test Bits		
TESTDB2	Enhanced label based test bit	354
TESTDB	Database test bit	354

Table 11.2 Row List of Relay Word Bits (Sheet 17 of 32)

Name	Bit Description	Row
TESTFM	Fast Meter test bit	354
TESTPUL	Pulse test bit	354
LPHDSIM	IEC 61850 Logical Node for physical device simulation	354
*	Reserved	354
*	Reserved	355
Virtual Bits		
VB249–VB256	Virtual Bit 249–256	356
VB241–VB248	Virtual Bit 241–248	357
VB233–VB240	Virtual Bit 233–240	358
VB225–VB232	Virtual Bit 225–232	359
VB217–VB224	Virtual Bit 217–224	360
VB209–VB216	Virtual Bit 209–216	361
VB201–VB208	Virtual Bit 201–208	362
VB193–VB200	Virtual Bit 193–200	363
VB185–VB192	Virtual Bit 185–192	364
VB177–VB184	Virtual Bit 177–184	365
VB169–VB178	Virtual Bit 169–178	366
VB161–VB168	Virtual Bit 161–168	367
VB153–VB160	Virtual Bit 153–160	368
VB145–VB152	Virtual Bit 145–152	369
VB137–VB144	Virtual Bit 137–144	370
VB129–VB136	Virtual Bit 129–136	371
VB121–VB128	Virtual Bit 121–128	372
VB113–VB120	Virtual Bit 113–120	373
VB105–VB112	Virtual Bit 105–112	374
VB097–VB104	Virtual Bit 097–104	375
VB089–VB096	Virtual Bit 089–096	376
VB081–VB088	Virtual Bit 081–088	377
VB073–VB080	Virtual Bit 073–080	378
VB065–VB074	Virtual Bit 065–074	379
VB057–VB064	Virtual Bit 057–064	380
VB049–VB056	Virtual Bit 049–056	381
VB041–VB048	Virtual Bit 041–048	382
VB033–VB040	Virtual Bit 033–040	383
VB025–VB032	Virtual Bit 025–032	384
VB017–VB024	Virtual Bit 017–024	385
VB009–VB016	Virtual Bit 009–016	386
VB001–VB008	Virtual Bit 001–008	387
Fast SER Enable Bits		
FSERP1	Fast SER enabled for PORT 1	388
FSERP2	Fast SER enabled for PORT 2	388

Table 11.2 Row List of Relay Word Bits (Sheet 18 of 32)

Name	Bit Description	Row
FSERP3	Fast SER enabled for PORT 3	388
FSERPF	Fast SER enabled for front port	388
FSERP5	Fast SER enabled for network port	388
*	Reserved	388
Synchrophasor SELOGIC Control Equations		
PMTRIG	Synchrophasor SELOGIC control equation trigger	389
TREA4	Synchrophasor SELOGIC control equation trigger reason 4	389
TREA3	Synchrophasor SELOGIC control equation trigger reason 3	389
TREA2	Synchrophasor SELOGIC control equation trigger reason 2	389
TREA1	Synchrophasor SELOGIC control equation trigger reason 1	389
FROKPM	Synchrophasor frequency measurement OK	389
PMTEST	Synchrophasor test mode	389
*	Reserved	389
RTC Synchrophasor Status		
RTCSEQB	RTC Channel B data in sequence	390
RTCSEQA	RTC Channel A data in sequence	390
RTCCFGB	RTC Channel B configuration complete	390
RTCCFGA	RTC Channel A configuration complete	390
*	Reserved	390
RTCDLYB	Max RTC delay exceeded for Channel B	390
RTCDLYA	Max RTC delay exceeded for Channel A	390
RTCROK	Valid aligned RTC data available on all enabled channels	390
RTCROKB	Valid aligned RTC data available on Channel B	391
RTCROKA	Valid aligned RTC data available on Channel A	391
RTCENB	Valid remote synchrophasors received on Channel B	391
RTCENA	Valid remote synchrophasors received on Channel A	391
*	Reserved	391
RTCAD01–RTCAD08	RTC channel A remote date bit 01–08	392
RTCAD09–RTCAD16	RTC channel A remote date bit 09–16	393
RTCBD01–RTCBD08	RTC channel B remote date bit 01–08	394
RTCBD09–RTCBD16	RTC channel B remote date bit 09–16	395
IRIG-B Control Bits		
YEAR80	IRIG-B year information, (add 80 years if bit asserted)	396
YEAR40	IRIG-B year information, (add 40 years if bit asserted)	396
YEAR20	IRIG-B year information, (add 20 years if bit asserted)	396
YEAR10	IRIG-B year information, (add 10 years if bit asserted)	396
YEAR8	IRIG-B year information, (add 8 years if bit asserted)	396
YEAR4	IRIG-B year information, (add 4 years if bit asserted)	396

Table 11.2 Row List of Relay Word Bits (Sheet 19 of 32)

Name	Bit Description	Row
YEAR2	IRIG-B year information, (add 2 years if bit asserted)	396
YEAR1	IRIG-B year information, (add 1 year if bit asserted)	396
*	Reserved	397
TUTCH	IRIG-B offset half-hour from UTC time, binary, add 0.5 if asserted	397
TUTC8	IRIG-B offset hours from UTC time, binary, add 8 if asserted	397
TUTC4	IRIG-B offset hours from UTC time, binary, add 4 if asserted	397
TUTC2	IRIG-B offset hours from UTC time, binary, add 2 if asserted	397
TUTC1	IRIG-B offset hours from UTC time, binary, add 1 if asserted	397
TUTCS	IRIG-B offset hours sign from UTC time, subtract the UTC offset if TUTCS is asserted, add otherwise	397
DST	Daylight-saving time	398
DSTP	IRIG-B daylight-saving time pending	398
LPSEC	Leap second is added	398
LPSECP	Leap second pending	398
TQUAL8	Time quality, binary, add 8 when asserted	398
TQUAL4	Time quality, binary, add 4 when asserted	398
TQUAL2	Time quality, binary, add 2 when asserted	398
TQUAL1	Time quality, binary, add 1 when asserted	398
DUMMY		399
*	Reserved	399
Ethernet Switch		
LINK5A	Link status of the PORT 5A connection	400
LINK5B	Link status of the PORT 5B connection	400
LINK5C	Link status of the PORT 5C connection	400
LINK5D	Link status of the PORT 5D connection	400
LNKFAIL	Link status of the active station bus port	400
LNKFL2	Link status of the active process bus port	400
LINK5E	Link status of the PORT 5E connection	400
*	Reserved	400
P5ASEL	PORT 5A active/inactive	401
P5BSEL	PORT 5B active/inactive	401
P5CSEL	PORT 5C active/inactive	401
P5DSEL	PORT 5D active/inactive	401
P5ESEL	PORT 5E active/inactive	401
*	Reserved	401
Signal Profiling		
SPEN	Signal profiling enabled	402
*	Reserved	402
DNP Event Lock		
EVELOCK	Lock DNP events	403
*	Reserved	403

Table 11.2 Row List of Relay Word Bits (Sheet 20 of 32)

Name	Bit Description	Row
Fast Operate		
FOPF_01–FOPF_08	Port Front Fast Operate transmit Bit 1–8	404
FOPF_09–FOPF_16	Port Front Fast Operate transmit Bit 9–16	405
FOPF_17–FOPF_24	Port Front Fast Operate transmit Bit 17–24	406
FOPF_25–FOPF_32	Port Front Fast Operate transmit Bit 25–32	407
FOP1_01–FOP1_08	PORT 1 Fast Operate transmit Bit 1–8	408
FOP1_09–FOP1_16	PORT 1 Fast Operate transmit Bit 9–16	409
FOP1_17–FOP1_24	PORT 1 Fast Operate transmit Bit 17–24	410
FOP1_25–FOP1_32	PORT 1 Fast Operate transmit Bit 25–32	411
FOP2_01–FOP2_08	PORT 2 Fast Operate transmit Bit 1–8	412
FOP2_09–FOP2_16	PORT 2 Fast Operate transmit Bit 9–16	413
FOP2_17–FOP2_24	PORT 2 Fast Operate transmit Bit 17–24	414
FOP2_25–FOP2_32	PORT 2 Fast Operate transmit Bit 25–32	415
FOP3_01–FOP3_08	PORT 3 Fast Operate transmit Bit 1–8	416
FOP3_09–FOP3_16	PORT 3 Fast Operate transmit Bit 9–16	417
FOP3_17–FOP3_24	PORT 3 Fast Operate transmit Bit 17–24	418
FOP3_25–FOP3_32	PORT 3 Fast Operate transmit Bit 25–32	419
Instantaneous Metering (Power Factor Sign)		
LD*mv*PF[a, d]	Leading power factor, Phase *m*, Terminal *v*	420, 421, 422, 423
LD*v*3PF[a]	Leading three-phase power factor, Terminal *v*	420, 421, 422, 423
LG*mv*PF[a, d]	Lagging power factor, Phase *m*, Terminal *v*	420, 421, 422, 423
LG*v*3PF[a]	Lagging three-phase power factor, Terminal *v*	420, 421, 422, 423
LD*m*GPF[d]	Leading power factor, Phase *m*, Generator	424
LDG3PF	Leading three-phase power factor, Generator	424
LG*m*GPF[d]	Lagging power factor, Phase *m*, Generator	424
LGG3PF	Lagging three-phase power factor, Generator	424
Reserved		
*	Reserved	425–427
Sync Check		
FAST*v*[a]	Polarizing voltage slipping faster than Breaker *v* synchronizing voltage	428
SLOW*v*[a]	Polarizing voltage slipping slower than Breaker *v* synchronizing voltage	428

Table 11.2 Row List of Relay Word Bits (Sheet 21 of 32)

Name	Bit Description	Row
SFZBK*v*[a]	Breaker *v* slip frequency is less than 5 mHz	429
SFBK*v*[a]	Breaker *v* slip frequency is within acceptable slip frequency window	429
25A*v*[a]	Breaker *v* voltage within sync angle window uncompensated	430
25WC*v*[a]	Breaker *v* voltages within sync angle window compensated and unsupervised	430
25C*v*[a]	Breaker *v* voltages within sync angle window compensated	431
*	Reserved	431
59VP*v*[a]	Breaker *v* polarizing voltage within healthy voltage window	432
59VS*v*[a]	Breaker *v* synchronizing voltage within healthy voltage window	432
BSYNBK*v*[a]	Breaker *v* synchronism check blocked	433
25ENBK*v*[a]	Breaker *v* synchronism check enabled	433
GENVHI*v*[a]	Generator voltage is higher than Breaker *v* system voltage	434
GENVLO*v*[a]	Generator voltage is lower than Breaker *v* system voltage	434
25VDIF*v*[a]	Breaker *v* voltage difference is within acceptable window	435
*	Reserved	435
CFA*v*[a]	Breaker *v* close fail angle alarm	436
25BFSP*v*[a]	Breaker *v* closed indication for breaker failure	436
*	Reserved	437–438
Axion Status		
IO500OK	Communication status of Interface Board 500 when installed/commissioned	439
IO400OK	Communication status of Interface Board 400 when installed/commissioned	439
IO300OK	Communication status of Interface Board 300 when installed/commissioned	439
*	Reserved	439
Time and Date Management (Continued)		
SER_SET	Qualify serial IRIG-B time source	440
SER_RST	Disqualify serial IRIG-B time source	440
BNC_SET	Qualify BNC IRIG-B time source	440
BNC_RST	Disqualify BNC IRIG-B time source	440
BNC_OK	IRIG-B signal from BNC port is available and has sufficient quality	440
SER_OK	IRIG-B signal from serial PORT 1 is available and has sufficient quality	440
UPD_BLK	Block updating internal clock period and master time	440
BNC_BNP	Bad jitter on BNC port and the IRIG-B signal is lost afterwards	440
SER_BNP	Bad jitter on serial port and the IRIG-B signal is lost afterwards	441
BNC_TIM	A valid IRIG-B time source is detected on BNC port	441
SER_TIM	A valid IRIG-B time source is detected on serial port	441
PTP_TIM	A valid PTP time source is detected	441
PTP_SET	Qualify PTP time source	441
PTP_RST	Disqualify PTP time source	441
PTP_OK	PTP is available and has sufficient quality	441
PTPSYNC	Synchronized to a high-quality PTP source	441
SERSYNC	Synchronized to a high-quality serial IRIG source	442
BNCSYNC	Synchronized to a high-quality BNC IRIG source	442

Table 11.2 Row List of Relay Word Bits (Sheet 22 of 32)

Name	Bit Description	Row
P5ABSW	PORT 5A or 5B has just become active	442
PTP_BNP	Bad jitter on PTP signals and the PTP signal is lost afterwards	442
P5CDSW	PORT 5C or 5D has just become active	442
*	Reserved	442–443
RTD Status Bits		
RTS01OK–RTS08OK	RTD01–RTD08 healthy	444
RTS09OK–RTS16OK	RTD09–RTD16 healthy	445
RTS17OK–RTS24OK	RTD17–RTD24 healthy	446
MAMBOK3	Element 3, ambient temperature source healthy	447
MAMBOK2	Element 2, ambient temperature source healthy	447
MAMBOK1	Element 1, ambient temperature source healthy	447
AMB_F	Ambient temperature fault condition	447
RTSCFB	SEL-2600 communication failure (RTDB)	447
RTSFLB	SEL-2600 RAM failure (RTDB)	447
RTSCFA	SEL-2600 communication failure (RTDA)	447
RTSFLA	SEL-2600 RAM failure (RTDA)	447
RTS01SC–RTS08SC	RTD01–RTD08 short circuited	448
RTS09SC–RTS16SC	RTD09–RTD16 short circuited	449
RTS17SC–RTS24SC	RTD17–RTD24 short circuited	450
*	Reserved	451
RTS01OC–RTS08OC	RTD01–RTD08 open circuited	452
RTS09OC–RTS16OC	RTD09–RTD16 open circuited	453
RTS17OC–RTS24OC	RTD17–RTD24 open circuited	454
*	Reserved	455
21P Phase Distance Element		
21PAB1P	Zone 1 backup phase distance for AB loop picked up	456
21PBC1P	Zone 1 backup phase distance for BC loop picked up	456
21PCA1P	Zone 1 backup phase distance for CA loop picked up	456
21PAB2P	Zone 2 backup phase distance for AB loop picked up	456
21PBC2P	Zone 2 backup phase distance for BC loop picked up	456
21PCA2P	Zone 2 backup phase distance for CA loop picked up	456
21PAB1T	Zone 1 backup phase distance for AB loop timed out	456
21PBC1T	Zone 1 backup phase distance for BC loop timed out	456
21PCA1T	Zone 1 backup phase distance for CA loop timed out	457
21PAB2T	Zone 2 backup phase distance for AB loop timed out	457

Table 11.2 Row List of Relay Word Bits (Sheet 23 of 32)

Name	Bit Description	Row
21PBC2T	Zone 2 backup phase distance for BC loop timed out	457
21PCA2T	Zone 2 backup phase distance for CA loop timed out	457
21PRAB1	Zone 1 backup phase distance for AB loop is within resistive blinder	457
21PRBC1	Zone 1 backup phase distance for BC loop is within resistive blinder	457
21PRCA1	Zone 1 backup phase distance for CA loop is within resistive blinder	457
21PRAB2	Zone 2 backup phase distance for AB loop is within resistive blinder	457
21PRBC2	Zone 2 backup phase distance for BC loop is within resistive blinder	458
21PRCA2	Zone 2 backup phase distance for CA loop is within resistive blinder	458
21PZ1TC	Zone 1 backup phase distance torque control	458
21PZ2TC	Zone 2 backup phase distance torque control	458
21PZ1T	Zone 1 backup phase distance timed out	458
21PZ2T	Zone 2 backup phase distance timed out	458
*	Reserved	458–459
PQ Based Loss-of-Field Element		
40P1	Loss-of-field PQ Zone 1 picked up	460
40P1T	Loss-of-field PQ Zone 1 timed out	460
40P1TC	Loss-of-field PQ Zone 1 torque control	460
40P2	Loss-of-field PQ Zone 2 picked up	460
40P2T	Loss-of-field PQ Zone 2 timed out	460
40P2TC	Loss-of-field PQ Zone 2 torque control	460
40PUV	Loss-of-field PQ zone undervoltage element picked up	460
40P4	Capability curve limit Zone 4 picked up	460
40P4T	Capability curve limit Zone 4 timed out	461
40P4TC	Capability curve limit Zone 4 torque control	461
40P4OE	Capability curve limit Zone 4 overexcitation segment picked up	461
40P4PLG	Capability curve limit Zone 4 over power lag PF segment picked up	461
40P4PLD	Capability curve limit Zone 4 over power lead PF segment picked up	461
40P4UE	Capability curve limit Zone 4 underexcitation segment picked up	461
40P3	Steady-state stability limit Zone 3 picked up	461
40P3T	Steady-state stability limit Zone 3 timed out	461
40P3TC	Steady-state stability limit Zone 3 torque control	462
40PDAQ	40P dynamic zone analog quality	462
40PAT	Loss-of-field undervoltage acceleration timed out	462
*	Reserved	462
Loss-of-Potential Elements		
LOPV	Loss-of-potential Terminal V	463
LOPSV	Loss-of-potential element set logic picked up, Terminal V	463
LOPRV	Loss-of-potential element reset logic picked up, Terminal V	463
LOPTCV	Loss-of-potential element torque control, Terminal V	463
LOPDVV	Loss-of-potential element incremental voltage picked up, Terminal V	463
LOPDIV	Loss-of-potential element current disturbance picked up, Terminal V	463

Table 11.2 Row List of Relay Word Bits (Sheet 24 of 32)

Name	Bit Description	Row
LOPRSV	Loss-of-potential element voltage reset logic picked up, Terminal V	463
LOPIV	Loss-of-potential element incremental voltage logic picked up, Terminal V	463
LOPQV	Loss-of-potential element negative-sequence voltage logic picked up, Terminal V	464
60LOPV	60 loss-of-potential element voltage unbalance logic picked up, Terminal V	464
LOPZ	Loss-of-potential Terminal Z	464
LOPSZ	Loss-of-potential element set logic picked up, Terminal Z	464
LOPRZ	Loss-of-potential element reset logic picked up, Terminal Z	464
LOPTCZ	Loss-of-potential element torque control, Terminal Z	464
LOPDVZ	Loss-of-potential element incremental voltage picked up, Terminal Z	464
LOPDIZ	Loss-of-potential element current disturbance picked up, Terminal Z	464
LOPRSZ	Loss-of-potential element voltage reset logic picked up, Terminal Z	465
LOPIZ	Loss-of-potential element incremental voltage logic picked up, Terminal Z	465
LOPQZ	Loss-of-potential element negative-sequence voltage logic picked up, Terminal Z	465
60LOPZ	60 loss-of-potential element voltage unbalance logic picked up, Terminal Z	465
LOP3PHV	Loss-of-potential three-phase element picked up, Terminal V	465
LOP3PHZ	Loss-of-potential three-phase element picked up, Terminal Z	465
*	Reserved	465
Out-of-Step Elements		
78Z1	Out-of-step positive seq. impedance inside the characteristic	466
78R1	Out-of-step Blinder 1 picked up	466
78R2	Out-of-step Blinder 2 picked up	466
78SWNG	Out-of-step swing detected	466
78OOS	Out-of-step protection picked up	466
78OST	Out-of-step protection timed out	466
78OSTR	Out-of-step protection trip raw	466
78GCNT	Out-of-step generator slips equal to count	466
78SCNT	Out-of-step system slips equal to count	467
78CNT	Out-of-step slips equal to count	467
78TC	Out -of-step torque control	467
*	Reserved	467
RTC Status Bits		
RTC01OK–RTC08OK	RTC01–RTC08 healthy	468
RTC09OK–RTC16OK	RTC09–RTC16 healthy	469
RTC17OK–RTC24OK	RTC17–RTC24 healthy	470
*	Reserved	471
RTC01SC–RTC08SC	RTC01–RTC08 short circuited	472
RTC09SC–RTC16SC	RTC09–RTC16 short circuited	473

Table 11.2 Row List of Relay Word Bits (Sheet 25 of 32)

Name	Bit Description	Row
RTC17SC–RTC24SC	RTC17–RTC24 short circuited	474
*	Reserved	475
RTC01OC–RTC08OC	RTC01–RTC08 open circuited	476
RTC09OC–RTC16OC	RTC09–RTC16 open circuited	477
RTC17OC–RTC24OC	RTC17–RTC24 open circuited	478
*	Reserved	479
RTC01Q–RTC08Q	RTC01–RTC08 quality healthy	480
RTC09Q–RTC16Q	RTC09–RTC16 quality healthy	481
RTC17Q–RTC24Q	RTC17–RTC24 quality healthy	482
*	Reserved	483
81A Element		
81AB1–81AB8	81A element Band 1–8 pickup	484
81AB1T–81AB8T	81A element Band 1–8 delayed pickup	485
81ATC	81A element torque control	486
81AC	81A element pickup	486
81AT	81A element delayed pickup	486
*	Reserved	486–487
49RTD Element Bits		
49R01S2–49R08S2	RTD Element 01–08 Level 2 asserted	488
*	Reserved	489
49R09S2–49R12S2	RTD Element 09–12 Level 2 asserted	489
49R01S1–49R08S1	RTD Element 01–08 Level 1 asserted	490
*	Reserved	491
49R09S1–49R12S1	RTD Element 09–12 Level 1 asserted	491
49RLV1P–49RLV4P	RTD Element Location 1–4 voted trip asserted	492
Reserved		
*	Reserved	492–495
IEC 61850 Mode Control		
SC850TM	SELOGIC control for IEC 61850 test mode	496
SC850BM	SELOGIC control for IEC 61850 blocked mode	496
SC850SM	SELOGIC control for IEC 61850 simulation mode	496
Reserved		
*	Reserved	496–499

Table 11.2 Row List of Relay Word Bits (Sheet 26 of 32)

Name	Bit Description	Row
Bay Control Disconnect Timers and Breaker Status (Continued)		
52YTEST	Breaker Y test position	500
52UTEST	Breaker U test position	500
52TTEST	Breaker T test position	500
52STEST	Breaker S test position	500
52YRACK	Breaker Y rack position	500
52URACK	Breaker U rack position	500
52TRACK	Breaker T rack position	500
52SRACK	Breaker S rack position	500
Reserved		
*	Reserved	501–503
IEC Thermal Elements		
*	Reserved	504
THRLA3	Element 3 thermal level alarm	504
THRLA2	Element 2 thermal level alarm	504
THRLA1	Element 1 thermal level alarm	504
*	Reserved	504
THRLT3	Element 3 thermal level trip	504
THRLT2	Element 2 thermal level trip	504
THRLT1	Element 1 thermal level trip	504
*	Reserved	505
THLSW3	Element 3 thermal level switch	505
THLSW2	Element 2 thermal level switch	505
THLSW1	Element 1 thermal level switch	505
Reserved		
*	Reserved	505–507
25A Autosynchronizer		
25AST*v*[a]	Breaker *v* autosynchronizer start	508
25ACN*v*[a]	Breaker *v* autosynchronizer cancel	508
25AACT	Autosynchronizer active	509
25AFR	Frequency raise command	509
25AFL	Frequency lower command	509
25AVR	Voltage raise command	509
25AVL	Voltage lower command	509
25PHOK	Autosynchronizer phasing check is OK	509
*	Reserved	509
25A*v*ACT[a]	Breaker *v* autosynchronizer active	510
25A*v*TO[a]	Breaker *v* autosynchronizer timed out	510
Reserved		
*	Reserved	511

Table 11.2 Row List of Relay Word Bits (Sheet 27 of 32)

Name	Bit Description	Row
46 Current Unbalance		
46Q11	Generator current unbalance Element 1 Level 1 picked up	512
46Q12	Generator current unbalance Element 1 Level 2 picked up	512
46Q21	Generator current unbalance Element 2 Level 1 picked up	512
46Q22	Generator current unbalance Element 2 Level 2 picked up	512
46Q1TC	Generator current unbalance Element 1 torque control	512
46Q2TC	Generator current unbalance Element 2 torque control	512
46Q1T1	Generator current unbalance Element 1 Level 1 timed out	512
46Q1T2	Generator current unbalance Element 1 Level 2 timed out	512
46Q1R2	Generator current unbalance Element 1 Level 2 reset	512
46Q2R2	Generator current unbalance Element 2 Level 2 reset	512
Reserved		
*	Reserved	513–515
64 Insulation Resistance		
64SIQ	64S remote insulation measurement quality bit	516
64S1	64S instantaneous Level 1 pickup	516
64S2	64S instantaneous Level 2 pickup	516
64S1T	64S time-delayed Level 1 pickup	516
64S2T	64S time-delayed Level 2 pickup	516
64S1TC	64S torque-controlled Element 1 picked up	516
64S2TC	64S torque-controlled Element 2 picked up	516
*	Reserved	516
*	Reserved	517
64FIQ	64F remote insulation measurement quality bit	518
64F1	64F instantaneous Level 1 pickup	518
64F2	64F instantaneous Level 2 pickup	518
64F1T	64F time-delayed Level 1 pickup	518
64F2T	64F time-delayed Level 2 pickup	518
64F1TC	64F torque-controlled Element 1 picked up	518
64F2TC	64F torque-controlled Element 2 picked up	518
64FFLT	64F indicate a non-functional SEL-2664 or communication failure	519
64FCF	64F indicate SEL-2664 communication failure	519
64FDF	64F indicate SEL-2664 status failure	519
64G Stator Ground		
64G1TC1	64G Element 1 Level 1 fundamental neutral overvoltage torque control	520
64G1TC2	64G Element 1 Level 2 fundamental neutral overvoltage torque control	520
64G11	64G Element 1 Level 1 pickup	520
64G12	64G Element 1 Level 2 pickup	520
64G1T1	64G Element 1 Level 1 delayed pickup	520
64G1T2	64G Element 1 Level 2 delayed pickup	520
64G1	64G Element 1 pickup	520

Table 11.2 Row List of Relay Word Bits (Sheet 28 of 32)

Name	Bit Description	Row
64G1T	64G Element 1 delayed pickup	520
64G2TC	64G Element 2 third-harmonic differential undervoltage torque control	521
64G2DIF	64G Element 2 third-harmonic differential asserted	521
64G2UV	64G Element 2 undervoltage asserted	521
64G2DEN	64G Element 2 third-harmonic differential internal enable	521
64G2UEN	64G Element 2 undervoltage internal enable	521
64G2	64G Element 2 pickup	521
64G2T	64G Element 2 delayed pickup	521
64GALT	64G alternative setting selected	521
64G3TC	64G Element 3 third-harmonic ratio torque control	522
64G3EN	64G Element 3 enable	522
64G3	64G Element 3 pickup	522
64G3T	64G Element 3 delayed pickup	522
64GATC	64G accelerated torque control	522
64GTIN	64G normal trip input asserted	522
64GAIN	64G accelerated input asserted	522
64GT	64G stator ground trip pickup	522
64GAOK	64G third-harmonic angle check OK	523
*	Reserved	523
Outputs (Continued)		
OUT202T	Aurora timer for OUT202 is timing	524
OUT2022	Aurora timer for OUT202 Binary 2	524
OUT2021	Aurora timer for OUT202 Binary 1	524
OUT201T	Aurora timer for OUT201 is timing	524
OUT2012	Aurora timer for OUT201 Binary 2	524
OUT2011	Aurora timer for OUT201 Binary 1	524
*	Reserved	524
Reserved		
*	Reserved	525–527
Transducer Analog		
AO201CL	AO201 is clamped to AO201L setting value	528
AO201CH	AO201 is clamped to AO201H setting value	528
AO201FL	AO201 loop is faulted	528
AO202CL	AO202 is clamped to AO202L setting value	528
AO202CH	AO202 is clamped to AO202H setting value	528
AO202FL	AO202 loop is faulted	528
*	Reserved	528
Reserved		
*	Reserved	529–531

Table 11.2 Row List of Relay Word Bits (Sheet 29 of 32)

Name	Bit Description	Row
Directional Element		
DIRBLK*v*[a]	Terminal *v* directional element block SELOGIC control equation	532
*	Reserved	532
*v*32QE[a]	Terminal *v* negative-sequence directional calculation enabled	533
*v*32PE[a]	Terminal *v* phase-directional calculation enabled	533
*v*F32Q[a]	Terminal *v* forward negative-sequence directional picked up	534
*v*R32Q[a]	Terminal *v* reverse negative-sequence directional picked up	534
*v*F32P[a]	Terminal *v* forward phase-directional picked up	535
*v*R32P[a]	Terminal *v* reverse phase-directional picked up	535
*v*32GE[a]	Terminal *v* ground directional calculation enabled	536
*	Reserved	536
*v*F32G[a]	Terminal *v* forward ground directional declared	537
*v*R32G[a]	Terminal *v* reverse ground directional declared	537
Reserved		
*	Reserved	538–539
60P Split Phase		
60P*m*HS[d]	Phase *m* highset level picked up	540
60P*m*HT[d]	Phase *m* highset level picked up with timer	540
60PHS	Highset level picked up	540
60PHT	Highset level picked up with timer	540
60P*m*LS[d]	Phase *m* lowset level picked up	541
60P*m*LT[d]	Phase *m* lowset level picked up with timer	541
60PLS	Lowset level picked up	541
60PLT	Lowset level picked up with timer	541
60PS	60P picked up	542
60PT	60P picked up with timer	542
60P*m*HSS[d]	Phase *m* highset level switched to secure	542
60P*m*LSS[d]	Phase *m* lowset level switched to secure	542
60PHTC	60P highset level torque control picked up	543
60PLTC	60P lowset level torque control picked up	543
60PLR	Lowset reset picked up	543
*	Reserved	543
60N Split Phase		
60NHS	Highset level picked up	544
60NHT	Highset level picked up with timer	544
60NLS	Lowset level picked up	544
60NLT	Lowset level picked up with timer	544
60NS	60N picked up	544
60NT	60N picked up with timer	544
60NHSS	Highset level switched to secure	544
60NLSS	Lowset level switched to secure	544

Table 11.2 Row List of Relay Word Bits (Sheet 30 of 32)

Name	Bit Description	Row
Reserved		
*	Reserved	545
IED Local Remote Bits		
LOC	Control authority at local (bay) level	548
SC850LS	SELOGIC control for control authority at station level	548
MLTLEV	Multi-level control authority	548
LOCSTA	Control authority at station level	548
*	Reserved	548
*	Reserved	548
*	Reserved	548
*	Reserved	548
Automation SELOGIC (Conditioning Timers)		
ACT01Q–ACT32Q	Automation SELOGIC Conditioning Timers 01–32 asserted	552–555
Local Bits and Local Control (Continued)		
LB*zz*[i]	Local Bit *zz* asserted	556–559
LB_SP*zz*[i]	Local Bit *zz* supervision enabled	560–563
LB_DP*zz*[i]	Local Bit *zz* status display enabled	564–567
Remote Bits (Continued)		
RB*zz*[i]	Remote Bit *zz* asserted	568–571
IEC 61850 Interlock		
89ENO01	Disconnect 1 open control operation enabled	572
89ENC01	Disconnect 1 close control operation enabled	572
89ENO02	Disconnect 2 open control operation enabled	572
89ENC02	Disconnect 2 close control operation enabled	572
89ENO03	Disconnect 3 open control operation enabled	573
89ENC03	Disconnect 3 close control operation enabled	573
89ENO04	Disconnect 4 open control operation enabled	573
89ENC04	Disconnect 4 close control operation enabled	573
89ENO05	Disconnect 5 open control operation enabled	573
89ENC05	Disconnect 5 close control operation enabled	573
89ENO06	Disconnect 6 open control operation enabled	573
89ENC06	Disconnect 6 close control operation enabled	573
89ENO07	Disconnect 7 open control operation enabled	573
89ENC07	Disconnect 7 close control operation enabled	573
89ENO08	Disconnect 8 open control operation enabled	573
89ENC08	Disconnect 8 close control operation enabled	573
89ENO09	Disconnect 9 open control operation enabled	573
89ENC09	Disconnect 9 close control operation enabled	573
89ENO10	Disconnect 10 open control operation enabled	574
89ENC10	Disconnect 10 close control operation enabled	574

Table 11.2 Row List of Relay Word Bits (Sheet 31 of 32)

Name	Bit Description	Row
*	Reserved	574
*	Reserved	574
*	Reserved	574
*	Reserved	574
*	Reserved	575
*	Reserved	575
*	Reserved	575
*	Reserved	575
*	Reserved	575
*	Reserved	575
*	Reserved	575
*	Reserved	575
BKENCS	Circuit Breaker S close control operation enabled	576
BKENOS	Circuit Breaker S open control operation enabled	576
BKENCT	Circuit Breaker T close control operation enabled	576
BKENOT	Circuit Breaker T open control operation enabled	576
BKENCU	Circuit Breaker U close control operation enabled	576
BKENOU	Circuit Breaker U open control operation enabled	576
BKENCY	Circuit Breaker Y close control operation enabled	576
BKENOY	Circuit Breaker Y open control operation enabled	576
SCBKSBC	SELOGIC control for IEC 61850 close block equation for Circuit Breaker S	577
SCBKSBO	SELOGIC control for IEC 61850 open block equation for Circuit Breaker S	577
SCBKTBC	SELOGIC control for IEC 61850 close block equation for Circuit Breaker T	577
SCBKTBO	SELOGIC control for IEC 61850 open block equation for Circuit Breaker T	577
SCBKUBC	SELOGIC control for IEC 61850 close block equation for Circuit Breaker U	577
SCBKUBO	SELOGIC control for IEC 61850 open block equation for Circuit Breaker U	577
SCBKYBC	SELOGIC control for IEC 61850 close block equation for Circuit Breaker Y	577
SCBKYBO	SELOGIC control for IEC 61850 open block equation for Circuit Breaker Y	577
Parallel Redundancy Protocol Supervision		
PRPAGOK	PRP **PORT 5A** GOOSE status	580
PRPBGOK	PRP **PORT 5B** GOOSE status	580
PRPCGOK	PRP **PORT 5C** GOOSE status	580
PRPDGOK	PRP **PORT 5D** GOOSE status	580
PRPASOK	PRP **PORT 5A** SV status	580
PRPBSOK	PRP **PORT 5B** SV status	580
High-Availability Seamless Redundancy (HSR) Supervision		
HSRAOK	HSR Port 5A status	582
HSRBOK	HSR Port 5B status	582

Table 11.2 Row List of Relay Word Bits (Sheet 32 of 32)

Name	Bit Description	Row
HSRCOK	HSR Port 5C status	582
HSRDOK	HSR Port 5D status	582

[a] v = S, T, U, Y.
[b] x = 1, 2, 3.
[c] n = 1–6.
[d] m= A, B, C.
[e] k = 1, 2.
[f] p = 01–08.
[g] xx = 1–10.
[h] yy = 1–32.
[i] zz = 33–64

S E C T I O N 1 2

Analog Quantities

This section contains tables of the analog quantities available within the SEL-400G Advanced Generator Protection System.

Use *Table 12.1* and *Table 12.2* as a reference for labels in this manual and as a resource for quantities you use in SELOGIC control equation relay settings. *Table 12.1* lists the analog quantities alphabetically, and *Table 12.2* groups the analog quantities by function.

Table 12.1 Analog Quantities Sorted Alphabetically (Sheet 1 of 10)

Analog Labels	Analog Quantity Description	Units
24RPU*a*[a]	Volts per hertz ratio element *a*	%
25AFCT	25A autosynchronizer frequency pulse count	Unitless
25ANG*n*[b]	25 sync-check angle difference for Breaker *n*	° (±180)
25ANGC*n*[b]	25 sync-check compensated angle difference for Breaker *n*	° (±180)
25AVCT	25A autosynchronizer voltage pulse count	Unitless
25DIFV*n*[b]	25 sync-check voltage difference for Breaker *n*	%
25SLIP*n*[b]	25 sync-check slip frequency Breaker *n*	Hz
25VPFA	25 sync-check polarizing voltage angle	° (±180)
25VPFM	25 sync-check polarizing voltage magnitude	V (secondary)
25VS*n*FA[b]	25 sync-check synchronizing voltage angle for Breaker *n*	° (±180)
25VS*n*FM[b]	25 sync-check synchronizing voltage magnitude for Breaker *n*	V (secondary)
3I0*r*A[c]	Instantaneous zero-sequence current angle, Terminal *r*	° (±180°)
3I0*r*I[c]	Instantaneous zero-sequence current, imaginary component, Terminal *r*	A (secondary)
3I0*r*M[c]	Instantaneous zero-sequence current magnitude, Terminal *r*	A (secondary)
3I0*r*R[c]	Instantaneous zero-sequence current, real component, Terminal *r*	A (secondary)
3I0*s*AC[d]	40 ms average zero-sequence current angle, Terminal *s*	° (±180°)
3I0*s*MC[d]	40 ms average zero-sequence current magnitude, Terminal *s*	A (primary)
3I0*s*MS[d]	1 s average zero-sequence current magnitude, Terminal *s*	A (secondary)
3I0GA	Instantaneous zero-sequence current angle, generator neutral side	° (±180°)
3I0GI	Instantaneous zero-sequence current, imaginary component, generator neutral side	A (secondary)
3I0GM	Instantaneous zero-sequence current magnitude, generator neutral side	A (secondary)
3I0GR	Instantaneous zero-sequence current, real component, generator neutral side	A (secondary)
3I2*r*A[c]	Instantaneous negative-sequence current angle, Terminal *r*	° (±180°)
3I2*r*I[c]	Instantaneous negative-sequence current, imaginary component, Terminal *r*	A (secondary)
3I2*r*M[c]	Instantaneous negative-sequence current magnitude, Terminal *r*	A (secondary)
3I2*r*R[c]	Instantaneous negative-sequence current, real component, Terminal *r*	A (secondary)
3I2*s*AC[d]	40 ms average negative-sequence current angle, Terminal *s*	° (±180°)
3I2*s*MC[d]	40 ms average negative-sequence current magnitude, Terminal *s*	A (primary)

Table 12.1 Analog Quantities Sorted Alphabetically (Sheet 2 of 10)

Analog Labels	Analog Quantity Description	Units
3I2*s*MS[d]	1 s average negative-sequence current magnitude, Terminal *s*	A (secondary)
3I2GA	Instantaneous negative-sequence current angle, generator neutral side	° (±180°)
3I2GI	Instantaneous negative-sequence current, imaginary component, generator neutral side	A (secondary)
3I2GM	Instantaneous negative-sequence current magnitude, generator neutral side	A (secondary)
3I2GR	Instantaneous negative-sequence current, real component, generator neutral side	A (secondary)
3P*s*FC[d]	40 ms average three-phase fundamental active power, Terminal *s*	MW (primary)
3P*s*FS[d]	1 s average three-phase fundamental active power, Terminal *s*	MW (primary)
3P*s*MWHN[d]	Three-phase active energy imported, Terminal *s*	MWh (primary)
3P*s*MWHP[d]	Three-phase active energy exported, Terminal *s*	MWh (primary)
3P*s*MWHT[d]	Total three-phase active energy, Terminal *s*	MWh (primary)
3P*t*F[e]	Instantaneous three-phase fundamental active power, Terminal *t*	W (secondary)
3PF*s*C[d]	Three-phase displacement power factor, Terminal *s*	— (unitless, ratio)
3Q*s*FC[d]	40 ms average three-phase fundamental reactive power, Terminal *s*	MVAR (primary)
3Q*s*FS[d]	1 s average three-phase fundamental reactive power, Terminal *s*	MVAR (primary)
3Q*s*MVHN[d]	Three-phase reactive energy imported, Terminal *s*	MVAR (primary)
3Q*s*MVHP[d]	Three-phase reactive energy exported, Terminal *s*	MVAR (primary)
3Q*s*MVHT[d]	Total three-phase reactive energy, Terminal *s*	MVAR (primary)
3Q*t*F[e]	Instantaneous three-phase fundamental reactive power, Terminal *t*	VARs (secondary)
3S*s*FC[d]	40 ms average three-phase fundamental apparent power, Terminal *s*	MVA (primary)
3S*s*FS[d]	1 s average three-phase fundamental apparent power, Terminal *s*	MVA (primary)
3S*t*F[e]	Instantaneous three-phase fundamental apparent power, Terminal *t*	VA (secondary)
3V0*k*A[f]	Instantaneous zero-sequence voltage angle, Terminal *k*	° (±180°)
3V0*k*AC[f]	40 ms average zero-sequence voltage angle, Terminal *k*	° (±180°)
3V0*k*I[f]	Instantaneous zero-sequence voltage, imaginary component, Terminal *k*	V (secondary)
3V0*k*M[f]	Instantaneous zero-sequence voltage magnitude, Terminal *k*	V (secondary)
3V0*k*MC[f]	40 ms average zero-sequence voltage magnitude, Terminal *k*	kV (primary)
3V0*k*R[f]	Instantaneous zero-sequence voltage, real component, Terminal *k*	V (secondary)
3V0Z3A	Instantaneous third-harmonic zero-sequence voltage angle, Terminal Z	° (±180°)
3V0Z3I	Instantaneous third-harmonic zero-sequence voltage, imaginary component, Terminal Z	V (secondary)
3V0Z3M	Instantaneous third-harmonic zero-sequence voltage magnitude, Terminal Z	V (secondary)
3V0Z3R	Instantaneous third-harmonic zero-sequence voltage, real component, Terminal Z	V (secondary)
3V0Z3AC	40 ms average filtered generator terminal third-harmonic voltage angle	° (±180°)
3V0Z3MC	40 ms average filtered generator terminal third-harmonic voltage magnitude	kV (primary)
3V2*k*A[f]	Instantaneous negative-sequence voltage angle, Terminal *k*	° (±180°)
3V2*k*AC[f]	40 ms average negative-sequence voltage angle, Terminal *k*	° (±180°)
3V2*k*I[f]	Instantaneous negative-sequence voltage, imaginary component, Terminal *k*	V (secondary)
3V2*k*M[f]	Instantaneous negative-sequence voltage magnitude, Terminal *k*	V (secondary)
3V2*k*MC[f]	40 ms average negative-sequence voltage magnitude, Terminal *k*	kV (primary)
3V2*k*R[f]	Instantaneous negative-sequence voltage, real component, Terminal *k*	V (secondary)
40PDAM	Loss-of-field dynamic zone parameter data	Unitless
40PPLD	Loss-of-field Zone 4 active power lead PF limit	W (secondary)

Table 12.1 Analog Quantities Sorted Alphabetically (Sheet 3 of 10)

Analog Labels	Analog Quantity Description	Units
40PPLG	Loss-of-field Zone 4 active power lag PF limit	W (secondary)
40PPMX	Loss-of-field Zone 4 maximum active power	W (secondary)
40PPU	Loss-of-field Zone 4 active power UPF limit	W (secondary)
40PQMN	Loss-of-field Zone 4 minimum reactive power	VARs (secondary)
40PQMX	Loss-of-field Zone 4 maximum reactive power	VARs (secondary)
40PQZ2	Loss-of-field Zone 2 reactive power limit	VARs (secondary)
51P[012]	51 element [012] pickup value	A (secondary)
51TD[012]	51 element [012] time dial setting	–
60LDVM	60 LOP voltage unbalance magnitude	V (secondary)
64FIR	64F field insulation resistance	kΩ
64GMMS	Multi-machine selectivity calculation	Unitless
64SIC	64S stator insulation capacitance	µF
64SIR	64S stator insulation resistance	kΩ
78CN	Out-of-step command pole slip count	Unitless
78GCN	Out-of-step generator pole slip count	Unitless
78SCN	Out-of-step system pole slip count	Unitless
81AB[8]S	81A element band [8] accumulated time	s
87*pr*DC[c, g]	DC component, Phase *p*, Terminal *r*	pu
87*p*M2*a*[a, g]	2nd harmonic current content of operating current, Phase *p*, Element *a*	pu
87*p*M4*a*[a, g]	4th harmonic current content of operating current, Phase *p*, Element *a*	pu
87*p*M5*a*[a, g]	5th harmonic current content of operating current, Phase *p*, Element *a*	pu
87*p*OPF*a*[a, g]	Filtered differential operating current, Phase *p*, Element *a*	pu
87*p*OPR*a*[a, g]	RMS differential operating current, Phase *p*, Element *a*	pu
87*p*RTF*a*[a, g]	Filtered differential restraint current, Phase *p*, Element *a*	pu
87*p*RTH*a*[a, g]	Biased differential harmonic restraint current, Phase *p*, Element *a*	pu
87*p*RTK*a*[a, g]	Biased differential restraint current, Phase *p*, Element *a*	pu
87QOPF*a*[a]	Negative-sequence differential operating current, Element *a*	pu
87QRTF*a*[a]	Negative-sequence differential restraint current, Element *a*	pu
ACN[032]CV	Automation SELOGIC Counter [032] current value	–
ACN[032]PV	Automation SELOGIC Counter preset value	–
ACT[032]DO	Automation SELOGIC conditioning timer dropout time	s
ACT[032]PU	Automation SELOGIC conditioning timer pickup time	s
ACTGRP	Active Settings Group (1–6)	
AMV[0256]	Automation SELOGIC math variable	–
AST[032]ET	Automation SELOGIC sequencing timer elapsed time	s
AST[032]PT	Automation SELOGIC sequencing timer preset time	s
B*n*ATRI*p*[b, g]	Breaker *n* accumulated trip current for Phase *p*	A (primary)
B*n*BCWP*p*[b, g]	Breaker *n* breaker-contact wear for Pole *p*	%
B*n*EOTC*p*[b, g]	Breaker *n* average electrical operating time (close for Phase *p*)	ms
B*n*EOTT*p*[b, g]	Breaker *n* average electrical operating time (trip for Phase *p*)	ms
B*n*LEOC*p*[b, g]	Breaker *n* last electrical operating time (close for Phase *p*)	ms

Table 12.1 Analog Quantities Sorted Alphabetically (Sheet 4 of 10)

Analog Labels	Analog Quantity Description	Units
B*n*LEOT*p*[b, g]	Breaker *n* last electrical operating time (trip for Phase *p*)	ms
B*n*LMOTC[b]	Breaker *n* last mechanical operating time (close)	ms
B*n*LMOTT[b]	Breaker *n* last mechanical operating time (trip)	ms
B*n*LTRI*p*[b, g]	Breaker *n* last interrupted trip current for Phase *p*	%
B*n*MOTC[b]	Breaker *n* average mechanical operating time (close)	ms
B*n*MOTT[b]	Breaker *n* average mechanical operating time (trip)	ms
B*n*OPCN[b]	Breaker *n* number of operations (trip)	N/A
BNCDSJI	BNC port 100 PPS data stream jitter	µs
BNCOTJF	Fast converging BNC port ON TIME marker jitter, coarse accuracy	µs
BNCOTJS	Slow converging BNC port ON TIME marker jitter, fine accuracy	µs
BNCTBTW	Time between BNC 100 PPS pulses	µs
CTR*r*[c]	Current transformer ratio for Terminal *r*	–
CTRY*b*[h]	Current transformer ratio for Terminal Y*b*	–
CUR_SRC	Current high-priority time source	
DCMAX	Maximum DC 1 voltage	V
DCMIN	Minimum DC 1 voltage	V
DCNE	Average negative-to-ground DC 1 voltage	V
DCPO	Average positive-to-ground DC 1 voltage	V
DCRI	AC ripple of DC 1 voltage	V
DDOM	UTC date, day of the month (1–31)	day
DDOW	UTC date, day of the week (1-SU,.., 7-SA)	–
DDOY	UTC date, day of the year (1–366)	day
DFDTPP	Rate-of-change-of-frequency for synchrophasor data, P Class	Hz/s
DFDTPPD	Rate-of-change-of-frequency for synchrophasor data, delayed for RTC alignment	Hz/s
DFREQPG	Generator rate-of-change-of-frequency	Hz/s
DFREQPS	System rate-of-change-of-frequency	Hz/s
DLDOM	Local date, day of the month (1–31)	day
DLDOW	Local date, day of the week (1-SU,.., 7-SA)	–
DLDOY	Local date, day of the year (1–366)	day
DLMON	Local date, month (1–12)	month
DLYEAR	Local date, year (2000–2200)	year
DM[010]	Demand metering value	A (secondary)
DMM[010]	Demand metering maximum value	A (secondary)
DMON	UTC date, month (1–12)	month
DYEAR	UTC date, year (2000–2200)	year
FOSPM	Fraction of second of the synchrophasor data packet	s
FOSPMD	Fraction of second of the synchrophasor data packet, delayed for RTC alignment	s
FREQPG	Generator frequency	Hz
FREQPP	Frequency for synchrophasor data, P Class	Hz
FREQPPD	Frequency for synchrophasor data, delayed for RTC alignment	Hz
FREQPS	System frequency	Hz

Table 12.1 Analog Quantities Sorted Alphabetically (Sheet 5 of 10)

Analog Labels	Analog Quantity Description	Units
HMAX*b*[h]	IEC equivalent max. thermal level, Element *b*	pu
HSRSRTP	Round-trip time for HSR supervision frames on process bus	µs
HSRSRTS	Round-trip time for HSR supervision frames on station bus	µs
I*pr*FA[c, g]	Instantaneous filtered phase current angle, Phase *p*, Terminal *r*	° (±180°)
I*pr*FI[c, g]	Instantaneous filtered phase current, imaginary component, Phase *p*, Terminal *r*	A (secondary)
I*pr*FM[c, g]	Instantaneous filtered phase current magnitude, Phase *p*, Terminal *r*	A (secondary)
I*pr*FR[c, g]	Instantaneous filtered phase current, real component, Phase *p*, Terminal *r*	A (secondary)
I*pr*PPAD[c, g]	Synchrophasor current angle, Phase *p*, Terminal *r*, delayed for RTC alignment	° (±180°)
I*pr*PPI[c, g]	Synchrophasor current imaginary component, P Class, Phase *p*, P Class, Terminal *r*	A (primary)
I*pr*PPID[c, g]	Synchrophasor current imaginary component, Phase *p*, Terminal *r*, delayed for RTC alignment	A (primary)
I*pr*PPMD[c, g]	Synchrophasor current magnitude, Phase *p*, Terminal *r*, delayed for RTC alignment	A (primary)
I*pr*PPR[c, g]	Synchrophasor current real component, P Class, Phase *p*, P Class, Terminal *r*	A (primary)
I*pr*PPRD[c, g]	Synchrophasor current real component, Phase *p*, Terminal *r*, delayed for RTC alignment	A (primary)
I*ps*FAC[d, g]	40 ms average filtered phase current angle, Phase *p*, Terminal *s*	° (±180°)
I*ps*FMC[d, g]	40 ms average filtered phase current magnitude, Phase *p*, Terminal *s*	A (primary)
I*ps*RMS[d, g]	Instantaneous rms phase current magnitude, Phase *p*, Terminal *s*	A (secondary)
I*p*GFA[g]	Instantaneous filtered phase current angle, Phase *p*, generator neutral side	° (±180°)
I*p*GFI[g]	Instantaneous filtered phase current, imaginary component, Phase *p*, generator neutral side	A (secondary)
I*p*GFM[g]	Instantaneous filtered phase current magnitude, Phase *p*, generator neutral side	A (secondary)
I*p*GFR[g]	Instantaneous filtered phase current, real component, Phase *p*, generator neutral side	A (secondary)
I*p*GRC[g]	40 ms average rms phase current magnitude, Phase *p*, Terminal G	A (primary)
I*p*GRS[g]	1 second average rms phase current magnitude, Phase *p*, Terminal G	A (secondary)
I*pp*GFCM[i]	Instantaneous filtered GSU compensated phase-to-phase current magnitude, Phase *pp*, generator neutral side	A (secondary)
I1*r*A[c]	Instantaneous positive-sequence current angle, Terminal *r*	° (±180°)
I1*r*I[c]	Instantaneous positive-sequence current, imaginary component, Terminal *r*	A (secondary)
I1*r*M[c]	Instantaneous positive-sequence current magnitude, Terminal *r*	A (secondary)
I1*r*PPAD[c]	Positive-sequence synchrophasor current angle, Terminal *r*, delayed for RTC alignment	° (±180°)
I1*r*PPI[c]	Positive-sequence synchrophasor current imaginary component, P Class, Terminal *r*	A (primary)
I1*r*PPID[c]	Positive-sequence synchrophasor current imaginary component, Terminal *r*, delayed for RTC alignment	A (primary)
I1*r*PPMD[c]	Positive-sequence synchrophasor current magnitude, Terminal *r*, delayed for RTC alignment	A (primary)
I1*r*PPR[c]	Positive-sequence synchrophasor current real component, P class, Terminal *r*	A (primary)
I1*r*PPRD[c]	Positive-sequence synchrophasor current real component, Terminal *r*, delayed for RTC alignment	A (primary)
I1*r*R[c]	Instantaneous positive-sequence current, real component, Terminal *r*	A (secondary)
I1*s*AC[d]	40 ms average positive-sequence current angle, Terminal *s*	° (±180°)
I1*s*MC[d]	40 ms average positive-sequence current magnitude, Terminal *s*	A (primary)
I1GA	Instantaneous positive-sequence current angle, generator neutral side	° (±180°)
I1GI	Instantaneous positive-sequence current, imaginary component, generator neutral side	A (secondary)
I1GM	Instantaneous positive-sequence current magnitude, generator neutral side	A (secondary)
I1GMB	Unbalance biased current for generator terminal	A (secondary)

Table 12.1 Analog Quantities Sorted Alphabetically (Sheet 6 of 10)

Analog Labels	Analog Quantity Description	Units
I1GR	Instantaneous positive-sequence current, real component, generator neutral side	A (secondary)
I2GP	Generator fundamental negative-sequence current	%
I2GPEQ	Generator negative-sequence equivalent harmonic current	%
IMAX*r*F[c]	Instantaneous filtered maximum phase-current magnitude, Terminal *r*	A (secondary)
IMAX*s*R[d]	Instantaneous rms maximum phase current, Terminal *s*	A (secondary)
IMAXGF	Instantaneous filtered maximum phase-current magnitude, generator neutral side	A (secondary)
IMIN*r*F[c]	Instantaneous filtered minimum phase-current magnitude, Terminal *r*	A (secondary)
IMIN*s*R[d]	Instantaneous rms minimum phase current, Terminal *s*	A (secondary)
IMINGF	Instantaneous filtered minimum phase-current magnitude, generator neutral side	A (secondary)
IOREFM*b*[h]	Operate current magnitude, Element *b*	pu
IRREFM*b*[h]	Reference current magnitude, Element *b*	pu
IY*b*FA[h]	Instantaneous filtered current angle, Terminal Y*b*	° (±180°)
IY*b*FAC[h]	40 ms average filtered current angle, Channel *b*, Terminal Y	° (±180°)
IY*b*FI[h]	Instantaneous filtered current, imaginary component, Terminal Y*b*	A (secondary)
IY*b*FM[h]	Instantaneous filtered current magnitude, Terminal Y*b*	A (secondary)
IY*b*FMC[h]	40 ms average filtered current magnitude, Channel *b*, Terminal Y	A (primary)
IY*b*FR[h]	Instantaneous filtered current, real component, Terminal Y*b*	A (secondary)
MAMB*b*[h]	Ambient temperature value in °C, Element *b*	°C
MB[7]A	Channel A received Mirrored Bit analog values	–
MB[7]B	Channel B received Mirrored Bit analog values	–
NEW_SRC	Selected high-priority time source	
P*ps*FC[d, g]	40 ms average phase fundamental active power, Phase *p*, Terminal *s*	MW (primary)
P*pt*F[e, g]	Instantaneous phase fundamental active power, Phase *p*, Terminal *t*	W (secondary)
PCN[032]CV	Protection SELOGIC Counter [032] current value	–
PCN[032]PV	Protection SELOGIC counter preset value	–
PCT[032]DO	Protection SELOGIC conditioning timer dropout time	s
PCT[032]PU	Protection SELOGIC conditioning timer pickup time	s
PF*ps*C[d, g]	Phase displacement power factor, Phase *p*, Terminal *s*	– (unitless, ratio)
PMV[064]	Protection SELOGIC math variable	–
PST[032]ET	Protection SELOGIC sequencing timer elapsed time	s
PST[032]PT	Protection SELOGIC sequencing timer preset time	s
PTPDSJI	PTP 100 PPS data stream jitter in µs	µs
PTPMCC	PTP master clock class enumerated value	
PTPOFST	Clock offset between PTP master and relay time	ns
PTPOTJF	Fast converging PTP ON TIME marker jitter in µs, coarse accuracy	µs
PTPOTJS	Slow converging PTP ON TIME marker jitter in µs, fine accuracy	µs
PTPPORT	Active PTP port number	N/A
PTPSTEN	PTP port state enumerated value	
PTPTBTW	Time between PTP 100 PPS pulses in µs	µs
PTR*k*[f]	Potential transformer ratio for Terminal *k*	–
PTRV*b*[h]	Potential transformer ratio for Terminal V*b*	–

Table 12.1 Analog Quantities Sorted Alphabetically (Sheet 7 of 10)

Analog Labels	Analog Quantity Description	Units
PTRZ2	Potential transformer ratio for Terminal Z2	–
Q*ps*FC[d, g]	40 ms average phase fundamental reactive power, Phase *p*, Terminal *s*	MVAR (primary)
Q*pt*F[e, g]	Instantaneous phase fundamental reactive power, Phase *p*, Terminal *t*	VAR (secondary)
RA[0256]	Remote analogs	N/A
RAO[064]	Remote analog output	–
REFGEN	Reference angle for generator side phasors	° (±180)
REFSYS	Reference angle for system side phasors	° (±180)
RLYTEMP	Relay temperature (°C temperature of the box)	°C
RTC[024]TV	Remote temperature value in °C, RTC[024]	°C
RTCAA0[8]	Channel A remote synchrophasor analogs (units depends on remote synchrophasor contents)	
RTCAP[032]	Channel A remote synchrophasor phasors (units depends on remote synchrophasor contents)	
RTCBA0[8]	Channel B remote synchrophasor analogs (units depends on remote synchrophasor contents)	
RTCBP[032]	Channel B remote synchrophasor phasors (units depends on remote synchrophasor contents)	
RTCDFA	Rate-of-change of Channel A remote frequency (from remote synchrophasors)	Hz/s
RTCDFB	Rate-of-change of Channel B remote frequency (from remote synchrophasors)	Hz/s
RTCFA	Channel A remote frequency (from remote synchrophasors)	Hz
RTCFB	Channel B remote frequency (from remote synchrophasors)	Hz
RTS[024]TV	RTD temperature value in °C, RTS[024]	°C
S*ps*FC[d, g]	40 ms average phase fundamental apparent power, Phase *p*, Terminal *s*	MVA (primary)
S*pt*F[e, g]	Instantaneous phase fundamental apparent power, Phase *p*, Terminal *t*	VA (secondary)
SERDSJI	Serial port 100 PPS data stream jitter	µs
SEROTJF	Fast converging serial port ON TIME marker jitter, coarse accuracy	µs
SEROTJS	Slow converging serial port ON TIME marker jitter, fine accuracy	µs
SERTBTW	Time between serial 100 PPS pulses	µs
SODPM	Second of day of the synchrophasor data packet	s
SODPMD	Second of day of the synchrophasor data packet, delayed for RTC alignment	s
SQUAL	Synchronization accuracy of the selected high-priority time source	µs
THR	UTC time, hour (0–23)	hr
THRL*b*[h]	IEC thermal level value, Element *b*	pu
THTCU*b*[h]	IEC thermal capacity used, Element *b*	Unitless
THTRIP*b*[h]	IEC thermal time to trip, Element *b*	s
TLHR	Local time, hour (0–23)	hr
TLMIN	Local time, minute (0–59)	min
TLMSEC	Local time, milliseconds (0–999)	ms
TLNSEC	Local time, nanoseconds (0–999999)	ns
TLODMS	Local time of day in milliseconds (0–86400000)	ms
TLSEC	Local time, seconds (0–59)	s
TMIN	UTC time, minute (0–59)	min
TMSEC	UTC time, milliseconds (0–999)	ms
TNSEC	UTC time, nanoseconds (0–999999)	ns
TODMS	UTC time of day in milliseconds (0–86400000)	ms

Table 12.1 Analog Quantities Sorted Alphabetically (Sheet 8 of 10)

Analog Labels	Analog Quantity Description	Units
TQUAL	Worst-case clock time error of the selected high-priority time source	s
TSEC	UTC time, seconds (0–59)	s
TUTC	Offset from local time to UTC time	hr
V*pk*FA[f, g]	Instantaneous filtered phase-to-neutral voltage angle, Phase *p*, Terminal *k*	° (±180°)
V*pk*FAC[f, g]	40 ms average filtered phase-to-neutral voltage angle, Phase *p*, Terminal *k*	° (±180°)
V*pk*FI[f, g]	Instantaneous filtered phase-to-neutral voltage, imaginary component, Phase *p*, Terminal *k*	V (secondary)
V*pk*FM[f, g]	Instantaneous filtered phase-to-neutral voltage magnitude, Phase *p*, Terminal *k*	V (secondary)
V*pk*FMC[f, g]	40 ms average filtered phase-to-neutral voltage magnitude, Phase *p*, Terminal *k*	kV (primary)
V*pk*FR[f, g]	Instantaneous filtered phase-to-neutral voltage, real component, Phase *p*, Terminal *k*	V (secondary)
V*pk*PPAD[f, g]	Synchrophasor voltage angle, Phase *p*, Terminal *k*, delayed for RTC alignment	° (±180°)
V*pk*PPI[f, g]	Synchrophasor voltage imaginary component, P class, Phase *p*, P Class, Terminal *k*	kV (primary)
V*pk*PPID[f, g]	Synchrophasor voltage imaginary component, Phase *p*, Terminal *k*, delayed for RTC alignment	kV (primary)
V*pk*PPMD[f, g]	Synchrophasor voltage magnitude, Phase *p*, Terminal *k* delayed for RTC alignment	kV (primary)
V*pk*PPR[f, g]	Synchrophasor voltage real component, P Class, Phase *p*, P Class, Terminal *k*	kV (primary)
V*pk*PPRD[f, g]	Synchrophasor voltage real component, Phase *p*, Terminal *k*, delayed for RTC alignment	kV (primary)
V*pk*RMS[f, g]	Instantaneous rms phase to neutral voltage, Phase *p*, Terminal *k*	V (secondary)
V*p*ZRC[g]	40 ms average rms phase-to-neutral voltage magnitude, Phase *p*, Terminal Z	kV (primary)
V*ppk*FA[f, i]	Instantaneous filtered phase-to-phase voltage angle, Phases *pp*, Terminal *k*	° (±180°)
V*ppk*FAC[f, i]	40 ms average filtered phase-to-phase voltage angle, Phases *pp*, Terminal *k*	° (±180°)
V*ppk*FI[f, i]	Instantaneous filtered phase-to-phase voltage, imaginary component, Phases *pp*, Terminal *k*	V (secondary)
V*ppk*FM[f, i]	Instantaneous filtered phase-to-phase voltage magnitude, Phases *pp*, Terminal *k*	V (secondary)
V*ppk*FMC[f, i]	40 ms average filtered phase-to-phase voltage magnitude, Phases *pp*, Terminal *k*	V (primary)
V*ppk*FR[f, i]	Instantaneous filtered phase-to-phase voltage, real component, Phases *pp*, Terminal *k*	V (secondary)
V*ppk*RMS[f, i]	Instantaneous rms phase-to-phase voltage Phases *pp*, Terminal *k*	V (secondary)
V*pp*ZFCM[i]	Instantaneous filtered GSU compensated generator terminal phase-to-phase voltage magnitude, Phases *pp*	V (secondary)
V*pp*ZRC[i]	40 ms average rms phase-to-phase voltage magnitude, Phases *pp*, Terminal Z	V (primary)
V1*k*A[f]	Instantaneous positive-sequence voltage angle, Terminal *k*	° (±180°)
V1*k*AC[f]	40 ms average positive-sequence voltage angle, Terminal *k*	° (±180°)
V1*k*I[f]	Instantaneous positive-sequence voltage, imaginary component, Terminal *k*	V (secondary)
V1*k*M[f]	Instantaneous positive-sequence voltage magnitude, Terminal *k*	V (secondary)
V1*k*MC[f]	40 ms average positive-sequence voltage magnitude, Terminal *k*	kV (primary)
V1*k*PPAD[f]	Positive-sequence synchrophasor voltage angle, Terminal *k*, delayed for RTC alignment	° (±180°)
V1*k*PPI[f]	Positive-sequence synchrophasor voltage imaginary component, P Class, Terminal *k*	kV (primary)
V1*k*PPID[f]	Positive-sequence synchrophasor voltage imaginary component, Terminal *k*, delayed for RTC alignment	kV (primary)
V1*k*PPMD[f]	Positive-sequence synchrophasor voltage magnitude, Terminal *k*, delayed for RTC alignment	kV (primary)
V1*k*PPR[f]	Positive-sequence synchrophasor voltage real component, P Class, Terminal *k*	kV (primary)
V1*k*PPRD[f]	Positive-sequence synchrophasor voltage real component, Terminal *k*, delayed for RTC alignment	kV (primary)
V1*k*R[f]	Instantaneous positive-sequence voltage, real component, Terminal *k*	V (secondary)
V3DIF	Third harmonic voltage difference	V (secondary)

Table 12.1 Analog Quantities Sorted Alphabetically (Sheet 9 of 10)

Analog Labels	Analog Quantity Description	Units
V3RAT	Third harmonic voltage ratio	pu
VDC	Station battery dc voltage	V
VG3FA	Total third harmonic voltage angle	° (±180°)
VG3FAC	40 ms average filtered total neutral third harmonic voltage angle	° (±180°)
VG3FI	Total third harmonic voltage imaginary component	V (secondary)
VG3FM	Total third harmonic voltage magnitude	V (secondary)
VG3FMC	40 ms average filtered total neutral third harmonic voltage magnitude	kV (primary)
VG3FR	Total third harmonic voltage real component	V (secondary)
VN3FA	Instantaneous third harmonic voltage angle at the neutral	° (±180°)
VN3FAC	40 ms average filtered generator neutral third harmonic voltage angle	° (±180°)
VN3FI	Instantaneous third harmonic voltage, imaginary component at the neutral	V (secondary)
VN3FM	Instantaneous third harmonic voltage magnitude at the neutral	V (secondary)
VN3FMC	40 ms average filtered generator neutral third harmonic voltage magnitude	kV (primary)
VN3FR	Instantaneous third harmonic voltage, real component at the neutral	V (secondary)
VNFA	Instantaneous filtered voltage angle at neutral terminal	° (±180°)
VNFAC	40 ms average filtered generator neutral voltage angle	° (±180°)
VNFI	Instantaneous filtered voltage imaginary component at neutral terminal	V (secondary)
VNFM	Instantaneous filtered voltage magnitude at neutral terminal	V (secondary)
VNFMC	40 ms average filtered generator neutral voltage magnitude	kV (primary)
VNFR	Instantaneous filtered voltage real component at neutral terminal	V (secondary)
VNMAX*k*F[f]	Instantaneous filtered maximum phase-to-neutral voltage magnitude, Terminal *k*	V (secondary)
VNMAX*k*R[f]	Instantaneous rms maximum phase-to-neutral voltage, Terminal *k*	V (secondary)
VNMIN*k*F[f]	Instantaneous filtered minimum phase-to-neutral voltage magnitude, Terminal *k*	V (secondary)
VNMIN*k*R[f]	Instantaneous rms minimum phase-to-neutral voltage, Terminal *k*	V (secondary)
VPMAX*k*F[f]	Instantaneous filtered maximum phase-to-phase voltage magnitude, Terminal *k*	V (secondary)
VPMAX*k*R[f]	Instantaneous rms maximum phase-to-phase voltage, Terminal *k*	V (secondary)
VPMIN*k*F[f]	Instantaneous filtered minimum phase-to-phase voltage magnitude, Terminal *k*	V (secondary)
VPMIN*k*R[f]	Instantaneous rms minimum phase-to-phase voltage, Terminal *k*	V (secondary)
VV*b*FA[h]	Instantaneous filtered phase-to-neutral voltage angle, Terminal V*b*	° (±180°)
VV*b*FI[h]	Instantaneous filtered phase-to-neutral voltage, imaginary component, Terminal V*b*	V (secondary)
VV*b*FM[h]	Instantaneous filtered phase-to-neutral voltage magnitude, Terminal V*b*	V (secondary)
VV*b*FR[h]	Instantaneous filtered phase-to-neutral voltage, real component, Terminal V*b*	V (secondary)
VZ2FA	Instantaneous filtered phase-to-neutral voltage angle, Terminal Z2	° (±180°)
VZ2FI	Instantaneous filtered phase-to-neutral voltage, imaginary component, Terminal Z2	V (secondary)
VZ2FM	Instantaneous filtered phase-to-neutral voltage magnitude, Terminal Z2	V (secondary)
VZ2FR	Instantaneous filtered phase-to-neutral voltage, real component, Terminal Z2	V (secondary)
Z1GFA	Instantaneous positive-sequence impedance angle, seen from generator side	° (±180°)
Z1GFI	Instantaneous positive-sequence impedance imaginary part, seen from generator side	Ω (secondary)

Table 12.1 Analog Quantities Sorted Alphabetically (Sheet 10 of 10)

Analog Labels	Analog Quantity Description	Units
Z1GFM	Instantaneous positive-sequence impedance magnitude, seen from generator side	Ω (secondary)
Z1GFR	Instantaneous positive-sequence impedance real part, seen from generator side	Ω (secondary)

[a] a = 1, 2.
[b] n = S, T, U, Y.
[c] r = S, T, U, W, X, Y.
[d] s = S, T, U, Y, G.
[e] t = S, T, U, W, X, Y, G.
[f] k = V, Z.
[g] p = A, B, C.
[h] b = 1, 2, 3.
[i] pp = AB, BC, CA.

Table 12.2 Analog Quantities Sorted by Function (Sheet 1 of 11)

Analog Labels	Analog Quantity Description	Units	Number of Analogs
25 Synchronism Check Analogs			
25ANG*n*[a]	25 sync-check angle difference for Breaker *n*	° (±180)	4
25ANGC*n*[a]	25 sync-check compensated angle difference for Breaker *n*	° (±180)	4
25DIFV*n*[a]	25 sync-check voltage difference for Breaker *n*	%	4
25SLIP*n*[a]	25 sync-check slip frequency Breaker *n*	Hz	4
25VPFA	25 sync-check polarizing voltage angle	° (±180)	1
25VPFM	25 sync-check polarizing voltage magnitude	V (secondary)	1
25VS*n*FA[a]	25 sync-check synchronizing voltage angle for Breaker *n*	° (±180)	4
25VS*n*FM[a]	25 sync-check synchronizing voltage magnitude for Breaker *n*	V (secondary)	4
Autosynchronizer Analogs			
25AFCT	25A autosynchronizer frequency pulse count	Unitless	1
25AVCT	25A autosynchronizer voltage pulse count	Unitless	1
Averaged Current			
3I0*s*AC[b]	40 ms average zero-sequence current angle, Terminal *s*	° (±180°)	5
3I0*s*MC[b]	40 ms average zero-sequence current magnitude, Terminal *s*	A (primary)	5
3I0*s*MS[b]	1 s average zero-sequence current magnitude, Terminal *s*	A (secondary)	5
3I2*s*AC[b]	40 ms average negative-sequence current angle, Terminal *s*	° (±180°)	5
3I2*s*MC[b]	40 ms average negative-sequence current magnitude, Terminal *s*	A (primary)	5
3I2*s*MS[b]	1 s average negative-sequence current magnitude, Terminal *s*	A (secondary)	5
I*ps*FAC[b, c]	40 ms average filtered phase current angle, Phase *p*, Terminal *s*	° (±180°)	15
I*ps*FMC[b, c]	40 ms average filtered phase current magnitude, Phase *p*, Terminal *s*	A (primary)	15
I*p*GRC[c]	40 ms average rms phase current magnitude, Phase *p*, Terminal G	A (primary)	3
I*p*GRS[c]	1 s average rms phase current magnitude, Phase *p*, Terminal G	A (secondary)	3
I1*s*AC[b]	40 ms average positive-sequence current angle, Terminal *s*	° (±180°)	5
I1*s*MC[b]	40 ms average positive-sequence current magnitude, Terminal *s*	A (primary)	5
IY*b*FAC[d]	40 ms average filtered current angle, Channel *b*, Terminal Y	° (±180°)	3
IY*b*FMC[d]	40 ms average filtered current magnitude, Channel *b*, Terminal Y	A (primary)	3
3I0*s*AC[b]	40 ms average zero-sequence current angle, Terminal *s*	° (±180°)	5

Table 12.2 Analog Quantities Sorted by Function (Sheet 2 of 11)

Analog Labels	Analog Quantity Description	Units	Number of Analogs
Averaged Power			
3P*s*FC[b]	40 ms average three-phase fundamental active power, Terminal *s*	MW (primary)	5
3P*s*FS[b]	1 second average three-phase fundamental active power, Terminal *s*	MW (primary)	5
3Q*s*FC[b]	40 ms average three-phase fundamental reactive power, Terminal *s*	MVAR (primary)	5
3Q*s*FS[b]	1 second average three-phase fundamental reactive power, Terminal *s*	MVAR (primary)	5
3S*s*FC[b]	40 ms average three-phase fundamental apparent power, Terminal *s*	MVA (primary)	5
3S*s*FS[b]	1 second average three-phase fundamental apparent power, Terminal *s*	MVA (primary)	5
P*ps*FC[b, c]	40 ms average phase fundamental active power, Phase *p*, Terminal *s*	MW (primary)	15
Q*ps*FC[b, c]	40 ms average phase fundamental reactive power, Phase *p*, Terminal *s*	MVAR (primary)	15
S*ps*FC[b, c]	40 ms average phase fundamental apparent power, Phase *p*, Terminal *s*	MVA (primary)	15
Averaged Power Factor			
3PF*s*C[b]	Three-phase displacement power factor, Terminal *s*	– (unitless, ratio)	5
PF*ps*C[b, c]	Phase displacement power factor, Phase *p*, Terminal *s*	– (unitless, ratio)	15
Averaged Voltage			
3V0*k*AC[e]	40 ms average zero-sequence voltage angle, Terminal *k*	° (±180°)	2
3V0*k*MC[e]	40 ms average zero-sequence voltage magnitude, Terminal *k*	kV (primary)	2
3V0Z3AC	40 ms average filtered generator terminal third harmonic voltage angle	° (±180°)	1
3V0Z3MC	40 ms average filtered generator terminal third harmonic voltage magnitude	kV (primary)	1
3V2*k*AC[e]	40 ms average negative-sequence voltage angle, Terminal *k*	° (±180°)	2
3V2*k*MC[e]	40 ms average negative-sequence voltage magnitude, Terminal *k*	kV (primary)	2
V*pk*FAC[c, e]	40 ms average filtered phase-to-neutral voltage angle, Phase *p*, Terminal *k*	° (±180°)	6
V*pk*FMC[c, e]	40 ms average filtered phase-to-neutral voltage magnitude, Phase *p*, Terminal *k*	kV (primary)	6
V*p*ZRC[c]	40 ms average rms phase-to-neutral voltage magnitude, Phase *p*, Terminal Z	kV (primary)	3
V*ppk*FAC[e, f]	40 ms average filtered phase-to-phase voltage angle, Phases *pp*, Terminal *k*	° (±180°)	6
V*ppk*FMC[e, f]	40 ms average filtered phase-to-phase voltage magnitude, Phases *pp*, Terminal *k*	V (primary)	6
V*pp*ZRC[f]	40 ms average rms phase-to-phase voltage magnitude, Phases *pp*, Terminal Z	V (primary)	3
V1*k*AC[e]	40 ms average positive-sequence voltage angle, Terminal *k*	° (±180°)	2
V1*k*MC[e]	40 ms average positive-sequence voltage magnitude, Terminal *k*	kV (primary)	2
VG3FAC	40 ms average filtered total neutral third harmonic voltage angle	° (±180°)	1
VG3FMC	40 ms average filtered total neutral third harmonic voltage magnitude	kV (primary)	1
VN3FAC	40 ms average filtered generator neutral third harmonic voltage angle	° (±180°)	1
VN3FMC	40 ms average filtered generator neutral third harmonic voltage magnitude	kV (primary)	1
VNFAC	40 ms average filtered generator neutral voltage angle	° (±180°)	1
VNFMC	40 ms average filtered generator neutral voltage magnitude	kV (primary)	1
Breaker Monitoring Analogs			
B*n*ATRI*p*[a, c]	Breaker *n* accumulated trip current for Phase *p*	A (primary)	12
B*n*BCWP*p*[a, c]	Breaker *n* breaker-contact wear for Pole *p*	%	12
B*n*EOTC*p*[a, c]	Breaker *n* average electrical operating time (close for Phase *p*)	ms	12
B*n*EOTT*p*[b, g]	Breaker *n* average electrical operating time (trip for Phase *p*)	ms	12
B*n*LEOC*p*[a, c]	Breaker *n* last electrical operating time (close for Phase *p*)	ms	12

Table 12.2 Analog Quantities Sorted by Function (Sheet 3 of 11)

Analog Labels	Analog Quantity Description	Units	Number of Analogs
B*n*LEOT*p*[a, c]	Breaker *n* last electrical operating time (trip for Phase *p*)	ms	12
B*n*LMOTC[a]	Breaker *n* last mechanical operating time (close)	ms	4
B*n*LMOTT[a]	Breaker *n* last mechanical operating time (trip)	ms	4
B*n*LTRI*p*[a, c]	Breaker *n* last interrupted trip current for Phase *p*	%	12
B*n*MOTC[a]	Breaker *n* average mechanical operating time (close)	ms	4
B*n*MOTT[a]	Breaker *n* average mechanical operating time (trip)	ms	4
B*n*OPCN[a]	Breaker *n* number of operations (trip)	N/A	4
Current and Potential Transformer Ratios			
CTR*r*[g]	Current transformer ratio for Terminal *r*	–	6
CTRY*b*[d]	Current transformer ratio for Terminal Y*b*	–	3
PTR*k*[e]	Potential transformer ratio for Terminal *k*	–	2
PTRV*b*[d]	Potential transformer ratio for Terminal V*b*	–	3
PTRZ2	Potential transformer ratio for Terminal Z2	–	1
Current Unbalance Analogs			
I2GP	Generator fundamental negative-sequence current	%	1
I2GPEQ	Generator negative-sequence equivalent harmonic current	%	1
Demand Metering Analogs			
DM[010]	Demand metering value	A (secondary)	10
DMM[010]	Demand metering maximum value	A (secondary)	10
Energy Metering Analogs			
3P*s*MWHN[b]	Three-phase active energy imported, Terminal *s*	MWh (primary)	5
3P*s*MWHP[b]	Three-phase active energy exported, Terminal *s*	MWh (primary)	5
3P*s*MWHT[b]	Total three-phase active energy, Terminal *s*	MWh (primary)	5
3Q*s*MVHN[b]	Three-phase reactive energy imported, Terminal *s*	MVARh (primary)	5
3Q*s*MVHP[b]	Three-phase reactive energy exported, Terminal *s*	MVARh (primary)	5
3Q*s*MVHT[b]	Total three-phase reactive energy, Terminal *s*	MVARh (primary)	5
Field Insulation Analogs			
64FIR	64F field insulation resistance	kΩ	1
Frequency Protection Analogs			
81AB[8]S	81A element band [8] accumulated time	s	8
Group Switch			
ACTGRP	Active settings group (1–6)		1
IEC Thermal Analogs			
HMAX*b*[d]	IEC equivalent max. thermal level, Element *b*	pu	3
THRL*b*[d]	IEC thermal level value, Element *b*	pu	3
THTCU*b*[d]	IEC thermal capacity used, Element *b*	Unitless	3
THTRIP*b*[d]	IEC thermal time to trip, Element *b*	s	3
IEEE 1588 PTP Status			
PTPDSJI	PTP 100 PPS data stream jitter in µs	µs	1
PTPMCC	PTP master clock class enumerated value		1
PTPOFST	Clock offset between PTP master and relay time	ns	1

Table 12.2 Analog Quantities Sorted by Function (Sheet 4 of 11)

Analog Labels	Analog Quantity Description	Units	Number of Analogs
PTPOTJF	Fast converging PTP ON TIME marker jitter in µs, coarse accuracy	µs	1
PTPOTJS	Slow converging PTP ON TIME marker jitter in µs, fine accuracy	µs	1
PTPPORT	Active PTP port number	N/A	1
PTPSTEN	PTP Port State enumerated value		1
PTPTBTW	Time between PTP 100 PPS pulses in µs	µs	1
Instantaneous Current			
3I0*r*A[g]	Instantaneous zero-sequence current angle, Terminal *r*	° (±180°)	6
3I0*r*I[g]	Instantaneous zero-sequence current, imaginary component, Terminal *r*	A (secondary)	6
3I0*r*M[g]	Instantaneous zero-sequence current magnitude, Terminal *r*	A (secondary)	6
3I0*r*R[g]	Instantaneous zero-sequence current, real component, Terminal *r*	A (secondary)	6
3I0GA	Instantaneous zero-sequence current angle, generator neutral side	° (±180°)	1
3I0GI	Instantaneous zero-sequence current, imaginary component, generator neutral side	A (secondary)	1
3I0GM	Instantaneous zero-sequence current magnitude, generator neutral side	A (secondary)	1
3I0GR	Instantaneous zero-sequence current, real component, generator neutral side	A (secondary)	1
3I2*r*A[g]	Instantaneous negative-sequence current angle, Terminal *r*	° (±180°)	6
3I2*r*I[g]	Instantaneous negative-sequence current, imaginary component, Terminal *r*	A (secondary)	6
3I2*r*M[g]	Instantaneous negative-sequence current magnitude, Terminal *r*	A (secondary)	6
3I2*r*R[g]	Instantaneous negative-sequence current, real component, Terminal *r*	A (secondary)	6
3I2GA	Instantaneous negative-sequence current angle, generator neutral side	° (±180°)	1
3I2GI	Instantaneous negative-sequence current, imaginary component, generator neutral side	A (secondary)	1
3I2GM	Instantaneous negative-sequence current magnitude, generator neutral side	A (secondary)	1
3I2GR	Instantaneous negative-sequence current, real component, generator neutral side	A (secondary)	1
I*pr*FA[c, g]	Instantaneous filtered phase current angle, Phase *p*, Terminal *r*	° (±180°)	18
I*pr*FI[c, g]	Instantaneous filtered phase current, imaginary component, Phase *p*, Terminal *r*	A (secondary)	18
I*pr*FM[c, g]	Instantaneous filtered phase current magnitude, Phase *p*, Terminal *r*	A (secondary)	18
I*pr*FR[c, g]	Instantaneous filtered phase current, real component, Phase *p*, Terminal *r*	A (secondary)	18
I*p*GFA[c]	Instantaneous filtered phase current angle, Phase *p*, generator neutral side	° (±180°)	3
I*p*GFI[c]	Instantaneous filtered phase current, imaginary component, Phase *p*, generator neutral side	A (secondary)	3
I*p*GFM[c]	Instantaneous filtered phase current magnitude, Phase *p*, generator neutral side	A (secondary)	3
I*p*GFR[c]	Instantaneous filtered phase current, real component, Phase *p*, generator neutral side	A (secondary)	3
I*pp*GFCM[f]	Instantaneous filtered GSU compensated phase to phase current magnitude, Phase *pp*, generator neutral side	A (secondary)	3
I1*r*A[g]	Instantaneous positive-sequence current angle, Terminal *r*	° (±180°)	6
I1*r*I[g]	Instantaneous positive-sequence current, imaginary component, Terminal *r*	A (secondary)	6
I1*r*M[g]	Instantaneous positive-sequence current magnitude, Terminal *r*	A (secondary)	6
I1*r*R[g]	Instantaneous positive-sequence current, real component, Terminal *r*	A (secondary)	6
I1GA	Instantaneous positive-sequence current angle, generator neutral side	° (±180°)	1
I1GI	Instantaneous positive-sequence current, imaginary component, generator neutral side	A (secondary)	1
I1GM	Instantaneous positive-sequence current magnitude, generator neutral side	A (secondary)	1
I1GMB	Unbalance biased current for generator terminal	A (secondary)	1
I1GR	Instantaneous positive-sequence current, real component, generator neutral side	A (secondary)	1

Table 12.2 Analog Quantities Sorted by Function (Sheet 5 of 11)

Analog Labels	Analog Quantity Description	Units	Number of Analogs
IMAX*r*F[g]	Instantaneous filtered maximum phase-current magnitude, Terminal *r*	A (secondary)	6
IMAXGF	Instantaneous filtered maximum phase-current magnitude, generator neutral side	A (secondary)	1
IMIN*r*F[g]	Instantaneous filtered minimum phase-current magnitude, Terminal *r*	A (secondary)	6
IMINGF	Instantaneous filtered minimum phase-current magnitude, generator neutral side	A (secondary)	1
IY*b*FA[d]	Instantaneous filtered current angle, Terminal Y*b*	° (±180°)	3
IY*b*FI[d]	Instantaneous filtered current, imaginary component, Terminal Y*b*	A (secondary)	3
IY*b*FM[d]	Instantaneous filtered current magnitude, Terminal Y*b*	A (secondary)	3
IY*b*FR[d]	Instantaneous filtered current, real component, Terminal Y*b*	A (secondary)	3
Instantaneous Differential Quantities			
87*pr*DC[c, g]	DC component, Phase *p* Terminal *r*	pu	18
87*p*M2*a*[c, h]	2nd harmonic current content of operating current, Phase *p*, Element *a*	pu	6
87*p*M4*a*[c, h]	4th harmonic current content of operating current, Phase *p*, Element *a*	pu	6
87*p*M5*a*[c, h]	5th harmonic current content of operating current, Phase *p*, Element *a*	pu	6
87*p*OPF*a*[c, h]	Filtered differential operating current, Phase *p*, Element *a*	pu	6
87*p*OPR*a*[c, h]	RMS differential operating current, Phase *p*, Element *a*	pu	6
87*p*RTF*a*[c, h]	Filtered differential restraint current, Phase *p*, Element *a*	pu	6
87*p*RTH*a*[c, h]	Biased differential harmonic restraint current, Phase *p*, Element *a*	pu	6
87*p*RTK*a*[c, h]	Biased differential restraint current, Phase *p*, Element *a*	pu	6
87QOPF*a*[h]	Negative-sequence differential operating current, Element *a*	pu	2
87QRTF*a*[h]	Negative-sequence differential restraint current, Element *a*	pu	2
Instantaneous Positive-Sequence Impedance			
Z1GFA	Instantaneous positive-sequence impedance angle, seen from generator side	° (±180°)	1
Z1GFI	Instantaneous positive-sequence impedance imaginary part, seen from generator side	Ω (secondary)	1
Z1GFM	Instantaneous positive-sequence impedance magnitude, seen from generator side	Ω (secondary)	1
Z1GFR	Instantaneous positive-sequence impedance real part, seen from generator side	Ω (secondary)	1
Instantaneous Power			
3P*t*F[i]	Instantaneous three-phase fundamental active power, Terminal *t*	W (secondary)	7
3Q*t*F[i]	Instantaneous three-phase fundamental reactive power, Terminal *t*	VAR (secondary)	7
3S*t*F[i]	Instantaneous three-phase fundamental apparent power, Terminal *t*	VA (secondary)	7
P*pt*F[c, i]	Instantaneous phase fundamental active power, Phase *p*, Terminal *t*	W (secondary)	21
Q*pt*F[c, i]	Instantaneous phase fundamental reactive power, Phase *p*, Terminal *t*	VAR (secondary)	21
S*pt*F[c, i]	Instantaneous phase fundamental apparent power, Phase *p*, Terminal *t*	VA (secondary)	21
Instantaneous RMS Voltage			
I*ps*RMS[b, c]	Instantaneous rms phase current magnitude, Phase *p*, Terminal *s*	A (secondary)	15
IMAX*s*R[b]	Instantaneous rms maximum phase current, Terminal *s*	A (secondary)	5
IMIN*s*R[b]	Instantaneous rms minimum phase current, Terminal *s*	A (secondary)	5
V*pk*RMS[c, e]	Instantaneous rms phase to neutral voltage, Phase *p*, Terminal *k*	V (secondary)	6
V*ppk*RMS[e, f]	Instantaneous rms phase-to-phase voltage Phases *pp*, Terminal *k*	V (secondary)	6
VNMAX*k*R[e]	Instantaneous rms maximum phase-to-neutral voltage, Terminal *k*	V (secondary)	2
VNMIN*k*R[e]	Instantaneous rms minimum phase-to-neutral voltage, Terminal *k*	V (secondary)	2

Table 12.2 Analog Quantities Sorted by Function (Sheet 6 of 11)

Analog Labels	Analog Quantity Description	Units	Number of Analogs
VPMAX*k*R[e]	Instantaneous rms maximum phase-to-phase voltage, Terminal *k*	V (secondary)	2
VPMIN*k*R[e]	Instantaneous rms minimum phase-to-phase voltage, Terminal *k*	V (secondary)	2
Instantaneous Voltage			
3V0*k*A[e]	Instantaneous zero-sequence voltage angle, Terminal *k*	° (±180°)	2
3V0*k*I[e]	Instantaneous zero-sequence voltage, imaginary component, Terminal *k*	V (secondary)	2
3V0*k*M[e]	Instantaneous zero-sequence voltage magnitude, Terminal *k*	V (secondary)	2
3V0*k*R[e]	Instantaneous zero-sequence voltage, real component, Terminal *k*	V (secondary)	2
3V03ZA	Instantaneous third harmonic zero-sequence voltage angle, Terminal Z	° (±180°)	1
3V03ZI	Instantaneous third harmonic zero-sequence voltage, imaginary component, Terminal Z	V (secondary)	1
3V03ZM	Instantaneous third harmonic zero-sequence voltage magnitude, Terminal Z	V (secondary)	1
3V03ZR	Instantaneous third harmonic zero-sequence voltage, real component, Terminal Z	V (secondary)	1
3V2*k*A[e]	Instantaneous negative-sequence voltage angle, Terminal *k*	° (±180°)	2
3V2*k*I[e]	Instantaneous negative-sequence voltage, Imaginary component, Terminal *k*	V (secondary)	2
3V2*k*M[e]	Instantaneous negative-sequence voltage magnitude, Terminal *k*	V (secondary)	2
3V2*k*R[e]	Instantaneous negative-sequence voltage, real component, Terminal *k*	V (secondary)	2
V*pk*FA[c, e]	Instantaneous filtered phase-to-neutral voltage angle, Phase *p*, Terminal *k*	° (±180°)	6
V*pk*FI[c, e]	Instantaneous filtered phase-to-neutral voltage, imaginary component, Phase *p*, Terminal *k*	V (secondary)	6
V*pk*FM[c, e]	Instantaneous filtered phase-to-neutral voltage magnitude, Phase *p*, Terminal *k*	V (secondary)	6
V*pk*FR[c, e]	Instantaneous filtered phase-to-neutral voltage, real component, Phase *p*, Terminal *k*	V (secondary)	6
V*ppk*FA[e, f]	Instantaneous filtered phase-to-phase voltage angle, Phases *pp*, Terminal *k*	° (±180°)	6
V*ppk*FI[e, f]	Instantaneous filtered phase-to-phase voltage, imaginary component, Phases *pp*, Terminal *k*	V (secondary)	6
V*ppk*FM[e, f]	Instantaneous filtered phase-to-phase voltage magnitude, Phases *pp*, Terminal *k*	V (secondary)	6
V*ppk*FR[e, f]	Instantaneous filtered phase-to-phase voltage, real component, Phases *pp*, Terminal *k*	V (secondary)	6
V*pp*ZFCM[f]	Instantaneous filtered GSU compensated generator terminal phase-to-phase voltage magnitude, Phases *pp*	V (secondary)	3
V1*k*A[e]	Instantaneous positive-sequence voltage angle, Terminal *k*	° (±180°)	2
V1*k*I[e]	Instantaneous positive-sequence voltage, imaginary component, Terminal *k*	V (secondary)	2
V1*k*M[e]	Instantaneous positive-sequence voltage magnitude, Terminal *k*	V (secondary)	2
V1*k*R[e]	Instantaneous positive-sequence voltage, real component, Terminal *k*	V (secondary)	2
VN3FA	Instantaneous third harmonic voltage angle at the neutral	° (±180°)	1
VN3FI	Instantaneous third harmonic voltage, imaginary component at the neutral	V (secondary)	1
VN3FM	Instantaneous third harmonic voltage magnitude at the neutral	V (secondary)	1
VN3FR	Instantaneous third harmonic voltage, real component at the neutral	V (secondary)	1
VNFA	Instantaneous filtered voltage angle at neutral terminal	° (±180°)	1
VNFI	Instantaneous filtered voltage imaginary component at neutral terminal	V (secondary)	1
VNFM	Instantaneous filtered voltage magnitude at neutral terminal	V (secondary)	1
VNFR	Instantaneous filtered voltage real component at neutral terminal	V (secondary)	1
VNMAX*k*F[e]	Instantaneous filtered maximum phase-to-neutral voltage magnitude, Terminal *k*	V (secondary)	2
VNMIN*k*F[e]	Instantaneous filtered minimum phase-to-neutral voltage magnitude, Terminal *k*	V (secondary)	2
VPMAX*k*F[e]	Instantaneous filtered maximum phase-to-phase voltage magnitude, Terminal *k*	V (secondary)	2

Table 12.2 Analog Quantities Sorted by Function (Sheet 7 of 11)

Analog Labels	Analog Quantity Description	Units	Number of Analogs
VPMIN*k*F[e]	Instantaneous filtered minimum phase-to-phase voltage magnitude, Terminal *k*	V (secondary)	2
VV*b*FA[d]	Instantaneous filtered phase-to-neutral voltage angle, Terminal V*b*	° (±180°)	3
VV*b*FI[d]	Instantaneous filtered phase-to-neutral voltage, imaginary component, Terminal V*b*	V (secondary)	3
VV[3]FM[d]	Instantaneous filtered phase-to-neutral voltage magnitude, Terminal V*b*	V (secondary)	3
VV*b*FR[d]	Instantaneous filtered phase-to-neutral voltage, real component, Terminal V*b*	V (secondary)	3
VZ2FA	Instantaneous filtered phase-to-neutral voltage angle, Terminal Z2	° (±180°)	1
VZ2FI	Instantaneous filtered phase-to-neutral voltage, imaginary component, Terminal Z2	V (secondary)	1
VZ2FM	Instantaneous filtered phase-to-neutral Voltage magnitude, Terminal Z2	V (secondary)	1
VZ2FR	Instantaneous filtered phase-to-neutral Voltage, real component, Terminal Z2	V (secondary)	1
High-Priority Time Analogs			
BNCDSJI	BNC port 100 PPS data stream jitter	µs	1
BNCOTJF	Fast converging BNC port ON TIME marker jitter, coarse accuracy	µs	1
BNCOTJS	Slow converging BNC port ON TIME marker jitter, fine accuracy	µs	1
BNCTBTW	Time between BNC 100 PPS pulses	µs	1
CUR_SRC	Current high-priority time source		1
NEW_SRC	Selected high-priority time source		1
SERDSJI	Serial port 100 PPS data stream jitter	µs	1
SEROTJF	Fast converging serial port ON TIME marker jitter, coarse accuracy	µs	1
SEROTJS	Slow converging serial port ON TIME marker jitter, fine accuracy	µs	1
SERTBTW	Time between serial 100 PPS pulses	µs	1
SQUAL	Synchronization accuracy of the selected high-priority time source	µs	1
TQUAL	Worst case clock time error of the selected high-priority time source	s, (second)	1
TUTC	Offset from local time to UTC time	hr, (hour)	1
HSR Analogs			
HSRSRTP	Round-trip time for HSR supervision frames on process bus	µs	1
HSRSRTS	Round-trip time for HSR supervision frames on station bus	µs	1
LOP Analogs			
60LDVM	60 LOP voltage unbalance magnitude	V (secondary)	1
Loss of Field Analogs			
40PDAM	Loss of field dynamic zone parameter data	Unitless	1
40PPLD	Loss of field Zone 3 active power lead PF limit	W (secondary)	1
40PPLG	Loss of field Zone 3 active power lag PF limit	W (secondary)	1
40PPMX	Loss of field Zone 3 maximum active power	W (secondary)	1
40PPU	Loss of field Zone 3 active power UPF limit	W (secondary)	1
40PQMN	Loss of field Zone 2 minimum reactive power	VAR (secondary)	1
40PQMX	Loss of field Zone 3 maximum reactive power	VAR (secondary)	1
40PQZ2	Loss of field Zone 2 reactive power limit	VAR (secondary)	1
MIRRORED BITS Analogs			
MB[7]A	Channel A received Mirrored Bit analog values	–	7
MB[7]B	Channel B received Mirrored Bit analog values	–	7

Table 12.2 Analog Quantities Sorted by Function (Sheet 8 of 11)

Analog Labels	Analog Quantity Description	Units	Number of Analogs
Out-of-Step Analogs			
78CN	Out-of-step command pole slip count	Unitless	1
78GCN	Out-of-step generator pole slip count	Unitless	1
78SCN	Out-of-step system pole slip count	Unitless	1
Overcurrent Analogs			
51P[012]	51 element [012] pickup value	A (secondary)	12
51TD[012]	51 element [012] Time dial setting	–	12
Protection Frequency			
DFREQPG	Generator rate of change of frequency	Hz/s	1
DFREQPS	System rate of change of frequency	Hz/s	1
FREQPG	Generator frequency	Hz	1
FREQPS	System frequency	Hz	1
Relay Temperature			
RLYTEMP	Relay temperature (°C temperature of the box)	°C (degrees Celsius)	1
Remote Analogs			
RA[0256]	Remote analogs	N/A	256
RAO[064]	Remote analog output	–	64
Restricted Earth Fault Analogs			
IOREFM*b*[d]	Operate current magnitude, Element *b*	pu	3
IRREFM*b*[d]	Reference current magnitude, Element *b*	pu	3
SELogic Analogs			
ACN[032]CV	Automation SELogic Counter [032] current value	–	32
ACN[032]PV	Automation SELogic counter preset value	–	32
ACT[032]DO	Automation SELogic conditioning timer dropout time	s	32
ACT[032]PU	Automation SELogic conditioning timer pickup time	s	32
AMV[0256]	Automation SELogic math variable	–	256
AST[032]ET	Automation SELogic sequencing timer elapsed time	s	32
AST[032]PT	Automation SELogic sequencing timer preset time	s	32
PCN[032]CV	Protection SELogic Counter [032] current value	–	32
PCN[032]PV	Protection SELogic counter preset value	–	32
PCT[032]DO	Protection SELogic conditioning timer dropout time	s	32
PCT[032]PU	Protection SELogic conditioning timer pickup time	s	32
PMV[064]	Protection SELogic math variable	–	64
PST[032]ET	Protection SELogic sequencing timer elapsed time	s	32
PST[032]PT	Protection SELogic sequencing timer preset time	s	32
Station DC Monitoring Analogs			
DCMAX	Maximum DC 1 voltage	V	1
DCMIN	Minimum DC 1 voltage	V	1
DCNE	Average negative to Ground DC 1 voltage	V	1
DCPO	Average positive to Ground DC 1 voltage	V	1

Table 12.2 Analog Quantities Sorted by Function (Sheet 9 of 11)

Analog Labels	Analog Quantity Description	Units	Number of Analogs
DCRI	AC ripple of DC 1 voltage	V	1
VDC	Station battery dc voltage	V	1
Stator Insulation Analogs			
64SIC	64S stator insulation capacitance	μF	1
64SIR	64S stator insulation resistance	kΩ	1
Synchrophasor Currents			
FOSPM	Fraction of second of the synchrophasor data packet	s	1
I*pr*PPI[c, g]	Synchrophasor current imaginary component, P class, Phase *p*, P class, Terminal *r*	A (primary)	18
I*pr*PPR[c, g]	Synchrophasor current real component, P class, Phase *p*, P class, Terminal *r*	A (primary)	18
I1*r*PPI[g]	Positive-sequence synchrophasor current imaginary component, P class, Terminal *r*	A (primary)	6
I1*r*PPR[g]	Positive-sequence synchrophasor current real component, P class, Terminal *r*	A (primary)	6
SODPM	Second of day of the synchrophasor data packet	s	1
Synchrophasor Frequency			
DFDTPP	Rate-of-change of Frequency for synchrophasor data, P class	Hz/s	1
FREQPP	Frequency for synchrophasor data, P class	Hz	1
Synchrophasor RTC Analogs			
DFDTPPD	Rate-of-change-of-frequency for synchrophasor data, delayed for RTC alignment	Hz/s	1
FOSPMD	Fraction of second of the synchrophasor data packet, delayed for RTC alignment	s	1
FREQPPD	Frequency for synchrophasor data, delayed for RTC alignment	Hz	1
I*pr*PPAD[c, g]	Synchrophasor current angle, Phase *p*, Terminal *r*, delayed for RTC alignment	° (±180°)	18
I*pr*PPID[c, g]	Synchrophasor current imaginary component, Phase *p*, Terminal *r*, delayed for RTC alignment	A (primary)	18
I*pr*PPMD[c, g]	Synchrophasor current magnitude, Phase *p*, Terminal *r*, delayed for RTC alignment	A (primary)	18
I*pr*PPRD[c, g]	Synchrophasor current real component, Phase *p*, Terminal *r*, delayed for RTC alignment	A (primary)	18
I1*r*PPAD[g]	Positive-sequence synchrophasor current angle, Terminal *r*, delayed for RTC alignment	° (±180°)	6
I1*r*PPID[g]	Positive-sequence synchrophasor current Imaginary component, Terminal *r*, delayed for RTC alignment	A (primary)	6
I1*r*PPMD[g]	Positive-sequence synchrophasor current magnitude, Terminal *r*, delayed for RTC alignment	A (primary)	6
I1*r*PPRD[g]	Positive-sequence synchrophasor current real component, Terminal *r*, delayed for RTC alignment	A (primary)	6
RTCAA0[8]	Channel A remote synchrophasor analogs (units depends on remote synchrophasor contents)		8
RTCAP[032]	Channel A remote synchrophasor phasors (units depends on remote synchrophasor contents)		32
RTCBA0[8]	Channel B remote synchrophasor analogs (units depends on remote synchrophasor contents)		8
RTCBP[032]	Channel B remote synchrophasor phasors (units depends on remote synchrophasor contents)		32
RTCDFA	Rate of change of Channel A remote frequency (from remote synchrophasors)	Hz/s	1
RTCDFB	Rate of change of Channel B remote frequency (from remote synchrophasors)	Hz/s	1
RTCFA	Channel A remote frequency (from remote synchrophasors)	Hz	1
RTCFB	Channel B remote frequency (from remote synchrophasors)	Hz	1

Table 12.2 Analog Quantities Sorted by Function (Sheet 10 of 11)

Analog Labels	Analog Quantity Description	Units	Number of Analogs
SODPMD	Second of day of the synchrophasor data packet, delayed for RTC alignment	s	1
V*pk*PPAD[c, e]	Synchrophasor voltage angle, Phase *p*, Terminal *k*, delayed for RTC alignment	° (±180°)	6
V*pk*PPID[c, e]	Synchrophasor voltage imaginary component, Phase *p*, Terminal *k*, delayed for RTC alignment	kV (primary)	6
V*pk*PPMD[c, e]	Synchrophasor voltage magnitude, Phase *p*, Terminal *k* delayed for RTC alignment	kV (primary)	6
V*pk*PPRD[c, e]	Synchrophasor voltage real component, Phase *p*, Terminal *k*, delayed for RTC alignment	kV (primary)	6
V1*k*PPAD	Positive-sequence synchrophasor voltage angle, Terminal *k*, delayed for RTC alignment	° (±180°)	2
V1*k*PPID[e]	Positive-sequence synchrophasor voltage imaginary component, Terminal *k*, delayed for RTC alignment	kV (primary)	2
V1*k*PPMD[e]	Positive-sequence synchrophasor voltage magnitude, Terminal *k*, delayed for RTC alignment	kV (primary)	2
V1*k*PPRD[e]	Positive-sequence synchrophasor voltage real component, Terminal *k*, delayed for RTC alignment	kV (primary)	2
Synchrophasor Voltages			
V*pk*PPI[c, e]	Synchrophasor voltage imaginary component, P class, Phase *p*, P class, Terminal *k*	kV (primary)	6
V*pk*PPR[c, e]	Synchrophasor voltage real component, P class, Phase *p*, P class, Terminal *k*	kV (primary)	6
V1*k*PPI[e]	Positive-sequence synchrophasor voltage imaginary component, P class, Terminal *k*	kV (primary)	2
V1*k*PPR[e]	Positive-sequence synchrophasor voltage real component, P class, Terminal *k*	kV (primary)	2
Thermal Monitor Analogs			
MAMB*b*[d]	Ambient temperature value in °C, Element *b*	°C (degrees Celsius)	3
RTC[024]TV	Remote temperature value in °C, RTC[024]	°C (degrees Celsius)	24
RTS[024]TV	RTD temperature value in °C, RTS[024]	°C (degrees Celsius)	24
Third Harmonic Analogs			
64GMMS	Multi-machine selectivity calculation	Unitless	1
V3DIF	Third harmonic voltage difference	V (secondary)	1
V3RAT	Third harmonic voltage ratio	pu	1
VG3FA	Total third harmonic voltage angle	° (±180°)	1
VG3FI	Total third harmonic voltage imaginary component	V (secondary)	1
VG3FM	Total third harmonic voltage magnitude	V (secondary)	1
VG3FR	Total third harmonic voltage real component	V (secondary)	1
Time and Date Management (UTC and Local Time)			
DDOM	UTC date, Day of the month (1–31)	day	1
DDOW	UTC date, Day of the week (1-SU,.., 7-SA)	–	1
DDOY	UTC date, Day of the year (1–366)	day	1
DLDOM	Local date, Day of the month (1–31)	day	1
DLDOW	Local date, Day of the week (1-SU,.., 7-SA)	–	1
DLDOY	Local date, Day of the year (1–366)	day	1
DLMON	Local date, Month (1–12)	month	1
DLYEAR	Local date, Year (2000–2200)	year	1

Table 12.2 Analog Quantities Sorted by Function (Sheet 11 of 11)

Analog Labels	Analog Quantity Description	Units	Number of Analogs
DMON	UTC date, Month (1–12)	month	1
DYEAR	UTC date, Year (2000–2200)	year	1
THR	UTC time, Hour (0–23)	hr	1
TLHR	Local time, Hour (0–23)	hr	1
TLMIN	Local time, Minute (0–59)	min	1
TLMSEC	Local time, Milliseconds (0–999)	ms	1
TLNSEC	Local time, Nanoseconds (0–999999)	ns	1
TLODMS	Local time of day in Milliseconds (0–86400000)	ms	1
TLSEC	Local time, Seconds (0–59)	s	1
TMIN	UTC time, Minute (0–59)	min	1
TMSEC	UTC time, Milliseconds (0–999)	ms	1
TNSEC	UTC time, Nanoseconds (0–999999)	ns	1
TODMS	UTC time of day in Milliseconds (0–86400000)	ms	1
TSEC	UTC time, Seconds (0–59)	s	1
Volts Per Hertz Analogs			
24RPU[2]	Volts per hertz ratio element [2]	% percent	2
Phasor Reference			
REFGEN	Reference angle for generator side phasors	° (±180)	1
REFSYS	Reference angle for system side phasors	° (±180)	1

[a] n = S, T, U, Y.
[b] s = S, T, U, Y, G.
[c] p = A, B, C.
[d] b = 1, 2, 3.
[e] k = V, Z.
[f] pp = AB, BC, CA
[g] r = S, T, U, W, X, Y.
[h] a = 1, 2.
[i] t = S, T, U, W, X, Y, G.

APPENDIX A

Firmware, ICD File, and Manual Versions

Firmware

Determining the Firmware Version

To determine the firmware version, view the status report by using the serial port **STATUS** command or the front-panel HMI. The status report displays the Firmware Identification (FID) number.

The firmware version will be either a standard release or a point release. A standard release adds new functionality to the firmware beyond the specifications of the existing version. A point release is reserved for modifying firmware functionality to conform to the specifications of the existing version.

A standard release is identified by a change in the R-number of the device FID number.

Existing firmware:

FID=SEL-400G-x-**R100**-V0-Z001001-Dxxxxxxxx

Standard release firmware:

FID=SEL-400G-x-**R101**-V0-Z001001-Dxxxxxxxx

A point release is identified by a change in the V-number of the device FID number.

Existing firmware:

FID=SEL-400G-x-R100-**V0**-Z001001-Dxxxxxxxx

Point release firmware:

FID=SEL-400G-x-R100-**V1**-Z001001-Dxxxxxxxx

The date code is after the D. For example, the following is firmware version number R100, date code December 10, 2003.

FID=SEL-400G-x-R100-V0-Z001001-**D20031210**

Similarly, the device SELBOOT firmware revision (BFID) will be reported as:

BFID=SLBT-4XX-Rxxx-Vx-Zxxxxxx-Dxxxxxxxx

Revision History

Table A.1 lists the firmware versions, revisions descriptions, and corresponding instruction manual date codes.

Starting with revisions published after March 1, 2022, changes that address security vulnerabilities are marked with “[Cybersecurity]”. Other improvements to cybersecurity functionality that should be evaluated for potential cybersecurity importance are marked with “[Cybersecurity Enhancement]”.

Table A.1 Firmware Revision History (Sheet 1 of 6)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-400G-R106-V0-Z007002-D20250214 SEL-400G-1-R106-V0-Z007002-D20250214	➤ Resolved an issue where the relay may not synchronize to a PTP time source when NETMODE = ISOLATEIP and PTPTR = LAYER2. This issue is only applicable if the relay receives PTP messages on the non-designated IP port. ➤ Added the High-Availability Seamless Redundancy (HSR) protocol feature to the five-port Ethernet card. ➤ Added the 1000BASE-X auto-negotiation feature to the five-port Ethernet card. ➤ Added Port 5 setting BUSMODE to allow merged mode when using the five-port Ethernet card. ➤ Resolved an issue that prevented large negative energy values from being displayed on the front-panel energy metering screen or in the **MET E** command response. ➤ Updated IEC 61850 protocol implementation to IEC 61850 Edition 2.1. ➤ Added support for deadband configuration, including the dbRef, dbAngRef, zeroDbRef, and zeroDb attributes, according to IEC 61850-7-3 Edition 2.1. ➤ Added support for indexed buffered and unbuffered MMS reports. ➤ Added support to allow the sAddr attribute to replace the esel:datasrc attribute in ICD files to improve compatibility with third-party system configuration tools. ➤ Added support for the remote bit pulse configuration according to IEC 61850-7-3. ➤ Modified the firmware to update the settings group control block (SGCB) and the LTRK logical node's last activation time-stamp attribute for Group settings switches that were not initiated by MMS and for changes to the active Group settings. ➤ Improved support for IEC 61850 Edition 1 MMS clients. ➤ Modified the firmware to allow the relay to accept GOOSE data with invalid or questionable validity. ➤ Modified the firmware to allow the GOOSE quality attribute to map to a remote analog. Additionally, the processed quality indicator now can be mapped to a virtual bit. ➤ Modified the firmware to accept retransmitted GOOSE messages with the test flag set to TRUE when the relay transitions into Test Mode. ➤ Modified the firmware to provide the IEC 61850 library version (LIB61850ID) to the LPHD logical node. ➤ Modified the IEC 61850 hierarchical relationship for the XCBR.Loc and XSWI.Loc data objects to exclude their inheritance from LLN0.Loc and CSWI.Loc. ➤ Enhanced support for the IEC 61850 logical device hierarchy, which enables additional levels of inheritance. This includes support for the Loc and LocSta data objects. ➤ Resolved an issue where the relay would set the validity attribute to invalid in GOOSE messages when resuming publications from Off to On mode. This is only applicable when EOFFMTX = N and the relay receives a CID file while in Off mode.	20250214
SEL-400G-R105-V0-Z006002-D20240529 SEL-400G-1-R105-V0-Z006002-D20240529	➤ Added support for the 6U and 7U chassis ordering options. ➤ Added support for EIA-232 serial communications with the SEL-2664 Field Ground Module.	20240529

Table A.1 Firmware Revision History (Sheet 2 of 6)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Increased the resolution of Group settings 46Q1P1, 46Q1P2, 46Q2P1, and 46Q2P2. ➤ Modified the firmware to allow the insulation and stator ground meter screens to be used in the front-panel rotating display. ➤ Modified the insulation meter screen to display the communications quality status associated with the received measurements. ➤ Modified the stator ground meter screen to include neutral third-harmonic voltage and neutral PT polarity check. ➤ Modified the firmware to allow both phase distance (21P) and voltage controlled/restrained overcurrent elements (51C/51V) to be enabled using Group setting EBUP. ➤ Modified the default value of Group settings ULTR*nn* to include the RSTTRGT Relay Word bit (where *nn* = 01–08). ➤ Resolved an issue where Group settings E59 and E27 were incorrectly forced to N when Group settings ESYSPT and EGNPT were set to OFF. ➤ Resolved an issue where the relay could indicate an incorrect time-synchronization status when the relay was transitioning between two Grandmaster clock sources and the active clock source was no longer available. This does not apply when both clocks are globally time-synchronized.	
SEL-400G-R104-V1-Z005002-D20240509 SEL-400G-1-R104-V1-Z005002-D20240509	Includes all the functions of SEL-400G-R104-V0-Z005002-D20231207 and SEL-400G-1-R104-V0-Z005002-D20231207 with the following addition: ➤ [Cybersecurity] Resolved an issue where a maliciously crafted web request sent to the relay from an unauthenticated user could cause a diagnostic restart. By design, three diagnostic restarts within 7 days cause the relay to disable. This issue can only be triggered when the Port 5 setting EHTTP is configured to Y.	20240509
SEL-400G-R104-V0-Z005002-D20231207 SEL-400G-1-R104-V0-Z005002-D20231207	➤ Resolved an issue where the relay calculates the neutral-side current incorrectly for generators with dual neutrals when the CTRW and CTRX settings have different values. ➤ Resolved an issue where the relay may calculate system frequency incorrectly in applications where the ESYSPT setting includes more than one single-phase voltage. Added Group settings FTSSV*n* (where *n* = 1, 2, 3) to select the proper voltage source reference for system frequency estimation. ➤ Resolved an issue where the compensated synchronism angle check logic incorrectly issues the close command at the 25ANGC*m* (where *m* = S, T, U, Y) setting value instead of issuing the command at zero degrees. ➤ Resolved an issue where the value of Protection and Automation SELOGIC latch bits were not maintained through a relay power cycle. Only firmware versions R103-V1 and R103-V2 are affected. ➤ Modified the minimum range of settings 25ANG*m* and 25ANGC*m* from 3 degrees to 0.1 degrees (where *m* = S, T, U, Y). ➤ Resolved an issue where voltage magnitude values may not be reported correctly in the filtered event reports. ➤ Resolved an issue where MMS time stamps do not match the SER time stamps for Relay Word bit state changes during a settings or IEC 61850 Mode/Behavior change. ➤ Resolved an issue where a change of an stSeld (status selector) attribute may not generate an MMS buffered or unbuffered report.	20231207

Table A.1 Firmware Revision History (Sheet 3 of 6)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Modified the firmware to allow overcurrent element Levels 1–3 to be set independently. Previously, these had to be configured sequentially. ➤ Modified the default value of the settings CL*m* to include the CC*m* Relay Word bit, respectively (where *m* = S, T, U, Y). ➤ Modified the default value of the settings ESERDEL, SRDLCNT, and SRDLTIM to Y, 10, and 0.5, respectively. ➤ Modified the default value of the setting ERDIG from S to A. ➤ Increased the upper range value of the thermal trip limit for the IEC 60255-149 thermal elements from 100% to 150%. ➤ Enhanced the SER to automatically include an entry when entering or exiting IEC 61850 Simulation Mode. ➤ Added support for MMS buffered and unbuffered report reservation. ➤ Modified the firmware to report zero for the Message Time Quality flag in the IEEE C37.118 synchrophasor configuration and data frames when the relay is connected to a PTP clock that is locked to a satellite-synchronized clock source. ➤ Modified the firmware to report PMU Time Quality in the synchrophasor data frame as defined in IEEE C37.118.2-2011. ➤ Modified the firmware to report zero for the Time Quality indicator code in the IEEE C37.111-2013 COMTRADE configuration file when the relay is connected to a PTP clock that is locked to a satellite-synchronized clock source. ➤ Resolved an issue where the relay may not synchronize to a PTP time source on one of the ports when NETMODE = PRP when using the four port Ethernet card. Only firmware version R103 is affected.	
SEL-400G-R103-V2-Z004002-D20231110 SEL-400G-1-R103-V2-Z004002-D20231110	Includes all the functions of SEL-400G-R103-V1-Z004002-D20230830 and SEL-400G-1-R103-V1-Z004002-D20230830 with the following addition: ➤ [Cybersecurity] Resolved an issue where MMS file transfers will cause the relay to disable. Only firmware version R103-V1 is affected.	20231110
SEL-400G-R103-V1-Z004002-D20230830 SEL-400G-1-R103-V1-Z004002-D20230830	Includes all the functions of SEL-400G-R103-V0-Z004002-D20230317 and SEL-400G-1-R103-V0-Z004002-D20230317 with the following additions: ➤ [Cybersecurity] Improved web server security against session hijacking. ➤ [Cybersecurity] Improved web server security against intentionally large files causing denial of service. ➤ [Cybersecurity] Improved web server security against cross-site scripting and misuse of session tokens. ➤ Improved the firmware so that access levels defined by the MAXACC setting apply correctly for MMS setting file transfers. Previously, MMS file transfer access was controlled only by MMS authentication. ➤ Improved the performance of protection and automation latch bits during diagnostic restart. ➤ Resolved a rare issue that could prevent the relay from restarting after a diagnostic failure.	20230830
SEL-400G-R103-V0-Z004002-D20230317 SEL-400G-1-R103-V0-Z004002-D20230317 **NOTE:** SELBOOT R302 or later is required for this and all new firmware versions. This provides the capability to convert to the five-port Ethernet card.	➤ Added support for the five-port Ethernet card. This card provides Parallel Redundancy Protocol (PRP) for both process bus and station bus, a dedicated Ethernet port for engineering access, and greater flexibility in configuring IEC 61850 solutions. ➤ Added the **COM PRP** command for the five-port Ethernet card. Modified the **COM PTP**, **ETH**, **GOO**, **MAC**, **STA**, and **VER** commands to include information related to the five-port Ethernet card.	20230317

Table A.1 Firmware Revision History (Sheet 4 of 6)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Modified the synchronization status values reported in IEC 61850 LTMS.TmSyn.stVal to accurately reflect the definitions in IEC 61850-9-2. ➤ Modified firmware to improve the IEC 61850 time accuracy value LTMS.TmAcc.stVal. ➤ Resolved an issue where IEC 61850 simulation mode is not retained following a relay power cycle. This is applicable when simulation mode is entered using IEC 61850 MMS. ➤ Added process bus support for PTP and IEC 61850 GOOSE communication. ➤ Modified firmware to allow bipolar unblocking logic to be set independently of the negative-sequence percentage-restrained differential element or waveshape-based inrush detection logic. ➤ Resolved an issue where the relay could report the incorrect frequency in the synchrophasor message following a change to the Global setting PMFRQST. ➤ Resolved an issue where the relay could become unresponsive after an Ethernet card hardware failure. ➤ Resolved a file transfer issue that could result in a loss of SEL Fast Message communications. ➤ Resolved a PTP issue where the TGLOBAL Relay Word bit could incorrectly assert during the transition from a local to global time source.	
SEL-400G-R102-V1-Z003002-D20230306 SEL-400G-1-R102-V1-Z003002-D20230306	Includes all the functions of SEL-400G-R102-V0-Z003002-D20220517 and SEL-400G-1-R102-V0-Z003002-D20220517 with the following addition: ➤ Resolved an issue in firmware version R102-V0 when disturbance recording is enabled (EDR := Y) where triggering an event could result in undesired behavior.	20230306
SEL-400G-R102-V0-Z003002-D20220517 SEL-400G-1-R102-V0-Z003002-D20220517	➤ [Cybersecurity] Resolved a rare, low-risk issue where deliberately crafted Ethernet traffic could cause the relay to perform a diagnostic restart. ➤ [Cybersecurity] Updated a third-party networking software component, which removes low-risk security vulnerabilities that could result in temporary loss of Ethernet communications. ➤ Added support for PTP Power Utility Automation profile (IEC/IEEE 61850-9-3). ➤ Modified the firmware to remove the 1 µs accuracy requirements to assert Relay Word bit TLOCAL. ➤ Modified the firmware to allow for a seamless transition from TGLOBAL to TLOCAL. ➤ Added IEC 61850 control interlocking functionality via CILO logical nodes. ➤ Added the blocked-by-interlocking AddCause to the control error response when an operation fails due to a control interlocking (CILO) check. ➤ Added IEC 61850 and PTP settings to COMTRADE event reports. ➤ Resolved an issue where PTP time synchronization could be lost in PRP network applications. ➤ Modified the firmware to address SER time-stamping accuracy and IEC 61850 mode control change following a power cycle. ➤ Improved the **MET DIF A** response to correctly display matrix compensating currents for all operating conditions. In previous firmware, matrix compensated currents could incorrectly display zero during unbalanced conditions.	20220523

Table A.1 Firmware Revision History (Sheet 5 of 6)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Added logic to increase the security of the bipolar low-set unblocking logic during transformer energization. ➤ Modified the firmware to address an issue where the Simulation mode status SimSt.stVal for the LGOS logical node does not transition from TRUE to FALSE for a change in the LPHD logical node Sim.stVal.	
SEL-400G-R101-V2-Z002002-D20211203 SEL-400G-1-R101-V2-Z002002-D20211203	Includes all the functions of SEL-400G-R101-V1-Z002002-D20210625 and SEL-400G-1-R101-V1-Z002002-D20210625 with the following additions: ➤ Resolved an issue where an MMS client may report the relay as offline when multiple MMS clients are simultaneously accessing reports. ➤ Resolved an issue where an MMS client may not be able to retrieve file attributes associated with IEEE C37.111-2013 COMTRADE event files.	20211203
SEL-400G-R101-V1-Z002002-D20210625 SEL-400G-1-R101-V1-Z002002-D20210625	Includes all the functions of SEL-400G-R101-V0-Z002002-D20210514 and SEL-400G-1-R101-V0-Z002002-D20210514 with the following addition: ➤ Modified firmware to improve the security of the phase distance element when configured with zero time delay.	20210625
SEL-400G-R101-V0-Z002002-D20210514 SEL-400G-1-R101-V0-Z002002-D20210514	➤ Added conditioning timers to Automation SELOGIC. ➤ Improved processing consistency of breaker and disconnect control bits in Automation SELOGIC. ➤ Improved Automation SELOGIC timer accuracy. Automation SELOGIC timer accuracy is now within ± 1% or ± 1 s for values up to 1 month. ➤ Added the following breaker monitor analog quantities: accumulated trip current, last interrupted current, operating times, and number of operations. ➤ Modified the dropout delay for the percentage-restrained differential element adaptive security timer. ➤ Increased the allowable TAPMAX/TAPMIN ratio when using 1 A and 5 A nominal CTs. ➤ Modified firmware by adding a 2.5 ms pickup delay to the blocking timer used in the REF element trip output logic. ➤ Enhanced the internal fault detection logic associated with the differential element. ➤ Added settings EACC, E2AC, and EPAC to support port access control using SELOGIC control equations. ➤ Enhanced the **MET DIF A** command response. This command response provides additional differential current metering. ➤ Modified firmware to ensure user-defined V/Hz settings are entered in increasing order. ➤ Resolved an issue where V/Hz metering was limited to 99.99%. ➤ Enhanced **STA A** and **CST** command responses to include high-accuracy PTP time status. ➤ Modified firmware by adding warm start (settings change, group switch) ride-through capability for control inputs. In this release, previously asserted control inputs do not change state during warm start. ➤ Resolved a rare issue where the SELBOOT checksum could be reported incorrectly in the **VER** command response. ➤ Reduced maximum relay automatic diagnostic restart response time. ➤ Resolved an issue where Automation SELOGIC latch bits would reset when the Automation SELOGIC settings are modified.	20210514

Table A.1 Firmware Revision History (Sheet 6 of 6)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Resolved an issue where uncommon and repetitive command line operations can cause a relay restart when the IEC 61850 GOOSE function is enabled. ➤ Enhanced the relay's logic to use both the BMCA algorithm and the network time-inaccuracy check in power profile to choose the best Grandmaster clock on a PRP network. ➤ Increased the number of available display points to 192. ➤ Increased the number of available local and remote bits to 64. ➤ Increased the number of available DNP binary output points to 160. ➤ Improved received GOOSE message processing speed for relay virtual bits mapped to GOOSE binary data. ➤ Added support for the IEC 61850 Local/Remote control feature defined in the IEC 61850-7-4 standard. ➤ Enhanced IEC 61850 processing to indicate when the invalid quality attribute is set in received GOOSE messages. ➤ Added SELOGIC variable SC850SM to change the IEC 61850 simulation mode of the relay. ➤ Corrected an issue where the Mode, Beh, and Health quality.validity = good is not maintained when Mode = OFF. ➤ Added IEC 61850 simulation mode indication to the **STA** and **GOO** commands.	
SEL-400G-R100-V3-Z001001-D20210625 SEL-400G-1-R100-V3-Z001001-D20210625	Includes all the functions of SEL-400G-R100-V2-Z001001-D20201009 and SEL-400G-1-R100-V2-Z001001-D20201009 with the following addition: ➤ Modified firmware to improve the security of the phase distance element when configured with zero time delay.	20210625
SEL-400G-R100-V2-Z001001-D20201009 SEL-400G-1-R100-V2-Z001001-D20201009	Includes all the functions of SEL-400G-R100-V1-Z001001-D20200518 and SEL-400G-1-R100-V1-Z001001-D20200518 with the following additions: ➤ Enhanced output contact behavior following a power cycle while the relay is in IEC 61850 "Blocked" or "Test/Blocked" operating mode. ➤ Resolved an extremely rare issue that could cause the relay to perform a diagnostic restart when configured for Parallel Redundancy Protocol (NETMODE = PRP) and the relay received abnormal Ethernet traffic.	20201009
SEL-400G-R100-V1-Z001001-D20200518 SEL-400G-1-R100-V1-Z001001-D20200518	➤ Initial version.	20200518

SELBOOT

NOTE: R3xx SELBOOT versions only support .zds digitally signed firmware upgrade files over a serial or Ethernet connection.

SELBOOT is a firmware package inside the relay that handles hardware initialization and provides the functions needed to support firmware upgrades. *Table A.2* lists the SELBOOT releases used with the SEL-400G, their revision and a description of modifications. The most recent SELBOOT revision is listed first.

Table A.2 SELBOOT Revision History

SELBOOT Firmware Identification (BFID)	Summary of Revisions
SLBT-4XX-R302-V0-Z001002-D20230317	➤ Modified SELBOOT to support the five-port Ethernet card.
SLBT-4XX-R300-V0-Z001002-D20200229	➤ First revision used with SEL-400G.

ICD File

To find the ICD revision number in your relay, view the configVersion by using the serial port **ID** command. The configVersion is the last item displayed in the information returned from the **ID** command.

configVersion = ICD-400G-R202-V0-Z306005-D20150421

The ICD revision number is after the R (e.g., 202) and the date code is after the D (e.g., 20150421). This revision number is not related to the relay firmware revision number. The configVersion revision displays the ICD file version used to create the CID file that is loaded in the relay.

NOTE: The Z-number representation is implemented with ClassFileVersion 005. Previous ClassFileVersions do not provide an informative Z-number.

NOTE: The instance number n for the I/O board logical nodes (INxGGIOn and OUTxGGIOn) may vary between relays and ClassFileVersions.

NOTE: ClassFileVersion 007 supports both the four- and five-port Ethernet cards.

The configVersion contains other useful information. The Z-number consists of six digits. The first three digits following the Z represent the minimum IED firmware required to be used with the ICD (e.g., 306). The second three digits represent the ICD ClassFileVersion (e.g., 005). The ClassFileVersion increments when there is a major addition or change to the IEC 61850 implementation of the relay.

Table A.3 list the ICD file versions, a description of modifications, and the instruction manual date code that corresponds to the versions. The most recent version is listed first.

Table A.3 ICD File Revision History (Sheet 1 of 2)

configVersion[a]	Summary of Revisions	Minimum Relay Firmware	ClassFile Version	Manual Date Code
ICD-400G-R105-V0-Z106010-D20250214	➤ IEC 61850 Edition 2.1 Conformance. ➤ Modified the LPHD logical node to include the IEC 61850 library version SelLibId.val. ➤ Added support for the cmdQual, onDur, offDur, and numPls pulse configuration attributes, according to IEC 61850-7-3. ➤ Added the LocKey data object support and changed the data source mapping for Loc and LocSta. ➤ Modified the ICD file to remove control blocks and default GOOSE and report data sets. ➤ Added HSRGGIO logical node for HSR status indication. ➤ Added GGIO logical nodes to support Automation SELOGIC Variables 129–256. ➤ Added support for the valImport and valKind attributes according to IEC 61850-6 for compatibility with third-party system configuration tools. ➤ Reduced the size of all GGIO lnTypes to a maximum of 32 indices. ➤ Modified logical nodes prefixes and instances.	R106	010	20250214
ICD-400G-R104-V0-Z104009-D20231207 **NOTE:** ClassFileVersion 008 did not production release.	➤ Updated IEC 61850 Edition 2 Conformance. ➤ Updated ClassFileVersion to 009. ➤ Resolved an issue where the InRef for DC8 was mapped to DC7.	R104	009	20231207

Table A.3 ICD File Revision History (Sheet 2 of 2)

configVersion[a]	Summary of Revisions	Minimum Relay Firmware	ClassFile Version	Manual Date Code
	➤ Added support for MMS buffered and unbuffered report reservation. ➤ Included the product and functional name in the CILO logical node path for SrcRef.			
ICD-400G-R103-V0-Z103007-D20230317	➤ Added support for the five-port Ethernet card. Added logical nodes PRPGGIO, PBLCCH, SBLCCH, EALCCH, and an additional ETHGGIO. Added multiple access points to allow for the segregation of process bus and station bus GOOSE transmission. ➤ Added the LNKFL2 attribute to the ETHGGIO logical node.	R103	007	20230317
ICD-400G-R102-V0-Z102006-D20220517	➤ Changed the CSWI logical node Loc.stVal data source from LOC to LOC OR LOCAL. ➤ Added the CILO logical node for each switch control object. ➤ Mapped the CILO logical node attributes to the blocking inputs of the CSWI logical nodes for each switch control object.	R102	006	20220523
ICD-400G-R101-V0-Z101006-D20201204	➤ Added PRBGGIO logical nodes to support pulsing remote bits. ➤ Corrected the IEC 61850 Data Object number extensions according to the Ed 2 number usage. ➤ Added support for the IEC 61850 Functional Naming feature. ➤ Added the IEC 61850 LTRK logical node for service tracking. ➤ Added new LBGGIO logical nodes for local bits 33–64. ➤ Added new RBGGIO logical nodes for remote bits 33–64. ➤ Added FltTyp and FltCaus data attributes to the FLTRDRE logical node. ➤ Added support for the IEC 61850 Local/Remote control feature defined in the IEC 61850-7-4 standard. Control messages need to include the orCat value associated with the active control authority.	R101	006	20210514
ICD-400G-R100-V0-Z100006-D20200430	➤ SEL-400G ICD file for firmware R100 or higher.	R100	006	20200401

configVersion Details:

ICD-[PN]-R[RN]-V[VS]-Z[FC]-D[RD] where:

[PN] = Product name (e.g., 487E-5S)
[RN][b] = Revision number (e.g., 001)
[VS] = Version specifications (e.g., 0)
[FC][c] = Minimum relay firmware and class file version (e.g., 400)
[RD] = Release date code (e.g., 20180910)

[a] The configVersion can be determined for the IED by performing an ID ASCII command from a terminal connection.
[b] This is the ICD file revision number, not IED firmware revision number.
[c] FC consists of six digits. The first three following the Z represent the minimum IED firmware required to be used with the ICD (e.g., 516). The second three represent the ICD ClassFileVersion (e.g., 006).

Instruction Manual

The date code at the bottom of each page of this manual reflects the creation or revision date.

Table A.4 lists the instruction manual versions and revision descriptions. The most recent instruction manual version is listed first.

Table A.4 Instruction Manual Revision History (Sheet 1 of 5)

Revision Date	Summary of Revisions
20250214	General ➤ Removed references to product literature DVD and firmware CD. Section 1 ➤ Updated *Figure 1.2: Functional Overview*. ➤ Updated *Specifications*. Section 2 ➤ Updated *Control Outputs*. ➤ Updated *Figure 2.13: I/O Interface Board INT8*. ➤ Updated *Figure 2.42: Typical DC Connection Diagram*. Section 5 ➤ Updated *Table 5.55: Field Ground Settings*. ➤ Updated *Harmonic Heating*. Section 10 ➤ Updated *Table 10.14: SEL-400G Analog Input Reference Data Map*, *Table 10.23 Logical Device: PRO (Protection), Table 10.24 Logical Device: MET (Metering),* and *Table 10.25 SEL-400G Specific Logical Device: ANN (Annunciation)*. Section 11 ➤ Updated *Table 11.2: Row List of Relay Word Bits*. Appendix A ➤ Updated for firmware version R106. ➤ Updated for ICD version R105.
20240927	Section 1 ➤ Changed *Object Penetration* to *Ingress Protection* and updated contents in *Specifications*.
20240529	Section 1 ➤ Updated *Overview*. ➤ Updated *Figure 1.2: Functional Overview*. ➤ Updated *Models and Options* and *Specifications*. Section 2 ➤ Updated *Relay Sizes*. ➤ Added *Figure 2.2: Rear Panel with Fixed Terminal Blocks (8U) and INT8 I/O Boards, Figure 2.3: Rear Panel Connectorized (7U) with INT2 I/O Boards*, and *Figure 2.4: Rear Panel Connectorized (6U) with INT4 I/O Board*. ➤ Updated *Plug-in Boards* and *1/0 Interface Board Jumpers*. ➤ Updated *Figure 2.17: SEL-400G Chassis Dimensions* and *Figure 2.20: Insulation Resistance and Capacitance Received From SEL-2664S*. ➤ Updated *SEL-2664/SEL-2664S/SEL-400G Communication Configuration.* Section 3 ➤ Updated *Table 3.14: Zone 1 Expected Pickup Currents and Corresponding Real and Reactive Power, Table 3.15: Zone 2 Expected Pickup Currents and Corresponding Real and Reactive Power, Table 3.20: Settings to Test the Directional Power Element*. ➤ Updated *Figure 3.17: 46 Element Testing Group Settings, Figure 3.28: PULSE OUT201 Event Report, Figure 3.29: PULSE OUT202 Event Report, Figure 3.30: PULSE OUT203 Event Report,* and *Figure 3.31: PULSE OUT204 Event Report*.

Table A.4 Instruction Manual Revision History (Sheet 2 of 5)

Revision Date	Summary of Revisions
	Section 4 ➤ Updated *Stator Ground Meter* and *Insulation R/C Meter*. Section 5 ➤ Updated *Inverting Polarity of Current and Voltage Inputs*. ➤ Updated *Figure 5.127: Voltage-Restrained, Phase Overcurrent Element (AB Loop Shown)*. ➤ Updated *Field Ground Protection, Control Pulse Calculations,* and *ULTRnn (Unlatch Trip Elements)*. Section 7 ➤ Updated *Fundamental Meter*. Section 8 ➤ Updated *Table 8.27: Relay Configuration, Table 8.31: Frequency Tracking Sources, Table 8.50: Current Unbalance (46) Elements 1 and 2, Table 8.60: Field Ground (64F) Element, Table 8.61: Stator Ground (64S) Element,* and *Table 8.79: Trip Logic*. Section 10 ➤ Added *Control Points*. ➤ Updated *Table 10.13: SEL-400G Analog Input Reference Data Map*. Section 11 ➤ Updated *Table 11.1: Alphabetical List of Relay Word Bits* and *Table 11.2: Row List of Relay Word Bits*. Appendix A ➤ Updated for firmware version R105.
20240509	Appendix A ➤ [Cybersecurity] Updated for firmware version R104-V1.
20231207	Section 1 ➤ Updated *Figure 1.4: Hydro Generator*. ➤ Updated *Table 1.3: SEL-400G Relay Characteristics*. ➤ Updated *Specifications*. Section 4 ➤ Updated *Figure 4.1: Sample ROTATING DISPLAY*.

Table A.4 Instruction Manual Revision History (Sheet 3 of 5)

Revision Date	Summary of Revisions
	Section 5 ➤ Added note beside *Table 5.2: Voltage Input Settings*. ➤ Updated *System Frequency Source* table. ➤ Updated *Figure 5.9: IPB Ground Fault Protection and Synchronism Check*. ➤ Added *Considerations for Generators With Two Neutrals*. ➤ Updated *Transverse Differential and Overall Differential*. ➤ Added *System Frequency Tracking Using Single-Phase Voltages* and *Generator Monitoring*. ➤ Removed *Case 4: Single-Phase PT Input, Connected to the A-Phase and C-Phase Inputs*. ➤ Updated *Table 5.10: Pumped Storage Settings*. ➤ Updated *Compensation Calculations*. ➤ Updated *Table 5.14: Pickup, Slope, and Security Settings*, *Table 5.16: Winding Compensation Settings*, and *Table 5.18: Inrush Restraint Settings*. ➤ Updated *Restricted Earth Fault Element*. ➤ Updated *Table 5.23: Third-Harmonic Alternative Switch Settings, Table 5.24: 64G2 Third-Harmonic Element Settings*, and *Table 5.27: Typical Motoring Power*. ➤ Updated *64G3 Third-Harmonic Element* equations. ➤ Updated *Sequence Voltage Acceleration.* ➤ Updated *Table 5.33: 40P Dynamic Function Common Settings* and *Table 5.36: 40Z Settings*. ➤ Added note to *Table 5.46: System Backup Compensation Matrices*. ➤ Updated *Undervoltage Supervision* equation. ➤ Updated *Table 5.50: Voltage-Restrained Time-Overcurrent Settings*, *Table 5.51: Load Encroachment Settings*, and *Table 5.52: Thermal Element Settings*. ➤ Updated *Thermal Model n Operating Quantity (THROn)* equation. ➤ Updated *Figure 5.152: Zero-Slip and Slip-Within-Limits Checks*, *Figure 5.155: Uncompensated Angle Acceptance Window, Figure 5.156: Compensated and Uncompensated Phasor Relationships, Figure 5.157: Compensated Synchronism-Check Logic,* and *Figure 5.158: Compensated Angle Acceptance Window*. ➤ Updated *Table 5.57: Synchronism-Check Element Settings.* ➤ Updated *Voltage Selection Examples*. ➤ Updated *Figure 5.165: Breaker n Voltage Control Logic, Figure 5.166: Breaker n Frequency Control Logic, Figure 5.168: Phase Check Logic, Figure 5.174: Current Disturbance Detector,* and *Figure 5.184: Breaker Failure Logic for Breaker n When BF_SCHM = Y*. ➤ Updated *Table 5.70: Over- and Undervoltage Settings*. ➤ Updated *Figure 5.203: Negative-Sequence Instantaneous Overcurrent Element, Figure 5.204: Zero-Sequence Instantaneous Overcurrent Element,* and *Figure 5.217: Zero-Sequence Directional Enable Logic*. ➤ Updated *Zero-Sequence Directional Element* and *Negative-Sequence Directional Element* equations. ➤ Added *Circuit Breaker Status*. Section 6 ➤ Updated *Figure 6.1: Example System Three-Line Diagram*. Section 7 ➤ Updated *Circuit Breaker Monitor*. Section 8 ➤ Updated *Table 8.43: Breaker n Synchronism Check (25)*. Section 12 ➤ Updated *Table 12.1: Analog Quantities Sorted Alphabetically* and *Table 12.2: Analog Quantities Sorted by Function*. Appendix A ➤ Updated for firmware version R104. ➤ Updated for ICD file version R104.
20231110	Appendix A ➤ Updated for firmware version R103-V2.
20230830	Appendix A ➤ Updated for firmware version R103-V1.

Table A.4 Instruction Manual Revision History (Sheet 4 of 5)

Revision Date	Summary of Revisions
20230317	Section 1 ➤ Updated *Figure 1.2: Functional Overview*. ➤ Update *Ethernet Connection Options* and *Ethernet Communications Protocols.* ➤ Updated *Figure 1.5: Combustion Gas Turbine*. ➤ Updated *Specifications*. Section 2 ➤ Updated *Figure 2.2: Rear Panel With Fixed Terminal Blocks, Figure 2.7 High-Speed Control Output Typical Terminals, INT8,* and *Figure 2.21: Communication Connection Between the SEL-400G, SEL-2664S, and SEL-2664.* ➤ Updated *Ethernet Network Connections*. Section 3 ➤ Updated *Figure 3.4: Voltage Test Connections* and *Figure 5.6: Connection Using One Three-Phase Voltage, Two Single-Phase and the Generator Neutral Voltage for PTCONZ = Y and PTCONV = 1PH.* ➤ Updated *Table 5.8: Power System Data Settings*. ➤ Updated *Internal Fault Detection Logic*. ➤ Updated *Figure 5.50 REF: 1 Element Enable Logic, Figure 5.52: REF Element Trip Output, Figure 5.73: 64G2 Third-Harmonic Undervoltage Logic*, and *Figure 5.76: 64G3 Third-Harmonic Ratio Logic*. ➤ Updated *Table 5.25: 64G Output Logic Settings*. ➤ Updated *Figure 5.123: Backup Distance Element, Figure 5.152: Angle Difference and Slip Calculation*, *Figure 5.214: U.S. Curves: U1, U2, U3, and U4*. Section 8 ➤ Updated *Table 8.11: Phasors Included in the Data q*. Section 9 ➤ Updated *Table 9.1: SEL-400G List of Commands*. Section 11 ➤ Updated *Table 11.1: Alphabetical List of Relay Word Bits* and *Table 11.2: Row List of Relay Word Bits*. Section 12 ➤ Updated *Table 12.1: Analog Quantities Sorted Alphabetically* and *Table 12.2: Analog Quantities Sorted by Function*. Appendix A ➤ Updated for firmware version R103. ➤ Updated for SELBOOT version R302. ➤ Updated for ICD version R103. SEL-400G Relay Command Summary ➤ Added COM PRP.
20230306	Appendix A ➤ Updated for firmware version R102-V1.
20220523	Section 1 ➤ Updated *Specifications*. Section 2 ➤ Updated *High-Speed, High-Current Interrupting Control Outputs*. Section 5 ➤ Updated *Waveshape-Based Bipolar Unblocking Logic*. Section 7 ➤ Added *COMTRADE Relay Word Bit Behavior*. Section 10 ➤ Updated *Table 10.22: Logical Device: PRO (Protection)*. Section 11 ➤ Updated *Table 11.1: Alphabetical List of Relay Word Bits* and *Table 11.2: Row List of Relay Word Bits* for IEC 61850 control interlocking Relay Word bits.

Table A.4 Instruction Manual Revision History (Sheet 5 of 5)

Revision Date	Summary of Revisions
	Appendix A ➤ Updated for firmware version R102-V0. ➤ Updated for ICD version R102-V0.
20211203	Appendix A ➤ Updated for firmware version R101-V2. ➤ Updated Summary of Revisions for ICD file version R101 in *Table A.3: ICD File Revision History*.
20210708	Section 1 ➤ Updated *Specifications*.
20210625	Section 1 ➤ Updated Specifications. Appendix A ➤ Updated for firmware versions R100-V3 and R101-V1.
20210514	Section 1 ➤ Updated *Table 1.3: SEL-400G Relay Characteristics*. ➤ Updated *Specifications*. Section 5 ➤ Updated *Internal Fault Detection Logic*. ➤ Updated *Figure 5.40: Overall Logic For an In-Zone Transformer* and *Figure 5.52: REF Element Trip Output*. ➤ Updated *Discussion on CT Connection Compensation* and *Torque Control*, Section 7 ➤ Updated *Differential Meter*. Section 10 ➤ Updated *Table 10.5: SEL-400G Database Structure—TARGET Region*, *Table 10.11: SEL-400G Binary Output Reference Data Map*, *Table 10.15: SEL-400G Object 12 Control Point Operations*, *Table 10.22: Logical Device: PRO (Protection)*, and *Table 10.23: Logical Device: MET (Metering)*. ➤ Added *Table 10.25: FLTYPE—Fault Type* and *Table 10.26: FLTCAUS—Fault Cause*. ➤ Updated *Table 10.42: 01h, 05h, 0Fh SEL-400G Output Coils* and *Table 10.52: Modbus Analog Quantities Table*. Section 11 ➤ Updated *Table 11.1: Alphabetical List of Relay Word Bits* and *Table 11.2: Row List of Relay Word Bits*. Section 12 ➤ Updated *Table 12.1: Analog Quantities Sorted Alphabetically* and *Table 12.2: Analog Quantities Sorted by Function*. Appendix A ➤ Updated for firmware version R101-V0. ➤ Updated for ICD version R101-V0.
20201204	Preface ➤ Updated *SEL-400 Series Relays Instruction Manual* and *Safety Marks*.
20201009	Appendix A ➤ Updated for firmware version R100-V2.
20200518	Section 5 ➤ Updated *Table 5.8: Power System Data Settings*. ➤ Update *Setting Guidelines for the 64G2 Third-Harmonic Element (Differential Mode)*. ➤ Added *Figure 5.72: Example of 64G2 Undervoltage Setting From Survey Data*.
20200401	➤ Initial version.

SEL-400G Relay Command Summary

Command[a, b]	Description
2ACCESS	Go to Access Level 2 (full control)
81A	Display frequency accumulated time report; load/reset data
89CLOSE *k*	Close Disconnect *k* (Isolator *k*) (*k* = 1–10)
89OPEN *k*	Open Disconnect *k* (Isolator *k*) (*k* = 1–10)
AACCESS	Go to Access Level A (automation configuration)
ACCESS	Go to Access Level 1 (monitor relay)
BACCESS	Go to Access Level B (monitor and control circuit breakers)
BNAME	ASCII names of Fast Meter status bits
BREAKER *n*	Display circuit breaker reports; preload/reset monitor data (*n* = S, T, U, Y)
CASCII	Generate the Compressed ASCII response configuration message
CBREAKER	Display Compressed ASCII breaker status report
CHISTORY	Display Compressed ASCII history report
CLOSE *n*	Close Circuit Breaker *n* (*n* = S, T, U, Y)
COM *c*	Display Channel *c* MIRRORED BITS communications data (*c* = A, B, or M [either enabled single channel])
COM PTP	Display a report on PTP data sets and statistics
COM PRP	Display PRP information and statistics for the five-port Ethernet card
COM RTC	Display statistics for synchrophasor client channels
CONTROL *nn*	Set, clear, or pulse Remote Bit *nn* (*nn* = 01–32)
COPY *m n*	Copy settings between instances in the same class (*m* and *n* are instance numbers; e.g., *m* = 1 is Group 1, *n* = 2 is Group 2, etc.)
CPR	Display Compressed ASCII signal profiling report
CSER	Display Compressed ASCII sequential events report
CSTATUS	Display Compressed ASCII relay status report
CSUMMARY	Display Compressed ASCII summary event report
DATE	Display and set the relay date
DNAME X	ASCII names of all relay digital points reported via Fast Meter
ETHERNET	Displays Ethernet port (PORT 5) configuration and status
EXIT	Reduce access level to Access Level 0 (exit relay control)
FILE	Transfer files between the relay and external software
GOOSE	Displays transmit and receive GOOSE messaging information
GROUP	Display the active group number or change the active group
HELP	List and describe available commands at each access level
HISTORY	View event summaries/history; clear event summary data
ID	Display the firmware ID, user ID, device code, part number, and configuration information
LOOPBACK	Connect MIRRORED BITS data from transmit to receive on the same port
MAC	Display MAC Addresses
MAP 1	View the relay database organization
METER	Display metering data and internal relay operating variables

Command[a, b]	**Description**
OACCESS	Go to Access Level O (output configuration)
OPEN *n*	Open Circuit Breaker *n* (*n* = S, T, U, Y)
PACCESS	Go to Access Level P (protection configuration)
PASSWORD *n*	Change relay password for Access Level *n*
PING *addr*	Sends an ICMP echo request message to the provided IP address *addr* to confirm connectivity
PORT *p*	Connect to remote devices via MIRRORED BITS virtual terminal (for **PORT p**; where *p* = 1–3, F)
PROFILE	Display signal profile records
PULSE OUT*nnn*	Pulse a relay control output (OUT*nnn* is a control output)
QUIT	Reduce access level to Access Level 0 (exit relay control)
RTC	Display configuration of received remote synchrophasors
SER	View Sequential Events Recorder (SER) report
SET	Set or modify relay settings
SHOW	Display relay settings
SNS	Display Sequential Events Recorder settings name strings (Fast SER)
STATUS	Display or clear relay status and SELOGIC control equation errors
SUMMARY	Display a summary event report
TARGET	Display relay elements for a row in the Relay Word bit table
TEST DB	Test interfaces to a virtual device database used by Fast Message protocol
TEST DB2	Test all communications protocols except Fast Message
TEST FM	Display or place values in Fast Meter interface
THE	Display transformer thermal information
TIME	Display and set the relay time clock
TRIGGER	Initiate a data capture and record an event report
VERSION	Display the relay hardware and software configuration
VIEW 1	View data from the Fast Message database

[a] See Section 9: ASCII Command Reference for more information.

[b] For help on a specific command, type **HELP [command] <Enter>** at an ASCII terminal communicating with the relay.

SEL-400G Relay Command Summary

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[a] See Section 9: ASCII Command Reference for more information.

[b] For help on a specific command, type **HELP [command] <Enter>** at an ASCII terminal communicating with the relay.

SEL-400 Series Relays

Instruction Manual

20250214

SCHWEITZER ENGINEERING LABORATORIES

Part Number: PM400-01

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Section 8: Monitoring

Section 9: Reporting

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Preface

This manual provides information and instructions for operating the SEL-400 series relays. This manual is for use by power and integration engineers and others experienced in protective relaying applications and SCADA integration. This manual describes features common to most SEL-400 series relays. Each SEL-400 series product includes its own instruction manual that describes the protection features and unique characteristics of that specific relay.

Manual Overview

This manual is a comprehensive work covering common aspects of SEL-400 series relay application and use. Read the sections that pertain to your application to gain valuable information about using SEL-400 series relays. An overview of each manual section and section topics follows.

Preface. Describes manual organization and conventions used to present information, as well as safety information.

Section 1: Introduction. Introduces SEL-400 series relays common features.

Section 2: PC Software. Explains how to use SEL Grid Configurator and ACSELERATOR QuickSet SEL-5030 Software.

Section 3: Basic Relay Operations. Describes how to perform fundamental operations such as applying power and communicating with the relay, setting and viewing passwords, checking relay status, viewing metering data, reading event reports and Sequential Events Recorder (SER) records, operating relay control outputs and control inputs, and using relay features to make relay commissioning easier.

Section 4: Front-Panel Operations. Describes the LCD messages and menu screens. Shows you how to use front-panel pushbuttons and read targets. Provides information about local substation control and how to make relay settings via the front panel.

Section 5: Control. Describes various control features of the relay, including circuit breaker operation, disconnect operation, remote bits, and one-line diagrams.

Section 6: Autoreclosing. Explains how to operate the two-circuit breaker multishot recloser. Describes how to set the relay for single-pole reclosing, three-pole reclosing, or both. Shows selection of the lead and follow circuit breakers.

Section 7: Metering. Provides information on viewing current, voltage, power, and energy quantities. Describes how to view other common internal operating quantities.

Section 8: Monitoring. Describes how to use the circuit breaker monitors and the substation dc battery monitors.

Section 9: Reporting. Explains how to obtain and interpret high-resolution raw data oscillograms, filtered event reports, event summaries, history reports, and SER reports. Discusses how to enter SER trigger settings.

Section 10: Testing, Troubleshooting, and Maintenance. Describes techniques for testing, troubleshooting, and maintaining the relay. Includes the list of status notification messages and a troubleshooting chart.

Section 11: Time and Date Management. Explains timekeeping principles, synchronized phasor measurements, and estimation of power system states using the high-accuracy time-stamping capability. Presents real-time load flow/power flow application ideas.

Section 12: Settings. Provides a list of all common SEL-400 series relay settings and defaults.

Section 13: SELOGIC Control Equation Programming. Describes multiple setting groups and SELOGIC control equations and how to apply these equations. Discusses expanded SELOGIC control equation features such as PLC-style commands, math functions, counters, and conditioning timers. Provides a tutorial for converting older format SELOGIC control equations to new freeform equations.

Section 14: ASCII Command Reference. Provides an alphabetical listing of all ASCII commands with examples for each ASCII command option.

Section 15: Communications Interfaces. Explains the physical connection of the relay to various communications network topologies. Describes the various software protocols and how to apply these protocols to substation integration and automation. Includes details about Ethernet IP protocols, SEL ASCII, SEL Compressed ASCII, SEL Fast Meter, SEL Fast Operate, SEL Fast SER, and enhanced MIRRORED BITS communications.

Section 16: DNP3 Communication. Describes the DNP3 communications protocol and how to apply this protocol to substation integration and automation. Provides a Job Done example for implementing DNP3 in a substation.

Section 17: IEC 61850 Communication. Describes the IEC 61850 protocol and how to apply this protocol to substation automation and integration. Includes IEC 61850 protocol compliance statements.

Section 18: Synchrophasors. Describes the phasor measurement unit (PMU) functions of the relay. Provides details on synchrophasor measurement and real-time control. Describes the IEEE C37.118 synchrophasor protocol settings. Describes the SEL Fast Message synchrophasor protocol settings.

Section 19: Digital Secondary Systems. Describes the basic concepts of digital secondary systems (DSS). This includes both the Time-Domain Link (TiDL) system and UCA 61850-9-2LE Sampled Values.

Appendix A: Manual Versions. Lists the current manual version and details differences between the current and previous versions.

Appendix B: Firmware Upgrade Instructions. Describes the procedure to update the firmware stored in Flash memory.

Appendix C: Cybersecurity Features. Describes the various features of the relay that impact cybersecurity.

Glossary. Defines various technical terms used in the SEL-400 series instruction manuals.

Safety Information

Dangers, Warnings, and Cautions

This manual uses three kinds of hazard statements, defined as follows:

⚠DANGER
Indicates an imminently hazardous situation that, if not avoided, **will** result in death or serious injury.

⚠WARNING
Indicates a potentially hazardous situation that, if not avoided, **could** result in death or serious injury.

⚠CAUTION
Indicates a potentially hazardous situation that, if not avoided, **may** result in minor or moderate injury or equipment damage.

Safety Symbols

The following symbols are often marked on SEL products.

	**⚠CAUTION** Refer to accompanying documents.	**⚠ATTENTION** Se reporter à la documentation.
	Earth (ground)	Terre
	Protective earth (ground)	Terre de protection
	Direct current	Courant continu
	Alternating current	Courant alternatif
	Both direct and alternating current	Courant continu et alternatif
	Instruction manual	Manuel d’instructions

Safety Marks

The following statements apply to this device.

General Safety Marks

⚠CAUTION There is danger of explosion if the battery is incorrectly replaced. Replace only with Rayovac no. BR2335 or equivalent recommended by manufacturer. See Owner's Manual for safety instructions. The battery used in this device may present a fire or chemical burn hazard if mistreated. Do not recharge, disassemble, heat above 100°C, or incinerate. Dispose of used batteries according to the manufacturer's instructions. Keep battery out of reach of children.	⚠ATTENTION Une pile remplacée incorrectement pose des risques d'explosion. Remplacez seulement avec un Rayovac no BR2335 ou un produit équivalent recommandé par le fabricant. Voir le guide d'utilisateur pour les instructions de sécurité. La pile utilisée dans cet appareil peut présenter un risque d'incendie ou de brûlure chimique si vous en faites mauvais usage. Ne pas recharger, démonter, chauffer à plus de 100°C ou incinérer. Éliminez les vieilles piles suivant les instructions du fabricant. Gardez la pile hors de la portée des enfants.
⚠CAUTION To ensure proper safety and operation, the equipment ratings, installation instructions, and operating instructions must be checked before commissioning or maintenance of the equipment. The integrity of any protective conductor connection must be checked before carrying out any other actions. It is the responsibility of the user to ensure that the equipment is installed, operated, and used for its intended function in the manner specified in this manual. If misused, any safety protection provided by the equipment may be impaired.	⚠ATTENTION Pour assurer la sécurité et le bon fonctionnement, il faut vérifier les classements d'équipement ainsi que les instructions d'installation et d'opération avant la mise en service ou l'entretien de l'équipement. Il faut vérifier l'intégrité de toute connexion de conducteur de protection avant de réaliser d'autres actions. L'utilisateur est responsable d'assurer l'installation, l'opération et l'utilisation de l'équipement pour la fonction prévue et de la manière indiquée dans ce manuel. Une mauvaise utilisation pourrait diminuer toute protection de sécurité fournie par l'équipement.
For use in Pollution Degree 2 environment.	Pour l'utilisation dans un environnement de Degré de Pollution 2.

Other Safety Marks (Sheet 1 of 3)

⚠DANGER Disconnect or de-energize all external connections before opening this device. Contact with hazardous voltages and currents inside this device can cause electrical shock resulting in injury or death.	⚠DANGER Débrancher tous les raccordements externes avant d'ouvrir cet appareil. Tout contact avec des tensions ou courants internes à l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠DANGER Contact with instrument terminals can cause electrical shock that can result in injury or death.	⚠DANGER Tout contact avec les bornes de l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠WARNING Use of this equipment in a manner other than specified in this manual can impair operator safety safeguards provided by this equipment.	⚠AVERTISSEMENT L'utilisation de cet appareil suivant des procédures différentes de celles indiquées dans ce manuel peut désarmer les dispositifs de protection d'opérateur normalement actifs sur cet équipement.
⚠WARNING Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.	⚠AVERTISSEMENT Seules des personnes qualifiées peuvent travailler sur cet appareil. Si vous n'êtes pas qualifiés pour ce travail, vous pourriez vous blesser avec d'autres personnes ou endommager l'équipement.
⚠WARNING This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.	⚠AVERTISSEMENT Cet appareil est expédié avec des mots de passe par défaut. A l'installation, les mots de passe par défaut devront être changés pour des mots de passe confidentiels. Dans le cas contraire, un accés non-autorisé á l'équipement peut être possible. SEL décline toute responsabilité pour tout dommage résultant de cet accés non-autorisé.
⚠WARNING Do not look into the fiber ports/connectors.	⚠AVERTISSEMENT Ne pas regarder vers les ports ou connecteurs de fibres optiques.
⚠WARNING Do not look into the end of an optical cable connected to an optical output.	⚠AVERTISSEMENT Ne pas regarder vers l'extrémité d'un câble optique raccordé à une sortie optique.
⚠WARNING Do not perform any procedures or adjustments that this instruction manual does not describe.	⚠AVERTISSEMENT Ne pas appliquer une procédure ou un ajustement qui n'est pas décrit explicitement dans ce manuel d'instruction.
⚠WARNING During installation, maintenance, or testing of the optical ports, use only test equipment qualified for Class 1 laser products.	⚠AVERTISSEMENT Durant l'installation, la maintenance ou le test des ports optiques, utilisez exclusivement des équipements de test homologués comme produits de type laser de Classe 1.

Other Safety Marks (Sheet 2 of 3)

⚠WARNING Incorporated components, such as LEDs and transceivers are not user serviceable. Return units to SEL for repair or replacement.	⚠AVERTISSEMENT Les composants internes tels que les leds (diodes électroluminescentes) et émetteurs-récepteurs ne peuvent pas être entretenus par l'usager. Retourner les unités à SEL pour réparation ou remplacement.
⚠CAUTION Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.	⚠ATTENTION Les composants de cet équipement sont sensibles aux décharges électrostatiques (DES). Des dommages permanents non-décelables peuvent résulter de l'absence de précautions contre les DES. Raccordez-vous correctement à la terre, ainsi que la surface de travail et l'appareil avant d'en retirer un panneau. Si vous n'êtes pas équipés pour travailler avec ce type de composants, contacter SEL afin de retourner l'appareil pour un service en usine.
⚠CAUTION Equipment damage can result from connecting ac circuits to Hybrid (high-current interrupting) control outputs. Do not connect ac circuits to Hybrid control outputs. Use only dc circuits with Hybrid control outputs.	⚠ATTENTION Des dommages à l'appareil pourraient survenir si un circuit CA était raccordé aux contacts de sortie à haut pouvoir de coupure de type "Hybrid." Ne pas raccorder de circuit CA aux contacts de sortie de type "Hybrid." Utiliser uniquement du CC avec les contacts de sortie de type "Hybrid."
⚠CAUTION Substation battery systems that have either a high resistance to ground (greater than 10 kΩ) or are ungrounded when used in conjunction with many direct-coupled inputs can reflect a dc voltage offset between battery rails. Similar conditions can exist for battery monitoring systems that have high-resistance balancing circuits or floating grounds. For these applications, SEL provides optional ground-isolated (optoisolated) contact inputs. In addition, SEL has published an application advisory on this issue. Contact the factory for more information.	⚠ATTENTION Les circuits de batterie de postes qui présentent une haute résistance à la terre (plus grande que 10 kΩ) ou sont isolés peuvent présenter un biais de tension CC entre les deux polarités de la batterie quand utilisés avec plusieurs entrées à couplage direct. Des conditions similaires peuvent exister pour des systèmes de surveillance de batterie qui utilisent des circuits d'équilibrage à haute résistance ou des masses flottantes. Pour ce type d'applications, SEL peut fournir en option des contacts d'entrée isolés (par couplage optoélectronique). De surcroît, SEL a publié des recommandations relativement à cette application. Contacter l'usine pour plus d'informations.
⚠CAUTION If you are planning to install an INT4 I/O interface board in your relay, first check the firmware version of the relay. If the firmware version is R111 or lower, you must first upgrade the relay firmware to the newest version and verify that the firmware upgrade was successful before installing the new board. Failure to install the new firmware first will cause the I/O interface board to fail, and it may require factory service. Complete firmware upgrade instructions are provided when new firmware is ordered.	⚠ATTENTION Si vous avez l'intention d'installer une Carte d'Interface INT4 I/O dans votre relais, vérifiez en premier la version du logiciel du relais. Si la version est R111 ou antérieure, vous devez mettre à jour le logiciel du relais avec la version la plus récente et vérifier que la mise à jour a été correctement installée sur la nouvelle carte. Les instructions complètes de mise à jour sont fournies quand le nouveau logiciel est commandé.
⚠CAUTION Field replacement of I/O boards INT1, INT2, INT5, INT6, INT7, or INT8 with INT4 can cause I/O contact failure. The INT4 board has a pickup and dropout delay setting range of 0–1 cycle. For all other I/O boards, pickup and dropout delay settings (IN201PU–IN224PU, IN201DO–IN224DO, IN301PU–IN324PU, and IN301DO–IN324DO) have a range of 0–5 cycles. Upon replacing any I/O board with an INT4 board, manually confirm reset of pickup and dropout delays to within the expected range of 0–1 cycle.	⚠ATTENTION Le remplacement en chantier des cartes d'entrées/sorties INT1, INT2, INT5, INT6, INT7 ou INT8 par une carte INT4 peut causer la défaillance du contact d'entrée/sortie. La carte INT4 présente un intervalle d'ajustement pour les délais de montée et de retombée de 0 à 1 cycle. Pour toutes les autres cartes, l'intervalle de réglage du délai de montée et retombée (IN201PU–IN224PU, IN201DO– IN224DO, IN301PU–IN324PU, et IN301DO–IN324DO) est de 0 à 5 cycles. Quand une carte d'entrées/sorties est remplacée par une carte INT4, vérifier manuellement que les délais de montée et retombée sont dans l'intervalle de 0 à 1 cycle.
⚠CAUTION Do not install a jumper on positions A or D of the main board J21 header. Relay misoperation can result if you install jumpers on positions J21A and J21D.	⚠ATTENTION Ne pas installer de cavalier sur les positions A ou D sur le connecteur J21 de la carte principale. Une opération intempestive du relais pourrait résulter suite à l'installation d'un cavalier entre les positions J21A et J21D.
⚠CAUTION Insufficiently rated insulation can deteriorate under abnormal operating conditions and cause equipment damage. For external circuits, use wiring of sufficiently rated insulation that will not break down under abnormal operating conditions.	⚠ATTENTION Un niveau d'isolation insuffisant peut entraîner une détérioration sous des conditions anormales et causer des dommages à l'équipement. Pour les circuits externes, utiliser des conducteurs avec une isolation suffisante de façon à éviter les claquages durant les conditions anormales d'opération.
⚠CAUTION Relay misoperation can result from applying other than specified secondary voltages and currents. Before making any secondary circuit connections, check the nominal voltage and nominal current specified on the rear-panel nameplate.	⚠ATTENTION Une opération intempestive du relais peut résulter par le branchement de tensions et courants secondaires non conformes aux spécifications. Avant de brancher un circuit secondaire, vérifier la tension ou le courant nominal sur la plaque signalétique à l'arrière.

Other Safety Marks (Sheet 3 of 3)

CAUTION Severe power and ground problems can occur on the communications ports of this equipment as a result of using non-SEL cables. Never use standard null-modem cables with this equipment.	**ATTENTION** Des problèmes graves d'alimentation et de terre peuvent survenir sur les ports de communication de cet appareil si des câbles d'origine autre que SEL sont utilisés. Ne jamais utiliser de câble de modem nul avec cet équipement.
CAUTION Do not connect power to the relay until you have completed these procedures and receive instruction to apply power. Equipment damage can result otherwise.	**ATTENTION** Ne pas mettre le relais sous tension avant d'avoir complété ces procédures et d'avoir reçu l'instruction de brancher l'alimentation. Des dommages à l'équipement pourraient survenir autrement.
CAUTION Use of controls or adjustments, or performance of procedures other than those specified herein, may result in hazardous radiation exposure.	**ATTENTION** L'utilisation de commandes ou de réglages, ou l'application de tests de fonctionnement différents de ceux décrits ci-après peuvent entraîner l'exposition à des radiations dangereuses.

General Information

The *SEL-400 Series Relays Instruction Manual* uses certain conventions that identify particular terms and help you find information. To benefit fully from reading this manual, take a moment to familiarize yourself with these conventions.

Typographic Conventions

There are three ways users typically communicate with SEL-400 series relays:

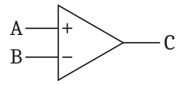
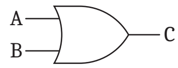
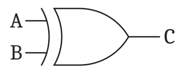
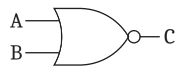
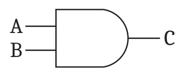
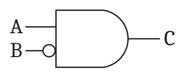
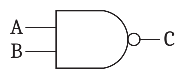
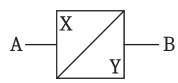
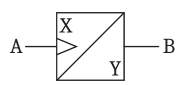
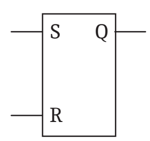
- ➤ Using a command line interface on a PC terminal emulation window
- ➤ Using the front-panel menus and pushbuttons
- ➤ Using SEL Grid Configurator or QuickSet software.

The instructions in this manual indicate these options with specific font and formatting attributes. The following table lists these conventions:

Example	Description
STATUS	Commands, command options, and command variables typed at a command line interface on a PC.
n **SUM *n***	Variables determined based on an application (in bold if part of a command).
<Enter>	Single keystroke on a PC keyboard.
<Ctrl+D>	Multiple/combination keystroke on a PC keyboard.
Start > Settings	PC software dialog boxes and menu selections. The > character indicates submenus.
ENABLE	Relay front- or rear-panel labels and pushbuttons.
`MAIN > METER`	Relay front-panel LCD menus and relay responses visible on the PC screen. The > character indicates submenus.

Logic Diagrams

Logic diagrams in this manual follow the conventions and definitions shown below.

NAME	SYMBOL	FUNCTION
Comparator		Input A is compared to Input B. Output C asserts if Input A is greater than Input B.
Input Flag		Input A comes from other logic.
OR		If either Input A or Input B asserts, Output C asserts.
Exclusive OR		If either Input A or Input B asserts, Output C asserts. If Input A and Input B are of the same state, Output C deasserts.
NOR		If neither Input A nor Input B asserts, Output C asserts.
AND		If Input A and Input B assert, Output C asserts.
AND w/ Inverted Input		If Input A asserts and Input B deasserts, Output C asserts. Inverter "O" inverts any input or output on any gate.
NAND		If Input A and/or Input B deassert, Output C asserts.
Time-Delayed Pick Up and/or Time-Delayed Drop Out		X is a time-delay-pickup value; Y is a time-delay-dropout value. Output B asserts Time X after Input A asserts; Output B does not assert if Input A does not remain asserted for Time X. If Time X is zero, Output B asserts when Input A asserts. If Time Y is zero, Input B deasserts when Input A deasserts.
Edge Trigger Timer		Rising edge of Input A starts timers. Output B asserts Time X after the rising edge of Input A. Output B remains asserted for Time Y. If Time Y is zero, Output B asserts for a single processing interval. Input A is ignored while the timers are running.
Set-Reset/Flip-Flop		Input S asserts Output Q until Input R asserts. Output Q deasserts or resets when Input R asserts.
Falling Edge		Output B asserts at the falling edge of Input A.
Rising Edge		Output B asserts at the rising edge of Input A.

Trademarks

All brand or product names appearing in this document are the trademark or registered trademark of their respective holders. No SEL trademarks may be used without written permission.

SEL trademarks appearing in this manual are shown in the following table.

ACSELERATOR Architect®	SELOGIC®
ACSELERATOR QuickSet®	SEL Compass®
Best Choice Ground Directional Element®	SYNCHROWAVE®
MIRRORED BITS®	Time-Domain Link (TiDL®) technology
SEL-2407®	

EtherCAT is registered trademark and patented technology, licensed by Beckhoff Automation GmbH, Germany.

Technical Support

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

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SECTION 1

Introduction

The SEL-400 series of relays feature high-performance protection for a variety of applications. All relays feature extensive metering, monitoring, and data recording, including high-resolution data capture and reporting.

Relays feature expanded SELOGIC control equation programming for easy and flexible implementation of custom protection and control schemes. The relays have separate protection and automation SELOGIC control equation programming areas with extensive protection and automation programming capability.

Relays provide extensive communications interfaces from standard SEL ASCII and enhanced MIRRORED BITS communications protocols to Ethernet connectivity with the optional Ethernet card. With the Ethernet card, you can employ common industry communications tools, including Telnet, File Transfer Protocol (FTP), DNP3 (serial and LAN/WAN), and the IEC 61850 Edition 2 standard suite of protocols.

NOTE: Some SEL-400 series relays are compliant with Edition 1 of the IEC 61850 standard.

NOTE: Some relays are only supported by SEL Grid Configurator. See Section 2: PC Software for more details.

Relays interface with SEL Grid Configurator or ACSELERATOR QuickSet SEL-5030 Software. SEL Grid Configurator or QuickSet assists you in setting, controlling, and acquiring data from the relays, both locally and remotely. ACSELERATOR Architect SEL-5032 Software enables you to view and configure IEC 61850 settings via a GUI.

Most relays support synchrophasor measurement. Synchrophasor measurements are available when a high-accuracy time source is connected to the relay. The relay supports the IEEE C37.118 standard for synchrophasors for power systems.

Most relays feature bay control functionality. The mimic display selected is displayed on the front-panel screen in one-line diagram format. The number of disconnects and breakers that can be controlled by the relay are a function of the selected mimic display screen. Control of the breakers and disconnects is available through front-panel pushbuttons, ASCII interface, Fast Message protocol, or SELOGIC control equations.

A simple and robust hardware design features efficient digital signal processing. Combined with extensive self-testing, these features provide relay reliability and enhance relay availability.

Common Features

Automation. Take advantage of enhanced automation features that include programmable elements for local control, remote control, protection latching, and automation latching. Local metering on the large-format front-panel LCD eliminates the need for separate panel meters. Use serial and Ethernet links to efficiently transmit key information, including metering data, protection element and control I/O status, Sequential Events Recorder (SER) reports, breaker monitor, relay summary event reports, and time synchronization. Use expanded SELOGIC control equations with math and comparison functions in control applications. Incorporate as many as 1000 lines of automation logic to speed and improve control actions.

Oscillography and Event Reporting. Record voltages, currents, and internal logic points as fast as an 8 kHz sampling rate. Phasor and harmonic analysis features allow investigation of relay and system performance.

Sequential Events Recorder (SER). Record the last 1000 entries, including setting changes, startups, and selectable logic elements.

High-Accuracy Time Stamping. Time-stamp binary COMTRADE event reports with real-time accuracy of better than 10 µs. View system state information to an accuracy of better than 1/4 of an electrical degree.

Digital Relay-to-Relay Communication. Use enhanced MIRRORED BITS communications to monitor internal element conditions between relays within a station, or between stations, by using SEL fiber-optic transceivers. Send digital, analog, and virtual terminal data over the same MIRRORED BITS channel.

Ethernet Access. Access all relay functions with the optional Ethernet card. Interconnect with automation systems by using IEC 61850 or DNP3 LAN/WAN protocols directly or through an SEL-3530 RTAC. Use FTP for high-speed data collection.

Time-Domain Link (TiDL). Reduce costs with TiDL technology. With this simple-to-configure solution, the relay ac inputs and most of its digital inputs and outputs are distributed using TiDL merging units.

Parallel Redundancy Protocol (PRP). Provide seamless recovery from any single Ethernet network failure with this protocol, in accordance with IEC 62439-3. The Ethernet network and all traffic are fully duplicated with both copies operating in parallel.

High-Availability Seamless Redundancy Protocol (HSR). Provide seamless recovery from any single Ethernet network failure with this protocol, in accordance with IEC 62439-3. All HSR compatible devices are connected in a ring and the traffic is fully duplicated and sent in both clockwise and counterclockwise directions around the ring.

Increased Security. Set unique passwords for each access level. The relay divides control and settings into seven relay access levels. The relay has separate breaker, protection, automation, and output access levels, among others.

Rules-Based Settings Editor. Communicate with and set the relay by using an ASCII terminal, or use the PC-based SEL Grid Configurator or QuickSet software.

Settings Reduction. Show only the settings for the functions and elements you have enabled using internal relay programming.

Alias Settings. Use as many as 200 aliases to rename any digital or analog quantity in the relay. The aliases are available for use in customized programming, making initial programming and maintenance easy.

SECTION 2

PC Software

Refer to *Table 2.1* to navigate to the information about the PC software program available based on your relay.

Table 2.1 SEL Software

Relay Model	Available Settings Software
SEL-400G	See *SEL Grid Configurator on page 2.1*
SEL-401	See *SEL Grid Configurator on page 2.1*
SEL-411L-0, -1, -A, -B	See *SEL Grid Configurator on page 2.1* or *ACSELERATOR QuickSet SEL-5030 Software on page 2.14*
SEL-411L-2	See *SEL Grid Configurator on page 2.1*
SEL-421-4, -5	See *ACSELERATOR QuickSet SEL-5030 Software on page 2.14*
SEL-421-7	See *SEL Grid Configurator on page 2.1*
SEL-451-5, -A	See *ACSELERATOR QuickSet SEL-5030 Software on page 2.14*
SEL-451-6	See *SEL Grid Configurator on page 2.1*
SEL-487B-1	See *ACSELERATOR QuickSet SEL-5030 Software on page 2.14*
SEL-487B-2	See *SEL Grid Configurator on page 2.1*
SEL-487E-3, -4	See *ACSELERATOR QuickSet SEL-5030 Software on page 2.14*
SEL-487E-5	See *SEL Grid Configurator on page 2.1*
SEL-487V	See *ACSELERATOR QuickSet SEL-5030 Software on page 2.14*

SEL Grid Configurator

SEL Grid Configurator is a tool for engineers and technicians to quickly and easily design, deploy, and manage device configurations for power system protection, control, metering, and monitoring. Through use of this software, you can perform the following:

- Configure settings for supported devices.
- Organize and manage device settings.
- Read and send settings for supported devices.
- Read reports from supported devices.

Installation

Overview

To install the software, you must have at least the following.

Table 2.2 Minimum Requirements

Supported Operating Systems:	Microsoft Windows 10 (64-bit) Microsoft Server 2016 (64-bit)
Processor Speed:	1 GHz (64-bit) or faster
RAM:	2 GB
Disk Space:	1 GB available
Printer:	Default printer installed for printer settings
Monitor:	1280 x 800 or higher resolution monitor **Note:** For best viewing of the application windows and text, you may need to enter your Windows operating system settings and adjust the screen resolution settings to make text and other items larger or smaller.
Other Peripherals:	Mouse or other pointing device
Communications:	Serial or Ethernet connections to allow communication with SEL devices
Required Third-Party Software:	Microsoft .NET Framework 4.7.2

Two different installations of SEL Grid Configurator are offered: an Admin Install and a User Install. Both install the same version of the software but support different use cases. SEL recommends using the Admin Install in most cases. *Table 2.3* illustrates the differences and the different use cases for the two installation types.

Table 2.3 Differences Between Admin Install and User Install

Admin Install	User Install
Requires administrative privileges to install on the computer.	Does NOT require administrative privileges to install on the computer.
Accessible by all users on the same computer.	Accessible only to the user that installed the software.
Uses the ACSELERATOR Database, the same database used by ACSELERATOR QuickSet Device Manager, if installed. This provides a means to view and access supported devices from both SEL Grid Configurator and Device Manager.	Uses a separate database from QuickSet Device Manager. The User Install of SEL Grid Configurator cannot connect to an ACSELERATOR Database.
May require an update to QuickSet and Device Manager for compatibility. If an update is necessary, the user will be notified during SEL Grid Configurator installation. The user will then have the opportunity to cancel installation at that time.	Never requires an update to an existing installation of QuickSet.

Examples of when to use the User Install:

- ➤ A user must install the software but lacks administrative privileges on the computer.
- ➤ A user wants to try a new version of SEL Grid Configurator before full deployment.
- ➤ A user must use SEL Grid Configurator on the same computer on which an incompatible (and unable to be upgraded) version of QuickSet is installed.

ACSELERATOR QuickSet Compatibility

If using the Legacy Device Driver, QuickSet version 6.3.0.7 or later is required for compatibility with SEL Grid Configurator. If using Device Manager, QuickSet version 6.8.2.0 or later is required for compatibility with SEL Grid Configurator.

Installation Instructions

NOTE: The following option is only available in the Admin Install. Skip Step 5 if you are running the User Install.

Once you have decided on the best installation, perform the following:

Step 1. Obtain the SEL Grid Configurator installation files from either the website (selinc.com/products/5037) or SEL Compass software.

Step 2. Run the installation file.

Step 3. If you agree to the terms of the license agreement, select **I accept the license agreement**.

Step 4. If you are running the User Install, select **Install** and go to *Step 6*. If you are running the Admin install, select **Next** and continue to *Step 5*.

Step 5. Select the desired installation type.

a. Select **Typical** to use all default installation options, and then select **Install** to install the application.

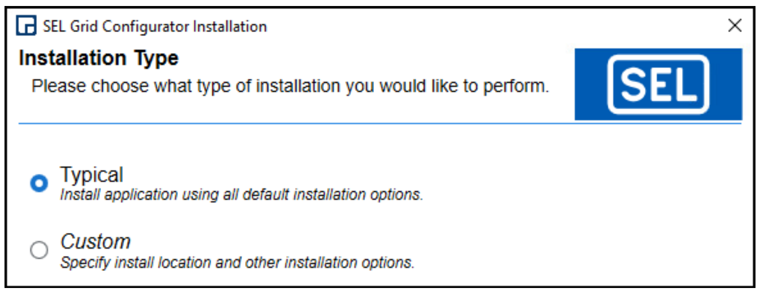


Figure 2.1 Select Typical to Accept All Default Installation Options or Select Custom to View or Modify Them

b. Select **Custom** to choose where to install the application and the ACSELERATOR Database.

c. Select **Next**.

d. Enter the desired folder location or select **Browse** to select a folder and then select **Next**.

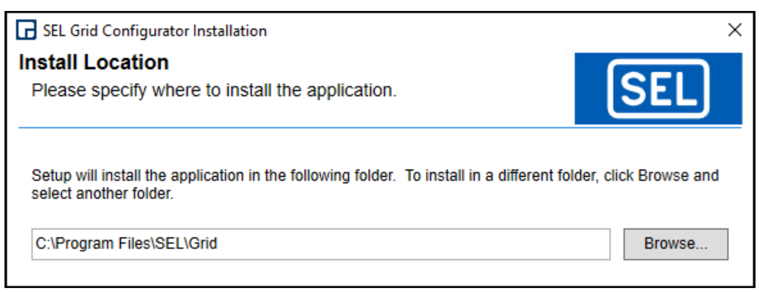


Figure 2.2 Select the Install Location for SEL Grid Configurator

e. Enter the desired folder locations for the database binaries and data or select **Browse** to select a folder and then select **Install**.

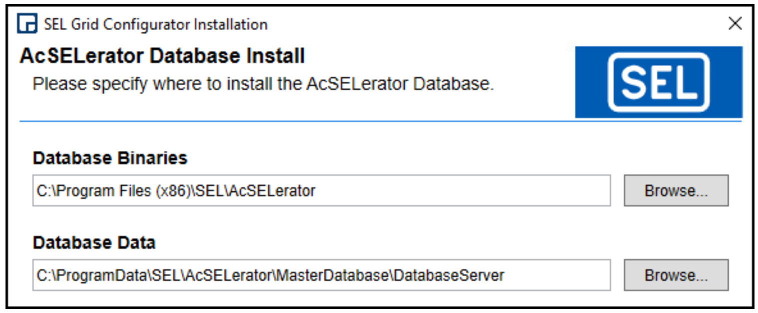


Figure 2.3 Select the Install Location for the ACSELERATOR Database

Step 6. After the installation process has been completed, select **Next**.

Step 7. Select **Finish** to close the installation wizard.

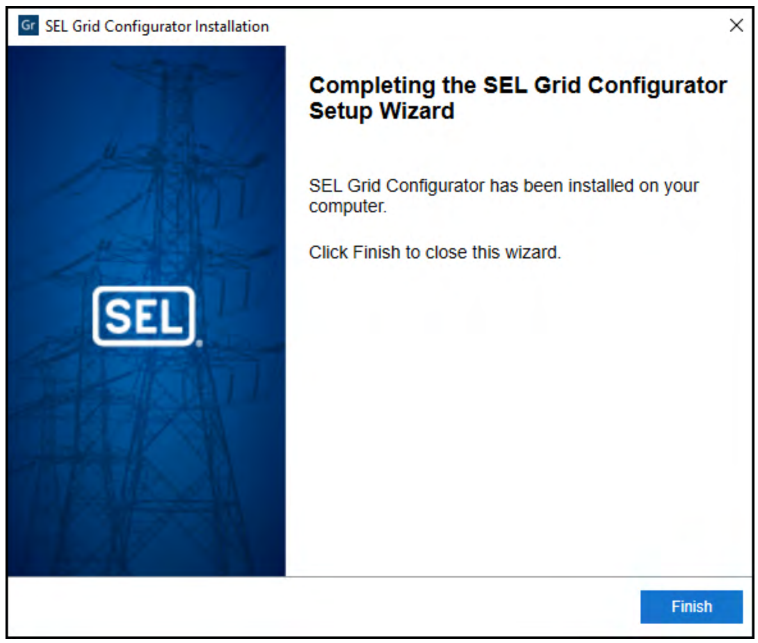


Figure 2.4 SEL Grid Configurator Installation Completed Successfully

Silent Installation

SEL Grid Configurator supports a command-line interface for silent, automated installations. The following parameters are supported:

- **/Silent**: Requires no end-user interaction and supports automated installs via scripting.
- **/AgreeEULA**: Represents an explicit approval of the License Agreement (EULA) to prevent showing the License Agreement form. This must be included with the /Silent option to perform a silent installation of SEL Grid Configurator.
- **/InstallPath**: Specifies the selected folder location when the default is not desired.
- **/DatabaseBinInstallPath**: Specifies the selected folder location for database binary files.
- **/DatabaseDataInstallPath**: Specifies the selected folder location for database data files.

Examples:

To perform a silent, default installation, execute the following:

```
SEL.Grid.UserInstaller-x.x.x.x.exe /Silent /AgreeEULA
```

To perform a silent installation while specifying the installation paths, execute the following:

```
SEL.Grid.AdminInstaller-x.x.x.x.exe /Silent /AgreeEULA /InstallPath="(Select file
    location)"
/DatabaseBinInstallPath="(Select database binaries location)"
    /DatabaseDataInstallPath=
"(Select Database data location)"
```

Uninstalling SEL Grid Configurator

SEL Grid Configurator supports uninstallation by the following methods:

- Through Windows Apps & features (Admin Install only)
- Through Windows Start Menu via an **Uninstall SEL Grid Configurator** shortcut in the **SEL Applications** folder (User Install only)
- Through SEL Compass
- Silently using the SEL Grid Configurator uninstaller's command-line interface

SEL Grid Configurator Uninstaller

The SEL Grid Configurator uninstaller (uninstall.exe) is located in the Uninstall folder in the SEL Grid Configurator install folder. The following parameters are supported:

- **/Silent**: A silent uninstallation shall be performed.
- **/RemoveDatabaseData**: Database data will be removed as part of uninstallation (User Install only).

Example:

To perform a silent uninstall, execute the following:

```
uninstall.exe /Silent
```

Removing Database Data (User Install Only)

The database data contains device information, settings, and collected device reports. By default, the database data will remain on the machine when uninstalling SEL Grid Configurator. An option to remove the database data is available with the User Uninstall but not the Admin Uninstall. If you intend to reinstall SEL Grid Configurator in the future, it is recommended to not remove this data. To remove the database data, select the box in the User Uninstallation Wizard (see *Figure 2.5*).

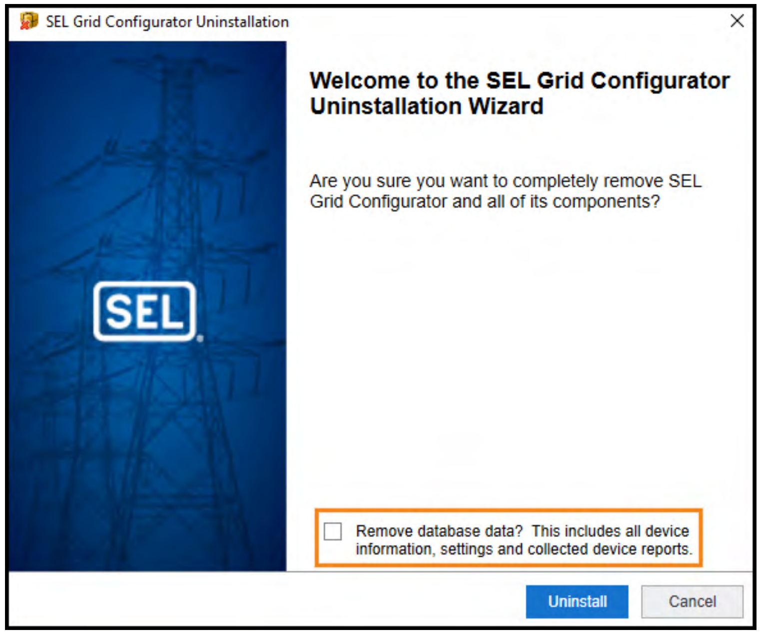


Figure 2.5 Option to Remove Database Data on Uninstallation (User Install Only)

In the case of the Admin Uninstall, the ACSELERATOR Database is not automatically removed. The ACSELERATOR Database requires manual removal via Windows Apps & features or SEL Compass.

Getting Started

This section provides the basic process for creating and deploying settings for a new device. More detailed information on each part of the user interface is available in the *SEL Grid Configurator Instruction Manual*. When you create a new device project, the software will prompt you for a part number. If you have none at the present time, start with the default part number; you may change it later.

Step 1. Using a computer on which Windows 10 is installed, open SEL Grid Configurator by selecting the Windows start button (left end of the Taskbar in Windows 10), scroll down and select **SEL Applications**, then select the SEL Grid Configurator icon. Alternatively, you can pin SEL Grid Configurator to the start panel, taskbar, or desktop on your computer.

Step 2. Create a new device by selecting **Add Device** from the context menu at the top of the System Explorer, as *Figure 2.6* illustrates.

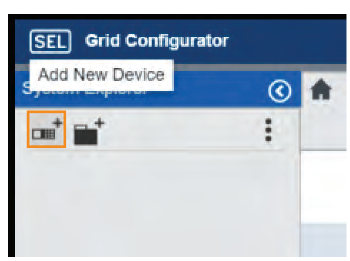


Figure 2.6 Add a New Device Project

Step 3. Select the type of device.

Step 4. Fill in a project name, setting version, and part number. Select **OK**. A device project includes all of the information (such as settings, comments, communications parameters, etc.) that SEL Grid Configurator manages for a device, *Figure 2.7* shows how a new device project looks in the System Explorer.

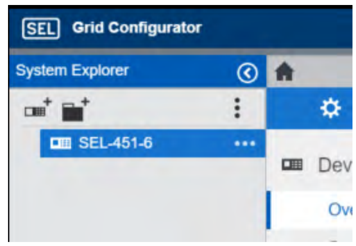


Figure 2.7 New Device in the System Explorer

Step 5. Select **Main Features > Protection Elements** from the Device Explorer, as illustrated in the green highlighted area of *Figure 2.8*. Using the controls next to the Available Protection Elements, enable as many protection functions as necessary. Repeat for each setting group by using the group selector (highlighted in orange in *Figure 2.8*) in the Device Commands menu. The features and groups SEL Grid Configurator shows in this view vary greatly depending upon the relay, meter, or distribution controller you are configuring. Refer to the device instruction manual for detailed information about the features available in your particular device.

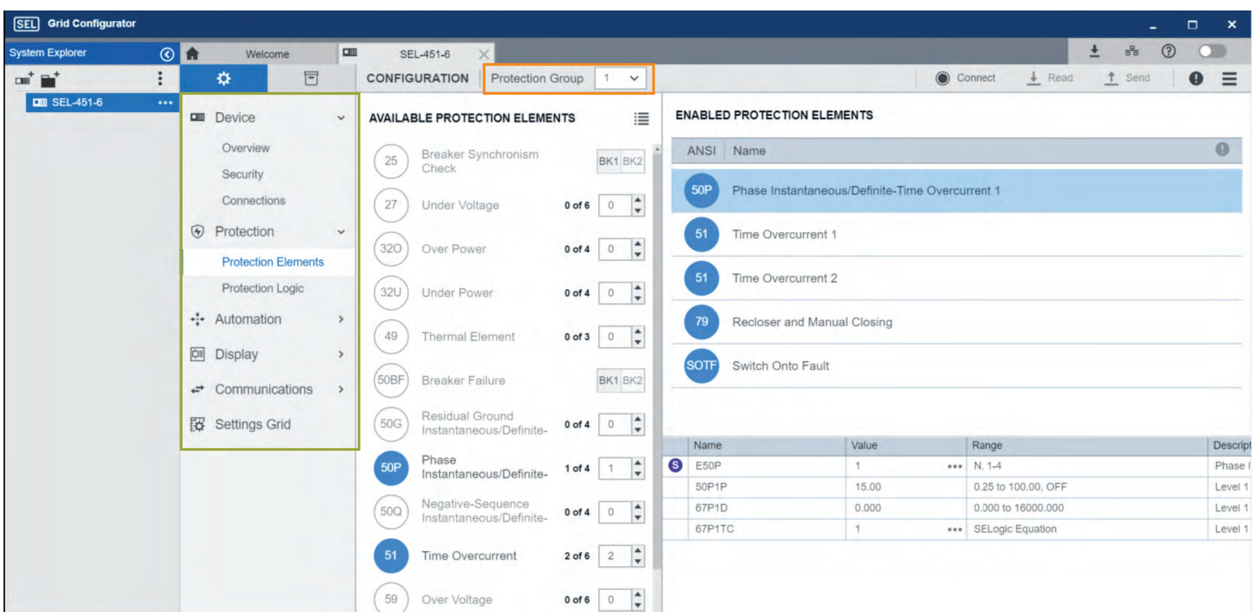


Figure 2.8 Protection Elements View

The views and editors available in the Device Explorer vary depending upon the device. The functionality of the device being configured determines the available settings groups. In the Settings Grid view, settings are organized hierarchically in a tree format. Settings categories have a small triangle to the left. When you select this triangle, the settings category expands to show additional available settings related to the overarching category, as shown in *Figure 2.9*. Select the triangle again to collapse that portion of the tree.

In any device settings view, such as Protection Elements or Settings Grid, an indicator displays next to any setting you have changed. The change indicator persists as long as you have the device project open.

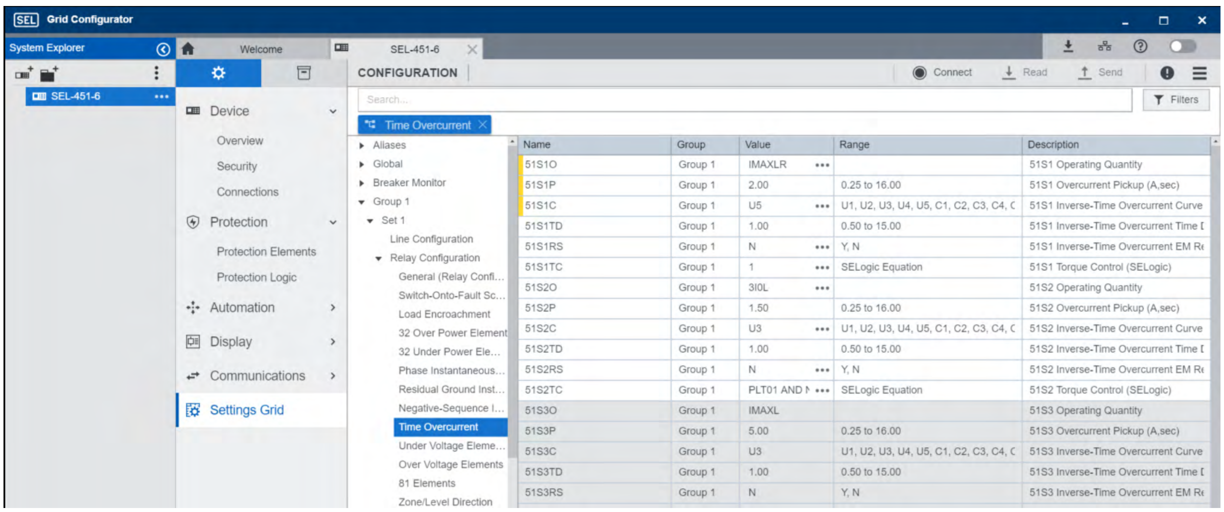


Figure 2.9 Settings Grid View

Some settings will be disabled (grayed out) by default. SEL Grid Configurator displays settings as disabled according to such various factors as your part number selection, which protections elements you have enabled, etc. Refer to your device instruction manual to learn details about the specific settings for your device. SEL Grid Configurator makes settings available for editing once you change the options that caused them to be unavailable.

Step 6. In the Settings Grid view, expand the tree to see all settings and groups available in your device. Select an entry in the tree to view the settings editor for that element. Edit the setting value either by directly editing in the grid or by selecting the ellipsis button in the Value cell if available. *Figure 2.10* shows an example of each editing workflow. For setting 50P1P, which requires a numerical entry, you can directly select and edit the necessary value in the Value cell. Setting 67P1TC requires a SELOGIC control equation, which provides a window to help the user build their desired torque-control equation. Select the ellipsis button in the Value cell to open the SELOGIC control equation builder. Create the equation and then select **OK**.

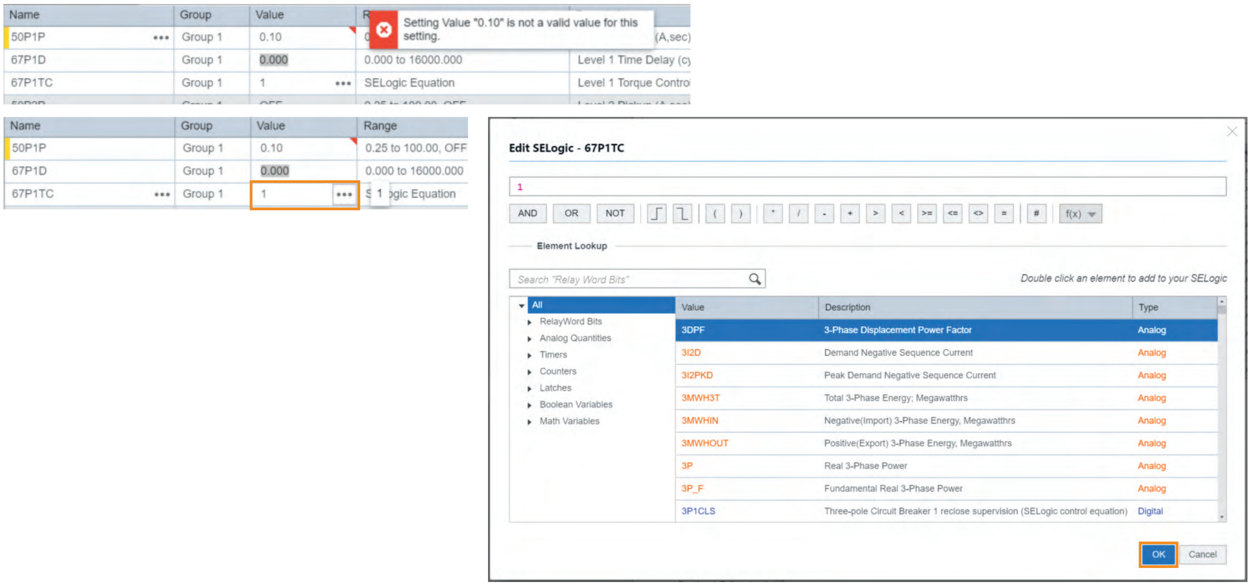


Figure 2.10 Editing Settings and Automatic Validation

If you enter a settings value into a field and that value is invalid or outside the acceptable range, as shown in *Figure 2.10*, SEL Grid Configurator displays an error icon in the Value cell for that setting. A message explaining the error displays if you hover over the Value cell. Correct these errors prior to deploying settings.

Select the alarm icon in the Device Commands menu, as shown in *Figure 2.11*, to see Project Notifications, a report of all settings errors in a device project. Select the notification message to immediately navigate to the invalid setting.

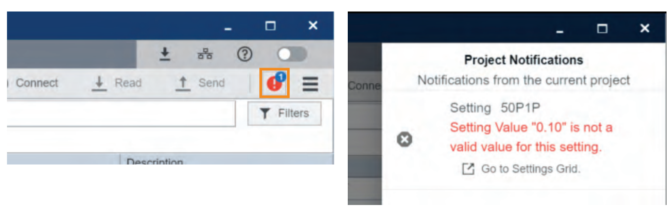


Figure 2.11 Viewing Project Notifications

Step 7. For all remaining settings, navigate the tree or use the search bar to find the necessary settings and alter the appropriate values.

Step 8. Select **Communications > Connections**, as shown in *Figure 2.12*. Enter the connection parameters for your device. SEL Grid Configurator can communicate with devices via serial or network connections.

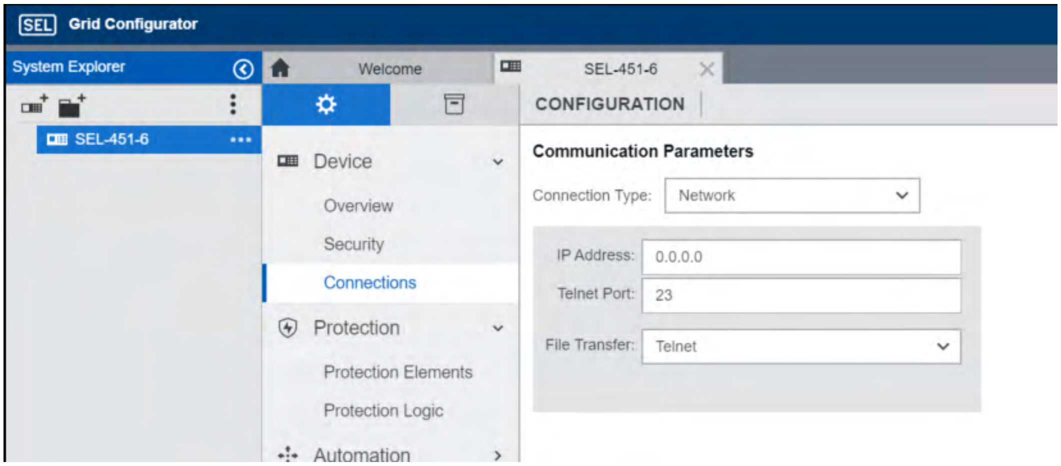


Figure 2.12 Configuring Communications Options

Step 9. Select **Communications > Security**, as illustrated in *Figure 2.13*. By default, SEL Grid Configurator has the default passwords for your device type. Enter custom passwords if you use them. Refer to your device instruction manual to learn about the access levels and password options for your device.

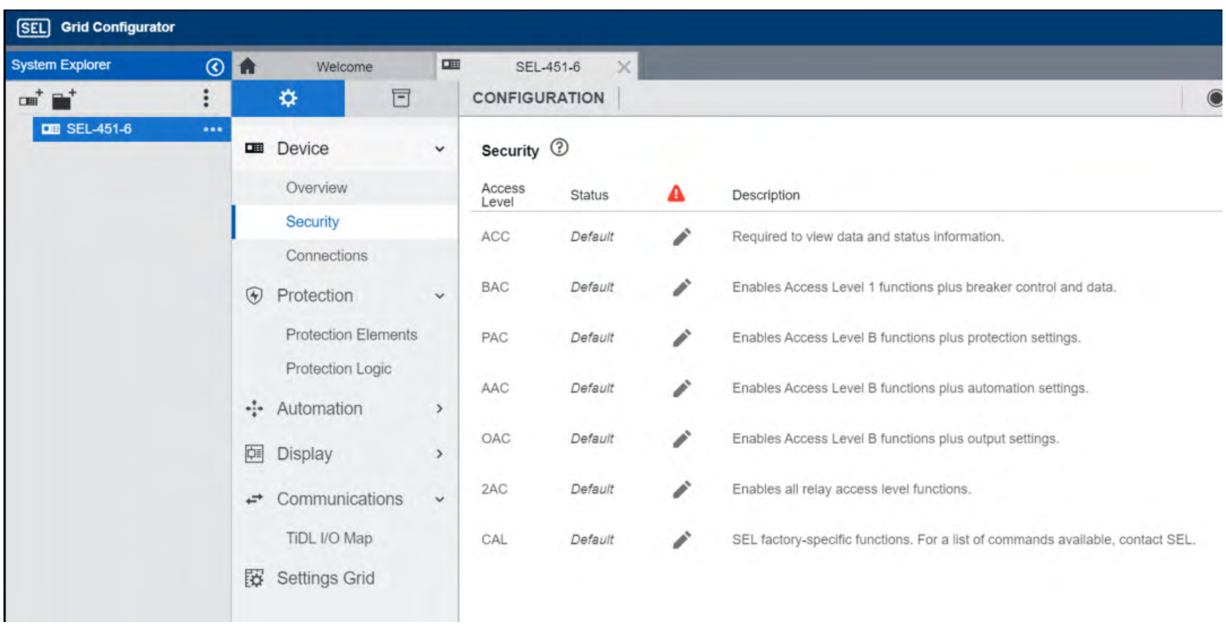


Figure 2.13 Configuring Security Options

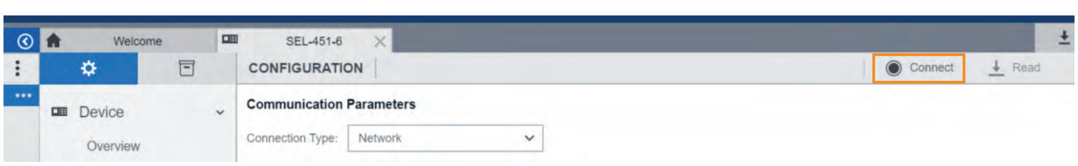


Figure 2.14 Connecting to a Device

Step 10. Select **Connect** in the Device Commands Menu, as shown in *Figure 2.14*. Once the connection is active, you will see a success message and a green dot displays in the device tab and next to the device name in the System Explorer. As long as SEL Grid Configurator has an active connection with the device shown in your workspace, device commands appear similar to *Figure 2.15*.

Figure 2.15 Device Commands Menu for Connected Devices

Step 11. Select the **Send** button, as shown in *Figure 2.15*, to deploy settings to the device. Select the green **Device Operations** icon in the Title Bar, as shown in *Figure 2.16*, to view the progress of the operation.

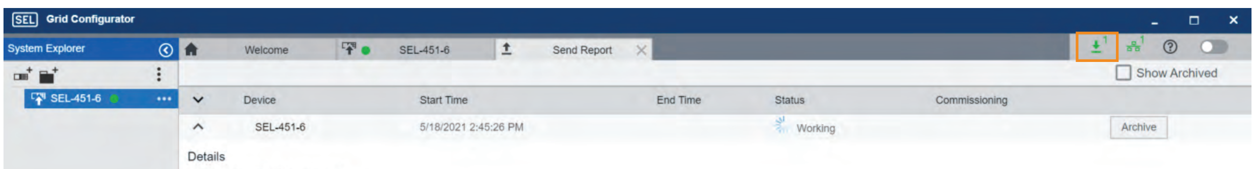


Figure 2.16 Title Bar During Settings Deployment

Step 12. To cancel an operation, select **Device Operations > Cancel Operation > OK**.

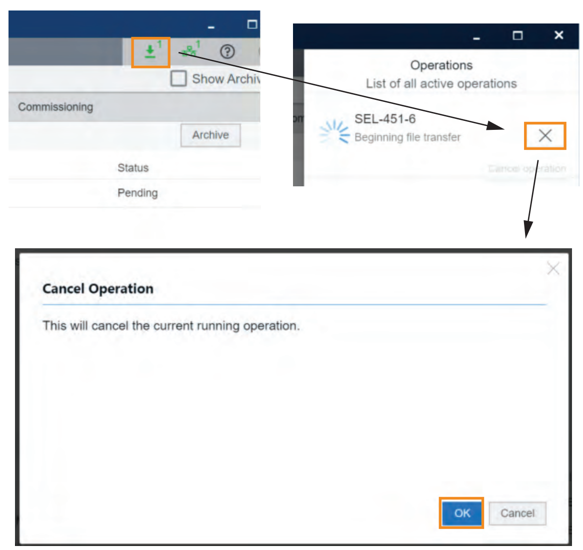


Figure 2.17 Opening the Send Report

Step 13. Select **Disconnect** from the Device Commands Menu to terminate the connection to the device.

SEL Grid Configurator Interface

Introduction

The user interface of SEL Grid Configurator is divided into a number of viewable areas that can generally be categorized as follows:

Navigators: One or more navigators can be open and visible in the user interface at any time. These generally sit vertically (top to bottom) in the user interface and contain content in rows. In some cases, the content will be hierarchical and collapsible so you can focus only on what you need. A scroll bar appears if the content still extends beyond the viewable space. When the scroll bar appears, SEL Grid Configurator offers three navigational options:

1. Press and drag with your mouse on the scroll bar
2. Hover the mouse over the sidebar and use the mouse scroll wheel
3. Touch the scroll bar and drag your finger in the direction you want the view to move

IMPORTANT: Opening multiple navigators on a smaller screen can make the workspace too confining. You can collapse or expand any navigator individually.

Title Bar: The blue bar at the top of the user interface. It contains the application title and a number of icons for common actions that affect the entire application.

Workspace: The previously mentioned sections of the user interface enable and support the core of the application, your workspace. The content (or view) in the workspace changes depending on the project type and workflow, but the workspace generally includes editable content and reports. Enter and edit content as necessary. Reports are read-only and provide information about your project. As with navigators, SEL Grid Configurator displays scroll bars if the content extends beyond the viewable space.

Accessing Contextual Information

The menu system in SEL Grid Configurator primarily displays via context menus. Select the ellipsis button, , to display the context menu for the item with which you are working. Select in the title bar to activate application help.

User Interface Sections

1. **Title Bar**: Includes the software title and such application-level controls as the light and dark theme.
2. **System Explorer**: A navigator that includes a hierarchical view of all devices in your system. Open device projects from the System Explorer.
3. **Workspace**: The display of any open view or project. Commands and features differ according to the use case for any particular view.

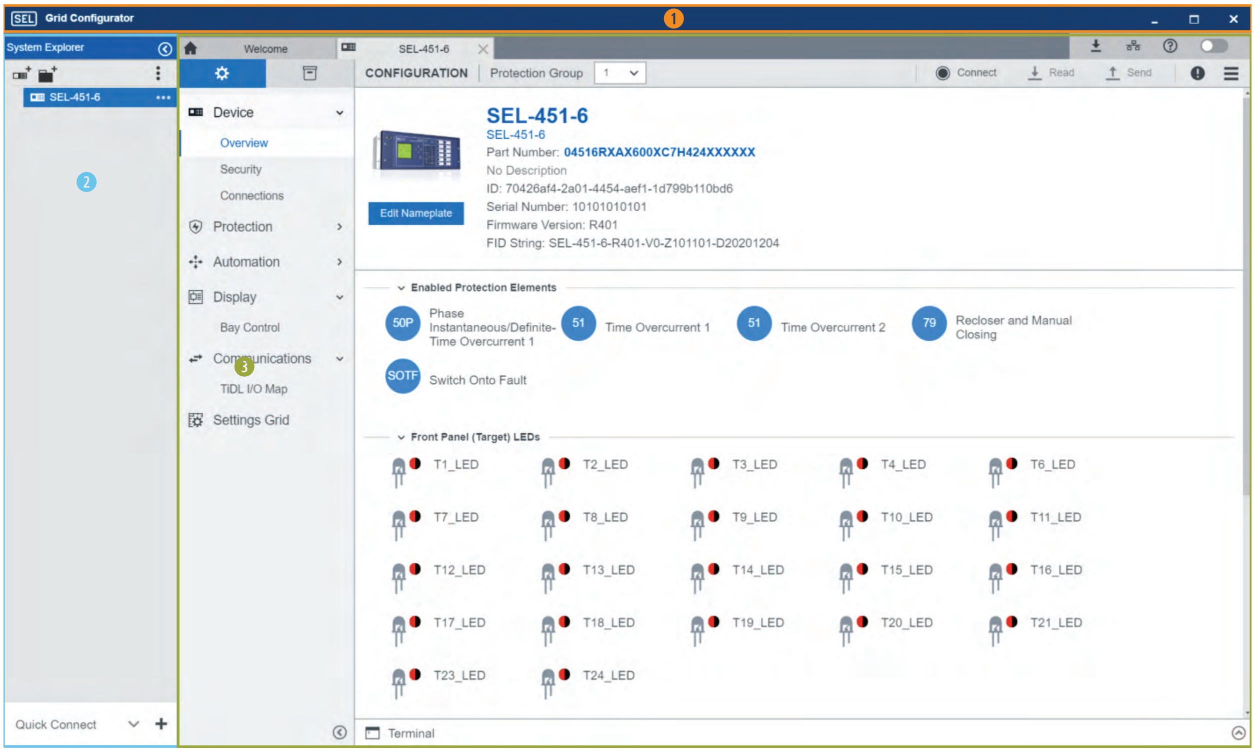


Figure 2.18 SEL Grid Configurator User Interface Overview

Light and Dark Theme

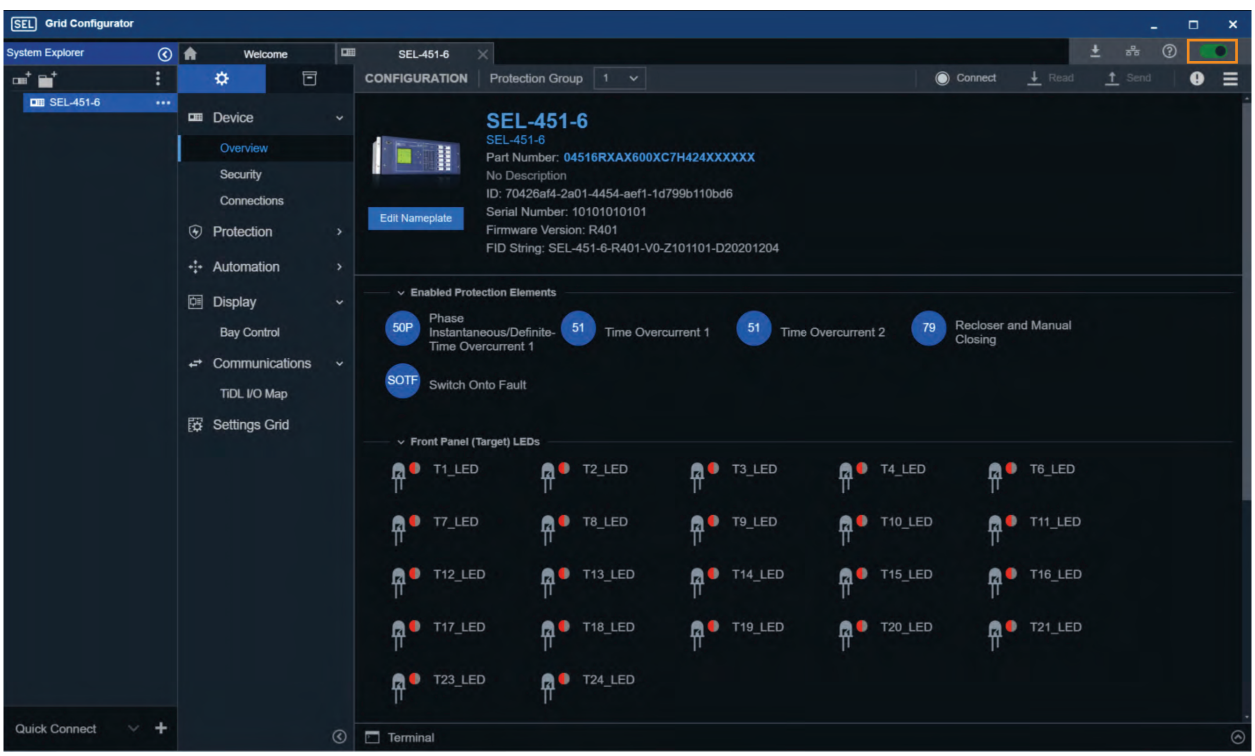


Figure 2.19 Dark Theme

As shown in *Figure 2.19*, toggle the rocker bar on the right side of the title bar to switch between the light and dark theme for the user interface.

SEL Grid Configurator Report Retrieval

Use SEL Grid Configurator to download the Sequence of Events records or relay oscillography records, as highlighted in *Figure 2.20*.

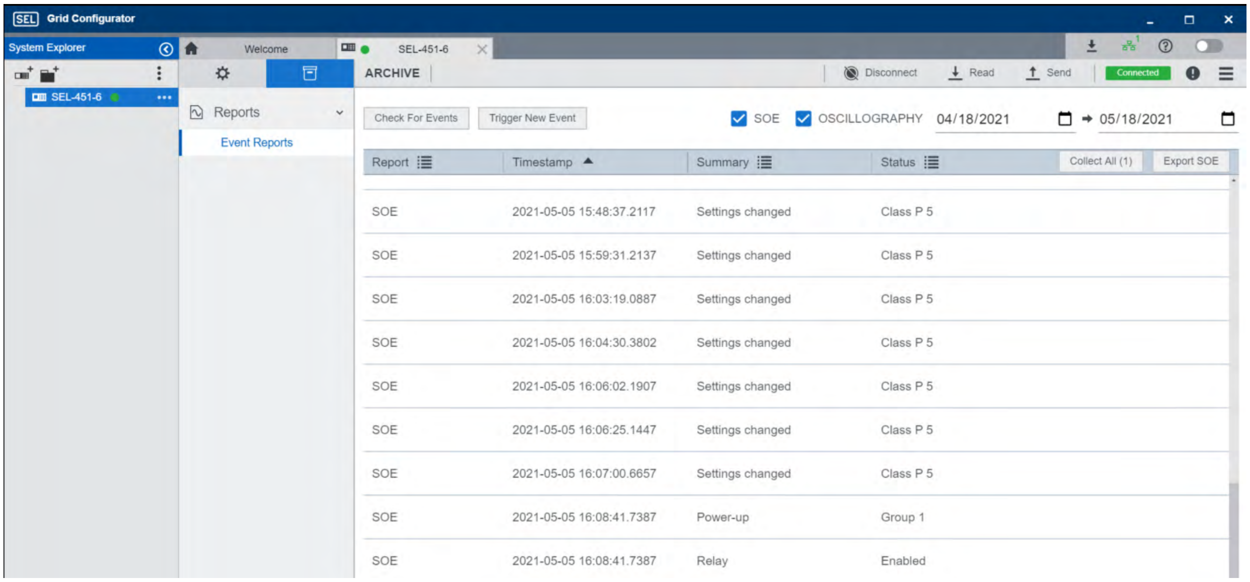


Figure 2.20 SEL Grid Configurator Report Retrieval

ACSELERATOR QuickSet SEL-5030 Software

This section provides information on the following topics:

- *QuickSet Setup on page 2.15*
- *Settings Database Management and Drivers on page 2.17*
- *QuickSet Main Menu on page 2.21*
- *Create and Manage Relay Settings on page 2.21*
- *QuickSet HMI on page 2.30*
- *Analyze Events on page 2.33*
- *QuickSet Help on page 2.34*

SEL-400 series relays come with ACSELERATOR QuickSet SEL-5030 Software, a powerful relay settings, analysis, and measurement tool, to aid you in applying and using the relay. QuickSet reduces engineering costs for relay settings, logic programming, and system analysis. QuickSet makes it easier for you to do the following:

- Create and manage relay settings
  - Create settings for one or more relays
  - Store and retrieve settings with Windows-based PCs
  - Upload and download relay settings files to and from relays
- Analyze events
  - Use the integrated waveform (single event reports) analysis tools

- Control the relay
  - Command relay operation through use of a GUI environment
  - Execute relay serial port commands in terminal mode
- Configure the serial port and passwords

SEL provides QuickSet for easier, more efficient configuration of the relay settings. However, you do not have to use QuickSet to configure a relay; you can use an ASCII terminal or a computer running terminal emulation software to access all relay settings and metering. QuickSet gives you the advantages of rules-based settings checks, SELOGIC control equation Expression Builder, and event analysis.

QuickSet Setup

Obtaining QuickSet

QuickSet can be obtained from the Download area of the SEL website. To have the software automatically update as new relay drivers are released, download and install SEL Compass Software, and then use Compass to download and install QuickSet. When you download QuickSet within Compass, you will be asked to select which relay drivers you wish to include. Select drivers for all SEL relays that you may be required to set. If later you find that additional drivers are required, QuickSet provides an easy method to request new drivers and updates (see *Updating QuickSet on page 2.15*).

QuickSet is also available on DVD upon request.

Updating QuickSet

The QuickSet software consists of a core application plus driver files for individual devices. As new device firmware versions are released, you may need to update QuickSet to add new driver files. This may be accomplished several ways:

- When the **Enable Update Notifications** check box is selected in the **Tools** > **Options** menu of SEL Compass, the Compass software will automatically check for updates on a specified schedule and facilitate the update process.
- The **Update** icon on the QuickSet startup screen starts SEL Compass and checks for updates.
- The **Install Devices** button on the Settings Editor Selection window starts SEL Compass and presents a menu of available drivers.
- **Check for updates** in the **Help** menu starts SEL Compass and checks for updates.

An Internet connection is required to add new drivers and to receive update notifications.

Serial Communication Parameters

QuickSet can communicate with a relay via any relay serial port set to SEL protocol or via Ethernet. Use the **Communication Parameters** dialog box to configure relay communications settings.

Step 1. Select the **Communication** menu on the top QuickSet toolbar.

Step 2. Select **Parameters** to open this dialog box.

Figure 2.21 shows the QuickSet **Communication Parameters** dialog box.

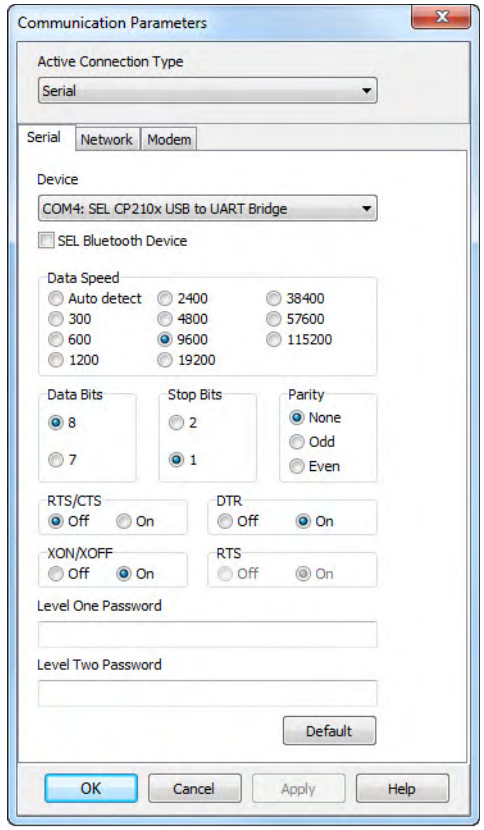


Figure 2.21 QuickSet Communication Parameters Dialog Box

You can use serial communication via relay Ports 1, 2, 3, and F (front panel). *Figure 2.21* shows the default serial port parameters (9600, 8, N, 1).

Step 1. Enter your relay Access Level 1 and Access Level 2 passwords in the respective text boxes.

Step 2. If you choose a connection type from the **Active Connection Type** dropdown list that is a telephone modem, enter the dial-up telephone number in the **Phone Number** text box.

Ethernet Card

Use the optional Ethernet card for File Transfer Protocol (FTP) and Telnet network communications.

FTP Setup

Step 1. Access the **Network** dialog box from the **Active Connection Type** dropdown list.

Step 2. Select the **FTP File Transfer Option** button to select FTP as the network communications protocol.

Step 3. Enter the IP address of the relay Ethernet port as the Host IP address.

Step 4. Enter the FTP port number.

Step 5. Enter the relay Access Level 1 and Access Level 2 passwords in the respective text boxes.

See *Changing the Default Passwords in the Terminal on page 3.11*.

Step 6. Use the **Save to Address Book** button to save the entered information with a Connection Name for later use.

Step 7. Enable the Ethernet port setting **FTPSERV**.

Telnet Setup

Step 1. Access the **Network** dialog box from the **Active Connection Type** dropdown list.

Step 2. Select the **Telnet File Transfer Option** button to select Telnet as the network communications protocol.

The Telnet session uses the relay passwords on the **Communication Parameters** dialog box (*Figure 2.21*). See *Telnet on page 15.17* for more information on Telnet.

Terminal Window

The terminal window provides an ASCII interface on which you can communicate with the relay. This is a basic terminal emulation. Many third-party terminal emulation programs are available with file transfer encoding schemes.

Step 1. Select the QuickSet **Communication** menu.

Step 2. Select **Terminal** to start the terminal window.

Another convenient method to start the terminal is to press **<Ctrl+T>**.

Terminal Logging

When you select the **Terminal Logging** check box in the **Communication** menu, QuickSet records communications events and errors in a log.

Step 1. Select **Communication > Logging > Connection Log** to view the log.

Step 2. Clear the log by selecting **Communication > Logging > Clear Connection Log**.

Settings Database Management and Drivers

Database Manager

QuickSet uses a relay database to save relay settings. QuickSet contains sets of all settings files for each relay that you specify in the **Database Manager**. Choose appropriate storage backup methods and a secure location for storing your relay database files. Use the **File > Database Manager** menu to retrieve a relay database from computer memory.

Relay Database

The default relay database file already configured in QuickSet is **Relay.rdb**. This database contains example settings files for the SEL products with which you can use QuickSet.

Step 1. Open the **Database Manage**r to access the database.

   a. Select **File** in the QuickSet top toolbar.

   b. Select the **Database Manager** menu item. You will see a dialog box similar to *Figure 2.22*.

Step 2. If you wish, you can enter descriptions of the database and/or relay in the **Database Description** and/or **Settings Description** text boxes.

A relay description would consist of special operating characteristics that describe the relay settings including the protection scheme settings and communications settings.

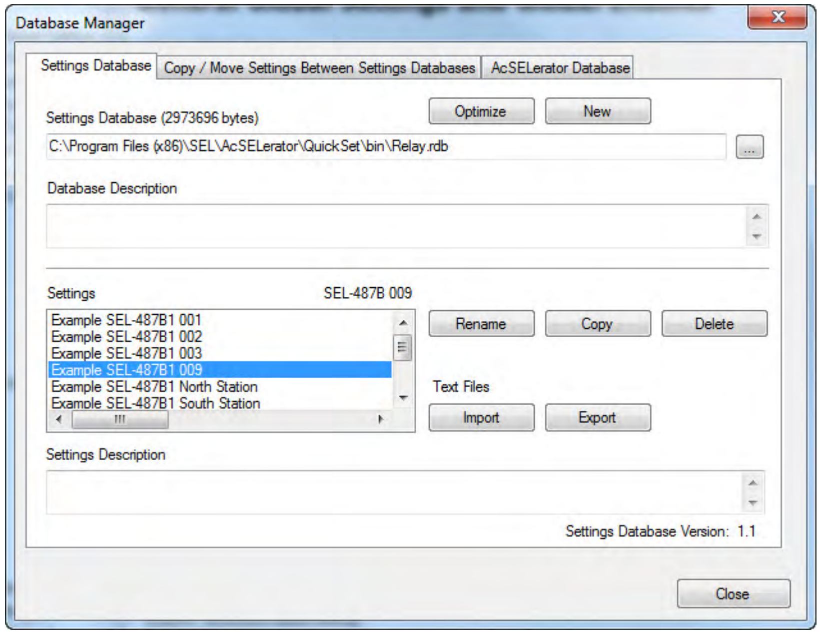


Figure 2.22 QuickSet Database Manager Relay Database

Step 3. Highlight one of the relays listed in **Settings**.

Step 4. Select **Copy** to create a new collection of relay settings.

QuickSet prompts you to provide a new name.

Copy/Move Relays Between Databases

You can create multiple relay databases with the **Database Manager**; these databases are useful for grouping similar protection schemes or geographic areas.

Step 1. Select the **Copy/Move Relays Between Settings Databases** tab to access the dialog box shown in *Figure 2.23*.

Step 2. Select the ellipsis next to **Settings Database B** to open a relay database.

Step 3. Navigate to the desired database location.

Step 4. Select **Open**.

For example, **Relay2.rdb** is the B relay database in *Figure 2.23*.

Step 5. Highlight a relay in the A database.

Step 6. Select **Copy** or **Move**.

Step 7. Select the **>** button to create a new relay in the B database.

Reverse this process to take relays from the B database to the A database.

Copy creates an identical relay that appears in both databases. **Move** removes the relay from one database and places the relay in another database.

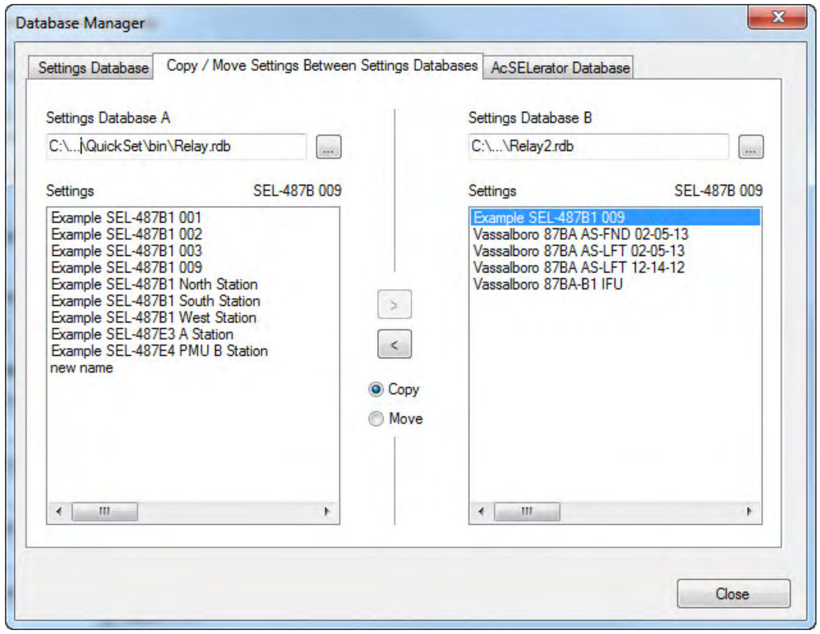


Figure 2.23 QuickSet Database Manager Copy/Move

Create a New Database

Step 1. To create and copy an existing database of relays to a new database, select the **File > Database Manager** menu.

Step 2. Select **Copy/Move Relays Between Databases** on the **Database Manager** dialog box.

QuickSet opens the last active database and assigns it as Database A (see *Figure 2.23*).

Step 3. Select the ellipsis next to **Settings Database B**.

QuickSet prompts you for a file location.

Step 4. Type a new database name.

Step 5. Select **Open**.

Step 6. Answer **Yes**.

The program creates a new empty database.

Step 7. Load relays into the new database as in *Copy/Move Relays Between Databases on page 2.18*.

Drivers

Relay settings folders in QuickSet are closely associated with the QuickSet relay driver that you used to create the settings. The relay settings and the QuickSet drivers must match.

Step 1. Use one of the following methods to view the relay FID (firmware identification) number to determine the active QuickSet drivers.

- ➢ Enter Access Level 1 and use the **STATUS** command from the serial port terminal emulation window.
- ➢ Type **ID <Enter>** in the computer emulation software window (**<Ctrl+T>** from QuickSet).

Step 2. Locate and record the Z-number in the FID string.

The Z-number helps determine the proper QuickSet relay settings driver version when creating or editing relay settings files.

Step 3. View the QuickSet settings driver information at the bottom of the **Settings Editor** window.

The first portion of the Z-number is the QuickSet settings driver version number (see *Figure 2.24*).

Step 4. Compare the QuickSet driver number and the relay FID number.

This QuickSet driver Z-number and the corresponding part of the relay FID must match.

Relay Settings Driver Version Number

FID = SEL-487B-1-R306-V0-Z007005-D20130606

HMI Version Number

Figure 2.24 QuickSet Software Driver Information in the FID String

Use the first portion of the Z-number (Z001XXX, for example) to determine the correct **Settings Editor** version to select.

Step 5. View the top of the **Settings Editor** window to check the **Settings Editor** driver number (see *Figure 2.25*).

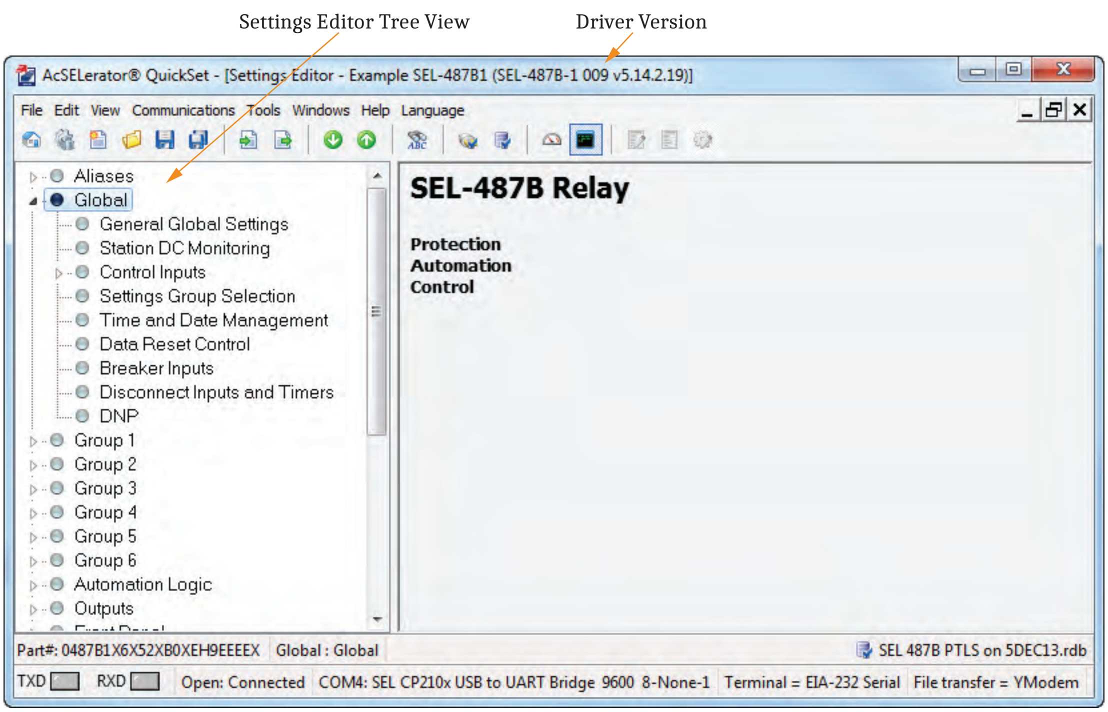


Figure 2.25 Relay Settings Driver Version Number

As SEL develops new drivers, you can update your existing QuickSet with specific relay drivers for each SEL product that uses QuickSet. Use SEL Compass (selinc.com/products/compass/) to download the latest QuickSet drivers.

QuickSet Main Menu

The main menu provides the following options and submenu options. Selected submenu options are explained in detail in *Table 2.4*.

Table 2.4 QuickSet Submenu Options

File	➤ New—Create new settings for a connected device or offline. ➤ Open—Open existing settings stored in a Relay Database (RDB) file. ➤ Close—Close settings instance that is open in the QuickSet window. ➤ Save/Save As—Save settings instance that is open in the QuickSet window to the active Relay Database (RDB) file. ➤ Print Device Settings—Print standard or custom settings reports. ➤ Read—Read settings from a connected device and display the settings in the QuickSet window. ➤ Send—Send settings instance that is open in the QuickSet window to a connected device. ➤ Active Database—Change which Relay Database (RDB) file is used for the Open and Save/Save As commands. ➤ Database Manager—Open Database Manager to create a new Relay Database (RDB) file, copy settings within the active Relay Database (RDB) file, add descriptions to settings within the database, and copy and move settings between different databases. ➤ Exit—Quit the QuickSet software.
Edit	➤ Copy—Copy settings from one Settings Group to another. ➤ Search—Search for a text string within the settings instance. ➤ Compare—Compare the settings instance that is open in the QuickSet window to another settings instance in the Relay Database file. ➤ Merge—Merge the settings instance that is open in the QuickSet window with another settings instance in the Relay Database file. ➤ Part Number—Change the current part number for the settings instance that is open in the QuickSet window.
Communications	➤ Connect—Request QuickSet to attempt to connect to a device by using the current Connection Parameters. ➤ Parameters—Modify the Communications Parameters, including connection type (Serial, Network, or Modem), PC port numbers, speed, and settings, device passwords, IP addresses, ports, and file transfer options, and modem phone numbers and speeds. ➤ Network Address Book—Select from a list of Ethernet-connected devices. Add or modify devices by specifying the Connection Name, IP Address, Telnet Port Number, User ID, and Password. ➤ Terminal—Open terminal window to issue ASCII commands directly to a connected relay. ➤ Logging—Initiate terminal logging to record terminal communications. View and clear the connection log.
Tools	➤ Settings—Convert settings between settings versions. Import and export settings from and to text files. ➤ HMI—Open HMI for connected device and manage custom HMI Device Overviews. ➤ Events—Collect event and view reports from connected devices. ➤ Options—Control QuickSet options, including Setting Comments, Event Viewer, and Terminal Options. ➤ Firmware Loader—Upgrade relay firmware.
Help	➤ Access program and settings help.

Create and Manage Relay Settings

QuickSet enables you to create settings for one or more relays. You can store existing relay settings downloaded from relays with QuickSet, creating a library of relay settings (see *Database Manager on page 2.17*). You can then modify and upload these settings from your settings library to a relay. QuickSet makes setting the relay easy and efficient.

Relay Part Number

The relay part number determines the settings that QuickSet displays and the functions that the software controls. When configuring QuickSet to control a particular relay, you should confirm that the QuickSet part number matches the relay part number so that you can access all of the settings you need for your relay.

Configuring the Relay Part Number

Step 1. Select the QuickSet **Edit** menu.

Step 2. Select **Part Number** in the dropdown list, as shown in *Figure 2.26*.

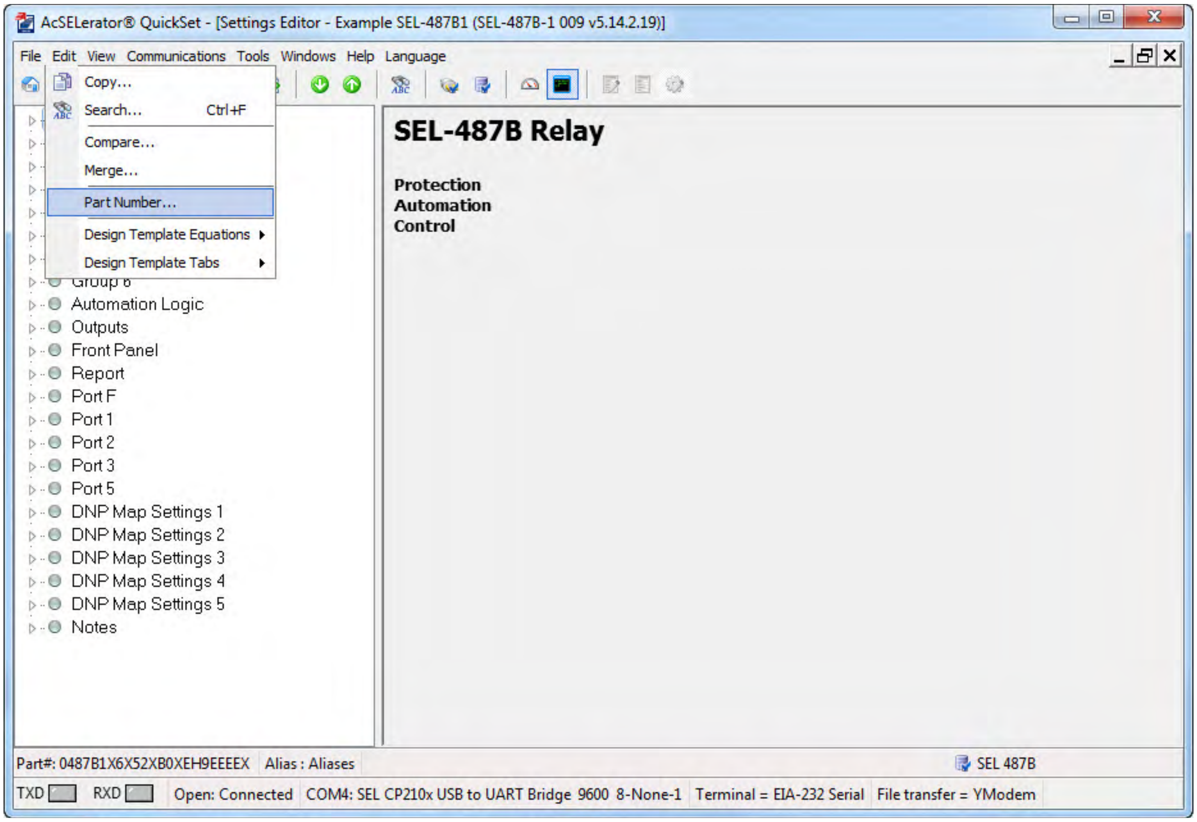


Figure 2.26 Retrieving the Device Part Number

You will see the **Device Part Number** dialog box, similar to the one shown in *Figure 2.27* for the SEL-487B.

Step 3. Use the arrows inside the text boxes to match corresponding portions of the **Device Part Number** dialog box to your relay. Alternatively, select **Edit** in the lower left corner of the **Device Part Number** screen and paste in the desired part number.

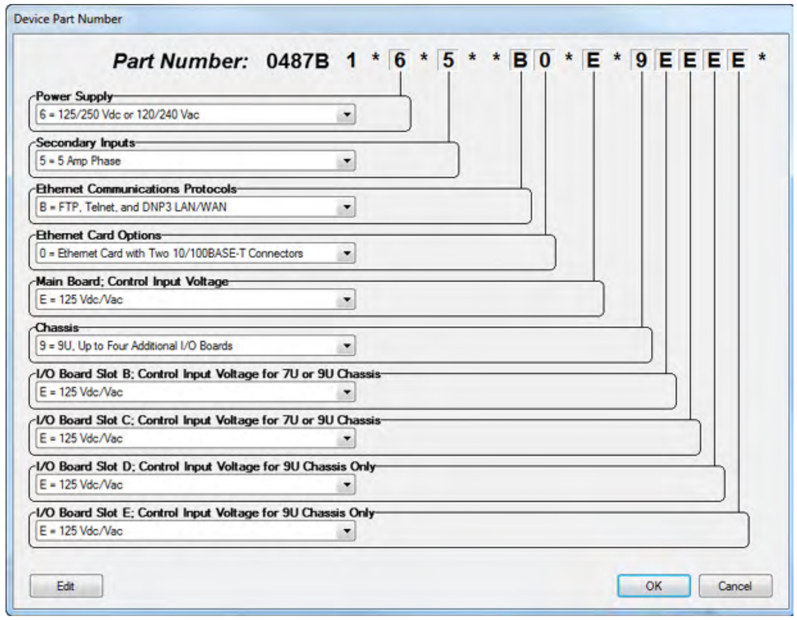


Figure 2.27 Setting the Relay Part Number in QuickSet

Settings Overview

QuickSet arranges relay settings in easy-to-understand categories (for an explanation of settings organization, see *Making Simple Settings Changes on page 3.15*). These categories of collected settings help you quickly set the relay. *Figure 2.28* is an example of relay settings categories in the **Settings Editor** tree view.

QuickSet shows all of the settings categories in the settings tree view. When you enable and disable settings categories, the tree view remains constant, but when you select the tree view to access the settings in a disabled category, the disabled settings are dimmed. For example try the following steps:

Step 1. Select **Global > Station DC Monitoring** and observe that the settings are dim.

Step 2. To enable the Station DC Monitor settings, select the **Global > General Global Settings/Enables** branch of the settings tree view.

Step 3. Change the **EDCMON Station DC Battery Monitor** setting to **Y**.

Step 4. *Figure 2.28* through *Figure 2.30* illustrates this feature of QuickSet.

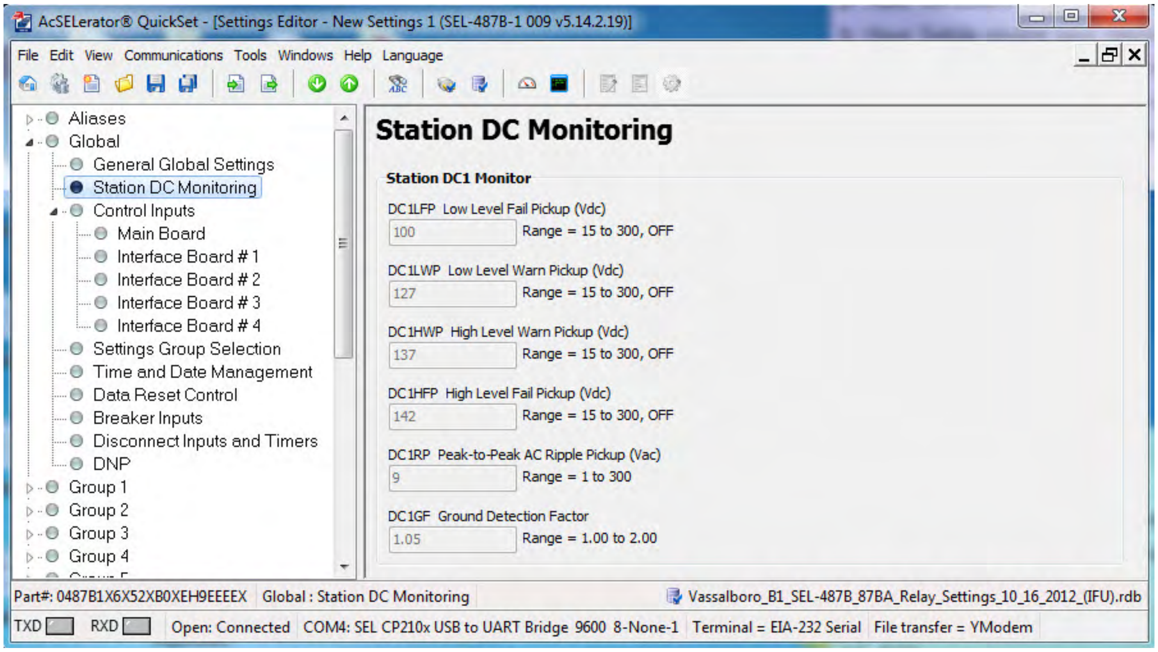


Figure 2.28 Station DC Settings

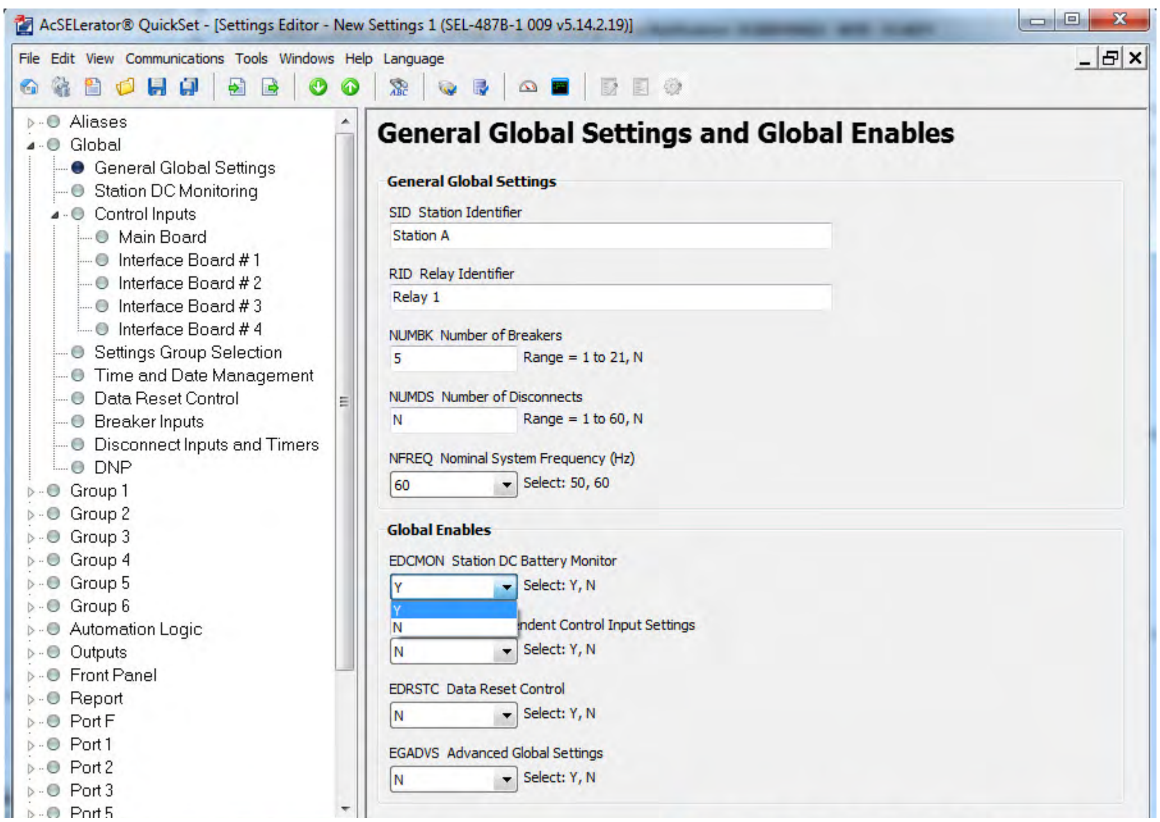


Figure 2.29 Enable EDCMON in Global Settings

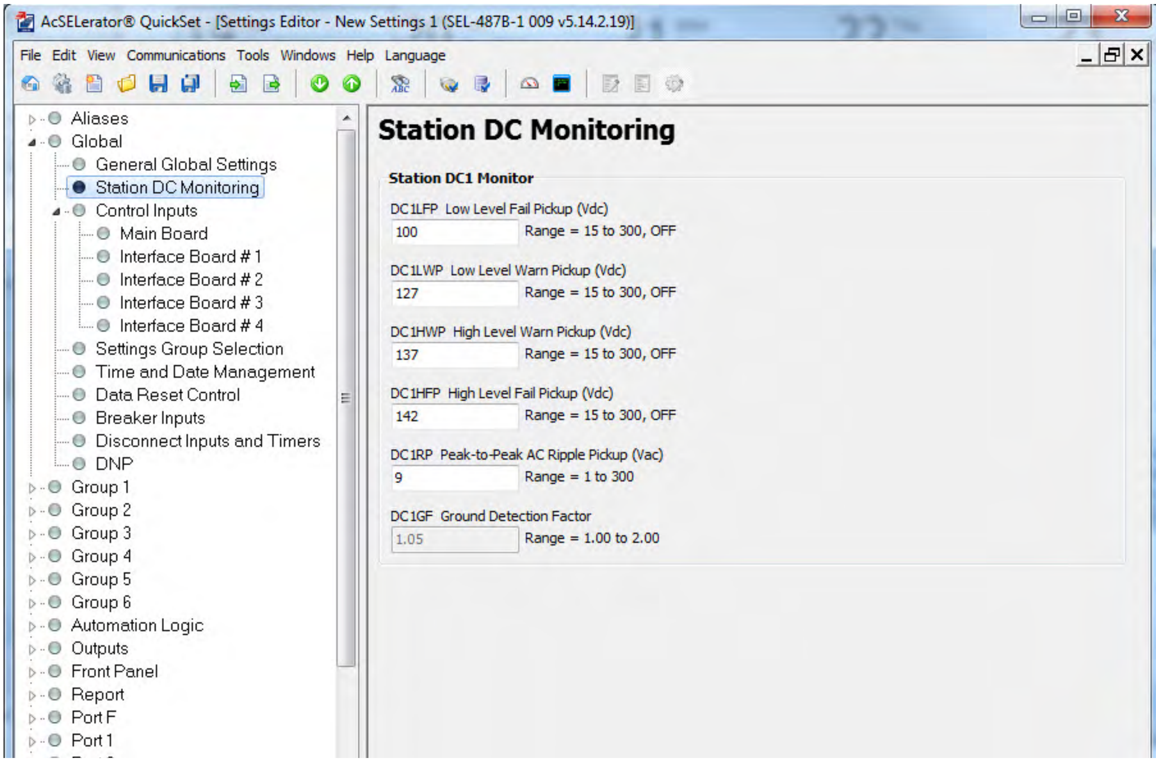


Figure 2.30 DC Monitor Settings Enabled

Settings Editor

Use the **Settings Editor** to enter relay settings. *Figure 2.31* illustrates the important features of the editor. These features include the QuickSet settings driver version number (the first three digits of the Z-number) in the lower left corner of the **Settings Editor**.

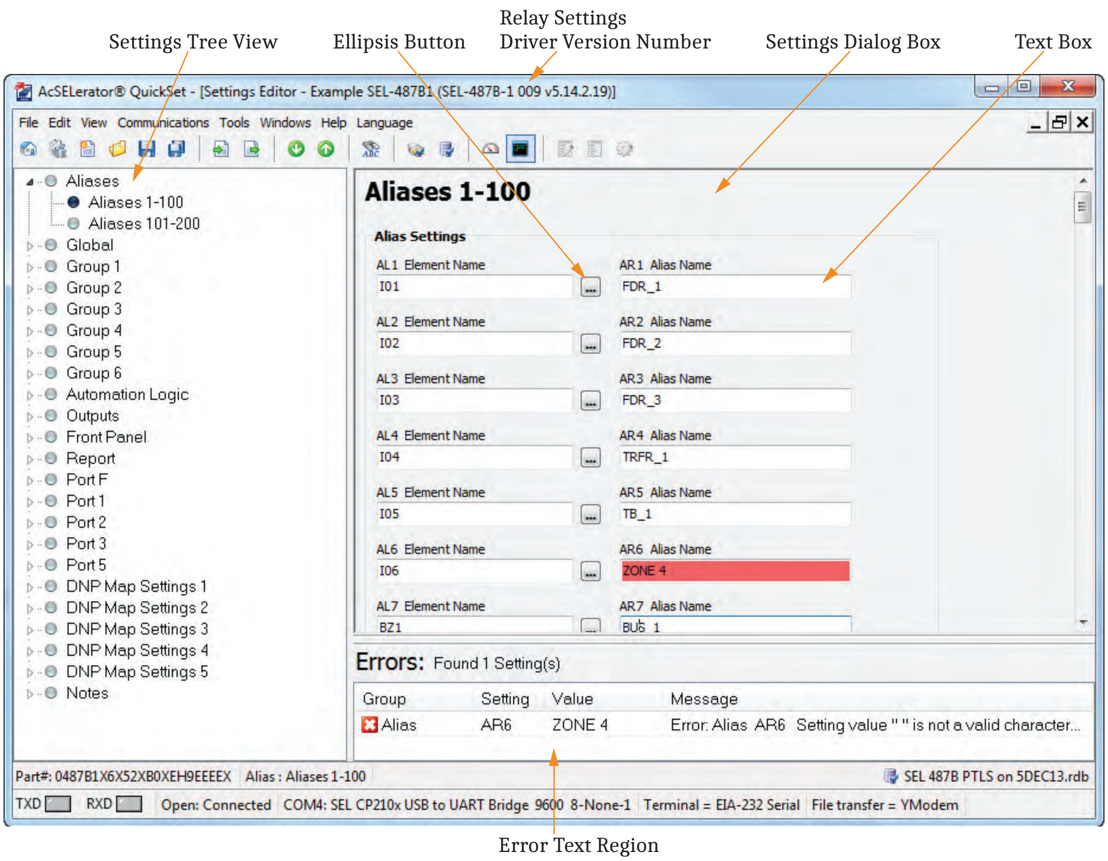


Figure 2.31 QuickSet Settings Editor

Entering Settings

Step 1. Select the arrows to expand the **Settings Tree View** (see *Figure 2.31*).

Step 2. Select the circle buttons to select the settings class, instance, and category that you want to change.

Step 3. Use the **<Tab>** key to move to the setting text book and from setting to setting when entering and editing.

Step 4. The right-click mouse button allows access to two special functions when you are editing settings: **Previous Value** and **Default Value**. It also allows the user to **Add a Comment** to the selected setting or **Search for Selected Text**.

Step 5. Use the following methods to edit the settings from QuickSet.

➢ Restore previous values. Right-click the mouse over the setting and select **Previous Value**.

➢ Restore default values. Right-click in the setting dialog box and select **Default Value**.

If you enter a setting that is out of range or has an error, an error message appears at the bottom of the **Settings Editor** window. To correct the error, proceed to *Step 6*.

Step 6. Correct settings errors.

a. Double-click the error listing in the **Settings Editor** window.

b. Enter a valid input for the setting where the error appears.

Ellipsis Button

QuickSet includes a feature called an **ellipsis button** (see *Figure 2.32*).

Figure 2.32 Ellipsis Button

The ellipsis button is a square button with three dots, as shown in *Figure 2.33*. Use the ellipsis button to build expressions or assist with entering settings in the relay. Whether the ellipsis button is an expression builder or a setting assistant depends on the selected relay function and is preprogrammed in the relay. For example, *Figure 2.33* shows the **ellipsis button** as a setting assistant, entering settings for the SER.

Step 1. Enter the SER settings by selecting on the **Report > SER Settings** in the **Tree View**.

Step 2. Select the **SITM1 SER Points and Alias, Point 1** ellipsis button, which makes the **R1-SITM1** window available.

Step 3. Select the Relay Word bit ellipsis button in the **R1-SITM1** window.

The software displays a list of Relay Word bits available in the relay that you can select to enter in the SER report.

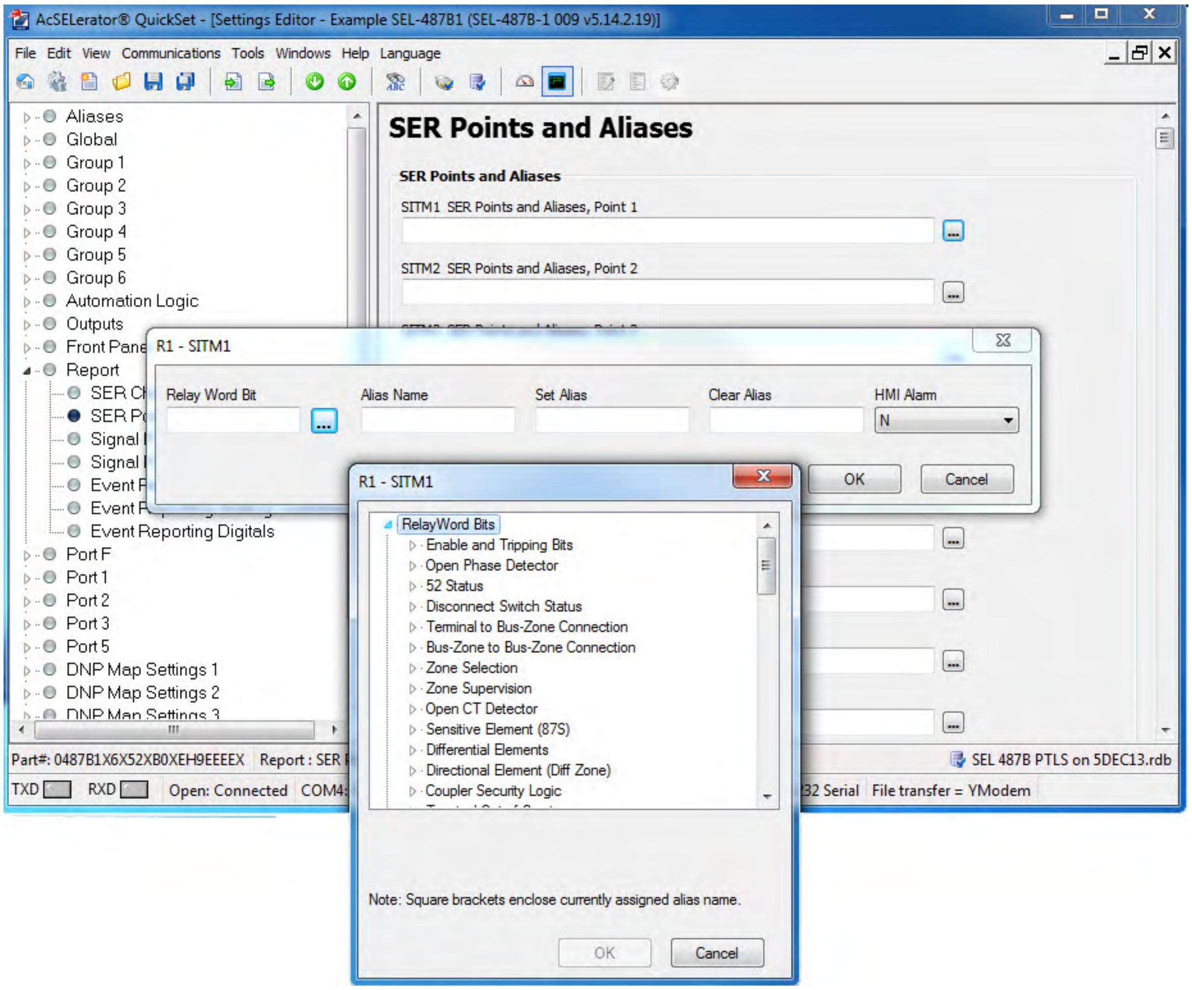


Figure 2.33 Location of Ellipsis Button

Expression Builder

The ellipsis button also allows access to an expression builder. SELOGIC control equations are a powerful means for customizing relay performance. Creating these equations can be difficult because of the large number of relay elements (Relay Word bits) and analog quantities in the relay. QuickSet simplifies this process with the expression builder, a rules-based editor for programming SELOGIC control equations. The expression builder organizes relay elements, analog quantities, and SELOGIC control equation variables and focuses your equation decision making.

Expression Builder Organization

The **Expression Builder** dialog box is organized into two main parts representing the left side (LVALUE) and right side (RVALUE) of the SELOGIC control equation. (The LVALUE is fixed for all settings except Protection Free-Form SELOGIC and Automation Free-Form SELOGIC control equation settings—see *Fixed SELOGIC Control Equations on page 13.6*.) *Figure 2.34* shows the two sides of the **Expression Builder**, with the SELOGIC control equation that you are constructing at the top of the dialog box. Note the dark vertical line and the equals sign (**:=**) separating the equation's left and right sides.

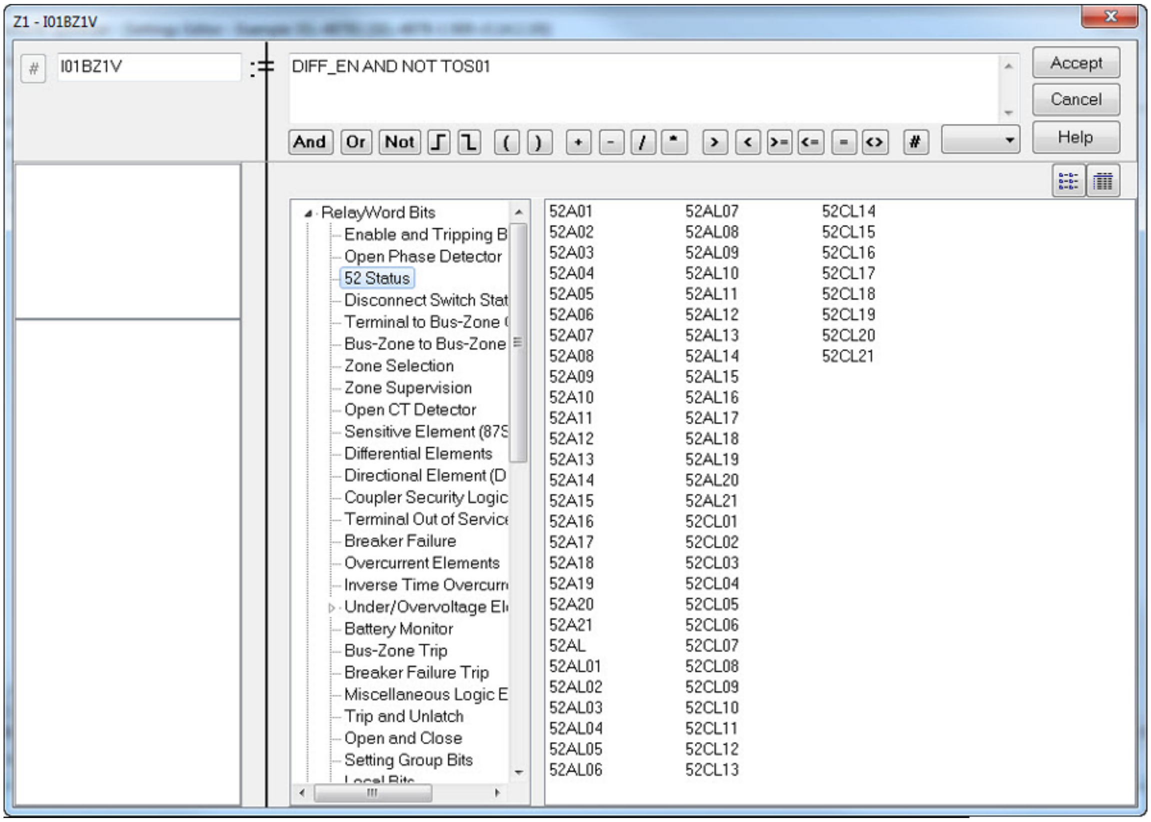


Figure 2.34 QuickSet Expression Builder

Using the Expression Builder

Step 1. For Protection Free-Form SELOGIC and Automation Free-Form SELOGIC control equations, select the type of result (LVALUE) for the SELOGIC control equation to use the **Expression Builder**.

QuickSet shows Relay Word bits available for use in compiling expressions. The program shows the relay elements for each type of SELOGIC control equation (e.g., Boolean Variables, Math Variables).

On the right side of the equation (RVALUE), you can select broad categories of relay elements, analog quantities, counters, timers, latches, Boolean variables, and math variables.

Step 2. Select a category in the RVALUE tree view.

The Expression Builder displays all elements for that category in the list at the bottom right side. Directly underneath the right side of the equation, you can choose operations to include in the RVALUE. These operations include basic logic functions, rising and falling-edge triggers, expression compares, and math functions. For more information on programming SELOGIC control equations, see *Section 13: SELOGIC Control Equation Programming*.

QuickSet HMI

Use the QuickSet HMI feature to view real-time relay information in a graphical format. Use the virtual relay front panel to read metering and targets (see *Figure 2.35*) for a representative example.

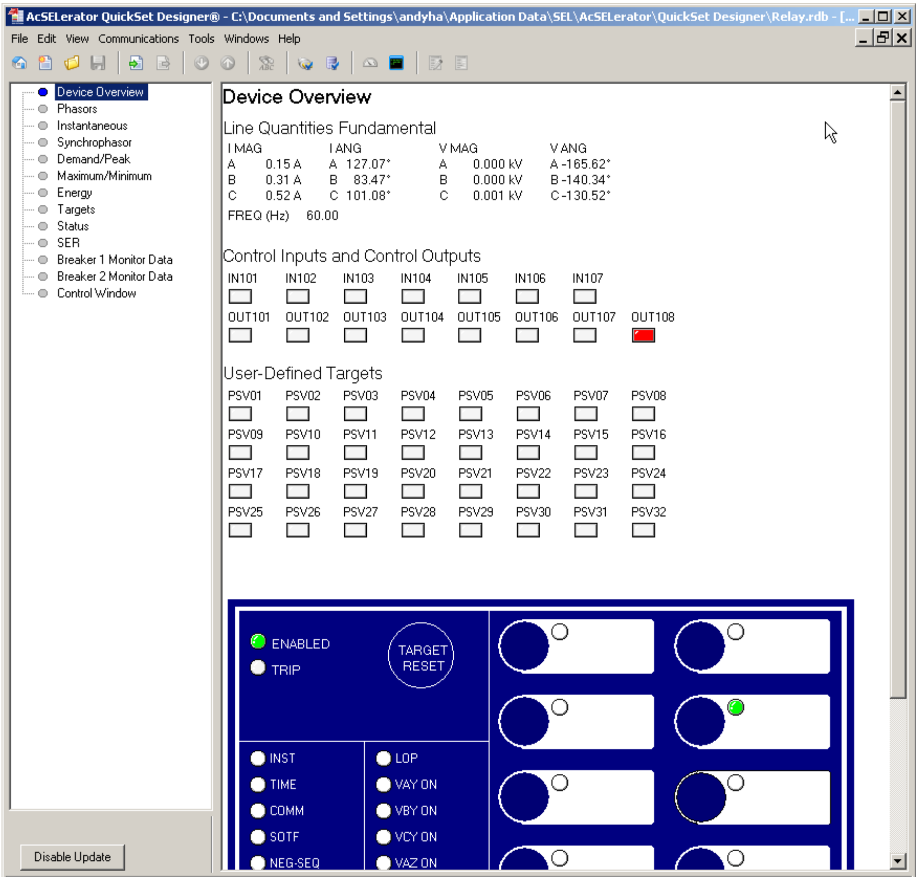


Figure 2.35 Virtual Relay Front Panel

Open the QuickSet HMI

Select **Tools > HMI > HMI** in the QuickSet menu bar. QuickSet opens the HMI window and downloads the interface data. The HMI can also be accessed by using the HMI icon.

QuickSet HMI Features

Table 2.5 lists typical functions in the HMI tree view and a brief explanation of each function. The specific options available for any specific relay depend on the features available in that relay.

Table 2.5 QuickSet HMI Tree View Functions (Sheet 1 of 2)

Function	Description
Device Overview	View general metering, selected targets, control input, control outputs, and the virtual front panel
Contact I/O	View status of contact inputs and contact outputs

Table 2.5 QuickSet HMI Tree View Functions (Sheet 2 of 2)

Function	Description
Phasors	A graphical and textual representation of phase and sequence voltages and currents.
Time and Communications	View for Time Quality, MIRRORED BITS Channel A or B, real-time control (RTC) Channel. Precision Time Protocol (PTP), or Sampled Values status.
Fundamental Metering	A table of instantaneous voltages, currents, powers, and frequency.
Zone Metering	View active Zone meter reports.
Differential Metering	View differential currents of all active zones.
Unbalance Metering	View the differential and unbalanced metering data.
Synchrophasor	A table of synchrophasor data.
Demand/Peak	A table showing demand and peak demand values. This display also allows demand and peak demand values to be reset.
Min/Max	A table showing maximum/minimum metering quantities. This display also allows maximum/minimum metering quantities to be reset.
Energy	A table showing energy import/export. This display also allows energy values to be reset.
Temperature	View the temperature measurements received from the SEL-2600A.
Protection Math Variables	View the protection math variable values.
Automation Math Variables	View the automation math variable values.
MIRRORED BITS Communications	View the MIRRORED BITS communications analog quantities.
Through Faults	View the through-fault data.
Thermal Monitoring	View the most recent saved thermal report of the transformer(s) monitored by the device.
Breaker *n* Monitoring (*n* can be S,T,U,W, or X)	View a comprehensive circuit breaker report that includes interrupted currents, number of operations, and mechanical and electrical operating times.
Analog Signal Profile	View the Signal Profile data for as many as 20 user-selectable analog values.
VSSI Report	View the voltage sag, swell, and interruption report.
Targets	View Relay Word bits in a row/column format.
Status	A list of relay status conditions.
LDP	View load profile data.
SER	Sequential Events Recorder (SER) data listed oldest to newest, top to bottom. Set the range of SER records with the dialog boxes at the bottom of the display.
SSI	View voltage Sag, Swell, and Interruption data.
Breaker Monitor Data	A table showing the latest circuit breaker monitor data.
Control Window	Metering and records reset buttons, trip and close control, output pulsing, target reset, time and date set, group switch, and remote bit control.

The flashing LED representation in the lower left of the QuickSet window indicates an active data update via the communications channel (see *Figure 2.35*). Select the button marked **Disable Update** to suspend HMI use of the communications channel.

HMI Device Overview

Select the **Device Overview** branch to display an overview of the relay operation. This view includes a summary of information from many of the other HMI branches, including fundamental metering, contact input/output status, and front-panel LED status.

The **Device Overview** colors and text can be customized. White LED symbols indicate a deasserted condition and LED symbols with any other color indicate an asserted condition. Select an LED symbol to change its assert color.

HMI Control Window

Select the **Control Window** branch to reset metering values, clear event records, trip and close reclosers/breakers, pulse output contacts, and set and clear remote bits (see *Figure 2.36*) for a representative example.

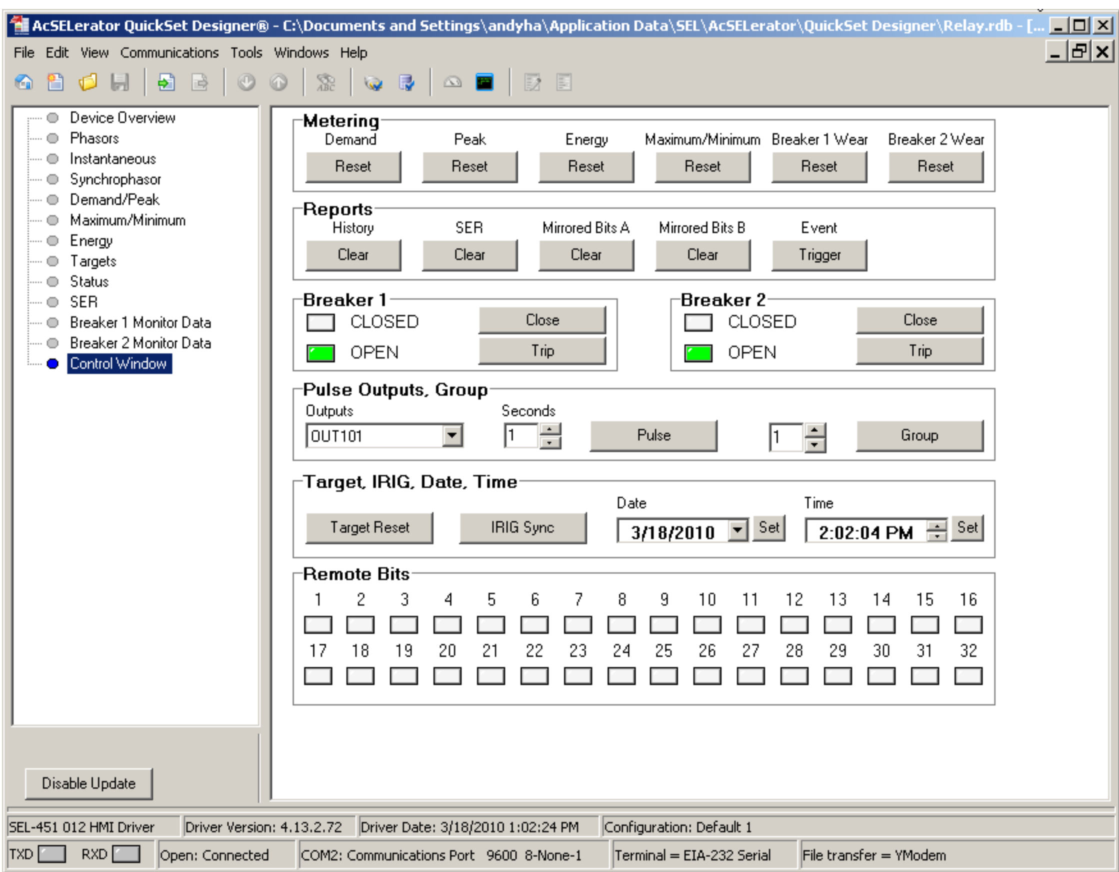


Figure 2.36 Control Window

Other HMI Branches

The remaining HMI branches display metering, targets, status, reporting, and monitoring information.

HMI Configurations

Customized **Device Overviews** can be saved as HMI Configurations. To save the current configuration, select **Tools > HMI > Save Configuration** to save the configuration under the current name, or **Tools > HMI > Save Configuration As** to specify a configuration name.

HMI configurations are identified by relay type and a configuration name. To use an existing configuration, select **Tools > HMI > Select Configuration**. To view available configurations, select **Tools > HMI > Manage Configurations**. To make an existing configuration the default configuration for a given relay type, select the configuration in the **Manage Configurations** window, select **Edit**, and select the **Default** check box.

Analyze Events

QuickSet has integrated analysis tools that help you retrieve information about protection system operations quickly and easily. Use the protection system event information that relays store to evaluate the performance of a protection system.

Event Waveforms

Relays record power system events for all trip situations and for other operating conditions programmed with SELOGIC control equations.

The relays provide two types of event data captures:

- Event report oscillography that uses filtered sample-per-cycle data
- Unfiltered (raw) data

Use QuickSet to view event report oscillograms, phasor diagrams, harmonic analysis, and settings.

Read History

You can retrieve event files stored in the relay and transfer these files to a computer. To download event files from the relay, open the QuickSet **Tools > Events** menu on the QuickSet toolbar and select **Get Event Files**. The **Event History** dialog box will appear (similar to *Figure 2.37*).

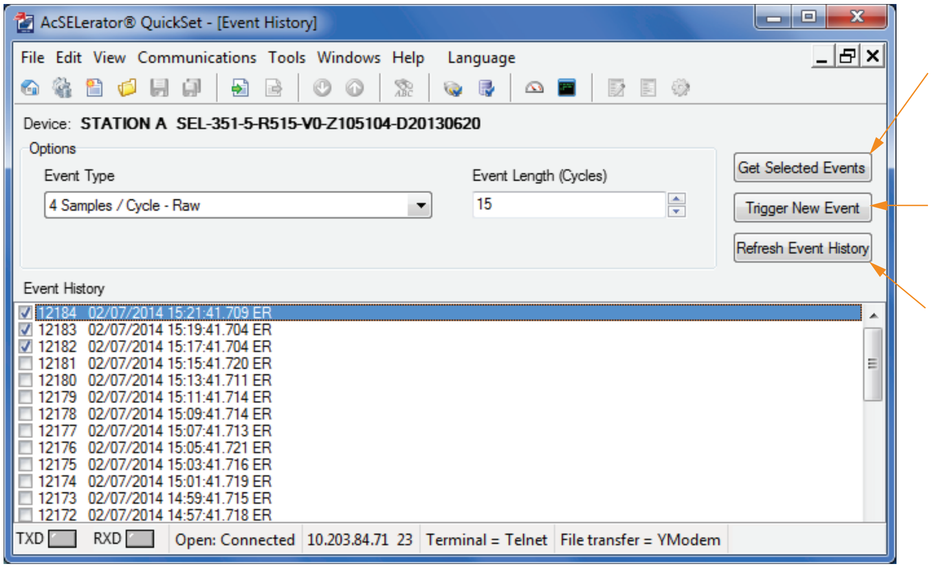


Figure 2.37 Retrieving an Event History

Get Event

Highlight the event you want to view and select the **Get Selected Event** button. The **Event Options** dialog box allows selection of Event Type and Event Length. When downloading is complete, QuickSet asks for a location to save the file on your computer. Select **Tools > Events> View Event Files with SynchroWAVe Event** and select an event file to view events saved on your computer.

QuickSet Help

Various forms of QuickSet help are available as shown in *Table 2.6*. Press **<F1>** to open a context-sensitive help file with the appropriate topic as the default. Other ways to access help are shown in *Table 2.6*.

Table 2.6 Accessing QuickSet Help

Help	Description
General QuickSet	Select **Help > Contents** from the main menu bar.
HMI Application	Select **Help > HMI Help** from the main menu bar.
Relay Settings	Select **Help > Settings Help** from the from the main menu bar.
Database Manager	Select **Help** from the bottom of the **Database Manager** window.
Communications Parameters	Select **Help** from the bottom of the **Communications Parameters** window.

SECTION 3

Basic Relay Operations

The SEL-400 series relays are powerful tools for power system protection and control. Understanding basic relay operation principles and methods will help you use the relay effectively. This section presents the fundamental knowledge you need to operate the relay, organized by task. These tasks help you become familiar with the relay and include the following:

Perform these tasks to gain a good understanding of relay operation, be able to confirm that the relay is properly connected, and be more effective when using the relay. To work through the examples in this section, you need to install the relay either in a final installation or in a laboratory configuration. See *Section 2: Installation* in the product-specific instruction manual for more information.

Inspecting a New Relay

NOTE: Do not connect power to the relay until you have completed your inspection of the relay. See the product-specific Installation section for details on applying power. Failure to follow these instructions can lead to equipment damage.

The following items are included in your shipment from SEL:

- Relay
- SEL Grid Configurator, ACSELERATOR QuickSet SEL-5030 Software, and ACSELERATOR Architect SEL-5032 Software
- Configurable Front-Panel Label Kit
- SEL Contact Card

If any item is missing or damaged, please contact your distributor or SEL immediately.

Initial Inspection

Perform the following initial inspection when the relay arrives:

Step 1. Remove the protective wrapping from the relay.

Step 2. Observe the outside of the front cover and the rear panel.

Step 3. Check that no significant scratches or dents are evident on any outer surface.

Step 4. Confirm that all terminal strips on the rear panel are secure.

Perform the following steps and use care when cleaning the relay:

Step 1. Use a mild soap or detergent solution and a damp cloth to clean the relay chassis.

Be careful cleaning the front and rear panels because a permanent plastic sheet covers each panel; do not use abrasive materials, polishing compounds, or harsh chemical solvents (such as xylene or acetone) on any relay surface.

Step 2. Allow the relay to air dry, or wipe dry with a soft dry cloth.

Verify Relay Configuration

When you first inspect the relay, confirm that the relay power supply voltage and nominal ac signal magnitudes are appropriate for your application. Examine the serial number label on the relay rear panel. *Figure 3.1* shows a sample rear-panel serial number label.

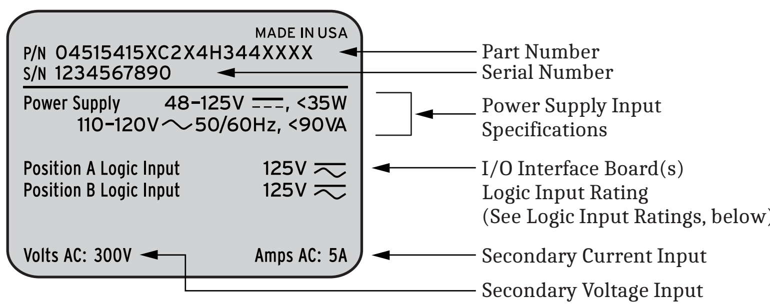


Figure 3.1 Sample Relay Serial Number Label

NOTE: Do not use this page for ordering a relay. For ordering information, refer to the relay Model Option Table available at selinc.com, or contact your SEL Sales Representatives.

Figure 3.1 shows a serial number label for an SEL-451 with additional I/O in a 4U horizontal chassis. This example serial number label is for a 5 A-per-phase secondary CT input relay. For information on CT and PT inputs, Do not use this page for ordering a relay. For ordering information, refer to the SEL-451 Model Option Table available at selinc.com/products/, or contact your SEL Sales Representatives.

The power supply specification in *Figure 3.1* indicates that this relay is equipped with a power supply that accepts a nominal 48–125 Vdc input. This power supply also accepts a 110–120 Vac input. Refer to the serial number label affixed to the back of your relay to determine the power supply voltage you should apply to the relay power supply input terminals. As this label indicates, the voltage source should be capable of providing at least 35 W for dc inputs and 90 VA for ac inputs. See *Section 1: Introduction and Specifications* in the product-specific instruction manual for more information on power supply specifications.

The serial number label does not list power system phase rotation and frequency ratings, because you can use relay settings to configure these parameters. The factory defaults are ABC phase rotation and 60 Hz nominal frequency. See *Making Settings Changes in Initial Global Settings on page 3.21* for details on setting these parameters.

Input Ratings

The serial number label in *Figure 3.1* only lists control input voltages for I/O Interface Boards that have optoisolated inputs, which is determined at ordering time. The other types of control inputs (direct-coupled) have settable pickup voltages, and do not appear on the serial number label. See *Control Input Assignment on page 3.61* for more information.

Establishing Communication

Once you have applied the correct power input successfully, you are ready to operate the relay. Use the relay front panel and the communications ports to communicate with the relay.

Front-panel control of relay functions involves use of a menu system that you access through the LCD and the six navigational pushbuttons shown in *Figure 3.2*. For complete instructions on using the front-panel menu system, see *Front-Panel Menus and Screens on page 4.14*.

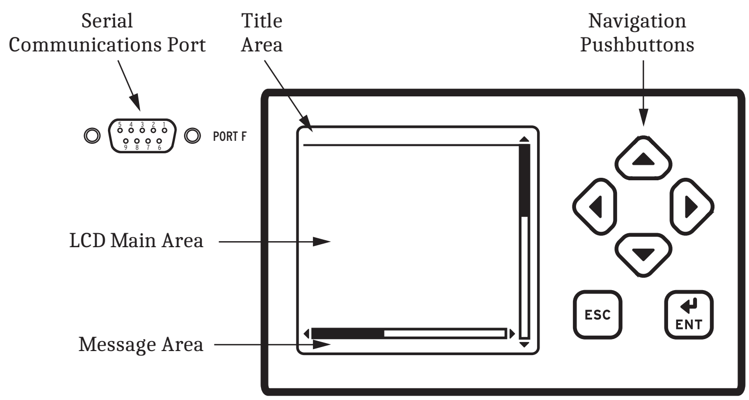


Figure 3.2 PORT F, LCD, and Navigation Pushbuttons

Fast and efficient communication with the relay is available through communications ports such as PORT F, also shown in *Figure 3.2*. A design philosophy for all SEL relays is that an ASCII or open terminal is all that you need to communicate with the relay. Many off-the-shelf computer programs provide terminal emulation. These programs are inexpensive and widely available.

Use the cable connections appropriate for your terminal configuration. See *Section 15: Communications Interfaces* for more information on communications ports.

All ASCII commands you send to the relay must terminate with a carriage return or carriage return/line feed; the terminal emulation program appends the necessary carriage return when you press **<Enter>**.

You can truncate commands to the first three characters: EVENT 1 becomes EVE 1. Use upper- and lowercase characters without distinction, except in passwords, which are case-sensitive. For a list of ASCII commands see *Section 14: ASCII Command Reference*.

Help

When you are using a terminal, you can access built-in relay help for each ASCII command. Relay help is access-level sensitive; you see only the ASCII commands for the present access level when you type **HELP <Enter>**. For in-depth information on a particular ASCII command, enter the command name after typing **HELP**. For example, for help on the **EVENT** ASCII command, type **HELP EVE <Enter>**.

When you are using QuickSet, press **<F1>** to get help, or select the **Help** menu from the QuickSet toolbars. The help information in QuickSet gives detailed information and sample screens in a GUI format.

Making an EIA-232 Serial Port Connection

The following steps use any popular computer terminal emulation software and SEL serial cables to connect to the relay.

Use an SEL-C234A cable to connect a 9-pin computer serial port to the relay. Use an SEL-C227A cable to connect a 25-pin computer serial port to the relay. For computers with USB ports, use an SEL-C662 USB-to-serial cable to connect to the relay. See *Section 15: Communications Interfaces* for further information on serial communications connections. These and other cables are available from SEL. Contact the factory or your local distributor for more information.

Step 1. Use the serial cable to connect the computer to the relay via **PORT F** on the relay front panel.

Step 2. Apply power to both the computer and to the relay.

Step 3. Start the computer terminal emulation program.

Step 4. Set your computer terminal emulation program serial communications parameters.

The default relay communications port settings are listed in *Table 3.1*.

Also set the terminal program to emulate either VT100 or VT52 terminals. These terminal emulations work best with SEL relays.

Table 3.1 General Serial Port Settings

Name	Description	Default
PROTO	Protocol (SEL, DNP, MBA, MBB, RTD, PMU)	SEL
SPEED	Data speed (300 to 57600, SYNC)	9600
DATABIT	Data bits (7, 8 bits)	8
PARITY	Parity (Odd, Even, None)	N
STOPBIT	Stop bits (1, 2 bits)	1
RTSCTS	Enable Hardware Handshaking (Y, N)	N

Step 5. To check the communications link, press **<Enter>** to confirm that you can communicate with the relay.

You will see the Access Level 0 = prompt at the left side of your computer screen (column 1).

If you do not see the prompt, check the cable connections and confirm the settings in your terminal emulation program match the default communications parameters shown in *Table 3.1*.

Step 6. Type **QUIT <Enter>** to view the relay report header.

You will see a computer screen display similar to that shown in *Figure 3.3*. (Text that you type is emphasized in bold letters.)

If you see jumbled characters, change the terminal emulation type in the computer terminal program.

```
=QUIT <Enter>

Relay 1                                     Date: 04/16/2004  Time: 00:01:05.209
Station A                                   Serial Number: 2001001234

=
```

Figure 3.3 Report Header

When you communicate with the relay at the Access Level 0 = prompt, you are in security Access Level 0. You cannot view or control relay functions at this level.

Higher access levels are password-protected and allow increased control over relay operation. For more information on access levels and password protection, see *Changing the Default Passwords in the Terminal on page 3.11*.

Making an Ethernet Telnet Connection

Factory-default settings for the Ethernet ports disable all Ethernet protocols. Enable the Telnet protocol with the SET P 5 command by using any of the serial ports. Command **SET P 5** accesses settings for all Ethernet ports on the relay.

Make the following settings by using the **SET P 5** command:

NOTE: For the five-port Ethernet card, set EINTF to **CD** and/or **E**. Then, set ETELNET to **CD** and/or **E**.

- ➤ EPORT = Y
- ➤ IPADDR = IP Address assigned by network administrator in classless inter-domain routing (CIDR) notation
- ➤ DEFRTR = Default router gateway IP Address assigned by network administrator
- ➤ NETMODE = FAILOVER
- ➤ ETELNET = Y

Leave all other settings at their default values.

NOTE: If connecting to a single-mode SFP, use an SEL-C809 cable (9 µm single-mode fiber-optic cable).

Connect an Ethernet cable between your PC or a network switch and any non-process bus Ethernet port on the relay. Verify that the amber **LINK** LED illuminates on the connected relay port. Many computers and most Ethernet switches support autocrossover, so nearly any Cat 5 Ethernet cable with RJ45 connectors, such as an SEL-C627 cable, will work. When the computer does not support autocrossover, use a crossover cable, such as an SEL-C628 cable. For fiber-optic Ethernet ports, use an SEL-C807 cable (62.5/200 µm multimode fiber-optic cable) or SEL-C808 cable (62.5/125 µm multimode fiber-optic cable). Use a Telnet client or QuickSet on the host PC to communicate with the relay. During Ethernet transmit or receive activity, the green Activity LED blinks on the relay Ethernet port. To terminate a Telnet session, use the command **EXI <Enter>** from any access level.

Making an Ethernet Web Server (HTTP) Connection

When **PORT 5** setting EHTTP is enabled, the relay serves read-only webpages displaying certain settings, metering, and status reports. The relay-embedded HTTP server has been optimized and tested to work with the most popular web browsers, but should work with any standard web browser. As many as four users can access the embedded HTTP server simultaneously.

To begin using the embedded read-only HTTP server, launch your web browser, and browse to http://IPADDR, where IPADDR is the **PORT 5** setting IPADDR (e.g., http://192.168.1.2). The relay responds with a login screen as shown in *Figure 3.4*.

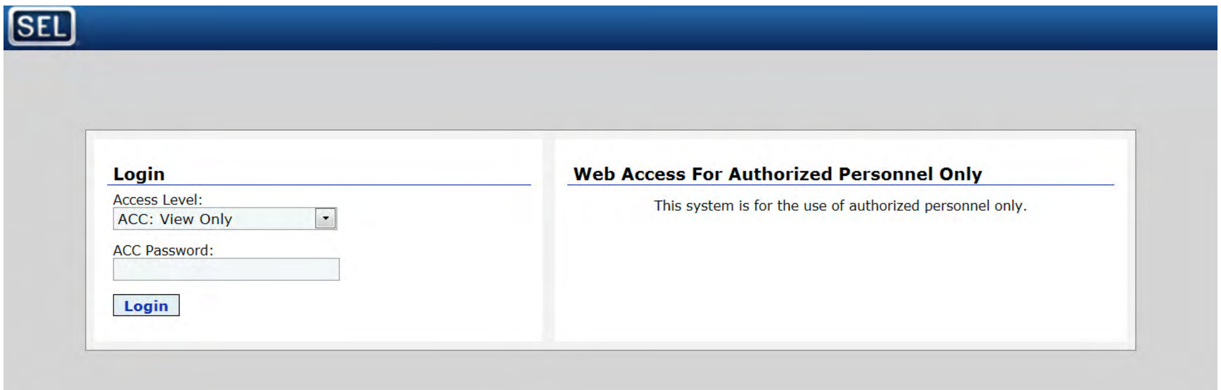


Figure 3.4 HTTP Server Login Screen

Choose **ACC** for the username, type in the relay Access Level 1 password, and select **Submit**. The only username allowed is ACC. The relay responds with the homepage shown in *Figure 3.5*. While you remain logged in to the relay, the webpage displays the approximate time as determined by the relay time-of-day clock, and increments the displayed time once per second based on the clock contained in your PC.

Once the user is logged in, the HTTP server displays the Meter webpage. This page will refresh within five seconds and includes all metering options available and enabled on the relay.

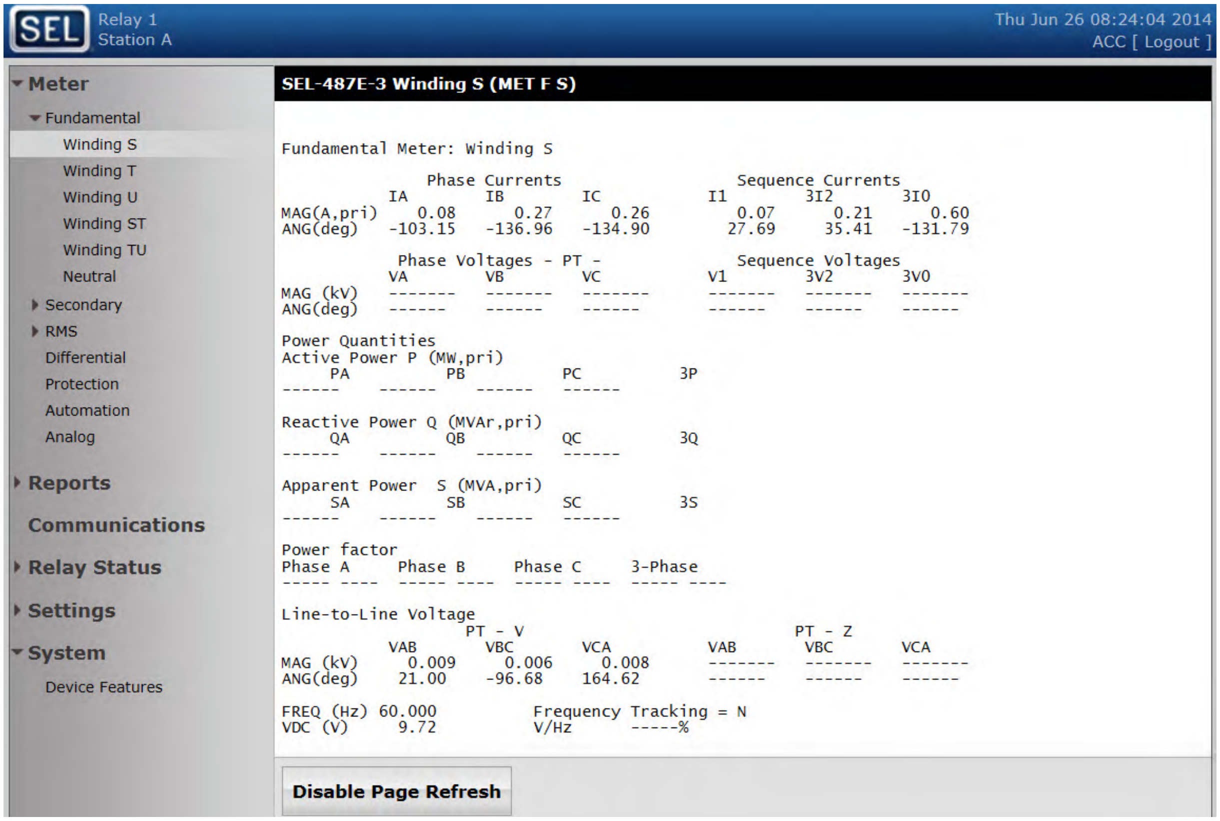


Figure 3.5 Example HTTP Server Meter Page

Select any menu selection in the left pane to navigate through the available web-pages.

Access Levels and Passwords

NOTE: Perform the password change steps described in Changing the Default Passwords in the Terminal on page 3.11.

It is extremely important that you change the factory-default passwords programmed in the relay. Setting unique passwords for the relay access levels increases the security of your substation and the power system.

This section begins with information on the access level/password system in SEL-400 series relays and includes an example of changing the default passwords.

Access Levels

Access levels control whether you can perform different operations within the relay. These security levels are labeled 0, 1, B, P, A, O, 2, and C. *Figure 3.6* presents an overview of the general access level structure in the relay.

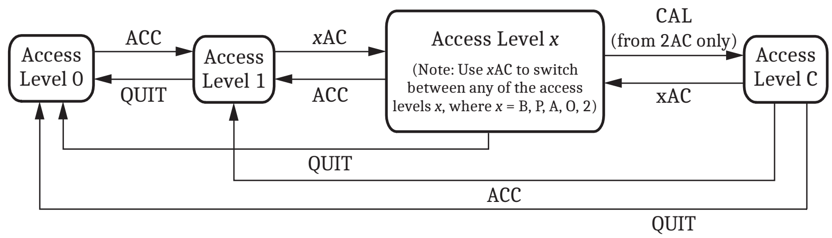


Figure 3.6 Access Level Structure

Access Level 0 is the least secure and most limited access level, and Access Level 2 is the most secure level at which you have total relay functionality (Level C is reserved for SEL factory operations. Only go to level C to change the level C password or under the direction of an SEL employee). For example, from Access Level 1, you can view settings, but you cannot change settings unless you are at a higher access level.

Table 3.2 lists access levels and operator functions for the relay.

Table 3.2 SEL-400 Series Relays Access Levels

Access Level	Prompt	Allowed Operations
0	=	Log in to Access Level 1.
1	=>	View data and status information.
B	==>	Access Level 1 functions plus breaker control and data.
P	P=>	Access Level B functions plus protection settings.
A	A=>	Access Level B functions plus automation settings.
O	O=>	Access Level B functions plus output settings.
2	=>>	Perform all relay access level functions.
C	==>>	SEL factory-specific functions. For a list of commands available, contact SEL.

The relay performs command interpretation and execution according to your validated access level. Each access level has a password that the relay must verify before you can control the relay at that level. *Table 3.3* lists the access level commands with corresponding passwords.

Table 3.3 Access Level Commands and Passwords

Access Level	Command	Factory-Default Password
0	QUIT	(None)
1	ACCESS	OTTER
B	BACCESS	EDITH
P	PACCESS	AMPERE
A	AACCESS	VOLTA
O	OACCESS	WATT
2	2ACCESS	TAIL
C	CAL	Sel-1

Communications Ports Access Levels

⚠WARNING
This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.

Entrance to the higher security levels is sequential. You must first enter a correct password to move from Access Level 0 to Access Level 1.

To enter Access Levels B, P, A, O, and 2, you must enter a correct password from Access Level 1. For example, to go to the O (Output) Access Level from Access Level 1, type **OAC <Enter>**. At the `Password: ?` prompt, type your Access Level O password.

To enter Access Level C, you must enter a correct password from Access Level 2.

Use the relay **QUIT** command from any access level to return the relay to Access Level 0. To reestablish control at a previous access level from Access Level 1, you must use the access level commands and passwords to log in to that previous access level.

When a connection with the relay times out, the relay reduces the access level to Access Level 0 for that communications port connection.

Use the MAXACC port setting to limit the maximum access level permitted on a station bus port. This can be useful to restrict what remote users can do. For the five-port Ethernet card, use the MAXACCE port setting to limit the maximum access level permitted on the engineering access port (**PORT 5E**).

Communications Ports Access Control

Port access control provides a flexible way to manage access permissions on designated ports. For example, a remote administrator (e.g., SCADA) can use this feature to grant temporary or limited access to personnel in the field.

Set port setting EPAC = Y to enable access control on a particular port. Use the Global SELOGIC equations EACC and E2AC to define the access criteria for all EPAC enabled ports. If EACC and E2AC evaluate to 0, all access requests are denied. If EACC evaluates to 1, Access Level 1 requests are permitted. If E2AC evaluates to 1, all access level requests are permitted (see *Figure 3.7*). Note that passwords are still required to escalate privilege.

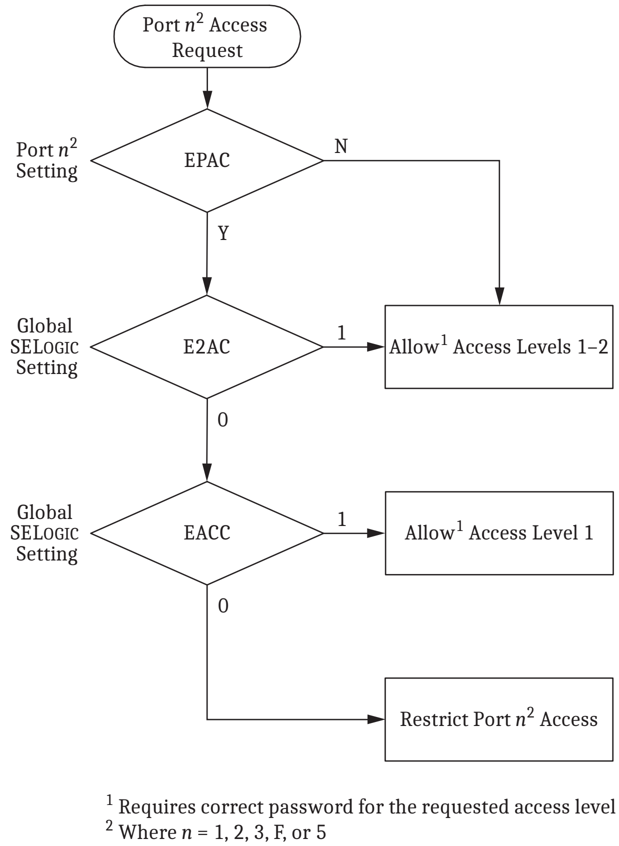


Figure 3.7 Port Access Control Flow Chart

Port access control does not apply when the relay is disabled, the password jumper is installed (PASSDIS = 1), or when EPAC = N, nor can it be used to decrease a user's current access level or exceed the MAXACC setting level of the port.

Front-Panel Access Levels

The lowest access level for the front panel is Access Level 1. To enter Access Levels B, P, A, O, and 2, you must enter a correct password from Access Level 1.

The front-panel LCD displays a password prompt when you attempt to control the relay at any access level higher than Access Level 1. (For more information on entering passwords from the front panel, see *PASSWORD on page 14.52*.)

The front-panel `MAIN MENU` item `RESET ACCESS LEVEL` returns the relay to Access Level 1. In addition, when the front-panel inactivity timer times out (indicated by the `ROTATING DISPLAY` on the front-panel LCD), the relay returns the front-panel access level to Access Level 1.

ACCESS Command

NOTE: You can shorten relay commands to the first three letters of the full command. Section 14: ASCII Command Reference for more information.

Enter the **ACCESS** (**ACC**) command to change to Access Level 1. Passwords are case-sensitive; you must enter a password exactly as set.

If you enter the password correctly, the relay moves to Access Level 1 and the Access Level 1 => prompt appears. If you are at a higher access level (B, P, A, O, and 2), you can reduce the access level to Access Level 1 by entering the **ACC** command. The relay performs no password validation to reduce the present access level.

Higher Access Level Commands

Enter the commands in *Table 3.3* to enter access levels above Access Level 1. For example, enter the **2ACCESS (2AC)** command to change to Access Level 2.

If you are presently at Access Level 1, B, P, A, or O, typing **2AC <Enter>** causes the relay to prompt you to type the Access Level 2 password. If the present level is Access Level 0, the relay responds with `Invalid Access Level`. The relay pulses alarm Relay Word bit SALARM when entering Access Levels B, P, A, O, and 2 from a lower access level.

If an incorrect password is entered three times, the relay asserts the BADPASS and SALARM Relay Word bits for one second and displays on a communications terminal screen the following error message:

```
WARNING: ACCESS BY UNAUTHORIZED PERSONS STRICTLY PROHIBITED
```

In addition, you cannot make further access level entry attempts for 30 seconds. The relay terminates the communications connection after the third failed attempt when you use Ethernet via an Ethernet card, DNP3 (Distributed Network Protocol version 3.0), or MIRRORED BITS communications virtual terminal mode. For more information on these protocols, see *Section 15: Communications Interfaces* and *Section 16: DNP3 Communication*.

If your connection to the relay has an inactivity time-out (in the **SET P** port settings), the relay automatically closes the communications connection and changes to Access Level 0 when the time-out occurs.

Passwords

⚠WARNING
This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.

Valid passwords are character sequences of as many as 12 characters. Valid password characters are any printable ASCII character. HMI password entry is limited to upper- and lowercase letters, numbers, underscore, and period, so you must limit your password to these characters if you need to do privileged operations from the front panel. Passwords are case-sensitive.

It is important that you change all of the passwords from their default values. This will protect you from unauthorized access.

Use strong passwords. Strong passwords contain a mix of the valid password characters in a combination that does not spell common words in any portion of the password.

Changing the Default Passwords in the Terminal

Step 1. Confirm that the relay is operating (see *Establishing Communication on page 3.3*).

Step 2. Establish communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4* to learn how to use a terminal to communicate with the relay).

Step 3. Enter Access Level C (Access Level 2 is sufficient except when changing the Access Level C password).

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password **OTTER** and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type **2AC <Enter>**.

NOTE: Passwords are case-sensitive; you must enter passwords exactly as set.

d. At the password prompt, type **TAIL <Enter>**.

e. You will see the Access Level 2 =>> prompt.

f. Type **CAL <Enter>**.

g. At the password prompt, type **Sel-1 <Enter>**.

You will see the Access Level C ==>> prompt.

Step 4. To set a new password for Access Level 2, type the following:

PAS 2 <Enter>.

Step 5. Before you can change to a new password, the relay prompts you to first confirm the existing password. Enter the existing password and press **<Enter>**.

```
Old Password:  ?**** <Enter>
```

Step 6. The relay prompts you for the new password, and a confirmation of the new password, as follows:

```
New Password:  ?**** <Enter>
Confirm New Password:  ?**** <Enter>
Password Changed
CAUTION: This password can be strengthened. Strong Passwords do not
    include a name, date, acronym or word. They consist of the maximum
    allowable characters, with at least one special character, number,
    lower-case letter, and upper-case letter. A change in password is
    recommended.
```

Notice that the new password is not displayed. After the confirmation, the new password is in effect. The relay will issue a weak password warning if the new password does not include at least one special character, number, lowercase letter, and uppercase letter.

Step 7. Set new passwords for each access level.

In a similar manner as the previous step, create new strong passwords for each access level.

Step 8. Commit these passwords to memory, permanently record your new passwords, and store this permanent record in a secure location.

To eliminate password verification for an access level, enter **DISABLE** in place of the new password. This action will disable the password of that level; therefore, the relay does not check for a password upon entering that access level.

If you forget a password or encounter difficulty changing the default passwords, you can temporarily disable password verification. See *Section 2: Installation* in the product-specific instruction manual for information on the password disable jumper.

Checking Relay Status

With continual self-testing, the relay monitors the internal operation of all circuits to verify optimal performance of relay functions. If an internal circuit, protection algorithm, or automation algorithm enters an out-of-tolerance operating range, the relay reports a status warning. In the unlikely event that an internal failure occurs, the relay reports a status failure. For more information on relay status, see *Relay Self-Tests on page 10.19*.

You can check relay status through a communications port by using a terminal, terminal emulation computer program, or QuickSet. In addition, you can use the relay front panel to view status information.

Checking Relay Status by Using the Terminal

The procedure in the following steps assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.11* to change the default access level passwords).

Step 1. Enter Access Level 1.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 2. Type **STA <Enter>**. The relay returns a status terminal screen similar to that in *Figure 3.8*.

```
=>STA <Enter>
Relay 1                                                 Date: 03/17/2023  Time:07:02:50.776
Station A                                               Serial Number: 1230769999
FID=SEL-451-5-Rxxx-V0-Zxxxxxx-Dyyyymmdd                   CID=0x9aed

Failures
  No Failures
Warnings
  No Warnings

SELogic Relay Programming Environment Errors
  No Errors
Relay Enabled
=>
```

Figure 3.8 Relay Status

Step 3. Type **STA A <Enter>** to view all relay status entries.

For more information on relay status report items, see *STATUS on page 14.60*.

Checking Relay Status in SEL Grid Configurator

You can use SEL Grid Configurator to check relay status.

The following procedure assumes that you are familiar with SEL Grid Configurator.

Step 1. Configure SEL Grid Configurator communications with the relay. See *Section 2: PC Software* for information on communicating with a relay in SEL Grid Configurator.

Step 2. Open a terminal communication session with the relay in SEL Grid Configurator.

a. Type **STA <Enter>**. The relay returns a status terminal similar to that in *Figure 3.9*.

```
=>STA <Enter>
Relay 1                                                Date: 03/17/2023  Time:07:02:50.776
Station A                                              Serial Number: 1230769999
FID=SEL-451-6-Rxxx-V0-Zxxxxxx-Dyyyymmdd                  CID=0x9aed

Failures
  No Failures
Warnings
  No Warnings

SELogic Relay Programming Environment Errors
  No Errors
Relay Enabled
=>
```

Figure 3.9 Relay Status

b. Type **STA A <Enter>** to view all relay status entries.

For more information on relay status report items, see *STATUS on page 14.60*.

Checking Relay Status in QuickSet

You can use QuickSet to check relay status. Use the **HMI > Meter Control** menu to view status conditions.

The following procedure assumes that you are familiar with QuickSet.

Step 1. Configure QuickSet communications with the relay. See *Section 2: PC Software* for information on communicating with a relay in QuickSet.

Step 2. Select **Tools** in the top toolbar and select the **HMI** menu to start the QuickSet operator interface.

Step 3. Select the **Status** button of the HMI tree view (see *Figure 3.10*).

QuickSet displays the relay status with a display similar to that in *Figure 3.10*.

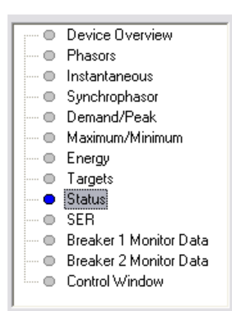


Figure 3.10 Retrieving Relay Status in QuickSet

Checking Relay Status From the Front Panel

Use the front-panel display and navigation pushbuttons to check relay status. See *Section 4: Front-Panel Operations* for information on using the relay front panel.

Step 1. Apply power to the relay, and note that the LCD shows a sequence of screens called the ROTATING DISPLAY.

(If you do not operate the front panel for a certain period, the relay will enter front-panel time-out mode and you will see the sequential screens of the ROTATING DISPLAY.)

Step 2. Press the **ENT** pushbutton to display the MAIN MENU as shown in *Figure 3.11*.

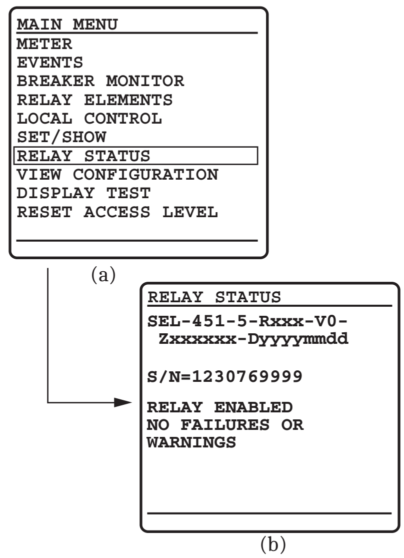


Figure 3.11 Checking Relay Status From the Front-Panel LCD

Step 3. View the relay status.

a. Press the **Up Arrow** and **Down Arrow** navigation pushbuttons to highlight the RELAY STATUS action item (see *Figure 3.11*).

b. Press the **ENT** pushbutton.

You will see the RELAY STATUS screen (the second screen of *Figure 3.11*).

Step 4. Press the **ESC** pushbutton to return to the MAIN MENU.

Step 5. Press **ESC** pushbutton again to return to the ROTATING DISPLAY.

For more information on the front-panel screen presentations and the items in the RELAY STATUS screens, see *Relay Status on page 4.30*.

Making Simple Settings Changes

⚠WARNING
Isolate the relay trip circuits while changing settings. When changing settings for multiple classes, it is possible to be in an intermediate state that will cause an unexpected trip.

The relay settings structure makes setting the relay easy and efficient. Settings are grouped logically, and relay elements that are not used in your selected protection scheme are hidden. SEL Grid Configurator or QuickSet uses a similar method to focus your attention on the active settings. Unused relay elements and inactive settings are dimmed (grayed) in the menus. See *Section 2: PC Software* for more information.

Settings Structure

SEL-400 series relays use a settings structure that assigns each relay setting to a specific location based on the setting type. A top-down organization allocates relay settings into these layers:

- ➤ Class
- ➤ Instance
- ➤ Category
- ➤ Setting

Examine *Figure 3.12* to understand the settings structure in a typical relay. The top layer of the settings structure contains classes and instances. Class is the primary sort level; all classes have at least one instance, and some classes have multiple instances. Settings classes and related instances for the SEL-451, which are typical of SEL-400 series relays, are listed in *Table 3.4*. See *Section 8: Settings* of the product-specific instruction manual for details on the classes and instances for a given relay.

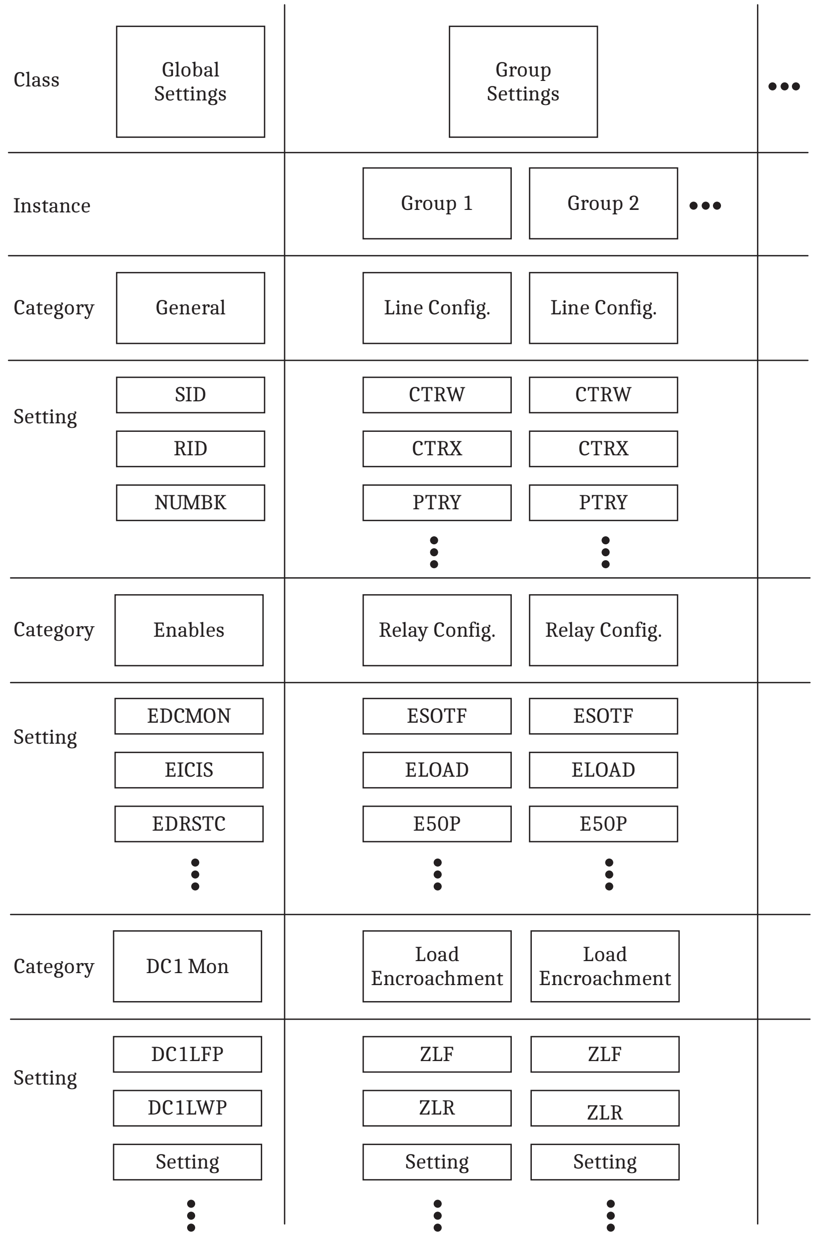


Figure 3.12 Example Relay Settings Structure Overview

Table 3.4 SEL-451 Settings Classes and Instances (Sheet 1 of 2)

Class	Description	Instance	Description	ASCII Command	Access Level
Global	Relay-wide applications settings	Global		SET G	P, A, O, 2
Group	Individual scheme settings	Group 1 • • • Group 6	Group 1 settings • • • Group 6 settings	SET 1, SET S 1 • • • SET 6, SET S 6	P, 2
Breaker Monitor	Circuit breaker monitoring settings	Breaker Monitor		SET M	P, 2

Table 3.4 SEL-451 Settings Classes and Instances (Sheet 2 of 2)

Class	Description	Instance	Description	ASCII Command	Access Level
Port	Communications port settings	PORT F PORT 1 • • • PORT 3 PORT 5 PORT 6 (TiDL relays only)	Front-panel port PORT 1 settings • • • PORT 3 settings Communications card settings TiDL Topology Settings (TiDL relays only)	SET P F SET P 1 • • • SET P 3 SET P 5 (Only available via Grid Conifgurator)	P, A, O, 2
Report	Report settings	Report		SET R	P, A, O, 2
Front Panel	Front-panel HMI settings	Front Panel		SET F	P, A, O, 2
Protection SELOGIC control equations	Protection-related SELOGIC control equations	Group 1 • • • Group 6	Group 1 protection SELOGIC control equations • • • Group 6 protection SELOGIC control equations	SET L 1 • • • SET L 6	P, 2
Automation SELOGIC control equations	Automation-related SELOGIC control equations	Block 1 • • • Block 10	Block 1 automation SELOGIC control equations • • • Block 10 automation SELOGIC control equations	SET A 1 • • • SET A 10	A, 2
DNP3	Direct Network Protocol data remapping	Map 1 • • • Map 5		SET D 1 • • • SET D 5	P, A, O, 2
Output SELOGIC control equations	Relay control output settings and MIRRORED BITS communication transmit equations	Output		SET O	O, 2
Bay	Bay control settings	Bay		SET B	P, 2
Alias	Set aliases	Analog or digital quantities		SET T	P, A, O, 2
Notes	Freeform programming to leave notes in the relay	Notes	100 lines	SET N	P, A, O, 2

Note that some settings classes have only one instance and you do not specify the instance designator when accessing these classes. An example is the Global settings class. You can view or modify Global settings with a communications terminal by entering **SET G** as shown in the ASCII Command column of *Table 3.4*. The relay presents the Global settings categories at the **SET G** command; no instance numbers follow **SET G**. Conversely, the Port settings command has five instances (PORT F, PORT 1, PORT 2, PORT 3, and PORT 5). To access the PORT 1 settings, type **SET P 1 <Enter>**. If you do not specify which port to set, the relay defaults to the active port (the port you are presently using).

The Group settings can have the optional one-letter acronym S attached to the command; you can enter **SET 1** or **SET S 1** for Group 1 settings, **SET 2** or **SET S 2** for Group 2 settings, etc. If you do not specify which group to set, the relay defaults to the present active group. If Group 6 is the active group, and you type **SET <Enter>**, for example, you will see the settings prompts for the Group 6 settings.

Alias Settings

Although the relay provides extensive programming facilities and opportunity for comments, troubleshooting customized programs is sometimes difficult. Aliases provide an opportunity to assign more meaningful names to the generic variable names to improve the readability of the program.

Rename, or assign as many as 200 alias names to any Relay Word bit or analog quantity in the relay. The maximum length of an alias is seven characters. Valid characters are 0–9, A–Z (only uppercase), and _ (underscore), and must contain at least one alphabetic character. Ensure that no Relay Word bit or analog quantity appears more than once in the Alias settings. Each alias name must be unique, i.e., you cannot use the name of an existing Relay Word bit or analog quantity. If you remove the alias name, all settings that referenced that alias revert to the original name.

Use the **SHO T** command to view the default settings, as shown in *Figure 3.13*.

```
=>>SHO T <Enter>
Alias
Relay Aliases
(RW Bit or Analog Qty. 7 Character Alias [0-9 A-Z _])
1: EN,"RLY_EN"
=>>
```

Figure 3.13 Default Alias Settings

Making Text-Edit Mode Alias Changes

Assign the alias name THETA to math variable PMV01 and the alias TAN to math variable PMV02. These variables are then used in calculating the tangent of theta, using their alias names in the equation.

Step 1. Prepare to control the relay at Access Level 2.

a. Type **ACC <Enter>** at a communications terminal.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type **2AC <Enter>**.

d. Type the correct password to go to Access Level 2.

You will see the =>> prompt.

Step 2. Type **SET T <Enter>** to access the Alias settings.

Figure 3.14 shows a representative computer terminal screen.

Step 3. Type **> <Enter>** for the relay to display the first line that you can edit.

Step 4. Type **PMV01,THETA <Enter>** at the Line 2 `?` settings prompt to set the alias for PMV01.

The relay verifies that this is a valid entry, then responds with the next line prompt `3:` followed by the `?` settings prompt.

Step 5. Type **PMV02,TAN <Enter>** at the Line 3 `?` settings prompt to set the alias for PMV02.

The relay verifies that this is a valid entry, then responds with the next line prompt `4:` followed by the `?` settings prompt.

Step 6. Type **END <Enter>** to end the settings session.

The relay scrolls a readback of all the front-panel settings, eventually displaying the `Save settings (Y, N) ?` prompt. At the end of the readback information, just before the `Save settings (Y, N) ?` prompt, you can verify the new display point information.

Step 7. Type **Y <Enter>** to save the new settings.

```
=>>SET T <Enter>
Alias
Relay Aliases
(RW Bit or Analog Qty. 7 Character Alias [0-9 A-Z _])
1: EN,"RLY_EN"
?   <Enter>
2:
?  PMV01,THETA <Enter>
3:
?  PMV02,TAN <Enter>

4:
?  END <Enter>
Alias
Relay Aliases
(RW Bit or Analog Qty. 7 Character Alias [0-9 A-Z _])
1: EN,"RLY_EN"
2: PMV01,"THETA"
3: PMV02,"TAN"

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 3.14 Using Text-Edit Mode Line Editing to Set Aliases

Use the alias names, instead of the Relay Word bits, in SELOGIC control equation programming. *Figure 3.15* shows an example of an alias used in protection logic programming.

```
=>>SET L <Enter>
Protection 1
1: PLT01S := PB1_PUL AND NOT PLT01 #GROUND ENABLED
?  > <Enter>
15:
?  THETA:=IO1FA <Enter>

16:
?  TAN:=SIN(THETA)/COS(THETA) <Enter>
17:
?  END <Enter>
Protection 1
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 3.15 Using Text-Edit Mode Line Editing to Set Protection Logic

Changing Settings by Using the Terminal

When you change settings (with any **SET** command) from a terminal, the relay shows the setting category, prompt, present value, and action prompt.

Figure 3.16 shows two settings examples: multiple-line settings (SID and RID) and an in-line setting (NUMBK) for relay Global settings from Access Level P (protection). The relay prompts you for input by presenting an action prompt. You have many options for navigating the settings at the `?` prompt.

Table 3.5 lists the operations possible from a settings action prompt.

```
==>SET G <Enter>
Global

General Global Settings                                        Category

Station Identifier (40 characters)                             Prompt
SID := "Station A"                                             Present Value
? <Enter>                                                      Action Prompt
Relay Identifier (40 characters)
RID := "Relay 1"
? <Enter>
Number of Breakers in Scheme (1,2)      NUMBK   := 1      ? <Enter>
            Prompt                            Present    Action
                                              Value      Prompt
```

Figure 3.16 Components of SET Commands

Table 3.5 Actions at Settings Prompts

Action	Relay Response
<Enter>	Accept setting and move to the next setting; if at the last setting, exit settings.
[*value*] <Enter>	Enter the given *value* and move to the next setting if valid; if at the last setting, exit settings.
^ <Enter>	Move to the previous setting; if at the top of settings, stay at the present setting.
< <Enter>	Move to the top of the previous settings category; if at the top of settings, stay at the present setting.
> <Enter>	Move to the top of the next settings category; if in the last category, exit settings.
END <Enter>	Go to the end of the present settings session. Prepare to exit settings via the `Save settings (Y,N) ?` prompt.
<Ctrl+X>	Abort the editing session without saving changes.

When you exit settings entry from the **SET** commands, the relay responds with `Save settings (Y,N)?`. If you answer **Y <Enter>**, the relay writes the new settings to nonvolatile storage. If you answer **N <Enter>**, the relay discards any settings changes you have made.

Making Settings Changes in Initial Global Settings

You must configure SEL-400 series relays for specific conditions found in the power system where you are connecting the relay. For example, in most SEL-400 series relays you must set the nominal frequency and phase rotation.

The procedure in the following steps assumes that you have successfully established communication with the relay; see *Making an EIA-232 Serial Port Connection on page 3.4* for a step-by-step procedure. In addition, you must be familiar with relay access levels and passwords. See *Changing the Default Passwords in the Terminal on page 3.11* to change the default access level passwords.

This example jumps to a Global setting that is not at the beginning of the Global settings list. Thus, you enter **SET G**, the setting name, and **<Enter>**. To start at the beginning of the Global settings, simply type **SET G <Enter>** without a settings name.

Step 1. Prepare to control the relay at Access Level 2.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type **2AC <Enter>**.

d. Type the correct password to go to Access Level 2.

You will see the Access Level 2 =>> prompt.

Step 2. Type **SET G NFREQ <Enter>** (this sets the nominal system frequency using the **NFREQ** setting, which has options of 50 Hz and 60 Hz).

The relay responds with a terminal screen display similar to that shown in *Figure 3.17*.

```
=>>SET G NFREQ <Enter>
Global

General Global Settings

Nominal System Frequency (50,60 Hz)              NFREQ   := 60     ? <Enter>
System Phase Rotation (ABC,ACB)                  PHROT   := ABC    ? <Enter>
Date Format (MDY,YMD,DMY)                        DATE_F  := MDY    ? YMD <Enter>
Fault Condition Equation (SELogic Equation)
FAULT := 51S1 OR 51S2 OR 50P1
?  END <Enter>
.
.
.

Save settings (Y,N)  ? Y <Enter>
Saving Settings, Please Wait..........
Settings Saved
=>>
```

Figure 3.17 Example Global Settings

Step 3. Accept the default settings.

a. For a 60 Hz system, press **<Enter>** to accept the NFREQ existing value of 60 (Hz).

The relay presents the next setting, which is the PHROT (phase rotation) setting.

b. Type **<Enter>** to accept the ABC phase rotation default.

Step 4. Set the date format:

The relay can report dates in three formats: MDY, YMD, and DMY (where M = month, D = date, and Y = year).

a. For this procedure, type **YMD <Enter>**.

At each setting in turn, the relay presents the settings prompt, name, present value, and action prompt.

Note that SELOGIC control equation settings, such as FAULT in *Figure 3.17*, can appear on multiple lines.

b. If you make a mistake or want to go backward through the settings, type the ^ character (on most computer keyboards, this is a shifted numeral 6) and **<Enter>**.

Refer to *Table 3.5* for this and other navigational aids.

Step 5. End the settings session.

a. Type **END <Enter>** at the `FAULT` action prompt.

(The Fault SELOGIC control equation remains unchanged.)

The relay next scrolls a readback of all the Global settings, eventually displaying the following prompt:

`Save settings (Y,N) ?`

(In *Figure 3.17*, a vertical ellipsis represents the relay information during readback.)

b. Examine the settings readback to verify your new settings.

c. Answer **Y <Enter>** to save your new settings.

The TERSE Option

You can avoid viewing the entire class settings summary the relay displays when you type **END <Enter>** midway through a settings class or instance.

On slow data speed links, waiting for the complete settings readback can clog your automation control system or take too much of your time for a few settings changes. Eliminate the settings readback by appending **TERSE** to the **SET** command.

Text-Edit Mode Line Editing

Some relay settings present multiple input lines to your terminal; you use basic line text editing commands to construct the setting. For display, the relay references each line of the setting by line number, not by the setting name. See *Making Text-Edit Mode Settings Changes on page 3.23* for an example of a text-edit mode setting.

While in the text-edit mode, you see a prompt consisting of the line number and the present setting for that line. You can keep the setting, enter a new setting, or delete the setting. *Table 3.6* lists the commands for text-edit mode.

Table 3.6 Actions at Text-Edit Mode Prompts

Action	Relay Response
<Enter>	Accept the setting and move to the next line; if at the last line or at a blank line, exit settings.
>*n* <Enter>	Move to line *n*. If this is beyond the end of the list, move to a blank line following the last line.
^ <Enter>	Move to the previous line; if at the first line, stay at the present line.
< <Enter>	Move to the first line.
> <Enter>	Move to a blank line following the last line.
LIST <Enter>	List all settings and return to the present action prompt.
DELETE [*n*] <Enter>	Delete the present line and subsequent lines for a total of *n* lines; *n* = 1 if not provided. Lines after deletion shift upward by the number of lines deleted.
INSERT <Enter>	Insert a blank line at the present location; the present line and subsequent lines shift downward.
END <Enter>	Go to the end of the present settings session. Prepare to exit settings via the `Save settings (Y,N) ?` prompt.
<Ctrl+X>	Abort editing session without saving changes.

NOTE: To begin an entry with one of these keywords, especially in notes settings, put the string in quotes: e.g., "END OF REPORT".

Use commas to separate the items in a text-edit mode setting when you are entering multiple items per line. After you enter each line, the relay checks the validity of the setting. If the entered setting is invalid, the relay responds with an error message and prompts you again for the setting.

Making Text-Edit Mode Settings Changes

The procedure in the following steps familiarizes you with basic text-edit mode line editing.

Example 3.1 Text-Edit Mode Line Editing

Set Display Point 1 through Display Point 3 to show the status of Circuit Breaker 1, Circuit Breaker 2, and the operational state (on or off) of the transformer cooling fans near the circuit breaker bay where you have installed the relay. See *Display Points on page 4.10* for information on programming display points.

For this example, use inputs IN101, IN102, and IN105. You can use other inputs for your particular application.

This procedure assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.11*) to change the default access level passwords.

Step 1. Prepare to control the relay at Access Level 2.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type **2AC <Enter>**.

d. Type the Access Level 2 password and press **<Enter>**.

You will see the Access Level 2 =>> prompt.

Step 2. Access the display point settings.

a. Type **SET F <Enter>** to modify the front-panel settings.

b. Advance through the front-panel settings (repeatedly type **>** and then **<Enter>**) until you reach the **Display Points** category.

Figure 3.18 shows a representative terminal screen. The relay displays the first line that you can edit. For the case of display points, the line number is the display point number.

Step 3. At the Line 1 settings `?` prompt, type the following to create Display Point 1:

IN101,CB1,CLOSED,OPEN <Enter>

The relay verifies that this is a valid entry, then responds with the next line prompt `2:` followed by the settings `?` prompt (see *Figure 3.18*).

Step 4. At the Line 2 settings `?` prompt, type the following to create Display Point 2:

IN102,CB2,CLOSED,OPEN <Enter>

The relay verifies that this is a valid entry, then responds with the next line prompt `3:` followed by the settings `?` prompt (see *Figure 3.18*).

Step 5. At the `Display Points` prompt, use the text-edit mode line editing commands to list the active display points. Type the following:

LIST <Enter>

After showing the active display points, the relay returns to Line 3 followed by the settings `?` prompt.

NOTE: Use quotation marks when entering alias strings that contain spaces or punctuation marks, as shown in the IN105 sample, Step 6.

Step 6. Type the following to create Display Point 3:

IN105,“5 MVA XFMR Fans”,ON,OFF <Enter>

The relay verifies that this is a valid entry, then responds with the next line prompt `4:` followed by the settings `?` prompt (see *Figure 3.18*).

Example 3.1 Text-Edit Mode Line Editing (Continued)

Step 7. Type **END <Enter>** to end the editing session.

The relay scrolls a readback of all the front-panel settings, eventually displaying the `Save settings (Y,N) ?` prompt. (A vertical ellipsis in *Figure 3.18* represents the readback.)

At the end of the readback information, just before the `Save settings (Y,N) ?` prompt, you can verify the new display point information.

Step 8. Answer **Y <Enter>** to save the new settings.

```
Display Points
(Boolean) : RWB Name, “Label”, “Set String”, “Clear String”, “Text Size”
(Analog) : Analog Quantity Name, “User Text and Formatting”, “Text Size”

1:
? IN101,CB1,CLOSED,OPEN <Enter>
2:
? IN102,CB2,CLOSED,OPEN <Enter>
3:
? LIST <Enter>
1: IN101,"CB1","CLOSED","OPEN",S
2: IN102,"CB2","CLOSED","OPEN",S

3:
? IN105,“5 MVA XFMR Fans”,ON,OFF <Enter>
4:
? END <Enter>
              .
              .
              .

Display Points
(Boolean) : RWB Name, “Label”, “Set String”, “Clear String”, “Text Size”
(Analog) : Analog Quantity Name, “User Text and Formatting”, “Text Size”
1: IN101,"CB1","CLOSED","OPEN",S
2: IN102,"CB2","CLOSED","OPEN",S
3: IN105,"5 MVA XFMR Fans","ON","OFF",S
              .
              .
              .

Save settings (Y,N)  ? Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
=>>
```

Figure 3.18 Using Text-Edit Mode Line Editing to Set Display Points

This procedure proposes connecting the transformer bank fan sensor to relay input IN105. In the **SET G** (GLOBAL) command, verify that the debounce time settings IN105PU and IN105DO are correct for your fan-running sensor. To access separate input parameters, you must first enable independent control input settings with setting EICIS. To change the input conditioning, enter the following settings:

EICIS := **Y** Enable Independent Control Input Settings (Y, N)

IN105PU := **0.3750** Pickup Delay for Contact Input IN105 (0.0000–5 cyc)

IN105DO := **0.3750** Dropout Delay for Contact Input IN105 (0.0000–5 cyc)

Use the appropriate interface hardware to connect the fan-running sensor to IN105. Choose any relay input that conforms to your requirements.

Example 3.2 Leaving a Note in the Relay

For this example, assume you are testing a line, but you will be away for a few days. You want to leave your colleague, Marius, a note telling him where you left the drawings and settings. Use the Notes function in the relay to leave the note, as shown in *Figure 3.19*. All relevant procedures in this section assume that you have successfully established communication with the relay. In addition, you must be familiar with relay access levels and passwords to change the default access level passwords. Furthermore, *Step 1* applies to all relevant tests, and is not repeated for each test.

Step 1. Prepare to control the relay at Access Level 2.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type **2AC <Enter>**.

d. Type the correct password to go to Access Level 2.

You will see the Access Level 2 =>> prompt.

Step 2. Access the Notes settings.

a. Type **SET N <Enter>** to access the Notes settings.

b. At the Line 1 settings `?` prompt, type the Line 1 text shown in *Figure 3.19* (as many as 70 characters without wrap), and press **<Enter>**.

The relay verifies that this is a valid entry, then responds with the next line prompt `2:` followed by the settings `?` prompt.

Step 3. At the Line 2 settings `?` prompt, type the Line 2 text shown in *Figure 3.19*.

Because there are more than 70 characters, the relay rejects the entry.

Re-enter the text, but keep the number of characters at 70 or fewer.

Step 4. After the last entry, type **END <Enter>**.

This tells the relay that you have completed the setting change.

Step 5. Type **Y <Enter>** at the prompt `Save settings (Y,N)` to save the settings.

```
=>>SET N <Enter>
Notes
1:
? Marius, this is the relay for CARR substation <Enter>
2:
? The Sacramento line drawings and setting sheets are in the top drawer in the sub\
station. <Enter>
Note cannot exceed 70 chars

2:
? The Sacramento line drawings and settings are in the <Enter>
3:
? top drawer in the substation. <Enter>
4:
? END <Enter>
Notes
1: Marius, this is the relay for CARR substation
2: The Sacramento line drawings and settings are in the
3: top drawer in the substation.

Save settings (Y,N) ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
```

Figure 3.19 Leave a Note in the Relay

To read the note, type **SHO N <Enter>**, as shown in *Figure 3.20*.

```
=>>SHO N <Enter>
Notes
1: Marius, this is the relay for CARR substation
2: Capacitor Bank 1 drawings and settings are in the
3: top drawer in the substation.
=>>
```

Figure 3.20 Read a Note in the Relay

Example 3.3 Deleting a Display Point

This example shows you how to delete a previously used display point. In the **SET F** command, at the Display Points and Aliases prompt, use the text-edit mode line editing commands to set and delete the display points. This procedure shows two previously programmed display points that indicate on the front-panel LCD the status of Circuit Breaker 1 and Circuit Breaker 2. Relay control inputs IN101 and IN102 are the Relay Word bits for the Circuit Breaker 1 and Circuit Breaker 2 display points, respectively (see *Making Text-Edit Mode Settings Changes on page 3.23*). You can use other inputs for your particular application.

The procedure in the following steps assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.11*).

Step 1. Prepare to control the relay at Access Level 2.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type **2AC <Enter>**.

d. Type the correct password to go to Access Level 2.

You will see the Access Level 2 =>> prompt.

Example 3.3 Deleting a Display Point (Continued)

Step 2. Access the `Display Points and Aliases` prompt.

a. Enter the **SET F** command.

b. Advance through the front-panel settings (repeatedly type **>** and then **<Enter>**) until you reach the `Display Points and Aliases` category.

Figure 3.21 shows a representative terminal screen. The relay displays the first line that you can edit. For display points, the line number is the display point number.

```
Display Points
(Boolean) : RWB Name, "Label", "Set String", "Clear String", "Text Size"
(Analog) : Analog Quantity Name, "User Text and Formatting", "Text Size"
1: IN101,"CB1","CLOSED","OPEN",S
?  LIST <Enter>
1: IN101,"CB1","CLOSED","OPEN",S
2: IN102,"CB2","CLOSED","OPEN",S
3: IN105,"5 MVA XFMR Fans","ON","OFF",S

1: IN101,"CB1","CLOSED","OPEN",S
?  <Enter>
2: IN102,"CB2","CLOSED","OPEN",S
?  DELETE <Enter>
2: IN105,"5 MVA XFMR Fans","ON","OFF",S
?  LIST <Enter>

1: IN101,"CB1","CLOSED","OPEN",S
2: IN105,"5 MVA XFMR Fans","ON","OFF",S
2: IN105,"5 MVA XFMR Fans","ON","OFF",S
?  END <Enter>
              .
              .
              .

Display Points
(Boolean) : RWB Name, "Label", "Set String", "Clear String", "Text Size"
(Analog) : Analog Quantity Name, "User Text and Formatting", "Text Size"
1: IN101,"CB1","CLOSED","OPEN",S
2: IN105,"5 MVA XFMR Fans","ON","OFF",S
              .
              .
              .

Save settings (Y,N)  ? Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
=>>
```

Figure 3.21 Using Text-Edit Mode Line Editing to Delete a Display Point

Step 3. List the present display points.

a. Type **LIST <Enter>** at the Display Points `?` prompt.

b. After showing the active display points, the relay returns to Line 1 followed by the settings `?` prompt.

Step 4. Type **<Enter>** once to proceed to the Line 2 present value and settings `?` prompt.

Step 5. Type **DELETE <Enter>** to delete Display Point 2.

Step 6. Type **LIST <Enter>** to examine the remaining display points.

Former Display Point 2 is eliminated, and Display Point 3 moves up to Position 2.

The relay returns to Line 2 followed by the settings `?` prompt.

Example 3.3 Deleting a Display Point (Continued)

Step 7. Type **END <Enter>** to end the settings process.

The relay next scrolls a readback of all the Front-Panel settings, eventually displaying the `Save settings (Y,N) ?` prompt. (In *Figure 3.21*, a vertical ellipsis represents this scrolling readback.)

At the end of the readback information, just before the `Save settings (Y,N) ?` prompt, you can verify the new display point information.

Step 8. Answer **Y <Enter>** to save your new settings.

Settings in SEL Grid Configurator

See *Getting Started on page 2.6* for steps on creating and deploying settings within SEL Grid Configurator.

Settings in QuickSet

See *Section 2: PC Software* for steps on creating and deploying settings within QuickSet.

Settings From the Front Panel

You can use the relay front panel to enter some of the relay settings. The relay presents the settings in order from class to instance (if applicable) to category to the particular setting, in a manner similar to setting the relay using a terminal.

Use the LCD and the adjacent navigation pushbuttons to enter each character of the setting in sequence. This can be a laborious process for some settings (e.g., long SELOGIC control equations). However, if you need to make a quick correction or have no faster means to make settings, settings functions are available at the front panel. For more information on making settings changes from the front panel, see *Set/Show on page 4.26*.

Entering DATE and TIME From the Front Panel

The purpose of the procedure in the following steps is to familiarize you with entering data from the relay front panel.

Step 1. Prepare to use the front panel by applying power to the relay.

Note that the relay front-panel display shows a sequence of LCD screens called the `ROTATING DISPLAY`. (If you do not operate the front panel for a certain period, the relay will enter front-panel time-out mode and you will see the sequential screens of the `ROTATING DISPLAY`.)

Step 2. Press the **ENT** pushbutton to display the `MAIN MENU` of *Figure 3.22*.

Step 3. View the settings screens.

a. Press the **Up Arrow** and **Down Arrow** navigation pushbuttons to highlight the SET/SHOW action item (see *Figure 3.22*).

b. Press the **ENT** pushbutton.

You will see the SET/SHOW submenu (the second screen in *Figure 3.22*).

Step 4. View the date/time screen.

a. Press the **Up Arrow** and **Down Arrow** navigation pushbuttons to highlight the DATE/TIME action item (*Figure 3.22*, second screen).

b. Press the **ENT** pushbutton.

The relay next displays the DATE/TIME submenu (the third screen of *Figure 3.22*).

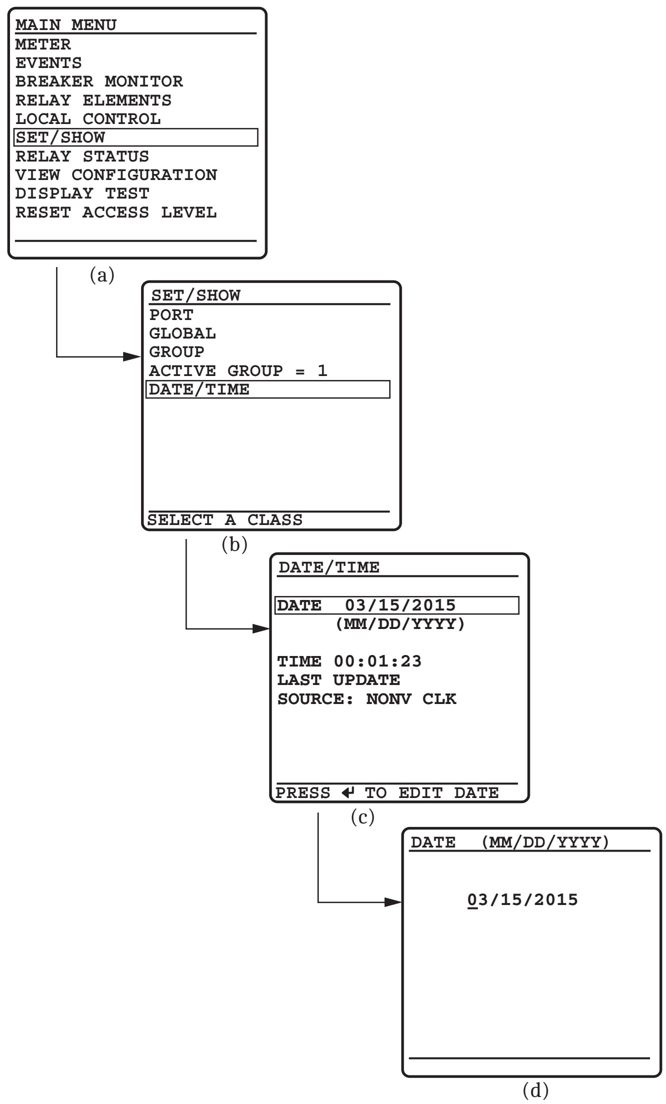


Figure 3.22 DATE and TIME Settings From Front-Panel LCD

Step 5. Set the date.

a. Press the **ENT** pushbutton.

The relay shows the last screen of *Figure 3.22*, the DATE edit screen.

b. Use the **Up Arrow** and **Down Arrow** navigation pushbuttons to increase and decrease the date position numbers.

Step to the next or previous position by using the **Left Arrow** and **Right Arrow** pushbuttons.

c. When finished adjusting the new date, press **ENT**.

The relay returns the display to the `DATE/TIME` submenu. Note that the relay reports the `TIME SOURCE` as `FP DATE` (front-panel date).

Step 6. Press **ESC** repeatedly to normalize the front-panel display.

Changing a Relay Setting From the Front Panel

The purpose of the procedure in the following steps is to provide additional practice at entering relay settings from the front panel. In this example, you change the `PORT F` front-panel communications port settings.

Step 1. View the `MAIN MENU`.

a. If you have been using the front panel (as in the previous example), press the **ESC** key repeatedly until you see the `MAIN MENU`.

b. If the relay is displaying the `ROTATING DISPLAY`, press the **ENT** pushbutton to display the `MAIN MENU`.

Figure 3.23(a) shows the `MAIN MENU` at the beginning of the front-panel settings process.

Step 2. View the settings screens.

a. Press the **Up Arrow** and **Down Arrow** navigation pushbuttons to highlight the `SET/SHOW` action item, as shown in *Figure 3.23(a)*.

b. Press the **ENT** pushbutton. You will see the `SET/SHOW` submenu screen, as shown in *Figure 3.23(b)*.

Step 3. Select `PORT F`.

a. Highlight `PORT` and press the **ENT** pushbutton.

The relay displays the `PORT` instances screen, as shown in *Figure 3.23(c)*.

b. Choose the port you want to configure by using the **Up Arrow** and **Down Arrow** navigation pushbuttons to move the screen arrow.

For this example, select `PORT F` and press **ENT**.

Step 4. View the **Communications Settings** category screen.

a. The relay displays the `Port F` category screen, as shown in *Figure 3.23(d)*. Use the **Up Arrow** and **Down Arrow** navigation pushbuttons to select the settings category.

b. For this example, highlight **Communications Settings** and press **ENT**.

The relay displays the `Communications Settings` screen, as shown in *Figure 3.23(e)*.

Step 5. Change settings.

a. Highlight the SPEED setting.

b. Press **ENT**.

(The relay possibly requires a password here; see *Passwords on page 3.11* and *Section 4: Front-Panel Operations*.)

The LCD displays the SPEED selection submenu that has all the possible choices for serial data speeds.

The highlighted selection in *Figure 3.23(f)* indicates the default setting of 9600 (bps).

c. Use the **Up Arrow** and **Down Arrow** navigation pushbuttons to select a different speed.

d. Once you have selected a data speed, press the **ENT** pushbutton.

NOTE: Once you have changed communications parameters, you must change the corresponding parameters in your terminal emulation program to communicate with the relay via a communications port.

Step 6. End the settings session.

a. The relay returns to the previous category settings list screen. Press **ESC** to return to the categories screen where you see the Save Settings item at the bottom of the screen.

b. Use the **Up Arrow** and **Down Arrow** pushbuttons to highlight Save Settings and press **ENT**.

c. Highlight YES, and then press **ENT**.

The relay validates the setting and returns to the PORT screen, as shown in *Figure 3.23(c)*.

Step 7. Press **ESC** repeatedly to return to the MAIN MENU.

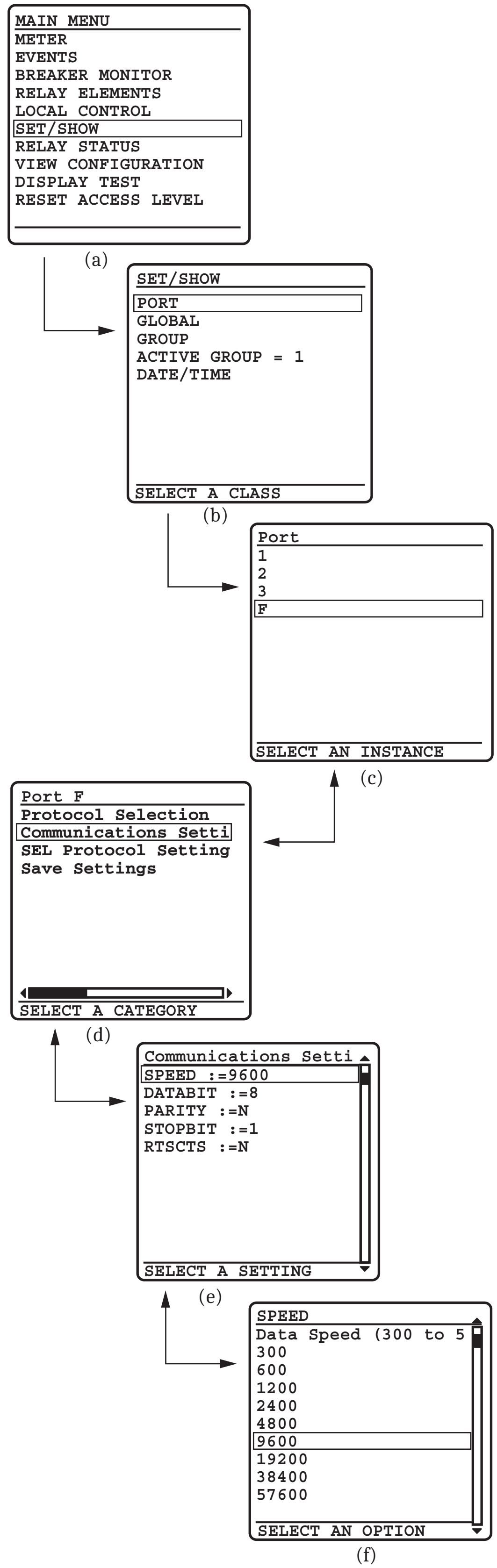


Figure 3.23 SET/SHOW Menus

Examining Metering Quantities

The SEL-400 series relays feature high-accuracy power system metering. You can view fundamental and rms quantities by using a communications terminal, QuickSet, or the front panel. For more information on relay metering, see *Section 7: Metering, Monitoring, and Reporting* in the product-specific instruction manual.

View Metering by Using the Terminal

The procedure in the following steps shows how to use a terminal or terminal emulation computer program to view power system metering. In this example, you connect specific voltages and currents for a 5 A, 60 Hz relay. Scale these quantities appropriately for your particular relay.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.11* to change the default access level passwords). *Step 1* through *Step 7* are necessary if you have not yet configured the relay and want to test metering by using a test source. If the relay is already connected to the system, you may jump to *Step 8* to view the system metering information.

Step 1. Prepare to control the relay at Access Level 2.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type **2AC <Enter>**.

d. Type the correct password to go to Access Level 2.

You will see the Access Level 2 =>> prompt.

Step 2. Set the relay to a nominal operation mode.

a. Use a terminal to perform the initial Global settings relay setup in *Making Settings Changes in Initial Global Settings on page 3.21*.

b. Set the relay for 60 Hz operation, ABC phase rotation.

Step 3. Some SEL-400 series relays support voltage and current source selection. In these relays, configure the source selection appropriate for metering testing. The following shows how to do this in an SEL-451 (see *Figure 3.24*). Use the terminal to set Global setting ESS := 1.

a. Type **SET G ESS TERSE <Enter>**.

b. Type **1 <Enter>**.

c. Type **END <Enter>** to finish this settings session.

d. Answer **Y <Enter>** to the save settings prompt.

```
=>>SET G ESS TERSE <Enter>
Global

Current and Voltage Source Selection

Current and Voltage Source Selection (Y,N,1,2,3,4)      ESS   := N    ? 1 <Enter>
Line Current Source (IW,COMB)                           LINEI := IW   ? END <Enter>


Save settings (Y,N) ? Y <Enter>
Saving Settings, Please Wait..........
Settings Saved
=>>
```

Figure 3.24 Setting ESS in the Terminal

Step 4. Set CT and PT ratios. The specific CT and PT configuration settings depends on the relay. The following shows a typical set of configuration choices. Use the terminal to set Group 1 setting CTRW := 200 (the CT W-input ratio), and PTRY := 2000.0 (the PT Y-input ratio).

a. Type **SET CTRW TERSE <Enter>**.

b. If the CTRW setting is not 200, type **200 <Enter>**.

c. Proceed as shown in *Figure 3.25* to PTRY and change PTRY to 2000.0, if needed.

d. Type **END <Enter>** to finish this settings session.

e. Answer **Y <Enter>** to the save settings prompt.

```
=>>SET CTRW TERSE <Enter>
Group 1

Line Configuration

Current Transformer Ratio - Input W (1-50000)       CTRW   := 120    ?200 <Enter>
Current Transformer Ratio - Input X (1-50000)       CTRX   := 120    ? <Enter>
Potential Transformer Ratio - Input Y (1.0-10000)   PTRY   := 180.0  ?2000.0 <Enter>
PT Nominal Voltage (L-L) - Input Y (60-300 V,sec)   VNOMY  := 115    ?END <Enter>


Save settings (Y,N) ? Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 3.25 Setting CTRW and PTRY in the Terminal

Step 5. Turn the relay off.

Step 6. Connect analog inputs. The specific connections depend on the relay. The following illustrates a typical set of voltage and current connections.

a. If three voltage sources and three current sources are available, connect the sources to the relay as shown in *Figure 3.26*.

If three voltage sources and two current sources are available, use the connection diagram of *Figure 3.27*.

b. Apply 67 V per phase (line-to-neutral) in ABC phase rotation.

c. Apply 2.0 A per phase, in phase with the applied phase voltages.

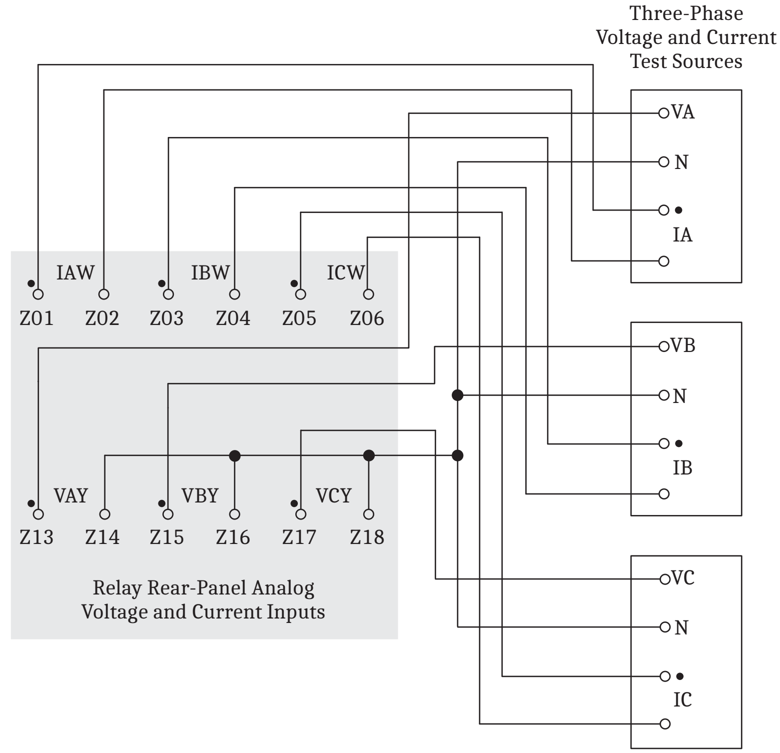


Figure 3.26 Test Connections Using Three Voltage Sources/Three Current Sources

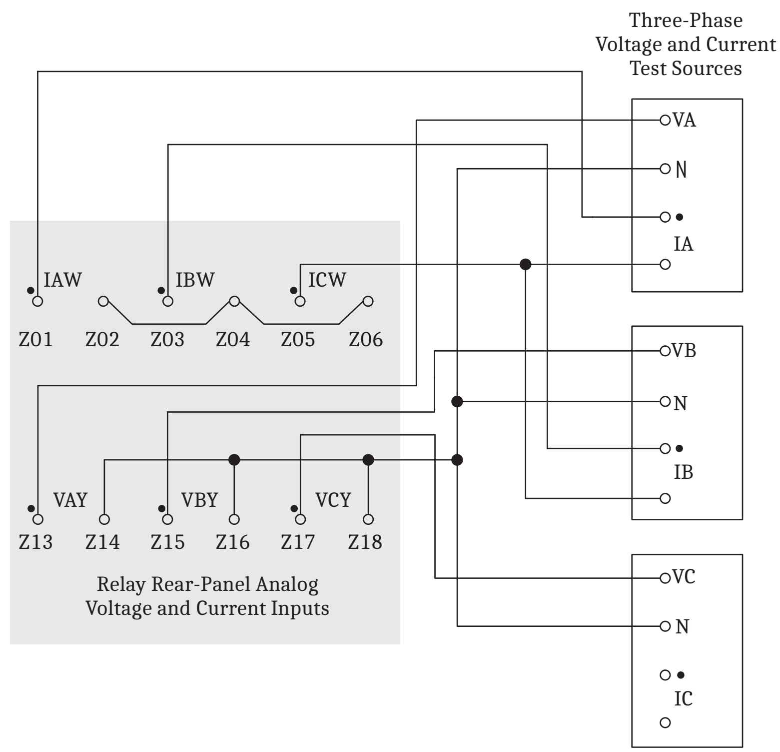


Figure 3.27 Test Connections Using Two Current Sources for Three-Phase Faults and METER Test

Step 7. Turn the relay on.

Step 8. View metering.

a. Type **ACC <Enter>** to log in to the relay at Access Level 1.

b. Type the password and press **<Enter>**.

c. Type **MET <Enter>**.

The relay displays the fundamental frequency (50 Hz or 60 Hz) metering information in a manner similar to that shown in *Figure 3.28*.

```
=>>MET <Enter>

Relay 1                                    Date: 03/17/2023  Time: 01:35:05.221
Station A                                  Serial Number: 1230769999

                     Phase Currents
                IA        IB        IC
I MAG (A)       398.882   399.041   398.784
I ANG (DEG)      -1.18   -120.97    119.21

                     Phase Voltages               Phase-Phase Voltages
                VA        VB        VC          VAB       VBC       VCA
V MAG (kV)      133.994   133.986   133.953     231.903   231.815   232.450
V ANG (DEG)      -0.17   -120.02    120.18       29.91    -89.92    150.01

                   Sequence Currents (A)         Sequence Voltages (kV)
                 I1        3I2       3I0        V1        3V2       3V0
MAG             398.901     2.159     2.588    133.977     0.692     0.713
ANG (DEG)        -0.98    -62.68   -115.80       0.00    -53.25   -120.79

                     A           B           C            3P
P (MW)           53.44       53.46       53.41        160.31
Q (MVAR)          0.95        0.89        0.91          2.75
S (MVA)          53.45       53.47       53.42        160.33
POWER FACTOR      1.00        1.00        1.00          1.00
                   LAG         LAG         LAG           LAG

FREQ (Hz)       60.00       VDC1(V)   125.00   VDC2(V)    48.00

=>>
```

Figure 3.28 Terminal Screen MET Metering Quantities

The metering quantities of *View Metering by Using the Terminal on page 3.34* are the fundamental line quantities. Other variants of the **MET** command give different relay metering quantities. See *Section 8: Metering, Monitoring, and Reporting* of the product-specific instruction manual for more information on the specific metering options available in a specific relay.

View Metering by Using QuickSet

Use the procedures in the following steps to examine the relay metering with the QuickSet HMI.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.11* to change the default access level passwords). You should also be familiar with QuickSet (see *Checking Relay Status in QuickSet on page 3.14* and *Section 2: PC Software*).

Step 1. Start QuickSet and establish a connection with the relay. See *Step 1* and *Step 2* of *Checking Relay Status in QuickSet on page 3.14* for details on how to do this.

Step 2. Set the relay to a nominal operation mode, and set it for 60-Hz operation, ABC phase rotation.

Step 3. Set a basic voltage and current configuration.

a. In the QuickSet **Settings** tree view, select the dropdown arrow next to **Global** to expand the **Global** branch (see *Figure 3.29*).

b. Select the **Current and Voltage Source Selection** branch.

You will see the **Current and Voltage Source Selection** dialog box as shown in *Figure 3.29*.

c. Choose **1** from the dropdown list under **ESS Current and Voltage Source Selection**.

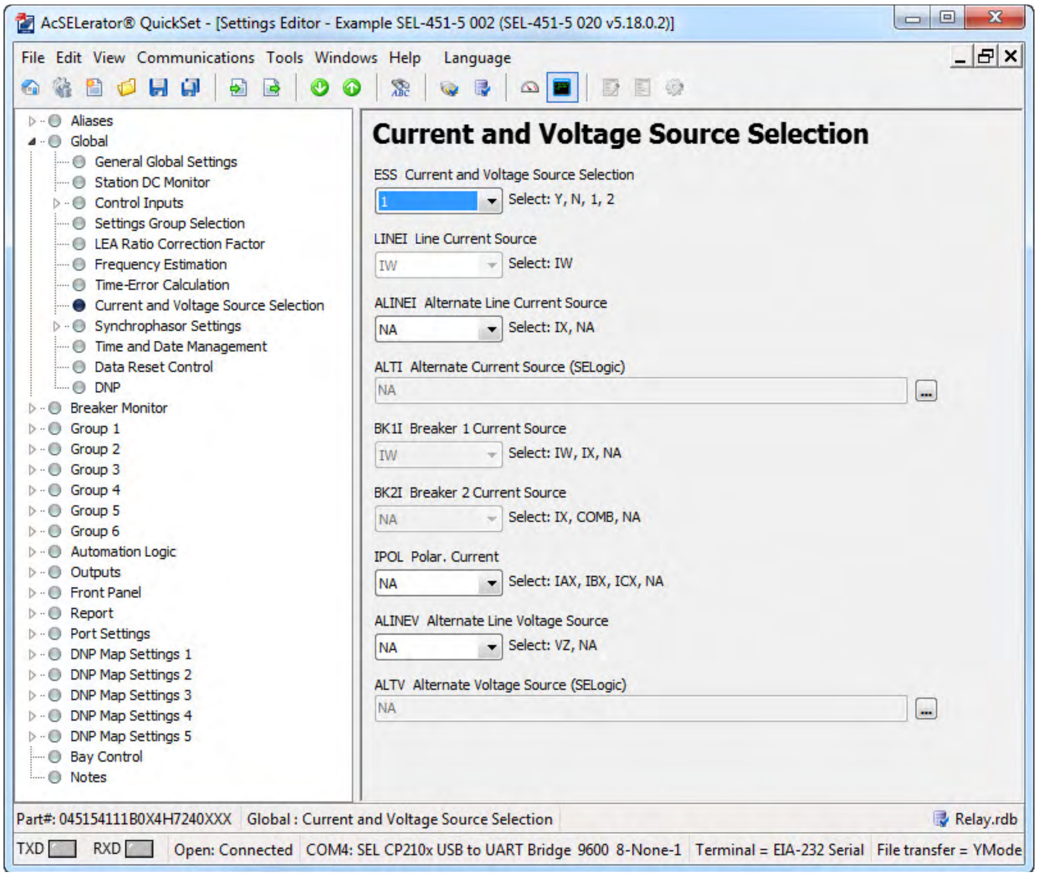


Figure 3.29 Global Alternate Source Selection Settings in QuickSet

Step 4. Set PT and CT ratios.

a. In the QuickSet **Settings** tree view, select the dropdown arrow next to **Group 1** to expand this branch (see *Figure 3.30*).

b. Select the dropdown arrow next to **Set 1**.

c. Select **Line Configuration**.

You will see the **Line Configuration** window similar to *Figure 3.30*.

d. Enter setting **CTRW Current Transformer Ratio - Input W** as **200**, and the **PTRY Potential Transformer Ratio - Input Y** as **2000**.

e. Save the settings and send the **Group 1** settings if you change the settings (see *Step 6* and *Step 7*).

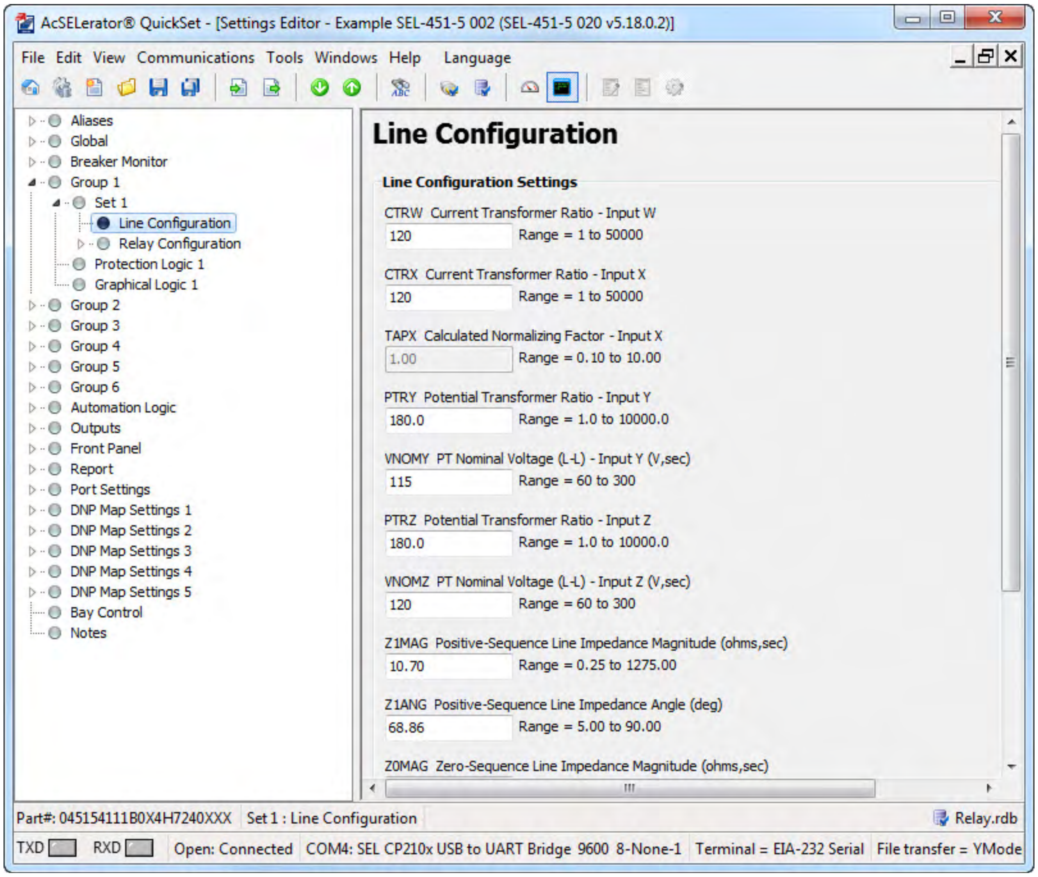


Figure 3.30 Group 1 Terminal Configuration Settings in QuickSet

Step 5. Start the QuickSet operator interface.

Step 6. In the top toolbar select **Tools** > **HMI** > **HMI** to start the GUI.

Step 7. Select the **Phasors** button of the HMI tree view (see *Figure 3.31*) to view phasors.

QuickSet displays fundamental line metering quantities with a display similar to *Figure 3.32*. (The test setup is adjusted for an approximately 30-degree lagging current.)

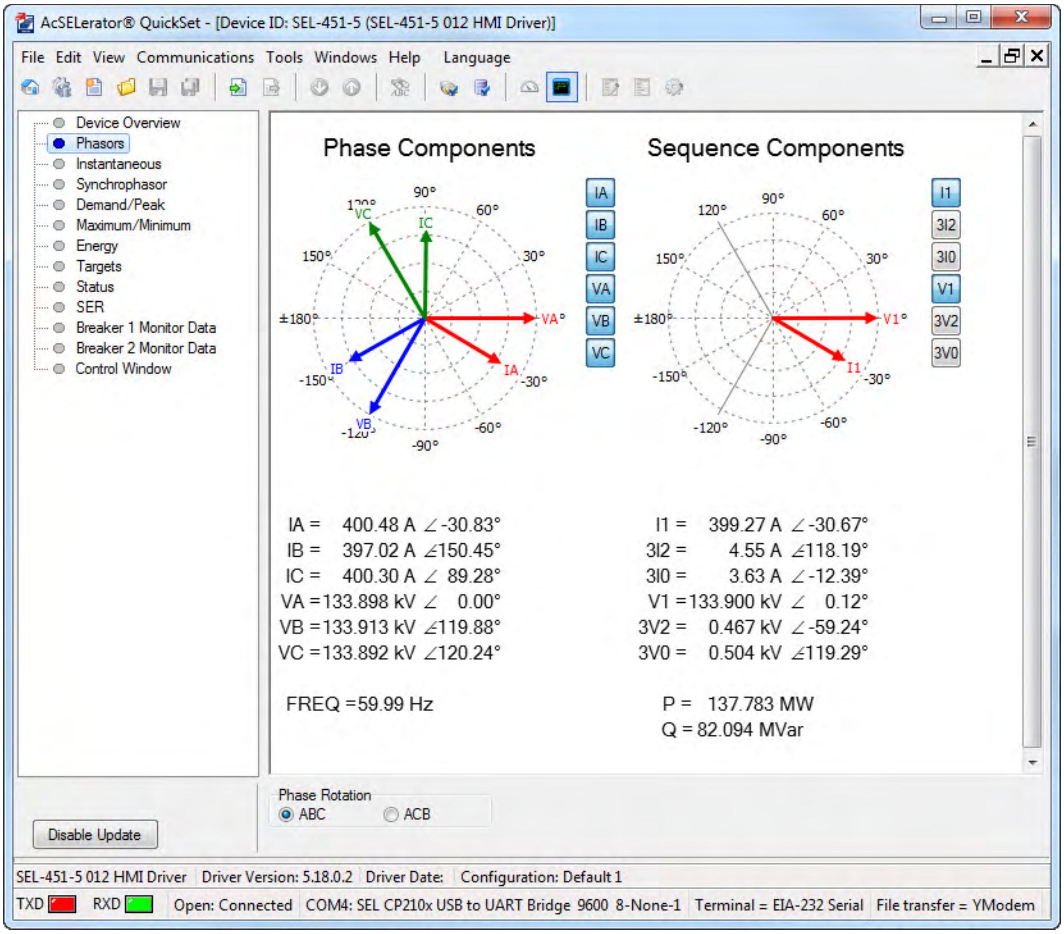


Figure 3.31 HMI Phasors View in QuickSet

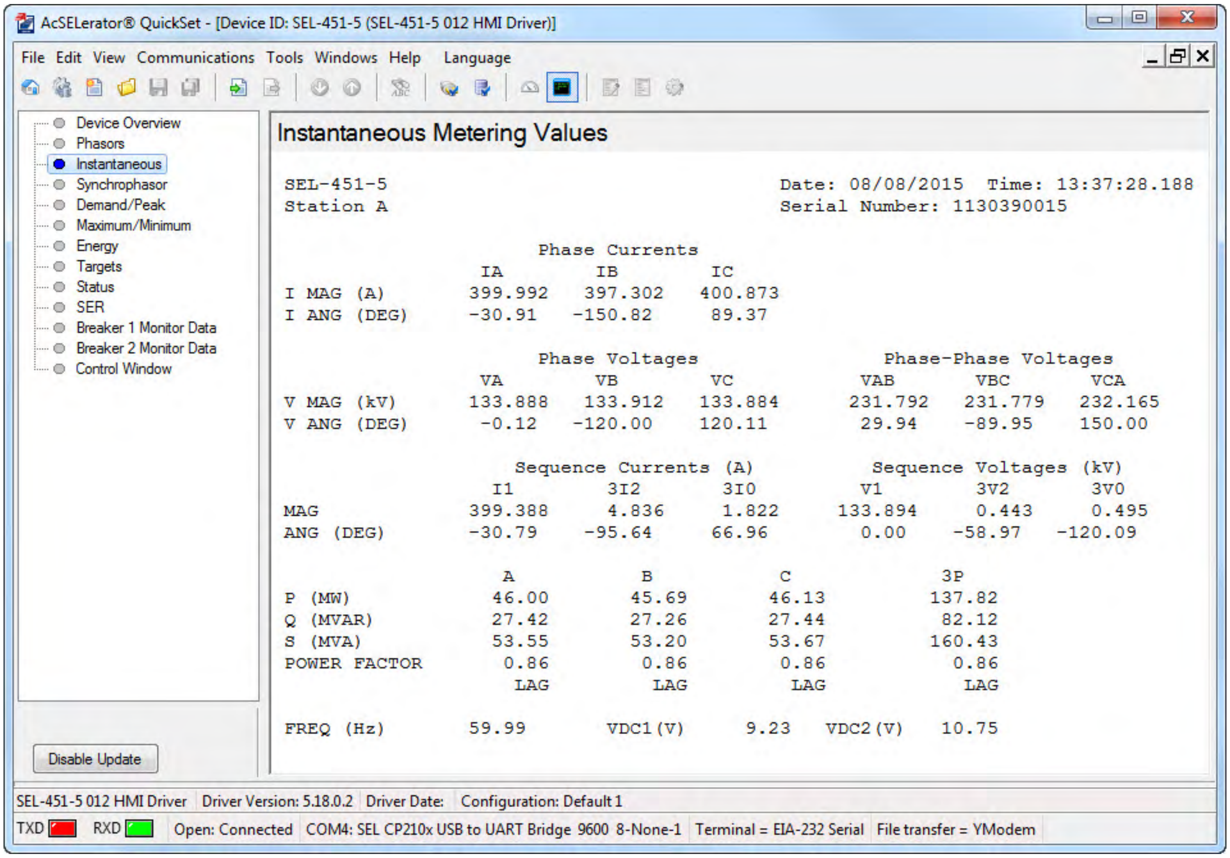


Figure 3.32 Instantaneous Metering Quantities in QuickSet HMI

Step 8. Select the **Instantaneous** button of the HMI tree view to see metering information similar to *Figure 3.32*.

View Metering From the Front Panel

In most SEL-400 series relays, you can use the front-panel display and navigation pushbuttons to view the metering quantities of the relay (see *Meter on page 4.16* for more information on viewing metering on the relay front panel). The screens in this procedure are for an SEL-451 with one circuit breaker, and this example assumes that you have not enabled the demand metering or synchronism-check features.

Step 1. Prepare to use the front panel by applying power to the relay.

Note that the LCD shows a sequence of screens called the ROTATING DISPLAY. (If you do not operate the front panel for a certain period, the relay will enter front-panel time-out mode and you will see the sequential screens of the ROTATING DISPLAY.)

Step 2. Press the **ENT** pushbutton to display the MAIN MENU at the top of *Figure 3.33*.

Step 3. View the metering selection screen.

a. Highlight the METER action item (see the first screen of *Figure 3.33*).

b. Press the **ENT** pushbutton.

The relay displays the METER submenu (the second screen in *Figure 3.33*).

Step 4. View the metering screens.

a. Press the **Up Arrow** and **Down Arrow** navigation pushbuttons to highlight the FUNDAMENTAL METER action item, as shown in *Figure 3.33(b)*.

b. Press the **ENT** pushbutton.

The relay displays the first FUNDAMENTAL METER screen, shown in *Figure 3.33(c)*.

c. Use the **Up Arrow** and **Down Arrow** navigation pushbuttons to move among the fundamental line quantities metering screens.

Step 5. Press the **ESC** pushbutton repeatedly to return to the MAIN MENU.

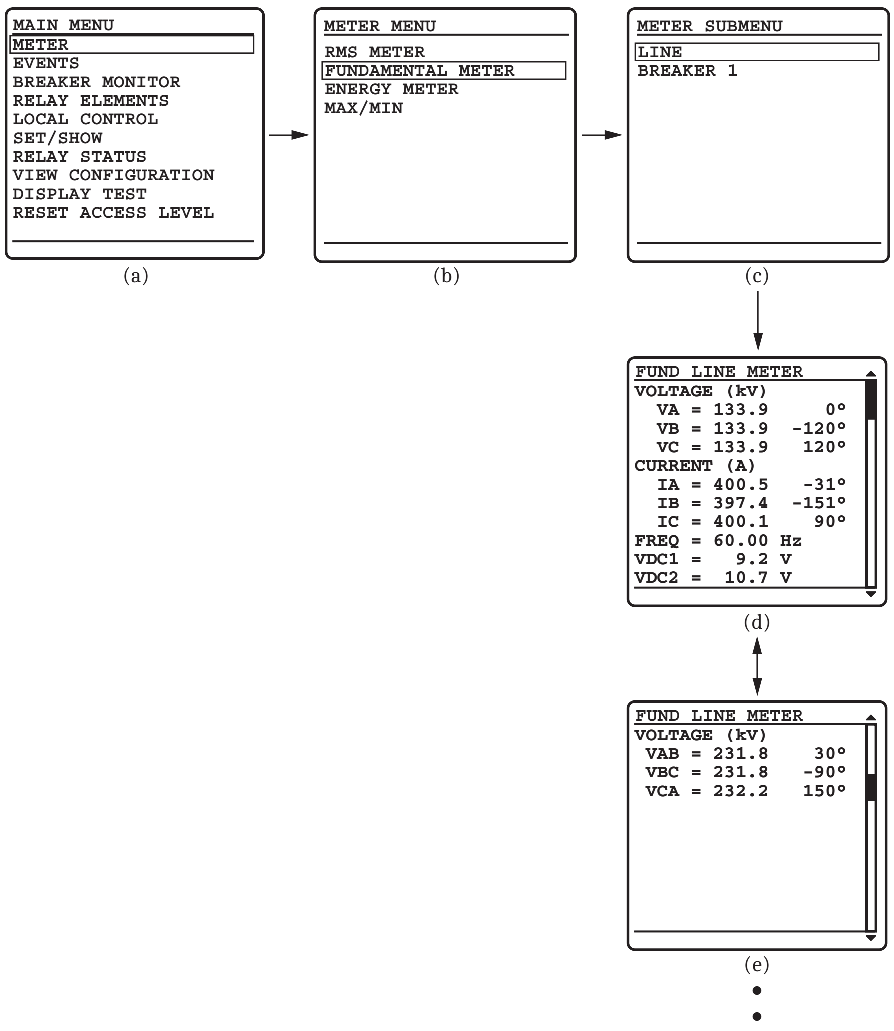


Figure 3.33 Front-Panel Screens for METER

Examining Relay Elements

Use the communications port **TAR** command or the front panel to display the state of relay elements, control inputs, and control outputs. Viewing a change in relay element (Relay Word bit) status is a good way to verify the pickup settings you have entered for protection elements.

View Relay Elements in the Terminal

The procedure in the following steps shows you how to view a change in state for the SEL-451 50P1 Phase-Instantaneous Overcurrent element from a communications port.

Table 3.7 Phase-Instantaneous Overcurrent Pickup

Setting	Description	Default
50P1P	Level 1 Pickup (OFF, 0.25–100 A secondary)	15.00

For this procedure, you must have a serial terminal or computer with terminal emulation software and a variable current source for relay testing.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.11* to change the default access level passwords and enter higher relay access levels).

Step 1. Type **ACC <Enter>** at a communications terminal.

Step 2. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 3. Connect a test source to the relay.

a. Set the current output of a test source to zero output level.

b. Connect a single-phase current output of the test source to the IAW analog input.

Step 4. Type **TAR 50P1 <Enter>** to view the initial element status.

The relay returns a target terminal screen similar to that shown in *Figure 3.34*.

```
=>TAR 50P1 <Enter>
50P1  50P2  50P3  50P4  67P1  67P2  67P3  67P4
0     0     0     0     0     0     0     0
=>
```

Figure 3.34 Sample Targets Display on a Serial Terminal

Step 5. View the element status change.

a. Type **TAR 50P1 1000 <Enter>** (this command causes the relay to repeat the **TAR 50P1** command 1000 times). For more information on the **TAR** command see *Section 14: ASCII Command Reference*.

b. Increase the current source to produce a current magnitude greater than 15.00 A secondary in the relay.

You will see the 50P1 element status change to 1 when the input current exceeds the 50P1P setting threshold.

c. Type **<Ctrl+X>** to stop the relay from presenting the target display before completion of the 1000 target repeats.

View Relay Elements From the Front-Panel LCD

You can use the front-panel display and navigation pushbuttons to check Relay Word bit elements. See *Section 4: Front-Panel Operations* for more information on using the relay front panel.

This procedure uses the SEL-451 50P1 Phase-Instantaneous Overcurrent element.

Step 1. Display the MAIN MENU.

Step 2. If the relay LCD is in the ROTATING DISPLAY, press the **ENT** pushbutton to display the MAIN MENU similar to that in *Figure 3.35*.

Step 3. Press the **Down Arrow** navigation pushbutton to highlight the RELAY ELEMENTS action item, as shown in *Figure 3.35(a)*.

Step 4. Press the **ENT** pushbutton.

You will see a RELAY ELEMENTS screen, as shown in *Figure 3.35(b)*.

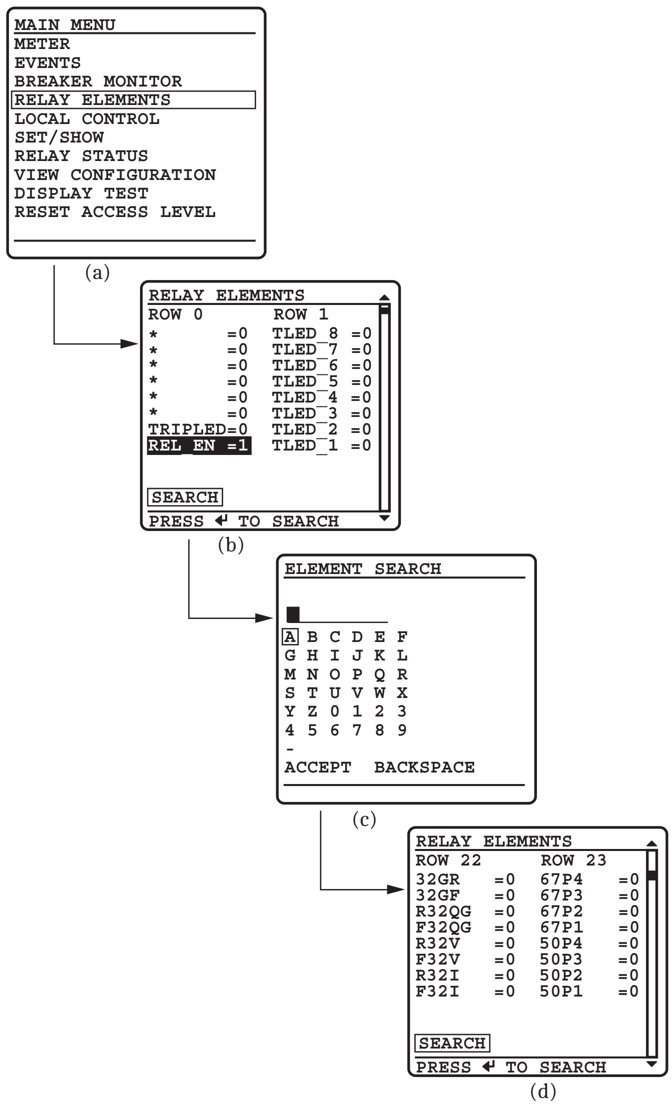


Figure 3.35 Viewing Relay Word Bits From the Front-Panel LCD

Step 5. Display the 50P1 Relay Word bit on the front-panel LCD screen.

a. Press **ENT** to go to the ELEMENT SEARCH submenu of *Figure 3.35(c)*.

b. Use the navigation keys to highlight 5 and then press **ENT** to enter the character 5 in the text input field.

c. Enter the 0, P, and 1 characters in the same manner.

d. Highlight ACCEPT and press **ENT**.

The relay displays the LCD screen containing the 50P1 element, as shown *Figure 3.35(d)*.

Step 6. Connect a test source to the relay.

a. Set the current output of a test source to zero output level.

b. Connect a single-phase current output of the test source to the IAW analog input.

Step 7. View the target status change.

a. Increase the current source to produce a current magnitude greater than 15.00 A secondary in the relay.

b. Observe the 50P1 target on the front-panel display.

You will see the 50P1 element status change to 1 when the input current exceeds the 50P1P setting threshold.

Step 8. Press **ESC** to return to the MAIN MENU.

View Relay Elements by Using the Front-Panel LED

The procedure in the following steps shows you how to use a front-panel LED to view a change in state for the SEL-451 50P1 Phase-Instantaneous Overcurrent element.

In this example, use SEL Grid Configurator or QuickSet to configure the relay. See *Section 2: PC Software* for information on creating and deploying settings. In addition, you need a variable current source suitable for relay testing.

Step 1. Read the relay settings.

Step 2. Set a pushbutton LED SELOGIC control equation.

a. Expand the **Front Panel** branch of the **Settings** tree view and select **Pushbuttons**.

b. Select in the **PB6_LED** text box and type **50P1**.

c. Tab or select to any other text box.

The software checks the validity of the setting.

Step 3. Send the new settings to the SEL-451.

Step 4. Connect a test source to the relay.

a. Set the current output of a test source to zero output level.

b. Connect a single-phase current output of the test source to the IAW analog input.

Step 5. View the target status change.

a. Increase the current source to produce a current magnitude greater than 15.00 A secondary in the relay.

b. Observe the LED next to Pushbutton 6 on the SEL-451 front panel.

You will see the LED illuminate when the input current exceeds the 50P1P setting threshold.

Reading Oscillograms, Event Reports, and SER

SEL-400 series relays have great capabilities for storing and reporting power system events. These include high-resolution oscillography with sampling as high as 8 kHz, event reports that encompass important variables in the power system, and the SER that reports changing power system conditions and relay operating states.

You can view oscillograms taken from high-resolution raw data or from filtered event report data. Each type of presentation gives you a unique view of the power system. High-resolution oscillograms are useful for viewing system transients and dc artifacts outside the relay filter system; event report oscillograms give you a picture of the quantities that the relay used in the protection algorithms.

The examples listed in this section give step-by-step procedures to acquaint you with these features. *Section 9: Reporting* provides a complete discussion of these relay features.

Generating an Event

To view high-resolution raw data oscillograms and event reports, you must generate a relay event. High-resolution oscillography and event reports use the same event triggering methods. The relay uses multiple sources to initiate a data capture, including any of the following: Relay Word bit TRIP asserts, SELOGIC control equation ER (event report trigger), or the **TRI** command. (Factory-default setup does not include the **PUL** command as an event report trigger. You can add the **PUL** command by entering the Relay Word bit TESTPUL in the ER SELOGIC control equation.)

You can use an event trigger to initiate capturing power system data. The procedure in the following steps shows how to use the **TRI** command (see *TRIGGER on page 14.73*), which triggers an event capture. In this example, the relay uses default parameters to record the event. These parameters are at a sampling rate (SRATE) of 2000 samples per second (2 kHz), a pre-trigger or pre-fault recording length (PRE) of 0.1 seconds, and an event report length (LER) of 0.5 seconds. See *Duration of Data Captures and Event Reports on page 9.9* for complete information on changing these default settings to match your application.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.11* to change the default access level passwords).

Step 1. Connect voltage and current sources to the relay secondary voltage and secondary current inputs (use the connections of *View Metering by Using the Terminal on page 3.34* and *Figure 3.26* or *Figure 3.27*).

Step 2. Apply power to the relay, and establish a terminal connection with the relay.

Step 3. Trigger an Event by typing **TRIG <Enter>**.

Reading the Event History

The relay has multiple convenient methods for checking whether you successfully captured power system data. The following describes how to view the event history data through use of the ASCII terminal interface.

Reading the Event History in the Terminal

The procedure in the following steps shows how to use the relay **HIS** command to confirm that you captured power system data with an event trigger. This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.11* to change the default access level passwords).

Step 1. Prepare to monitor the relay at Access Level 1.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 2. Type **HIS <Enter>** to examine the event history

You will see a screen display similar to *Figure 3.36*.

```
=>HIS <Enter>

Relay 1                                   Date: 04/20/2015  Time: 17:27:44.140
Station A                                 Serial Number: 1150019999


#       DATE        TIME     EVENT  LOCAT   CURR GRP TARGETS
10024 03/03/2015 08:33:29.201 TRIP  $$$$.$$     0  1
10023 03/02/2015 15:41:35.777 ER    $$$$.$$     0  1
10022 03/02/2015 15:41:35.227 ER    $$$$.$$     0  1
10021 03/02/2015 15:41:34.577 ER    $$$$.$$     0  1
10020 03/02/2015 15:41:34.152 ER    $$$$.$$     0  1
10019 03/02/2015 15:41:32.702 ER    $$$$.$$     0  1
10018 02/24/2015 15:22:19.496 TRIG  $$$$.$$     1  3

10017 02/24/2015 15:22:17.705 TRIG  $$$$.$$     1  3
10016 02/23/2015 17:42:56.581 TRIG  $$$$.$$     1  3
10015 02/20/2015 19:23:41.369 BCG      0.02  3442  3
10014 02/20/2015 17:14:40.056 CA T     7.28  2449  3  TIME A_FAULT C_FAULT

=>
```

Figure 3.36 Sample HIS Command Output in the Terminal

For more information on the event history, see *Event History on page 9.27*.

Viewing High-Resolution Oscillograms

Once you have successfully generated an event, you can view high-resolution oscillograms and event report oscillograms about this event. When gathered from a field-installed relay, this information helps you assess power system operating conditions. In addition, when you first install the relay, this reporting information helps you confirm that you have connected the relay correctly.

The relay provides high-resolution oscillography data in the binary COMTRADE file format (IEEE/ANSI standard C37.111-1999 and C37.111-2013 formats are supported). File transfer is the only mechanism for retrieving high-resolution COMTRADE data from the relay.

The SEL-5601-2 SYNCHROWAVE Event is a program you can use to view COMTRADE data. Many third-party software suppliers can provide you with programs to display and manipulate COMTRADE files.

Retrieving High-Resolution COMTRADE Data in the Terminal

The relay recorded the event triggered in *Generating an Event on page 3.46*. The procedure in the following steps shows you how to retrieve the high-resolution raw oscillography data for this event.

Perform the steps listed in *Generating an Event on page 3.46* before executing the instructions in this example. For this procedure, you must use a communications terminal emulation computer program capable of file transfers.

If you need help finding a terminal emulation program, contact the SEL factory or your local Technical Service Center.

Step 1. Prepare to monitor the relay at Access Level 1.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 2. Type **FILE DIR EVENTS <Enter>** to view the contents of the events file directory.

The relay lists file names for recently recorded events in a manner similar to that shown in *Figure 3.37*.

The relay shows three high-resolution oscillography files with the file name extensions .HDR, .CFG, and .DAT for each event.

This example uses the IEEE C37.111-1999 COMTRADE file HR_10000 as the number of the event that you recently triggered; use the event number corresponding to your triggered event.

```
==>>file dir events
171101,155138316,OT,SID,RID,CONAM,HR,10000.CFG        R   11/01/2017 08:51:38
171101,155138316,OT,SID,RID,CONAM,HR,10000.DAT        R   11/01/2017 08:51:38
171101,155138316,OT,SID,RID,CONAM,HR,10000.HDR        R   11/01/2017 08:51:38
C4_10000.TXT                                          R   11/01/2017 08:51:38
C8_10000.TXT                                          R   11/01/2017 08:51:38
CHISTORY.TXT                                          R
E4_10000.TXT                                          R   11/01/2017 08:51:38
E8_10000.TXT                                          R   11/01/2017 08:51:38
HISTORY.TXT                                           R
HR_10000.CFG                                          R   11/01/2017 08:51:38
HR_10000.DAT                                          R   11/01/2017 08:51:38
HR_10000 .HDR                                         R   11/01/2017 08:51:38
```

Figure 3.37 EVENTS Folder Files

Step 3. Type **FILE READ EVENTS HR_10000.* <Enter>** to ready the relay to transfer the HR_10000.HDR, HR_10000.CFG, and HR_10000.DAT files to your computer.

Step 4. Download the files. Perform the steps necessary for your terminal emulation program to receive a file.

Typically, these are the file transfer steps:

➢ Specify the destination file location in your computer file storage system and file name.

➢ Select the transfer type as **YModem** (if this transfer type is not already enabled).

➢ Select **Receive**.

You will usually see a confirmation message when the file transfer is complete.

When these files have transferred successfully, you have the entire COMTRADE file for the high-resolution raw data capture.

Step 5. Use SYNCHROWAVE Event, QuickSet, or other COMTRADE-capable programs to play back high-resolution raw data oscillograms of the high-resolution raw data capture files you just transferred.

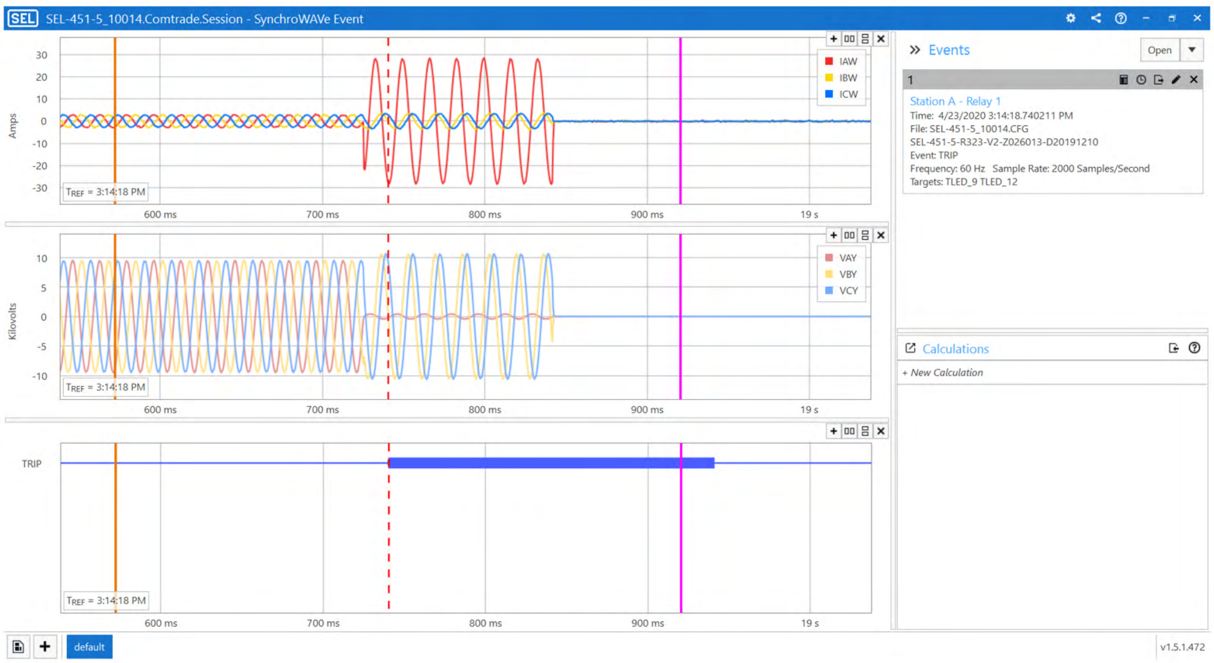


Figure 3.38 Sample Event Oscillogram

You can also examine a phasors display, an event harmonic analysis display, and the event summary from the **Event Waveform View** menu. See *Section 9: Reporting* for more information.

Viewing Event Report Data

Examine relay event reports to inspect the operating quantities the relay used at each triggered event. Unlike the raw data samples/second high-resolution oscillography files, these reports contain the filtered samples/cycle data the relay uses to make protection decisions. Event reports are useful for determining why the relay operated for a particular set of power system conditions. For more information on event reports, see *Event Report on page 9.14*.

The relay recorded the event triggered in *Generating an Event on page 3.46*. The procedure in the following steps shows you how to retrieve the event report data files for this event. Perform the steps listed in *Generating an Event on page 3.46* before executing the instructions in this example. For this procedure, you must use a terminal program capable of Ymodem protocol file transfer.

Step 1. Prepare to monitor the relay at Access Level 1.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 2. Type **FILE DIR EVENTS <Enter>** to view the events file directory.

The relay lists file names for recently recorded events in a manner similar to that shown in *Figure 3.37*.

In the figure, the relay shows two event report files: E4_10000.TXT and E8_10000.TXT, and two Compressed ASCII event report files: C4_10000.TXT and C8_10000.TXT.

Step 3. Type **FILE READ EVENTS C8_10000.TXT <Enter>** to transfer the Compressed ASCII event report file to your computer.

Step 4. Download the file. Perform the steps necessary for your terminal emulation program to receive a file.

Typically, these are the file transfer steps:

- ➢ Specify the destination file location in your computer file storage system and file name.
- ➢ Select the transfer type as **YModem** (if not already enabled).
- ➢ Select **Receive**.

You will usually see a confirmation message when the file transfer is complete.

Step 5. When this file has transferred successfully, use SYNCHROWAVE Event to play back the event report oscillograms of the 8-samples/cycle event report file you just transferred.

Viewing SER Records

The relay SER records relay operating changes and relay element states. In response to an element change of state, the SER logs the element, the element state, and a time stamp. Program the relay elements that the relay stores in the SER records, thus capturing significant system events such as an input/output change of state, element pickup/dropout, recloser state changes, etc.

The relay stores the latest 1000 entries to a nonvolatile record. Use the relay communications ports or QuickSet to view the SER records. For more information on the SER, see *Section 9: Reporting*.

The latest 200 SER events are viewable from the front panel. For more information, see *Section 4: Front-Panel Operations*.

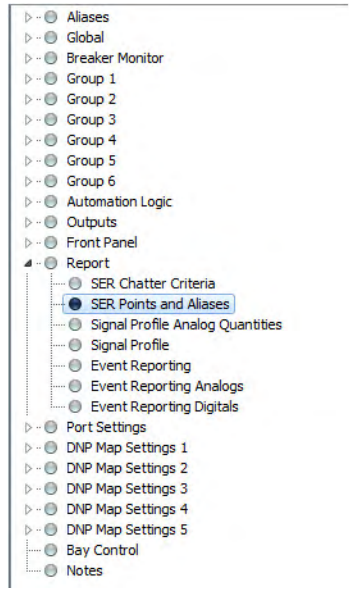


Figure 3.39 Selecting SER Points and Aliases Settings in QuickSet

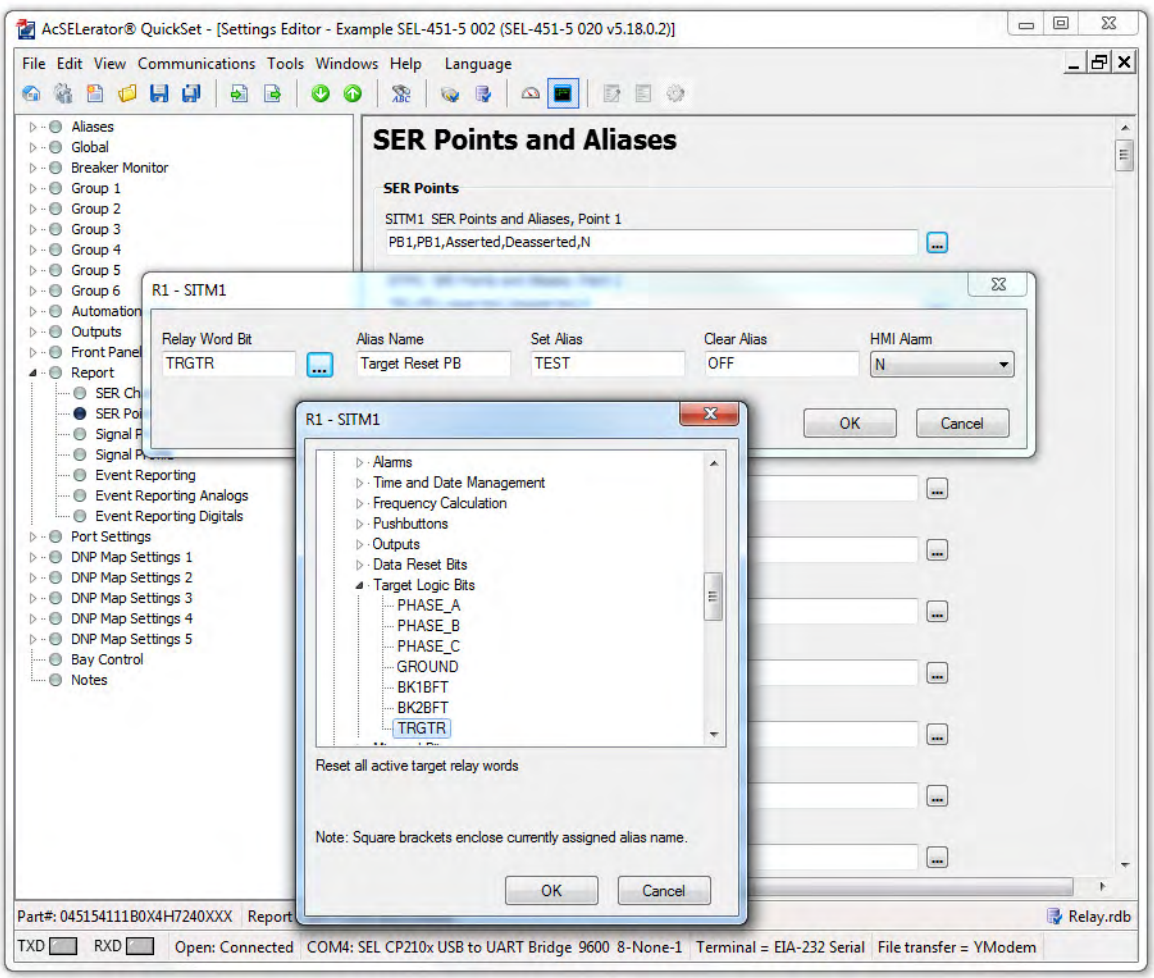


Figure 3.40 SER Points and Aliases Settings in QuickSet

NOTE: SITMn (where n = 1–250) are the setting names associated with your SER points.

Step 6. Enter SER settings.

a. For this example, open the entry form by selecting the button beside the **SITM1 SER Points and Aliases**, **Point 1** entry field. We will change this SER point to report the operation of the TARGET RESET pushbutton.

b. Select the button beside the **Relay Word Bit** entry field.

c. Select **Target Logic Bits**, and then double-click **TRGTR** to copy the TRGTR name into the **Relay Word Bit** field. This also copies TRGTR to the Reporting Name (or alias) field.

d. Type **Target Reset PB** in the **Alias Name** field.

e. Type **TEST** in the **Set Alias** field.

f. Type **OFF** in the **Clear Alias** field.

g. Select **OK**.

Step 7. Select **File > Save** to save the new settings in QuickSet.

Step 8. Upload the new settings to the relay.

a. Select **File > Send**.

QuickSet prompts you for the settings class you want to send to the relay, as shown in the first dialog box of *Figure 3.41*.

b. Select the **Report** check box.

c. Select **OK**.

QuickSet responds with the second dialog box of *Figure 3.41*.

If you see no error message, the new settings are loaded in the relay.

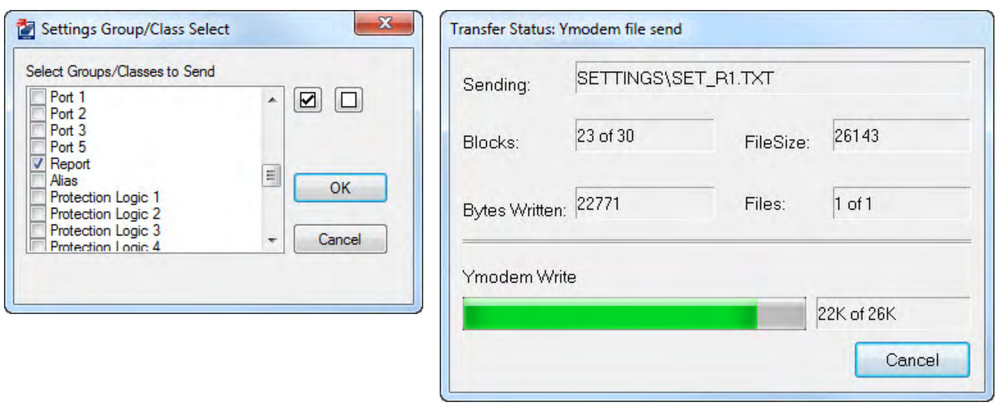


Figure 3.41 Uploading Report Settings to the Relay

Step 9. Press and release the front-panel TARGET RESET pushbutton to generate an SER record.

Step 10. View the SER report.

a. Start the QuickSet operator interface.

b. In the top toolbar **Tools** menu, select **HMI > HMI**.

c. Select the **SER** button of the HMI tree view (see *Figure 3.42*).

QuickSet displays the SER records with a display similar to *Figure 3.43*.

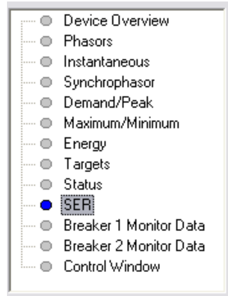


Figure 3.42 Retrieving SER Records With QuickSet

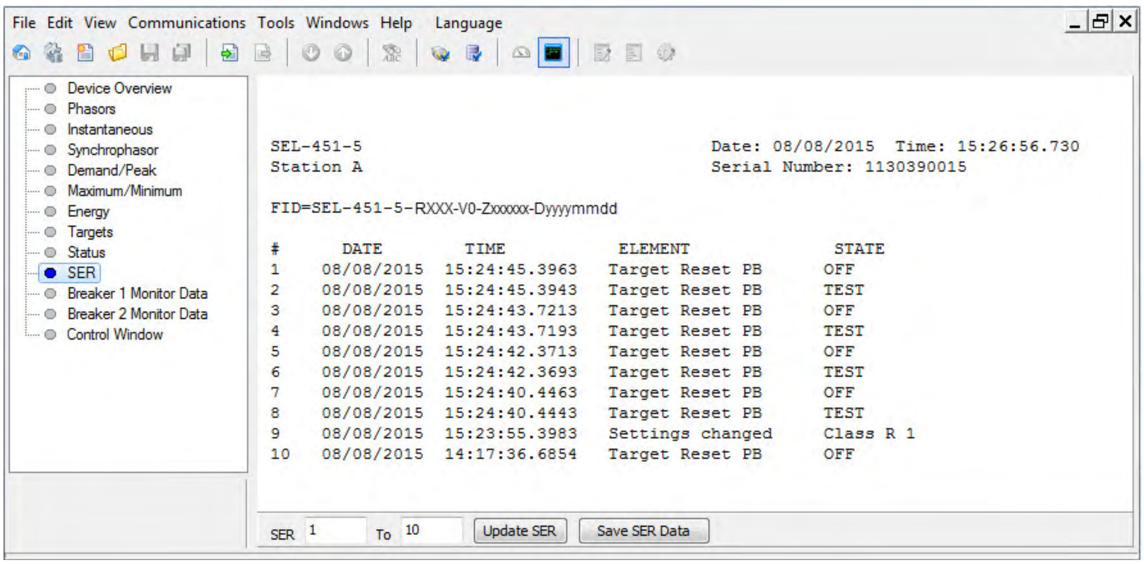


Figure 3.43 SER Records in the QuickSet HMI

The relay lists the SER records in chronological order from top to bottom as shown in *Figure 3.43*. In addition, the relay numbers each record with the most recent record as number 1; new events are usually more important for determining the effects of recently occurring power system events.

For each application of power to the relay, the SER reports a "Power-up" indication and the active settings group. A properly operating relay immediately goes to the enabled state, an event that causes the SER to report another SER record. The SER reports the **TARGET RESET** button when you press the pushbutton and it remains asserted for one processing interval.

Setting the SER and Examining the SER Record in the Terminal

The procedure in the following steps shows how to use a terminal connected to a relay communications port to set an element in the SER. Use text-edit mode line editing to enter the SER settings (see *Text-Edit Mode Line Editing on page 3.23*). Also included is a procedure for viewing the SER report with a terminal.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.11* to change the default access level passwords).

Step 1. Prepare to control the relay at Access Level 2.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type **2AC <Enter>**.

d. Type the correct password to go to Access Level 2.

You will see the Access Level 2 =>> prompt.

Step 2. Enter SER trigger data.

a. Type **SET R TERSE <Enter>** to access the **Report** settings (see *Figure 3.44*).

b. Press **<Enter>** to move past the **SER Chatter Criteria** setting.

c. At the `SER Points ?` prompt line, type the following:

TRGTR,“TARGET RESET PB”,TEST,OFF,N <Enter>.

At the next line, type **END <Enter>**.

d. The relay prompts you to save the new setting; type **Y <Enter>**.

```
=>>SET R TERSE <Enter>
Report
SER Chatter Criteria
Automatic Removal of Chattering SER Points (Y,N)   ESERDEL := N   ? <Enter>


SER Points
(Relay Word Bit, Reporting Name, Set State Name, Clear State Name, HMI Alarm)
1:
? TRGTR,“TARGET RESET PB”,TEST,OFF,N <Enter>
2:
? END <Enter>

Save settings (Y,N) ? Y <Enter>
Saving Settings, Please Wait..........
Settings Saved
=>>
```

Figure 3.44 Setting an SER Element: Terminal

Step 3. Press and release the front-panel TARGET RESET pushbutton to generate an SER record.

Step 4. Type **SER <Enter>** (at the Access Level 1 prompt or higher) to view the SER report.

The relay presents a screen similar to the SER display of *Figure 3.43*.

Downloading an SER Report File

The procedure in the following steps shows you how to retrieve the SER report stored in the relay as a file. For this procedure, you must use a terminal emulation program with file transfer capability.

Step 1. Prepare to monitor the relay at Access Level 1.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 2. Type **FILE DIR REPORTS <Enter>** to view the events file directory.

The terminal lists the file names for standard reports as shown in *Figure 3.45*.

Step 3. Prepare the relay to download the SER report.

a. Type **FILE READ REPORTS SER.TXT <Enter>**.

b. If you want the Compressed ASCII file, type the following:

FILE READ REPORTS CSER.TXT <Enter>

```
=>FILE DIR REPORTS <Enter>
BRE_1.TXT                    R
BRE_2.TXT                    R
BRE_S1.TXT                   R
BRE_S2.TXT                   R
CBRE.TXT                     R
CHISTORY.TXT                 R
CPRO.TXT                     R
CSER.TXT                     R
HISTORY.TXT                  R
PRO.TXT                      R
SER.TXT                      R
=>
```

Figure 3.45 Example Reports File Structure

Step 4. Download the SER report. Perform the steps necessary for your terminal emulation program to receive a file.

Typically, these are the file transfer steps:

NOTE: Transferring SER files (or CSER files) with the **FILE READ REPORTS SER.TXT** command, performs an **SER CV** command as part of the transfer. SER CV clears the SER information from the present port. With the SER information cleared, there are no data available for subsequent SER or CSER transfers from the same port.

- ➢ Specify the destination file location in your computer file storage system and file name.
- ➢ Select the transfer type as **YModem** (if not already enabled).
- ➢ Select **Receive**.

You will usually see a confirmation message when the file transfer is complete.

Step 5. When the SER.txt file has transferred successfully, use a word-processing program to view the contents of the file.

You will see the SER records in a format similar to *Figure 3.43*.

Operating the Relay Inputs and Outputs

The SEL-400 series relays give you great ability to perform control actions at bay and substation locations via the relay control outputs. The control outputs close and open circuit breakers, switch disconnects, and operate auxiliary station equipment such as fans and lights. The relay reads data from the power system and interfaces with external signals (contact closures and data) through the control inputs. This section is an introduction to operating the control outputs and control inputs. For more information on connecting and applying the control outputs and control inputs, see *Section 2: Installation* in the product-specific instruction manual.

Control Output

The relay features standard, hybrid (high-current interrupting), and high-speed high-current interrupting control outputs that you can use to control circuit breakers and other devices in an equipment bay or substation control house.

Pulsing a Control Output in the Terminal

When first connecting the relay, or at any time that you want to test relay control outputs, perform the following procedure. The procedure in the following steps shows how to use a communications terminal to pulse the control output contacts. Perform the steps in this example to become familiar with relay control and serial communication. For more information on the **PULSE** command, see *PULSE on page 14.55*.

This example assumes that you have successfully established communication with the relay; see *Making an EIA-232 Serial Port Connection on page 3.4* for a step-by-step procedure. In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.11* to change the default access level passwords).

NOTE: To pulse an output, the circuit breaker control enable jumper must be installed on the main board.

Step 1. Prepare to control the relay at Access Level B.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type **BAC <Enter>**.

d. Type the correct password to go to Access Level B.

You will see the Access Level B ==> prompt.

Step 2. Attach an indicating device (ohmmeter with a beep sounder or a test set) to the terminals for control output OUT104.

This output is a standard control output and is not polarity-sensitive.

Step 3. Perform the pulse operation.

a. Type **PULSE OUT104 <Enter>**.

The relay confirms your request to pulse an output with a prompt such as that shown in *Figure 3.46*.

b. Type **Y <Enter>** at the prompt.

You will see or hear the indicating device turn on for a second and then turn off.

```
==>PULSE OUT104 <Enter>
Pulse contact OUT104 for 1 seconds(Y/N)       ? Y <Enter>
==>
```

Figure 3.46 Terminal Display for PULSE Command

You can also pulse an output for longer than the default one-second period. If you enter a number after the **PULSE** command, that number specifies the duration in seconds for the pulse. For example, if you enter **PULSE OUT104 3 <Enter>**, the relay pulses OUT104 for three seconds.

Pulsing a Control Output on the Front Panel

The procedure in the following steps shows you how to use the front-panel display and navigation pushbuttons to check for proper operation of the relay control outputs. See *Section 4: Front-Panel Operations* for information on using the relay front panel.

Step 1. Attach an indicating device (an ohmmeter with a beep sounder or a test set) to the terminals for control output OUT104.

This output is a standard control output and is not polarity-sensitive.

Step 2. View the front-panel display.

After applying power to the relay, note that the LCD shows a sequence of screens called the `ROTATING DISPLAY`.

(Also, if you do not operate the front panel for a certain period, the relay will enter front-panel time-out mode and you will see the sequential screens of the `ROTATING DISPLAY`.)

Step 3. Press the **ENT** pushbutton to view the `MAIN MENU`, similar to that in *Figure 3.47(a)*.

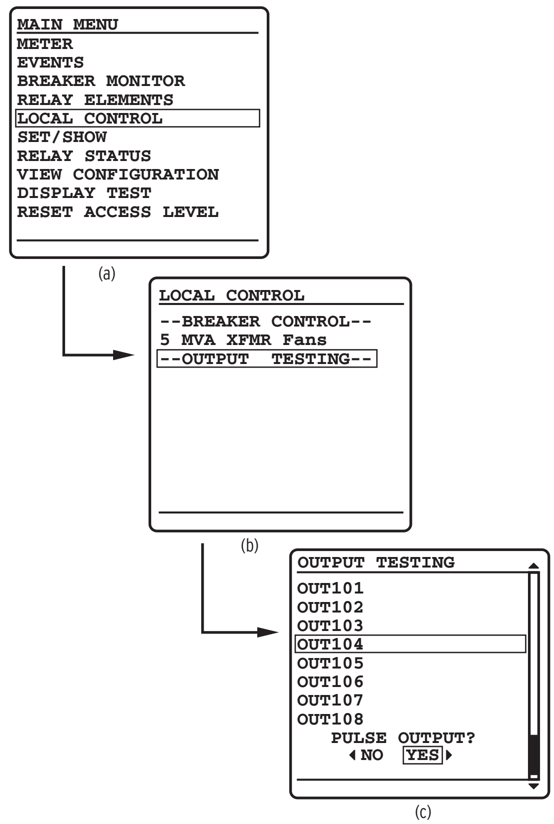


Figure 3.47 Front-Panel Menus for Pulsing OUT104

Step 4. View the `LOCAL CONTROL` screen.

a. Press the **Up Arrow** and **Down Arrow** navigation pushbuttons to highlight the `LOCAL CONTROL` action item, as shown in *Figure 3.47(a)*.

b. Press the **ENT** pushbutton.

You will see the `LOCAL CONTROL` submenu as shown in *Figure 3.47(b)*.

Step 5. View the `OUTPUT TESTING` screen.

a. Press the **Up Arrow** and **Down Arrow** navigation pushbuttons to highlight the `--OUTPUT TESTING--` action item, as shown in *Figure 3.47(b)*.

b. Press the **ENT** pushbutton.

The relay displays the `OUTPUT TESTING` submenu, as shown in *Figure 3.47(c)*.

Step 6. Command the relay to pulse the control output.

a. Press the **Up Arrow** and **Down Arrow** navigation pushbuttons to highlight `OUT104` as shown in *Figure 3.47(c)*.

b. Press the **Right Arrow** navigation pushbutton to highlight `YES` under `PULSE OUTPUT?`

c. Press the **ENT** pushbutton.

The relay detects your request for a function at an access level for which you do not yet have authorization. Whenever this condition occurs, the relay displays the password access screen as shown in *Figure 3.48*.

Figure 3.48 Password Entry Screen

Step 7. Input a password and pulse the output.

a. Enter a valid Access Level B, P, A, O, or 2 password.

(The front panel is always at Access Level 1, so you do not enter the Access Level 1 password.)

Enter a valid password by using the navigation pushbuttons to select, in sequence, the alphanumeric characters that correspond to your password.

b. Press the **ENT** pushbutton at each password character.

(If you make a mistake, highlight the `BACKSPACE` option and press **ENT** to reenter a character or characters.)

c. After entering all password characters, press the **Up Arrow** or **Down Arrow** pushbuttons to highlight `ACCEPT`, and press **ENT**.

The relay pulses the output, and you will see the indicating device turn on for a second and then turn off.

Controlling a Relay Control Output With a Local Bit in the Terminal

In this example, you set Local Bit 3 to start the transformer cooling fans near the breaker bay where you have installed the SEL-451. Thus, you can use the LCD screen and navigation pushbuttons to toggle relay Local Bit 3 to control the state of the cooling fans. Relay Word bit LB_SP03 provides supervision for Local Bit 3. Relay Word bit LB_SP03 must be asserted for successful Local Bit 3 operations. For more information on local bits, see *Local Control Bits on page 4.22*.

The procedure in the following steps proposes connecting the transformer bank fan control to relay output **OUT105**. You can choose any relay output that conforms to your requirements.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.11* to change the default access level passwords).

Step 1. Prepare to control the relay at Access Level 2.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type **2AC <Enter>**.

d. Type the correct password to go to Access Level 2.

You will see the Access Level 2 =>> prompt.

Step 2. Access the local control settings.

a. Type **SET F <Enter>**.

b. Repeatedly type **>** and then **<Enter>** to advance through the front-panel settings until you reach the **Local Control** category.

Figure 3.49 shows a representative terminal screen.

```
Local Control
(Local Bit, Local Label, Local Set State, Local Clear State, Pulse Enable)

1:
? LIST <Enter>
1:
? LB03,"5 MVA XFMR Fans",ON,OFF,N <Enter>
2:
? END <Enter>
           .
           .
           .
Local Control
(Local Bit, Local Label, Local Set State, Local Clear State, Pulse Enable)

1: LB03,"5 MVA XMFR Fans","ON","OFF",N
Save settings (Y,N) ? Y <Enter>
Saving Settings, Please Wait..........
Settings Saved
 =>>
```

Figure 3.49 Using Text-Edit Mode Line Editing to Set Local Bit 3

Step 3. Type **LIST <Enter>** at the `Local Control ?` prompt to list the active control points.

This example assumes that you are using no local bits, so the relay returns you to Line 1 followed by the settings `?` prompt.

Step 4. Type **LB03,“5 MVA XFMR Fans”,ON,OFF,N <Enter>** at the Line `?` prompt.

The relay checks that this is a valid entry and responds with the next line prompt `2:` followed by the settings `?` prompt.

Step 5. End the settings session.

a. Type **END <Enter>**.

The relay displays a readback of all the front-panel settings, eventually displaying the `Save settings (Y,N) ?` prompt. (In *Figure 3.49* a vertical ellipsis represents the readback.)

At the end of the readback information, just before the `Save settings (Y,N) ?` prompt, you can see the new local bit information.

b. Type **Y <Enter>** to save your new settings.

Step 6. Set OUT105 to respond to Local Bit 3.

a. Type **SET O OUT105 <Enter>** (see *Figure 3.50*).

b. At the `?` prompt, type **LB03 <Enter>**.

c. At the next `?` prompt, type **END <Enter>**.

d. When prompted to save settings, type **Y <Enter>**.

```
=>>SET O OUT105 <Enter>
Output
Main Board
OUT105 :== NA
? LB03 <Enter>
OUT106 := NA
? END <Enter>
Output

Main Board
OUT101 := T3P1 #BREAKER 1 TRIP
OUT102 := T3P1 #EXTRA BREAKER 1 TRIP
OUT103 := BK1CL #BREAKER 1 CLOSE
OUT104 := NA
OUT105 := LB03
OUT106 := NA
OUT107 := NA
OUT108 := NOT (HALARM OR SALARM)

Save settings (Y,N) ? Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
=>>
```

Figure 3.50 Setting Control Output OUT105 in the Terminal

Step 7. Test the connection and programming.

a. Use the appropriate interface hardware to connect the fan control start circuit to OUT105.

b. At the relay front-panel `MAIN MENU`, select `LOCAL CONTROL` and press the **ENT** pushbutton as shown in *Figure 3.51(a)*.

c. Select `5 MVA XFMR Fans` on the `LOCAL CONTROL` screen as shown in *Figure 3.51(b)*.

d. Press **ENT** to see the `5 MVA XFMR Fans` as shown in *Figure 3.51(c)*.

e. Highlight `1 ON` and press **ENT**.

The graphical local control handle moves to the 1 position. At this time, the transformer fans will begin running.

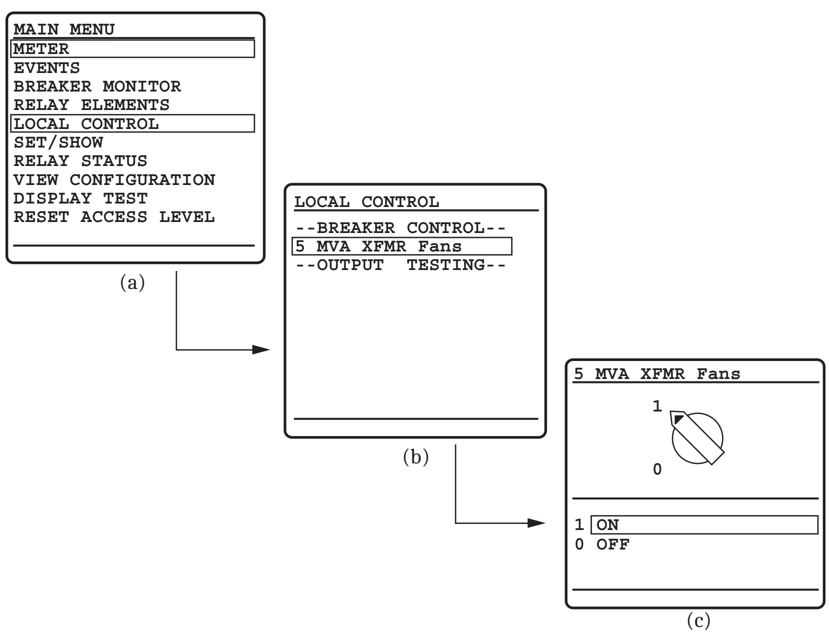


Figure 3.51 Front-Panel LOCAL CONTROL Screens

Setting Outputs for Tripping and Closing

To actuate power system circuit breakers, you must configure the control outputs to operate the trip bus and close bus. The relay uses internal logic and SELOGIC control equations to activate the control outputs.

Trip Output Signals

All SEL-400 series relays are capable of three-pole tripping and some are capable of single-pole tripping. There are many Relay Word bits (e.g., T3P1, T3P2, and 3PT) that you can program to drive control outputs to trip circuit breakers. See *Section 5: Protection* in the product-specific instruction manual for complete information on tripping equations and settings. For target illumination at tripping, see *Section 4: Front-Panel Operations*.

Close Output Signals

Some SEL-400 series relays feature an automatic recloser for single-circuit breaker and two-circuit breaker applications, with as many as four autoreclose shots. See *Section 6: Autoreclosing* for more information.

Assigning Control Outputs for Tripping and Closing

The procedure in the following steps shows a method for setting the relay to operate the trip bus and the close bus at a typical substation. This procedure assigns a close output at OUT106. This example is specific to the SEL-451 relay, but similar configuration changes can be made in all SEL-400 series relays.

This example assumes that are familiar with SEL Grid Configurator or QuickSet (see *Section 2: PC Software*).

Step 1. Read the relay settings.

Step 2. Access the **Main Board** output settings.

   a. Expand the **Outputs** branch of the Settings tree view.

   b. Select **Main Board**.

Step 3. Assign a control output for the close bus.

   a. In the **Main Board Outputs** dialog box, select the **OUT106** text box and type the following:

   BK1CL #ADDITIONAL BREAKER 1 CLOSE

   (The # indicates that a comment follows.)

   b. Select or tab to another text box.

   The software checks that your entry is valid.

Step 4. Upload the new settings to the relay.

Control Input Assignment

Most SEL-400 series relays have control inputs on the main board (IN101–IN107), and on one or more optional I/O interface boards (IN201–IN2xx, IN301–IN3xx, etc.), if so equipped.

There are two types of input circuitry: direct-coupled and optoisolated. *Table 3.8* lists the main differences between the two types of control inputs. Only the SEL-421 and SEL-451 are available with interface boards that support direct-coupled inputs. All SEL-400 series relays support optoisolated inputs.

Table 3.8 Control Input Characteristics

	Direct-Coupled	**Optoisolated**
Pickup characteristics:	Pickup voltage can be selected via Global settings. Can have different pickup voltages on each input.	Pickup voltage is determined by hardware: one of six voltage levels determined at time of factory order. All pickup voltages are the same on each I/O interface board.
Polarity-sensitive:	Yes (will not respond to reverse polarity signals). A + polarity mark is printed over the positive terminals.	No (will respond to signals of either polarity). No polarity mark. AC signal detection is possible.[a]
Where found:	INT1, INT5, and INT6 I/O Interface Boards (available in SEL-421 and SEL-451 relays).	SEL-400 Series Main Board (IN101–IN107). All other interface boards.

[a] With appropriate debounce settings (see Section 2: Installation of the product-specific instruction manual).

The default value for Global setting EICIS (Enable Independent Control Input Settings) is N, which hides all individual control input settings and only presents some overall settings that will apply to all control inputs. Set EICIS := Y to gain full access to the individual control input settings.

Setting a Control Input for Circuit Breaker Auxiliary Contacts (52A) in the Terminal

This is a step-by-step procedure to configure a control input that reflects the state of the circuit breaker auxiliary (52A) NO (normally open) contact. A common relay input is from circuit breaker auxiliary contacts; the relay monitors the 52A contacts to detect the closed/open status of the circuit breaker. Perform the following steps to connect three-pole circuit breaker auxiliary contacts to the relay. This example was created using an SEL-451. Refer to the product-specific instruction manual for the correct Relay Word bit names for each product.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.11* to change the default access level passwords).

Step 1. Prepare to control the relay at Access Level 2.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the => prompt.

c. Type **2AC <Enter>**.

d. Type the correct password to go to Access Level 2.

You will see the Access Level 2 =>> prompt.

Step 2. Configure the relay to read the circuit breaker auxiliary contact.

a. Type **SET M <Enter>** (see *Figure 3.52*).

These settings are the breaker monitor settings.

b. Type **<Enter>** to bypass the Breaker 1 Monitoring enable, and **<Enter>** again to bypass the Breaker 2 Monitoring enable (NUMBK := 2 in this example).

The relay displays the 52AA1 SELOGIC control equation action prompt.

c. Type **IN101 <Enter>** at the ? prompt to specify input IN101 as the control input that represents the close/open state of Circuit Breaker 1.

   Press **<Enter>** until the relay displays the 52AA2 SELOGIC control equation action prompt.

d. Type **IN102 <Enter>** at the ? prompt to specify input IN102 as the control input that represents the close/open state of Circuit Breaker 2.

Step 3. End the settings process. The relay next scrolls a readback of all the Global settings, eventually displaying the `Save settings (Y,N) ?` prompt.

a. In the readback information, just before the `Save settings (Y,N) ?` prompt, confirm the new control input information.

b. Answer **Y <Enter>** to save your new settings.

```
=>>SET M <Enter>
Breaker Monitor
Breaker Configuration
Breaker 1 Monitoring (Y,N) EB1MON  := N ? <Enter>
Breaker 2 Monitoring (Y,N) EB2MON  := N ? <Enter>
Breaker 1 Inputs

N/O Contact Input -BK1 (SELogic Equation)
52AA1 := NA
?  IN101 <Enter>
Breaker 2 Inputs
N/O Contact Input -BK2 (SELogic Equation)
52AA2 := NA
?  IN102 <Enter>
Breaker Monitor

Breaker Configuration
EB1MON  := N        EB2MON  := N
Breaker 1 Inputs
52AA1   := IN101
Breaker 2 Inputs
52AA2   := IN102
Save settings (Y,N)  ? Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
=>>
```

Figure 3.52 Setting 52AA1 in the Terminal

Setting a Control Input for Circuit Breaker Auxiliary Contacts (52A) Via Software

The procedure in the following steps shows how to program the relay control input IN101 to read the state of circuit breaker auxiliary contacts. This example uses a single three-pole tripping breaker. Modify the procedure listed here for your application.

This example assumes that you are familiar with SEL Grid Configurator or QuickSet (see *Section 2: PC Software*).

Step 1. Read the relay settings.

Step 2. Access the **Control Inputs** settings.

a. Select the arrow next to the **Global** branch of the **Settings** tree view.

b. Select the arrow next to the **Control Inputs** branch of the **Settings** tree view.

Step 3. Set **EICIS Independent Control Input Settings** to **Y**.

Step 4. Set the control input IN101 debounce time.

For this example, assume that the auxiliary contacts are slow and noisy; you must provide a slightly longer debounce time for these contacts.

a. Double-click the mouse cursor (or press **<Tab>**) to highlight **IN101PU Pickup Delay for Contact Input**.
b. Delete the present setting by pressing **<Delete>**.
c. Type **0.25 <Enter>**.
d. Similarly change the **IN101DO Input IN101 Dropout Delay** to **0.25**.

   The software checks the value.

Step 5. Configure the relay to read the circuit breaker auxiliary contact.

a. Expand the **Breaker Monitor** branch of the **Settings** tree view by selecting the **+** button.
b. In the tree view, select **Breaker 1** to select circuit breaker monitor settings for Circuit Breaker 1.
c. Set the 52AA1 SELOGIC control equation by selecting in the text box labeled **52AA1 N/O Contact Input**.
d. Type **IN101**, and then select or **<Tab>** to another field to specify input IN101 as the control input that represents the close/open state of Circuit Breaker 1.

Step 6. Upload the new settings to the SEL-451.

Special Considerations for TiDL

In Time-Domain Link (TiDL) systems, IN301–IN324, OUT301–OUT316, IN401–IN424, OUT401–OUT416, IN501–IN524, and OUT501–OUT516 are provided from TiDL merging units. See *Section 19: Digital Secondary Systems* for more information on TiDL I/O.

Configuring Timekeeping

The relay features high-accuracy timekeeping when supplied with an IRIG-B or Ethernet Precision Time Protocol (PTP) signal. When the supplied clock signal is sufficiently accurate, most SEL-400 series relays can act as a phasor measurement unit (PMU) and transmit synchrophasor data representative of the power system at fixed time periods to an external data processor. The relay can also record COMTRADE event report data by using the high-accuracy time stamp. See *Oscillography on page 9.9* and *Time-Synchronized Triggers on page 11.9* for details on these applications.

IRIG-B and PTP

NOTE: The SEL-487V does not support PTP.

The relay has two input connectors that accept IRIG-B (Inter-Range Instrumentation Group-B) demodulated time-code format: the IRIG-B pins of aerial **PORT 1**, and the IRIG-B BNC connector. In relays with Ethernet, Precision Time Protocol (PTP) can also be used to provide high-accuracy time. See *Section 11: Time and Date Management* for more information on using IRIG-B and PTP.

Monitoring High-Accuracy Time Source Status

The purpose of the procedure in the following steps is to show one method for deriving the TIME Q Time Source information from Relay Word bits TSOK and TIRIG when using an IRIG Time Source. The TSOK Relay Word bit is at logical 1 when the relay is in HIRIG time mode. For this application example, use a protection SELOGIC variable (PSV) to monitor timekeeping status.

PSV02 asserts when the relay is synchronized to the HIRIG source. A departure from this condition asserts the relay alarm output (OUT108 for this application example).

This example assumes that you are familiar with SEL Grid Configurator or QuickSet (see *Section 2: PC Software*).

Step 1. Read the relay settings

Step 2. Access the protection free-form SELOGIC settings.

a. Select the arrow next to **Group 1** in the **Settings** tree view.

b. Select the **Protection Logic 1** settings.

Step 3. Enter the two lines of SELOGIC control equation programming in the **Protection Free-Form Logic Settings** shown in *Figure 3.53*.

```
SET L <Enter>
17: #CHECK THE TIME SYNCHRONIZATION RELAY WORD BIT FOR HIRIG
18: PSV02 := TSOK
```

Figure 3.53 Programming a PSV to Monitor HIRIG in QuickSet

Step 4. Configure a control output to alarm a loss-of-HIRIG mode.

a. In the **Settings** tree view, select **Outputs** and then select **Main Board**.

b. In the **OUT108 Main Board Outputs** text box, enter the OR NOT PSV02 condition to the preexisting OUT108 := NOT (SALARM OR HALARM) equation.

Step 5. Upload the new settings to the relay.

To confirm that you have prepared an out-of-synchronization/loss-of-HIRIG mode alarm, disconnect the IRIG-B input. The relay alarm will activate.

Readying the Relay for Field Application

Before applying the relay in your power system, set the relay for your particular field application. Be sure to modify the relay factory-default settings for your power system conditions to enable relay features to help you protect and control your system.

This procedure is a guide to help you ready the relay for field application. If you are unfamiliar with the steps in this procedure, see the many relay usage examples presented in this section. This is a suggested procedure; modify the procedure as necessary to conform to your standard company practices.

Step 1. Open the appropriate low-voltage breaker(s) and remove fuses to verify removal of control power and ac signals from the relay.

Step 2. Isolate the relay TRIP control output.

Step 3. Perform point-to-point continuity checks on the circuits associated with the relay to verify the accuracy and correctness of the ac and dc connections.

Step 4. Apply power to the relay.

The green **ENABLED** LED on the front panel will illuminate.

Step 5. Use an SEL-C234A cable to connect a serial terminal to the relay.

Step 6. Start the terminal (usually a PC with terminal emulation software).

Step 7. Establish communication with the relay at Access Level 0.

Step 8. Proceed to Access Level 2 (see *Changing the Default Passwords in the Terminal on page 3.11*).

Step 9. Change the default passwords (see *Changing the Default Passwords in the Terminal on page 3.11*).

Step 10. Set the DATE and TIME (see *Making Simple Settings Changes on page 3.15*).

Step 11. Use test sources to verify relay ac connections (see *Examining Metering Quantities on page 3.34*).

Step 12. Verify control input connections.

Step 13. Verify control output connections.

Step 14. Perform protection element tests.

Step 15. Set the relay (see *Making Simple Settings Changes on page 3.15, Section 12: Settings,* and *Section 6: Protection and Protection Application Examples* in the product-specific instruction manual).

Step 16. Connect the relay for tripping/closing duty.

Step 17. From Access Level 2, use a communications terminal to issue applicable commands (listed in *Table 3.9*) to clear the relay data buffers.

Table 3.9 Communications Port Commands That Clear Relay Buffers

Communications Port Command	Task Performed
MET RD	Reset demand meter data
MET RP	Reset peak demand meter data
MET RE	Reset energy meter data
MET RM	Reset maximum/minimum meter data
HIS CA	Reset event report and history buffers
SER CA	Reset Sequential Events Recorder data

Step 18. Connect the secondary voltage and current inputs.

Step 19. Use the **MET** command or the QuickSet HMI to view relay metering to confirm secondary connections (see *Examining Metering Quantities on page 3.34*).

SECTION 4

Front-Panel Operations

The relay front panel makes power system data collection and system control quick and efficient. Using the front panel, you can analyze power system operating information, view and change relay settings, and perform relay control functions. The relay features a straightforward menu-driven control structure presented on the front-panel LCD. Front-panel targets and other LED indicators provide a quick look at relay operation status. You can perform often-used control actions rapidly by using the large direct-action pushbuttons. All of these features help you operate the relay from the front panel and include:

- Reading metering
- Inspecting targets
- Accessing settings
- Controlling relay operations

This section describes features found in many, but not necessarily all, SEL-400 series relays. See the relay-specific instruction manuals to determine which front-panel features are supported in that relay. This section includes the following:

Front-Panel Layout

Some SEL-400 series relays come with a front panel with 16 target LEDs and 8 operator pushbuttons. Others come with 24 target LEDs and 12 operator pushbuttons. Refer to the product-specific instruction manual to see which displays are available for any specific relay. *Figure 4.1*, *Figure 4.2*, and *Figure 4.3* show what these front-panel options look like in the SEL-451 and the SEL-487E relays. Some relays are also available with direct-action pushbuttons for breaker control, which is illustrated in *Figure 4.2*.

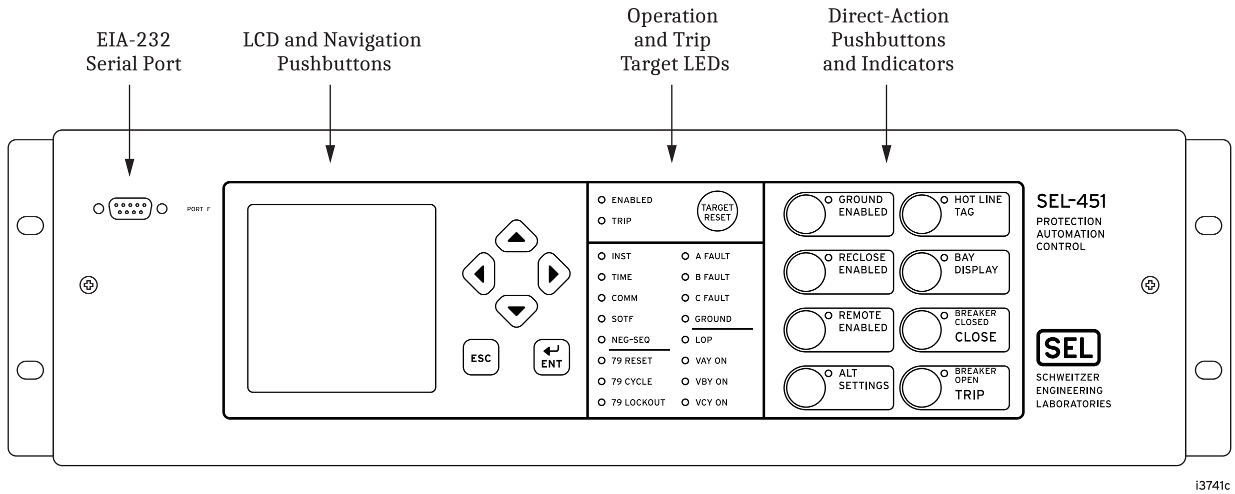


Figure 4.1 SEL-451 Front Panel (8-Pushbutton Model)

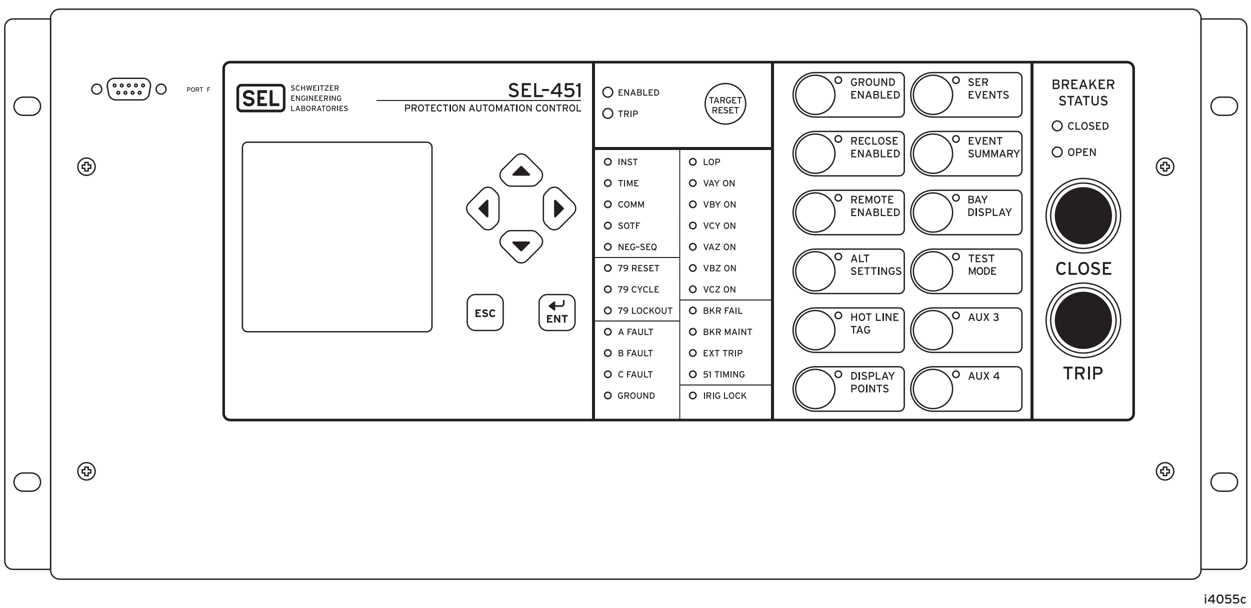


Figure 4.2 SEL-451 Front Panel (12-Pushbutton Model) with Optional Auxiliary Trip/Close Buttons

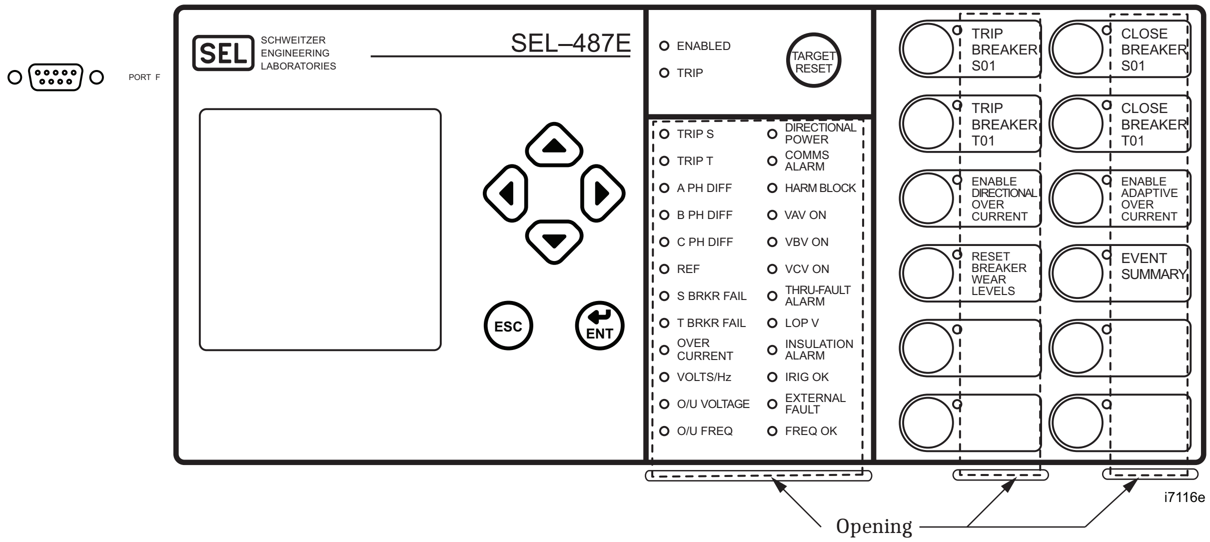


Figure 4.3 SEL-487E Front Panel

A 128 x 128 pixel LCD shows relay operating data including event summaries, metering, settings, and relay self-test information.

Six navigation pushbuttons adjacent to the LCD window control the relay menus and information screens. Sequentially rotating display screens provide important power system metering parameters; you can easily change this ROTATING DISPLAY to suit your particular onsite monitoring needs. Use a simple and efficient menu structure to operate the relay from the front panel. With these menus you can quickly access relay metering, control, and settings.

Front-panel LEDs indicate the relay operating status. You can confirm that the relay is operational by viewing the **ENABLED** LED. The relay illuminates the **TRIP** LED target to indicate a tripping incident. The relay is factory programmed for particular relay elements to illuminate the other target LEDs. You can program these target LEDs to show the results of the most recent relay trip event. The asserted and deasserted colors for the LEDs are programmable.

Select relay models feature auxiliary **TRIP/CLOSE** pushbuttons. These pushbuttons are electrically isolated from the rest of the relay.

The relay front panel features large operator control pushbuttons with annunciator LEDs that facilitate local control. Factory-default settings associate specific relay functions with these direct-action pushbuttons and LEDs. Using SELOGIC control equations or front-panel settings PB*n*_HMI, you can readily change the default direct-action pushbutton functions and LED indications to fit your specific control and operational needs. Change the pushbutton and pushbutton LED labels with the slide-in labels adjacent to the pushbuttons. The asserted and deasserted colors for the LEDs are programmable in 12-pushbutton models.

The relay front panel includes an EIA-232 serial port (labeled **PORT F**) for connecting a communications terminal or using the ACSELERATOR QuickSet SEL-5030 Software program. Use the common EIA-232 open ASCII communications protocol to communicate with the relay via front-panel **PORT F**. Other communications protocols available with the front-panel port are MIRRORED BITS communications, and DNP3. For more information on communications protocols and **PORT F**, see *Section 15: Communications Interfaces*.

Front-Panel LCD

The LCD is the prominent feature of the relay front panel. *Figure 4.4* shows the following areas contained in the LCD:

- ➤ Title area
- ➤ Main area
- ➤ Message area
- ➤ Scroll bars

The scroll bars are present only when a display has multiple screens.

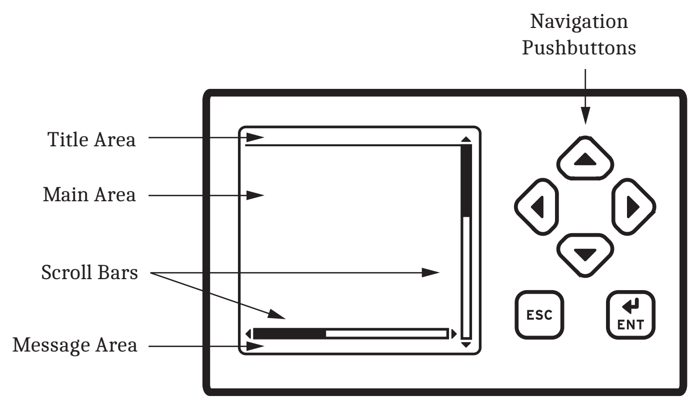


Figure 4.4 LCD and Navigation Pushbuttons

Front-Panel Inactivity Time-Out

An LCD backlight illuminates the screen when you press any front-panel pushbutton. This backlight extinguishes after a front-panel inactivity time-out period. You can control the duration of the time-out with relay setting FP_TO, listed in *Table 4.1*.

To set FP_TO, use the SET F (set front panel) settings from any communications port or use the Front Panel branch of the QuickSet Settings tree view. The maximum backlight time is 60 minutes (FP_TO = 60). When the front panel times out, the relay displays an automatic `ROTATING DISPLAY`, described later in this section under *Screen Scrolling on page 4.5*.

Table 4.1 Front-Panel Inactivity Time-Out Setting

Name	Description	Range	Default
FP_TO	Front-panel display time-out	OFF, 1–60 minutes	15 minutes

Navigating the Menus

The relay front panel presents a menu system for accessing metering, settings, and control functions. Use the LCD and the six pushbuttons adjacent to the display (see *Figure 4.4*) to navigate these front-panel menus.

The navigation pushbutton names and functions are the following:

- ➤ **ESC**—Escape pushbutton
- ➤ **ENT**—Enter pushbutton
- ➤ **Left Arrow**, **Right Arrow**, **Up Arrow**, and **Down Arrow**—Navigation pushbuttons

Menus show lists of items that display information or control the relay. A rectangular box around an action or choice indicates the menu item you have selected. This rectangular box is the menu item highlight.

Figure 4.5 shows an example of RELAY ELEMENTS highlighted in an example MAIN MENU. When you highlight a menu item, pressing the **ENT** pushbutton selects the highlighted item.

```
MAIN MENU
METER
EVENTS
BREAKER MONITOR
RELAY ELEMENTS
LOCAL CONTROL
SET/SHOW
RELAY STATUS
VIEW CONFIGURATION
DISPLAY TEST
RESET ACCESS LEVEL
```

Figure 4.5 RELAY ELEMENTS Highlighted in Example MAIN MENU

The **Up Arrow** pushbutton and **Down Arrow** pushbutton scroll the highlight box to the previous or next menu selection, respectively. When there is more than one screen of menu items, pressing the **Up Arrow** while at the first menu item causes the display to show the previous set of full-screen menu items, with the last menu item highlighted. Pressing the **Down Arrow** while at the bottom menu item causes the display to show the next set of full-screen menu items, with the first menu item highlighted.

Pressing the **ESC** pushbutton reverts the LCD to the previous screen. Pressing **ESC** repeatedly returns you to the MAIN MENU. If a status warning, alarm condition, or event condition is active (not acknowledged or reset), the relay displays the full-screen status warning, alarm screen, or trip event screen in place of the MAIN MENU.

Screen Scrolling

SEL-400 series relays have two screen scrolling modes: autoscrolling mode and manual-scrolling mode. After front-panel time-out, the LCD presents each of the display screens in this sequence:

- One-line diagram (if applicable)
- Any active (filled) alarm points screens
- Any active (filled) display points screens
- Other enabled screens

See the product-specific instruction manual for the details of the other screens that are supported and how they are enabled.

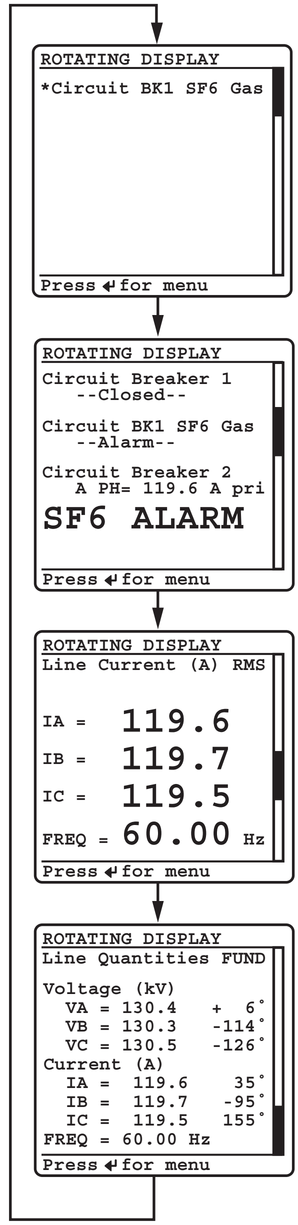


Figure 4.6 Sample ROTATING DISPLAY

Figure 4.6 illustrates an example rotating display sequence. The active alarm points are the first screens in the ROTATING DISPLAY (see *Alarm Points on page 4.7*). Each alarm points screen shows as many as 11 alarm conditions. The relay can present a maximum of six alarm points screens.

NOTE: The SEL-487E supports 256 display points. The SEL-487V supports 96 display points.

The active display points are the next screens in the ROTATING DISPLAY after alarm points (see *Display Points on page 4.10*). Each display points screen shows as many as 11 enabled display points (with 192 display points, the relay can present a maximum of 18 display points screens). If a display point does not have text to display, the screen space for that display point is maintained.

Autoscrolling Mode

Autoscrolling mode shows each screen for a user-configurable period of time. Front Panel setting SCROLD defines the period of time for which each screen is shown. When you first apply power to the relay, the LCD shows the autoscrolling ROTATING DISPLAY. With SCROLD := OFF, the screen remains on the first screen in the rotating display order; automatic rotation of additional screens is disabled.

The autoscrolling ROTATING DISPLAY also appears after a front-panel inactivity time-out (see *Front-Panel Inactivity Time-Out on page 4.4*). The relay retrieves data prior to displaying each new screen. The relay does not update screen information during the display interval. At any time during autoscrolling mode, pressing **ENT** takes you to the MAIN MENU. Pressing any of the four navigation pushbuttons switches the display to manual-scrolling mode.

Manual-Scrolling Mode

In manual-scrolling mode, you can use the directional navigation arrow pushbuttons to select the next or previous screen. Pressing the **Down Arrow** or **Right Arrow** pushbuttons switches the display to the next screen; pressing the **Up Arrow** or **Left Arrow** pushbuttons switches the display to the previous screen.

In manual-scrolling mode, the display shows arrows at the top and bottom of the vertical scroll bar. The screen arrows indicate that you can navigate between the different screens at will. The relay retrieves data prior to displaying each new screen. Unlike the autoscrolling mode, the relay continues to update screen information while you view it in the manual-scrolling mode. To return to autoscrolling mode, press **ESC** or wait for a front-panel time-out.

Alarm Points

You can display messages on the front-panel LCD that indicate alarm conditions in the power system. The relay uses alarm points to place these messages on the LCD.

Figure 4.7 shows a sample alarm points screen. The relay is capable of displaying as many as 66 alarm points. The relay automatically displays new alarm points while in manual-scrolling mode and in autoscrolling mode. While you navigate the HMI menu structure, the relay does not automatically display the alarm points. Instead, ALARM EVENT displays in the footer. When you escape the HMI menu structure, the relay will display the alarm points screen.

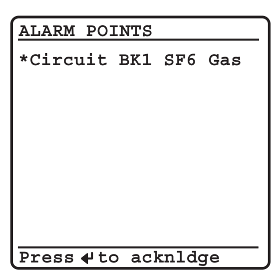


Figure 4.7 Sample Alarm Points Screen

The alarm point setting is an element of the SER settings. To enable an alarm point, enable the HMI alarm parameter of the SER Point Settings listed in *Table 4.2*. The format for entering the SER point data is the following comma-delimited string:

Relay Word Bit, Reporting Name, Set State Name, Clear State Name, HMI Alarm

Names can contain any valid ASCII character. Enclose the name within quotation marks. See *Example 4.1* for particular information on the format for entering SER point data.

Table 4.2 SER Point Settings

Description	Range
Relay Word Bit	Any valid relay element
Reporting Name	20-character maximum ASCII string
SET State Name (logical 1)	20-character maximum ASCII string
CLR State Name (logical 0)	20-character maximum ASCII string
HMI Alarm	Y, N

If you enter a Relay Word bit that does not match a valid relay element, the relay displays: `Unknown relay word reference`. If you enter an alias or name that is too long, the relay displays: `Alias label too long`.

The relay displays alarm points in a similar fashion as the SER. As many as 19 characters of the given alias are displayed, with one character reserved for the "*." The asterisk denotes if the element is asserted. Initially, an alarm point must be asserted to be displayed; after the corresponding element deasserts, the asterisk is removed, but the alias is not. The relay displays alarm points in reverse chronological order, just as in the SER, with the most recently asserted alarm displayed on the top. Deasserted alarms may be removed from the display with user acknowledgment, as shown in *Example 4.1*.

Example 4.1 Creating an Alarm Point

Alarm points screens provide operator feedback about the status of system conditions. An alarm points screen contains 11 alarm points; this example demonstrates a method to set the alarm point message that is shown in *Figure 4.7*. This example is based on the Relay Word bit IN101 asserting when Circuit Breaker 1 is in an alarm condition.

In the Report settings (SET R), enter the following after the SER Points Line 1 prompt:

1: **IN101,"Circuit BK1 SF6 Gas","Alarm","Normal","Y"**

The circuit breaker alarm condition is indicated by the set state, "Alarm" and the circuit breaker normal condition is indicated by the clear state "Normal." The HMI Alarm parameter is set to "Y" to enable alarm points screen display of this element.

While in the scrolling mode, the assertion of IN101 will cause the alarm points screen (as shown in *Figure 4.7*) to be automatically displayed. Upon the deassertion of IN101, the asterisk will disappear, as shown in *Figure 4.8*.

Example 4.1 Creating an Alarm Point (Continued)

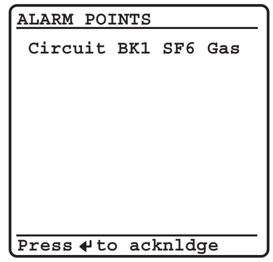


Figure 4.8 Deasserted Alarm Point

Pressing the ENT pushbutton will allow the user to acknowledge and clear deasserted alarms. Before clearing, you will be prompted to confirm that this is the intended action, as shown in *Figure 4.9*.

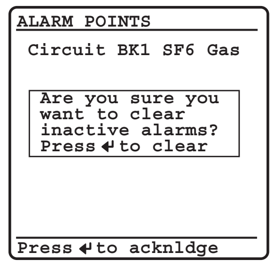


Figure 4.9 Clear Alarm Point Confirmation Screen

In the case that all alarms are deasserted, pressing the ENT pushbutton will allow the user to acknowledge and clear all alarms. After clearing, a screen showing the results of the action will be shown, as in *Figure 4.10*.

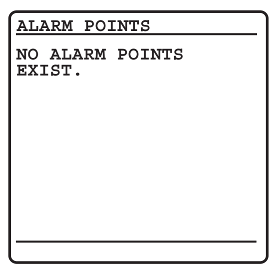


Figure 4.10 No Alarm Points Screen

Alarm points are not updated for a particular element if it has been deleted from the SER because of chatter criteria (see *Automatic Deletion and Reinsertion on page 9.31*). Upon reinsertion, the element state will be updated on the alarm point display. If the relay enters a period of SER data loss, the status of alarm points cannot be determined. The screen shown in *Figure 4.11* will appear until you exit the data loss condition, at which point the alarm point elements will be polled and displayed if asserted. Subsequent alarm point assertions will be displayed above the data loss message.

Example 4.1 Creating an Alarm Point (Continued)

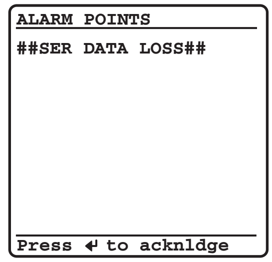


Figure 4.11 Alarm Points Data Loss Screen

Display Points

You can display messages on the relay front-panel LCD that indicate conditions in the power system. The relay uses display points to place these messages on the LCD.

Figure 4.12 shows a sample display points screen. Display points can show the status of Relay Word bits or display the value of analog quantities. The relay has 192 possible display points; *Table 4.3* and *Table 4.4* list the display points settings. The relay updates the display points data once per second if you are viewing the display points in manual-scrolling mode; in autoscrolling mode the relay updates the display points information each time the screen appears in the ROTATING DISPLAY sequence.

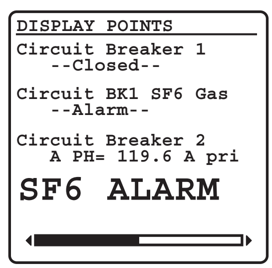


Figure 4.12 Sample Display Points Screen

To enable a display point, enter the display point settings listed in *Table 4.3* or *Table 4.4*. All display points occupy one, and only one, line on the display at all times. The height of the line is determined by the “Text Size” setting parameter. Display points of single-line height span one screen in total width. Display points of double-line height span two screens in total width. You can use multiple display points to simulate multiple lines.

Use the following syntax to display the given Relay Word bit exactly as seen in the navigational menu (name and value).

DPxx := **Name**

Use the following syntax to display the given Relay Word bit as seen in the navigational menu, replacing the name of the value with the given alias string. The text size determines if the display will be in single font or double font. If the text size is empty, the display will be in single font.

DPxx := **Name, “Alias”, “Text Size”**

Use the following syntax to display the given Relay Word bit with the given alias. If the Relay Word bit is asserted (logical 1), the LCD displays the set string in the place of the value. If the Relay Word bit is deasserted (logical 0), the LCD displays the clear string in the place of the value. One or all of Alias, Set String, or Clear String can be empty. If Alias is empty, then the LCD displays only the Set or Clear Strings. If either Set String or Clear String is empty, then an empty line is displayed when the bit matches that state. The text size determines if the display will be in single font or double font. If the text size is empty, the display will be in single font.

DPxx := **Name, “Alias”, “Set String”, “Clear String”, “Text Size”**

Use the following syntax to display the given analog quantity with the given text and formatting. Formatting must be in the form Width.Decimal,Scale with the value of Name, scaled by “Scale,” formatted with total width “Width” and “Decimal” decimal places. The width value includes the decimal point and sign character, if applicable. The “Scale” value is optional; if omitted, the scale factor is processed as 1. If the numeric value is smaller than the field size requested, the field is padded with spaces to the left of the number. If the numeric value will not fit within the field width given, “$” characters are displayed. The text size determines if the display will be in single font or double font. If the text size is empty, the display will be in single font.

DPxx := **Name, “(Text1 Width.Decimal,Scale) Text2”, “Text Size”**

Table 4.3 Display Point Settings—Boolean

Description	Range
Relay Word Bit Name	See the relay-specific instruction manual for a list of Relay Word bits available in that relay.
Alias	ASCII string
Set String	ASCII string
Clear String	ASCII string
Text Size	S, D

Table 4.4 Display Point Settings—Analog

Description	Range
Analog Quantity Name	See the relay-specific instruction manual for a list of available analog quantities
“User Text and Formatting”	ASCII string
Text Size	S, D

Table 4.5 Display Point Settings—Boolean and Analog Examples (Sheet 1 of 2)

Example Display Point Setting Value	Example Display
IN101	`IN101=1` `IN101=0`
MWHAIN,“{7.2}”	`1234.56`
50P1,Overcurrent,,	`Overcurrent=1` `Overcurrent=0`
PSV01,Control,On,Off	`Control=On` `Control=Off`
PSV02,Breaker,Tripped,	`Breaker=Tripped` *Empty Line*

Table 4.5 Display Point Settings—Boolean and Analog Examples (Sheet 2 of 2)

Example Display Point Setting Value	Example Display
50P1,,,Overcurrent	*Empty Line* `Overcurrent`
MWHAIN,“A Ph Import={7.2}”	`A Ph Import=1234.56`
MWHAIN,“A Ph Import={7.3}”	`A Ph Import=$$$.$$$`
MWHAIN,“A Ph Imp {4}MWh”	`A Ph Imp 1234MWh`
PAD,“{7.2}”	`1234.56`
PAD,“A Ph Dem Pwr={4.1}”	`A Ph Dem Pwr=1234.5`
ICD,“C Demand={5}”	`C Demand= 1230`
ICD,“C Demand={4.2,0.001} kA”	`C Demand=1.23 kA`
MWHAOUT,“A Phase Out={3, 1000}”	`A Phase Out=1234`
MWHAOUT,“A Phase Out={3, 1000} kWH”	`A Phase Out=$$$ kWh`
1,“Fixed Text”	`Fixed Text`
0,“Fixed Text”	`Fixed Text`
1,	*Empty Line*
0,	*Empty Line* *Display Point is hidden*

If you enter a Relay Word bit or Analog Quantity that does not match a valid relay element, the relay displays: `Invalid element`. If you enter a display point that exceeds the allowable length, the relay displays: `Too many characters`. If you enter an invalid scale factor, invalid width, too many parameters, or omit necessary quotation marks or brackets, the relay displays an error message. If a display point was used previously and you want to remove the display point, you can delete the display point. In the Front Panel settings (SET F), at the Display Points and Aliases prompt, use the text-edit mode line editing commands to set the display points (see *Text-Edit Mode Line Editing on page 3.23* for information on text-edit mode line editing). To delete Display Point 1, type **DELETE <Enter>** at the Front Panel settings Line 1 prompt.

Example 4.2 Creating a Display Point

Display points screens can be used to provide operator feedback about the readiness of equipment connected to the relay. A display points screen contains 11 display points; this example demonstrates a method to set the display point messages that are shown in *Figure 4.12*. This example uses an SEL-451 with an additional I/O interface board.

This example is based on a three-pole circuit breaker. Relay Word bit 52AA1 will assert when Circuit Breaker 1 is in the closed position.

IN109 will assert when Circuit Breaker 1 is in an alarm condition. B2IAFIM is the filtered instantaneous magnitude for the A-Phase current through Circuit Breaker 2.

In the Front Panel settings (**SET F**), enter the following after the Display Points and Aliases Line 1 prompt:

1: **1,“Circuit Breaker 1”**

2: **52AA1,,“ --Closed--”,“ --Open--”**

Example 4.2 Creating a Display Point (Continued)

3: **0**

4: **0,“Circuit BK1 SF6 Gas”**

5: **IN109,,“ --Alarm--”,“ --Normal--”**

6: **1**

7: **1,“Circuit Breaker 2”**

8: **B2IAFIM,“ A PH=(6.1,1) A pri”**

9: **IN109,, “SF6 ALARM”, D**

Fixed text is set by assigning an alias to a “1” or “0.” Blank lines are set by assigning a blank alias to a “1” or “0.” The circuit breaker closed condition is indicated by the set state, “--Closed--” where leading spaces are added to center the set state message. Add a clear state named “--Open--” to show that the circuit breaker is open. The circuit breaker alarm condition is indicated by the set state, “--Alarm--” where leading spaces are added to center the set state message. Add a clear state named “--Normal--” to show that the circuit breaker is not in alarm. User text “A PH=” and “A pri” allows for customized display of the Circuit Breaker 2 A-Phase current, which has been formatted to display numerically as XXXX.X. Double font display is used to give greater visibility to the SF6 Alarm. A horizontal scroll appears while in manual-scrolling mode regardless of whether or not the display point label width requires two full screens to display.

Example 4.3 Monitoring Test Modes With Display Points

This example uses the Relay Word bit TESTFM (Fast Meter test running) to activate a front-panel display point that alerts an onsite operator that the relay is in Fast Meter test mode.

In the Front Panel settings (**SET F**), enter the following after the Line 10 prompt:

10: **TESTFM,,“FAST METER TEST!!!!”**

The LCD displays the screen shown in *Figure 4.13* as a part of the ROTATING DISPLAY if the Fast Meter test is running. (Instruct the operator to view the relay front panel for messages or warnings as the last item on a “Leaving the Substation” checklist.)

Again, this display point application example does not require a clear state, so the clear state is blank. If the Fast Meter test is not running and no other display points are active, the relay shows a blank screen in the ROTATING DISPLAY.

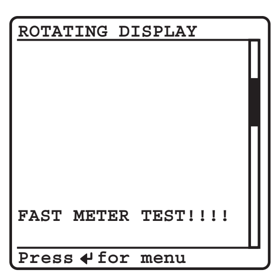


Figure 4.13 Fast Meter Display Points Sample Screen

Front-Panel Menus and Screens

Operate the relay front panel through a sequence of menus that you view on the front-panel display. The MAIN MENU is the introductory menu for other front-panel menus (see *Figure 4.5*). These additional menus allow you onsite access to metering, control, and settings for configuring the relay to your specific application needs. The following menus and screens are representative of what is typically found in SEL-400 series relays, but each relay has a slightly different list. See the relay-specific instruction manual to see what is available in that relay.

- Support Screens
  - Contrast
  - Password
- MAIN MENU
  - METER
  - EVENTS
  - BREAKER MONITOR
  - RELAY ELEMENTS
  - LOCAL CONTROL
  - SET/SHOW
  - RELAY STATUS
  - VIEW CONFIGURATION
  - DISPLAY TEST
  - RESET ACCESS LEVEL
  - ONE LINE DIAGRAM

Support Screens

The relay displays special screens over the top of the menu or screen that you are using to control the relay or view data. These screens are the ADJUST CONTRAST screen and the PASSWORD REQUIRED screen.

Contrast

You can adjust the LCD screen contrast to suit your viewing angle and lighting conditions. To change screen contrast, press and hold the **ESC** pushbutton for one second. The relay displays a contrast adjustment box superimposed over the display.

Figure 4.14 shows the contrast adjustment box with the MAIN MENU screen in the background. Pressing the **Right Arrow** pushbutton increases the contrast. Pressing the **Left Arrow** pushbutton decreases the screen contrast. When finished adjusting the screen contrast, press the **ENT** pushbutton.

Figure 4.14 Contrast Adjustment

Password

⚠WARNING
This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.

The relay uses passwords to control access to settings and control menus. The relay has six access-level passwords. See *Access Levels and Passwords on page 3.7* for more information on access levels and setting passwords. The relay front panel is at Access Level 1 upon initial power-up and after front-panel time out.

Password validation occurs only when you request a menu function that is at a higher access level than the presently authorized level. At this point, the relay displays a password entry screen, shown in *Figure 4.15*. This screen has a blank password field and an area containing alphabetic, numeric, and special password characters with a movable highlight box.

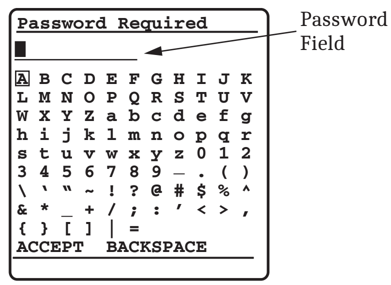


Figure 4.15 Enter Password Screen

Enter the password by pressing the navigation pushbuttons to move the highlight box through the alphanumeric field. When at the desired character, press **ENT**. The relay enters the selected character in the password field and moves the dark box cursor one space to the right. You can backspace at any time by highlighting the `BACKSPACE` character and then pressing **ENT**. When finished, enter the password by highlighting the `ACCEPT` option and then pressing **ENT**.

If you entered a valid password for an access level greater than or equal to the required access level, the relay authorizes front-panel access to the combination of access levels (new level and all lower levels) for which the password is valid. The relay replaces the password screen with the menu screen that was active before the password validation routine. When you enter Access Levels B, P, A, O, and 2, the Relay Word bit SALARM pulses for one second.

If you did not enter a valid password, the relay displays the error screen shown in *Figure 4.16*. Entering a valid password for an access level below the required access level also causes the relay to generate the error screen. In both password failure cases, the relay does not change the front-panel access level (it does not reset to Access Level 1 if at a higher access level). The relay displays the `PASSWORD INVALID` screen for five seconds. If you do not want to wait for the relay to remove the message, press any of the six navigational pushbuttons during the five-second error message to return to the previous screen in which you were working.

Figure 4.16 Invalid Password Screen

If three failed login attempts occur within a 1-minute interval, the relay disables login attempts for 30 seconds and pulses the SALARM and BADPASS Relay Word bits for 1 second. If the user tries to login within the 30 seconds, the error message in *Figure 4.17* displays for 4 to 6 seconds. Pressing the navigation buttons while this message is displayed removes the error message sooner but the password entry remains disabled for the original 30 seconds.

```
Access Denied


Maximum Passord
Attempts Exceeded,
Access Temporarily
Denied
```

Figure 4.17 Password Lockout Screen

Main Menu

The MAIN MENU is the starting point for all other front-panel menus. A representative relay MAIN MENU is shown in *Figure 4.18*. When the front-panel LCD is in the ROTATING DISPLAY, press the **ENT** pushbutton to show the MAIN MENU.

```
MAIN MENU
METER
EVENTS
BREAKER MONITOR
RELAY ELEMENTS
LOCAL CONTROL
SET/SHOW
RELAY STATUS
VIEW CONFIGURATION
DISPLAY TEST
RESET ACCESS LEVEL
```

Figure 4.18 MAIN MENU

Meter

The relay displays metering screens on the LCD. Highlight METER and press **ENT** on the MAIN MENU screen to select these screens. The metering screens available are relay-specific and are described in each relay-specific instruction manuals.

Events

The relay front panel features summary event reporting, which simplifies post-fault analysis. These summary event reports include all trip events, event and data capture triggering (via the ER SELOGIC control equation), and manual triggers. The relay displays event reports based on the Relay Word bit elements in the ER (event report trigger) SELOGIC control equation. See *Event Report on page 9.14* for more information on event reports.

The front-panel event buffer size is 100 summaries. The relay numbers summary events in order from 10000 through 42767 and displays the most recent summaries on the LCD.

You can view summary event reports from the relay front-panel display by selecting `EVENTS` from the `MAIN MENU`. The relay presents the `Events Menu` as shown in *Figure 4.19*. Select `Event Summary` from the `Events Menu` to view event summary data. *Figure 4.20* shows sample `Event Summary` screens for a phase-to-phase-to-ground fault. Use the **Right Arrow** and **Left Arrow** pushbuttons to show each of the summary screens for the event. Event reports can also be viewed via a front-panel automatic message (see *Front-Panel Automatic Messages on page 4.32*) or programmable front-panel operator control pushbutton (see *Front-Panel Operator Control Pushbuttons on page 4.35*).

```
Events Menu
Event Summary
SER Events
```

Figure 4.19 Events Menu Screen

The horizontal scroll bar indicates that you can view other event 10002 screens. Use the **Up Arrow** and **Down Arrow** pushbuttons to move among the events in the summary buffer. Press **ESC** to return to the `Events Menu` and **ESC** again to return to the `MAIN MENU`.

```
EVENT SUMMARY 10002
03/15/2001   GROUP 1
00:00:05.387

EVENT:          BCG T
LOCATION:       48.47
FREQ:           60.00
SHOT:            3P=1
BK1   OPEN
BK2 CLOSED
```

```
EVENT SUMMARY 10002
TARGETS:
COMM
PHASE B
PHASE C
GROUND
50
```

```
EVENT SUMMARY 10002
FAULT QUANTITIES
(kV/A)
VA =    131     0.7°
VB =    113  -123.4°
VC =    113   124.7°

IA =    200    -0.5°
IB =   2478   172.3°
IC =   2480     6.7°
IG =    212   -11.3°
```

Figure 4.20 Example EVENT SUMMARY Screens

SER

The Sequential Events Recorder (SER) records state changes of user-programmable Relay Word bits. State changes are time-tagged for future analysis of relay operations during an event. See *Sequential Events Recorder (SER) on page 9.28* for more information on SER events. To view SER events from the front panel, select `EVENTS` from the `MAIN MENU` and `SER Events` from the `Events Menu` as shown in *Figure 4.19*. SER events are also viewable using programmable front-panel operator control pushbuttons; see *Front-Panel Operator Control Pushbuttons on page 4.35*.

Figure 4.21 illustrates the SER Events display screen. Data reported in this screen for each event are the SER Point Alias Name, Asserted or Deasserted state, and the Date and Time of the event. When in the `SER Events` screen, three SER records are displayed on one screen. Using the navigation pushbuttons, the most recent 200 SER events are viewable on the front-panel display. The top event is the most recent event, and the bottom event is the oldest. The upper right of the screen displays the sequential indexes of the SER events currently being viewed. If a new event occurs while viewing the SER events, the display does not update with the new event automatically. To include the new SER event in the display, exit the SER screen by pressing **ESC** and re-enter the `SER Events` screen by pressing **ENT** with the `SER Events` selection highlighted. This rebuilds the `SER Events` display and contains the latest SER events triggered.

```
SER Events   001-003
Local
Disabled
02/16/06 11:11:01.993

Local
Enabled
02/16/06 10:11:19.090

IN101
Asserted
02/16/06 03:22:01.988
```

Figure 4.21 SER Events Screen

If no SER events are available, the message shown in *Figure 4.22* is displayed.

```
SER Events

     No SER Events
       Available
```

Figure 4.22 No SER Events Screen

While viewing the SER events, front-panel pushbuttons provide navigation and control functions as indicated in *Table 4.6*.

Table 4.6 Front-Panel Pushbutton Functions While Viewing SER Events

Pushbutton	Description
Up Arrow, Down Arrow	Navigates one screen at a time up or down. Each screen contains three SER events. Accelerated scrolling is obtained when the pushbutton remains pressed (see accelerated scrolling behavior below).
Left Arrow, Right Arrow	Navigates between SER events to allow adjacent SER events to be displayed on one screen. For example, if events 1, 2, and 3 are displayed, press the **Right Arrow** once to display events 2, 3, and 4 in the same screen. No accelerated scrolling is provided with the **Left Arrow** and **Right Arrow** pushbuttons.
ESC	Returns to the `Events Menu`
ENT	Does nothing

Hold down either the **Up Arrow** or **Down Arrow** to achieve accelerated scrolling. Holding down the **Up Arrow** or **Down Arrow** navigates one screen at a time for the first five screens, and then increases to five screens at a time if the button remains pressed. Accelerated scrolling stops at the newest or oldest SER event record available, depending on the direction of the scrolling.

When the upper limit of the SER events is reached, press the **Down Arrow** one more time and the report will wrap around to display the screen containing the first SER event. Similarly, when the lower limit of the SER events is reached, press the **Up Arrow** one more time and the report will wrap around to display the screen containing the last SER event.

By default, three SER events are shown per screen. You can change this to five per screen by setting SER_PP to Y. This will cause the element name and state information to be shown on the same line, with the element name truncated to ten characters and the state truncated to eight characters.

Breaker Monitor

Some SEL-400 series relays feature an advanced circuit breaker monitor. Select BREAKER MONITOR from the MAIN MENU to view circuit breaker monitor alarm data on the front-panel display. See the relay-specific instruction manual for the supported options and example screens.

Relay Elements (Relay Word Bits)

You can view the RELAY ELEMENTS screen to check the state of the Relay Word bits in the relay. The relay has two unique manual-scrolling features for viewing these elements:

- ➤ Accelerated navigation
- ➤ Search

These Relay Word bit scrolling features make selecting elements from among the many relay targets easy and efficient. *Figure 4.23* shows an example of the RELAY ELEMENTS screen. If an alias exists for an element, the alias name is displayed instead of the element name. An asterisk character (*—shown in *Figure 4.23*) indicates that this Relay Word bit position is reserved for future use.

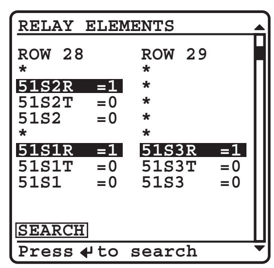


Figure 4.23 RELAY ELEMENTS Screen

When you move item by item through the Relay Word bit table, pressing the **Up Arrow** or **Down Arrow** pushbuttons shows each previous or next screen in turn.

Accelerated navigation occurs when you press and hold the **Up Arrow** or **Down Arrow** pushbuttons. Holding the **Up Arrow** or **Down Arrow** pushbuttons repeats the regular pushbutton action at two rows every second for the first ten rows. Continue pressing the **Up Arrow** or **Down Arrow** pushbutton to cause the relay screen scrolling to accelerate to 20 rows per second. When you are scrolling up in accelerated scrolling, scrolling will stop at the first relay elements screen. When you are scrolling down, scrolling will stop at the last screen.

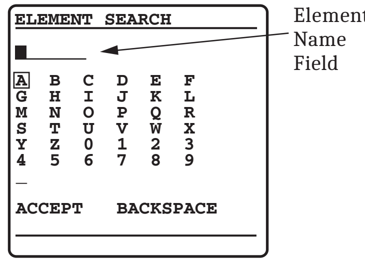


Figure 4.24 ELEMENT SEARCH Screen

Search mode allows you to find a specific relay target element quickly. *Figure 4.24* shows the menu screen that the relay displays when you select the `SEARCH` option of the `RELAY ELEMENTS` initial menu.

When you first enter this search menu, the block cursor is at the beginning of the element name field and the highlight box in the alphanumeric field is around the letter A. Use the navigation pushbuttons to move through the alphanumeric characters. If the highlight is on one of the characters, pressing **ENT** enters the character at the block cursor location in the element name field. Next, the block cursor moves automatically to the character placeholder to the right. If the block cursor was already at the first character position on the left, the block cursor remains at the end of the name field. To backspace the cursor in the element name field, move the highlight to `BACKSPACE` and press **ENT**. When you have finished entering an element name, move the highlight to `ACCEPT` and press **ENT**. At any time, pressing **ESC** returns the display to the `RELAY ELEMENTS` screen.

If the highlight is on `ACCEPT`, the relay finds the matching relay element when you press **ENT**. The relay first searches for alias names, seeking an exact match. If the relay does not find an exact alias name match, it searches for an exact primitive name match. If there is no exact primitive name match, the relay initiates a partial alias name string search, followed by a partial primitive name string search. If the relay finds no match, the screen displays an error message and stays in the `ELEMENT SEARCH` screen. If the relay finds a match, the screen displays the element row containing the matching element.

Local Control

The relay provides great flexibility in power system control through the `LOCAL CONTROL` menus. You can use the front-panel `LOCAL CONTROL` menus to perform these relay functions:

- Trip and close circuit breakers (password required)
- Assert, deassert, and pulse relay control outputs to command station control actions
- Test relay outputs (password required)

In the first `LOCAL CONTROL` submenu of *Figure 4.25*, you can choose `BREAKER CONTROL`, `LOCAL BITS CONTROL`, or `OUTPUT TESTING`. You must install the circuit breaker control enable jumper to enable circuit breaker control and output testing capability. The submenu will not display the `--BREAKER CONTROL--` option and the `--OUTPUT TESTING--` option if the breaker jumper is not installed. (The relay checks the status of the breaker jumper whenever you activate the front-panel settings and at power-up.) If the breaker jumper is not installed, and there are no local bits enabled, the relay displays an information message when you attempt to enter `LOCAL CONTROL` and the screen returns to the `MAIN MENU` after a short delay.

Local bit names that you have programmed (see *Example 4.4*) appear in the local control bit names field between --BREAKER CONTROL-- and --OUTPUT TESTING--, as shown in *Figure 4.25*. Use the **Up Arrow** and **Down Arrow** pushbuttons to highlight the local control action you want to perform. Pressing **ENT** takes you to the specific LOCAL CONTROL screen.

```
LOCAL CONTROL
--BREAKER CONTROL--
Enable Bus Switching
North Bus MOD
South Bus MOD
Bus Tie Interlock
Alternate Settings 3
--OUTPUT TESTING--
```

Figure 4.25 LOCAL CONTROL Initial Menu

Breaker Control

The BREAKER CONTROL option presents a circuit breaker selection submenu if the relay is configured to control multiple breakers. Use the navigation pushbuttons and **ENT** to select the circuit breaker you want to control.

Figure 4.26 shows the BREAKER CONTROL submenu and sample circuit breaker control screens for BREAKER 1. Use the **Up Arrow** and **Down Arrow** pushbuttons to highlight the TRIP BREAKER 1 or CLOSE BREAKER 1 control actions.

When you highlight the trip option and press **ENT**, the relay displays the confirmation message OPEN COMMAND ISSUED and trips Circuit Breaker 1 (Relay Word bit OC1 pulses). The BREAKER 1 STATUS changes to OPEN.

When you highlight the close option and press **ENT**, the relay displays the confirmation message CLOSE COMMAND ISSUED and closes Circuit Breaker 1 (Relay Word bit CC1 pulses). The BREAKER 1 STATUS changes to CLOSED. (Be aware that not all SEL-451 relays support breaker close operations.)

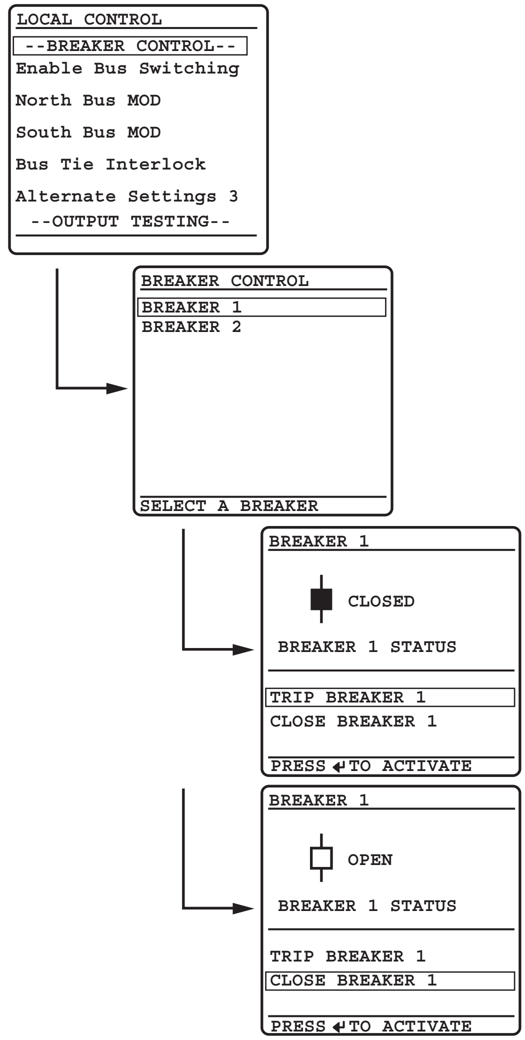


Figure 4.26 Example BREAKER CONTROL Screens

Local Control Bits

NOTE: The SEL-487E supports 96 local bits.

NOTE: The default settings for LB_SPnn are "1". The default settings satisfy the local bit supervision logic so that local bit operations can take place.

NOTE: The default settings for LB_DPnn are LBnn. The default settings cause the local bit switch to move to the corresponding state of the local bit (asserted = 1, deasserted = 0).

The relay provides 64 local control bits with SELOGIC control equation supervision. These local bits replace substation control handles to perform switching functions such as bus transfer switching. The relay saves the states of the local bits in nonvolatile memory and restores the local bit states at relay power-up.

Local control bit supervision is available through a SELOGIC control equation provided in the Front Panel settings (LB_SP*nn*). For local bit operations to take place, the corresponding LB_SP*nn* must be asserted. *Table 4.8* defines the local bit SELOGIC settings available in the Front Panel settings class. *Figure 4.28* illustrates the logic that supervises all local bit operations (Set, Clear, Pulse).

The SELOGIC control equation local bit status (LB_DP*nn*) is provided to return the status of a device that is being controlled by the local bit. The LB_DP*nn* Relay Word bit drives the state of the graphical switch on the display (i.e., with LB_DP*nn* deasserted, the switch points to 0).

Any unused local control bits default to the clear (logical 0) state. Also, any reconfigured local bit retains the existing bit state after you change the bit setting. Deleting a local bit sets that bit to the clear (logical 0) state.

In the top part of *Figure 4.27*, the following custom-labeled functions are those controlled by local control bit operation.

- ➤ Enable Bus Switching
- ➤ North Bus MOD
- ➤ South bus MOD
- ➤ Bus Tie Interlock
- ➤ Alternate Settings 3

In addition, *Figure 4.27* gives an example of a custom labeled function, Bus Tie Interlock. The LCD shows a graphic representation of a substation control handle. The LB_DP*nn* SELOGIC control equation determines the state of the switch position on the LCD. If the LB_DP*nn* Relay Word bit is deasserted, the graphic control handle points to 0; if the LB_DP*nn* Relay Word bit is asserted, the switch points to 1.

You can program names or aliases for the local bit clear and set states—these appear next to logical 0 and logical 1, respectively, in the lower portion of the sample Bus Tie Interlock screens of *Figure 4.27*. Use the **Up Arrow** and **Down Arrow** pushbuttons to highlight the set (1) or clear (0) control actions. Highlighting the set option (shown in *Figure 4.27* as `Closed (OK to TIE)`) and pressing **ENT** changes the local control bit and performs the required control action. If the LB_DP*nn* Relay Word bit asserts, the graphical switch moves to 1 to indicate the asserted local bit status.

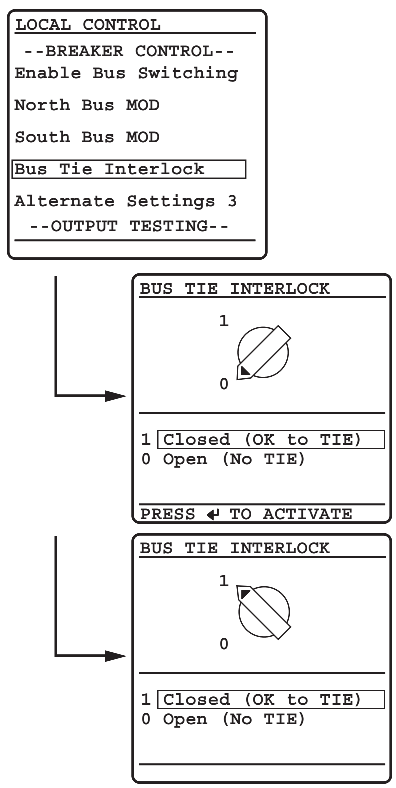


Figure 4.27 LOCAL CONTROL Example Menus

To enable a local bit, enter the local bit settings in *Table 4.7*. The format for entering the local bit data is the comma-delimited string:

local bit,control function name,alias for the set state,alias for the clear state,pulse enable

Names or aliases can contain any printable ASCII character except double quotation marks. Use double quotation marks to enclose the name or alias. See *Example 4.4* for particular information on enabling a local control bit.

NOTE: The SEL-487E supports 96 local bits.

Table 4.7 Local Bit Control Settings[a]

Description	Range	Default
Local Bit *n*	1–64	1
Local Bit *n* Name	20-character maximum ASCII string	(blank)
Local Bit *n* Set Alias (1 state)	20-character maximum ASCII string	(blank)
Local Bit *n* Clear Alias (0 state)	20-character maximum ASCII string	(blank)
Pulse Local Bit *n*	Y, N	N

[a] n = 1–64.

The pulse state enable setting at the end of the setting string is optional. If your application requires a pulsed or momentary output, you can activate an output pulse by setting the option at the end of the local bit command string to Y (for Yes). The default for the pulse state is N (for No); if you do not specify Y, the local bit defaults at N and gives a continuous set or clear switch level.

If you enter an invalid setting, the relay displays an error message prompting you to correct your input. If you do not enter a valid local bit number, the relay displays A local bit element must be entered. If you enter a local bit number and that local bit is already in use, the relay displays the local bit element is already in use. Likewise, if you do not enter valid local bit name, set alias, and clear alias, the relay returns an error message. If an alias is too long, the relay displays the message `Too many characters`.

Table 4.8 Local Bit SELOGIC[a]

Description	Range	Default
Local Bit Supervision *n*	SELOGIC Control Equation, NA	1
Local Bit Status Display *n*	SELOGIC Control Equation, NA	LB*n*

[a] n = 1–64, and only available if the corresponding local bit is defined.

The Local Bit Supervision SELOGIC control equation provides supervision of Local Bit Set, Clear, and Pulse operations.

The Local Bit Status Display SELOGIC control equation returns the status of the local bit switch state.

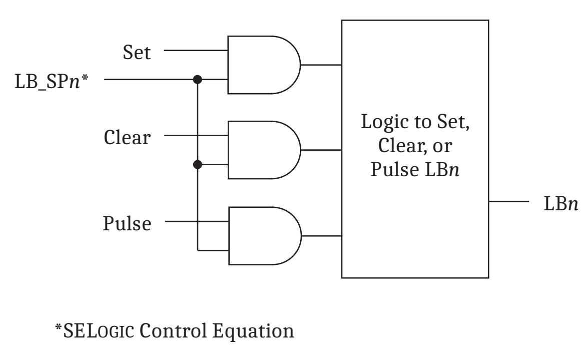


Figure 4.28 Local Bit Supervision Logic

Example 4.4 Enabling Local Bit Control

This application example demonstrates a method to create one of the control points in the LOCAL CONTROL screens of *Figure 4.27* to control the interlock on a power bus tie circuit breaker. Perform the following actions to create a local control bit:

- ➤ Eliminate previous usage of the local bit and condition the state of the local bit
- ➤ Set the local bit
- ➤ Assign the local bit to a relay output

If you are using a previously used local bit, delete all references to the local bit from the SELOGIC control equations already programmed in the relay. A good safety practice would be to disconnect any relay output that was programmed to that local bit.

To change the local bit state, select the bit and set it to the state you want. In addition, you can delete the local bit, which changes the state of this local bit to logical 0 when you save the settings. To delete, use the front-panel settings. When using a communications port and terminal, use the text-edit mode line setting editing commands at the Local Bits and Aliases prompt to go to the line that lists Local Bit 9. (See *Text-Edit Mode Line Editing on page 3.23* for information on text-edit mode line editing.) To delete Local Bit 9, type **DELETE <Enter>** after the line that displays Local Bit 9 information. For example, if a previously programmed Local Bit 9 appears in the **SET F** line numbered listings on Line 1, then typing **DELETE <Enter>** at Line 1 deletes Local Bit 9.

Next, set the local bit. In the Front Panel settings (SET F), enter the following:

1: **LB09,“Bus Tie Interlock”,“Closed (OK to TIE)”,“Open (No TIE)”,N**

This sets Local Bit 9 to “Bus Tie Interlock” with the set state as “Closed (OK to TIE)” and the clear state as “Open (No TIE).”

Assign the local bit to a relay output. In the Output settings (**SET O**), set the SELOGIC control equation, OUT201, to respond to Local Bit 9.

OUT201 := **LB09**

Use the appropriate interface hardware to connect the circuit breaker interlock to OUT201.

Output Testing

NOTE: The circuit breaker control enable jumper BREAKER must be installed to perform output testing.

You can check for proper operation of the relay control outputs by using the OUTPUT TESTING submenu of the LOCAL CONTROL menu. A menu screen similar to *Figure 4.29* displays a list of the control outputs available in your relay configuration.

```
OUTPUT TESTING
OUT201
OUT202
OUT203
OUT204
OUT205
OUT206
OUT207
OUT208
    PULSE OUTPUT?
     ◂NO  YES▸
PRESS ↵ TO PULSE
```

Figure 4.29 OUTPUT TESTING Screen

Set/Show

You can use the SET/SHOW menus to examine or modify relay port settings, Global settings, active Group settings, and date/time. See *Table 4.9* for a list of settings classes and settings that you can change from the front panel.

Table 4.9 Settings Available From the Front Panel

Class/Setting	Description
PORT	Relay communications port settings
GLOBAL	Global relay settings
GROUP	Relay Group settings
ACTIVE GROUP	Active settings group number 1–6
DATE/TIME	Date and time settings

Figure 4.30 shows an example of entering the SEL-451 setting CTRW (Terminal W CT ratio) from the front panel. At the MAIN MENU, select the SET/SHOW item and press **ENT**. The LCD screen displays the SET/SHOW screen as shown in *Figure 4.30*. You can use the navigation pushbuttons to select the relay settings class (PORT, GROUP, and GLOBAL) or to change the ACTIVE GROUP or the DATE/TIME. For this example, select the GROUP class.

Next, select the particular instance of the settings class. For the PORT settings class, the instances are PORT 1, PORT 2, PORT 3, PORT F, and PORT 5. For the GROUP class, the instances are the numbered groups from 1 through 6 and M, the breaker monitor (see the GROUP screen in *Figure 4.30*). The class GLOBAL, the setting ACTIVE GROUP = n (where *n* is a number from 1 to 6), and the settings for DATE/TIME have no settings instance screens. In the GROUP screen, move the highlight box to 3 and press **ENT**.

Proceed to selecting the settings category. The GROUP submenu in *Figure 4.30* is an example of settings Group 3 categories. Once you have highlighted the settings category, pressing **ENT** causes the relay to display the particular settings in that category. The LINE CONFIGURATION screen in *Figure 4.30* shows the settings that you can set in the line configuration settings category.

To edit or examine a setting, use the **Up Arrow** and **Down Arrow** pushbuttons to highlight that setting, then press **ENT**. The relay displays a settings entry screen with the existing setting value (see the SET CTRW screen in *Figure 4.30*). If the prompt for the selected setting does not fit on the line, the relay scrolls the setting prompt across the screen.

Enter the setting name by using a method similar to the method described in *Relay Elements (Relay Word Bits) on page 4.19*. Place characters in the element name field (with the block cursor) by using the navigation pushbuttons.

For the SEL-411L, SEL-421, SEL-451, and SEL-487E, if you are setting an element that supports combinations, and the number of possible combinations is small, the relay displays the possible combinations allowed for the setting that you can select. If there is a high number of possible combinations for a setting, a window of selectable ASCII characters displays (see the **Character or String or SELogic control equations** display in *Figure 4.31*), and you will need to input the necessary combination by using the ASCII character display.

If the data you entered are valid (within settings range checks), the front-panel display returns to the settings category screen that shows each setting and corresponding present value (see the LINE CONFIGURATION screen of *Figure 4.30*). If the data you entered are invalid, the relay displays an error message screen, then returns to the particular settings entry screen so you can attempt a valid settings entry (see the `CTRW` screen of *Figure 4.30*).

When finished entering the new settings data, press **ESC**. The relay prompts you with a `Save Settings` screen. Using the navigation pushbuttons, answer `YES` to make the settings change(s), or `NO` to abort the settings change(s).

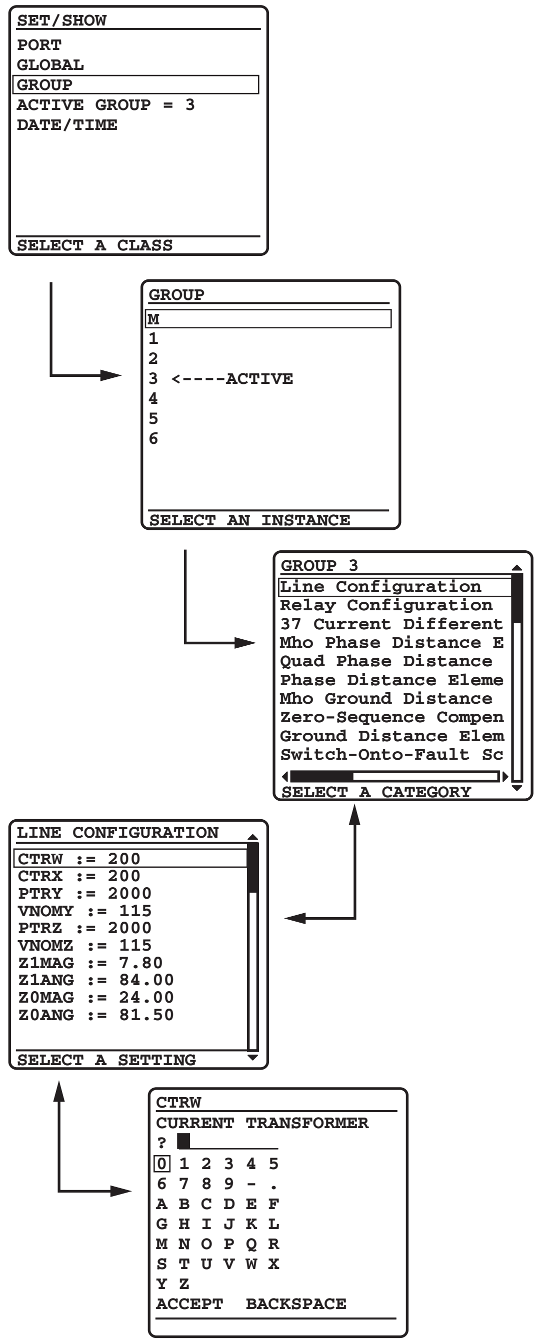
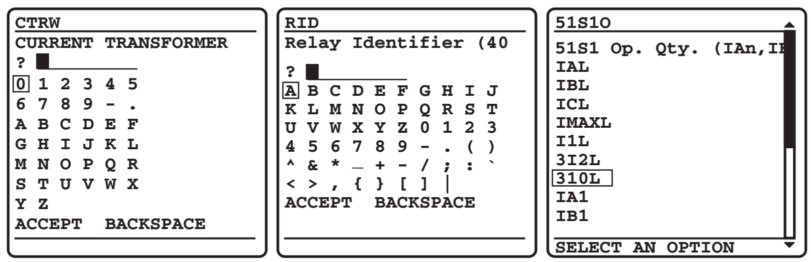


Figure 4.30 Example SET/SHOW Screens

The relay displays different settings entry screens depending on the settings type. For the CTRW setting in *Figure 4.30*, the relay requires basic alphanumeric input. Other settings can have other data input requirements. The front-panel settings input data types are the following:

- ➤ Basic alphanumeric
- ➤ Character or string or SELOGIC control equations
- ➤ Setting options

For alphanumeric settings, the relay presents the character or string input screen. Some settings have specific options; use the setting options screens to select these options. *Figure 4.31* shows examples of the settings input screens.



Basic Alphanumeric | Character or String or SELOGIC Control Equations | Setting Options

Figure 4.31 Sample Settings Input Screens

Active Group

Perform the following steps to change the active setting group:

Step 1. Select the ACTIVE GROUP option of the SET/SHOW submenu screen (shown in *Figure 4.30*) to change the settings group.

The relay performs a password validation test at this point to confirm that you have Breaker Access Level authorization or above.

Step 2. If access is allowed, and all the results of SELOGIC control equations SS1–SS6 are not logical 1 (asserted), then the relay displays the EDIT ACTIVE GROUP screen in *Figure 4.32*.

The relay shows the active group and underlines the group number after NEW GROUP =.

Step 3. Use the **Up Arrow** and **Down Arrow** pushbuttons to increase or decrease the NEW GROUP number.

Step 4. Once you have selected the new active group, press **ENT** to change the relay settings to this new settings group.

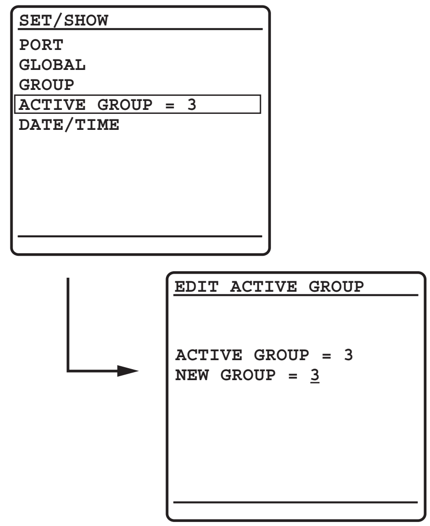


Figure 4.32 Changing the ACTIVE GROUP

Date/Time

Another submenu item of the SET/SHOW first screen (*Figure 4.30*) is the DATE/TIME screen shown in *Figure 4.33*. By default, the relay generates date and time information internally; you can also use external high-accuracy time modes with time sources such as a GPS receiver.

Figure 4.33 shows the relay date/time screen when a high-accuracy source is in use. Possible time sources, qqqqq, are listed in *Table 11.6*. If you use a high-accuracy time source, edits are disabled, the DATE/TIME display does not show the highlight, and the screen does not show the help message on the bottom line.

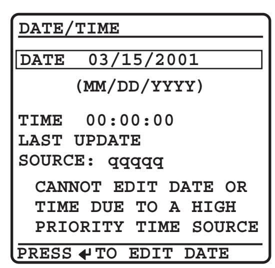


Figure 4.33 DATE/TIME Screen

When no external time source is connected, you can use the front-panel DATE and TIME entry screens to set the date and time.

Figure 4.34 shows an example of these edit screens. Use the **Left Arrow** and **Right Arrow** navigation pushbuttons to move the underscore cursor; use the **Up Arrow** and **Down Arrow** navigation pushbuttons to increment or decrement each date and time digit as appropriate to set the date and time. For a description of the LAST UPDATE SOURCE field, see *Configuring Timekeeping on page 3.64*.

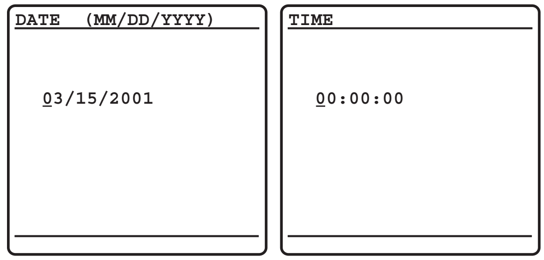


Figure 4.34 Edit DATE and Edit TIME Screens

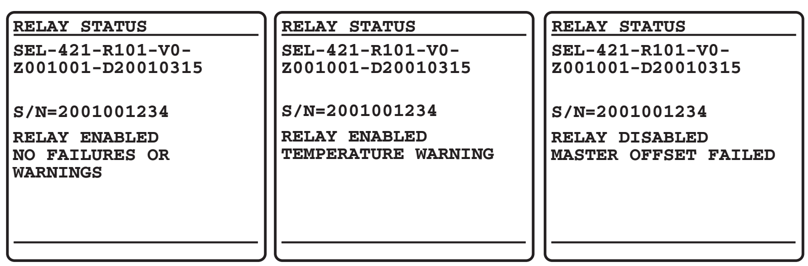
To enable a high-accuracy external time source, connect an IRIG-B or Precision Time Protocol (PTP) clock to the relay. For a discussion of the timing modes in the relay see *Section 11: Time and Date Management*.

Relay Status

The relay performs continuous hardware and software self-checking. If any vital system in the relay approaches a failure condition, the relay issues a status warning. If the relay detects a failure, the relay displays the status failure RELAY STATUS screen immediately on the LCD.

For both warning and failure conditions, the relay shows the error message for the system or function that caused the warning or failure condition. You can access the RELAY STATUS screen via the MAIN MENU. The RELAY STATUS screen shows the firmware identification number (FID), serial number, whether the relay is enabled, and any status warnings.

Figure 4.35 shows examples of a normal RELAY STATUS screen, a status warning RELAY STATUS screen, and a status failure RELAY STATUS screen. For more information on status warning and status failure messages, see *Relay Self-Tests on page 10.19*.



Normal | Status Warning | Status Failure

Figure 4.35 Relay STATUS Screens

View Configuration

You can use the front panel to view detailed information about the configuration of the firmware and hardware components in the relay. In the MAIN MENU, highlight the VIEW CONFIGURATION option by using the navigation pushbuttons. A series of screens will be presented describing the relay configuration. See the relay-specific instruction manual to see the specific information provided in that relay.

Display Test

You can use the DISPLAY TEST option of the MAIN MENU to confirm operation of all of the LCD pixels. The LCD screen alternates the on/off state of the display pixels once every time you press **ENT**. *Figure 4.36* shows the resulting two screens. The DISPLAY TEST option also illuminates all of the front-panel LEDs. To exit the test mode, press **ESC**.

NOTE: The LCD DISPLAY TEST does NOT reset the front-panel LED targets.

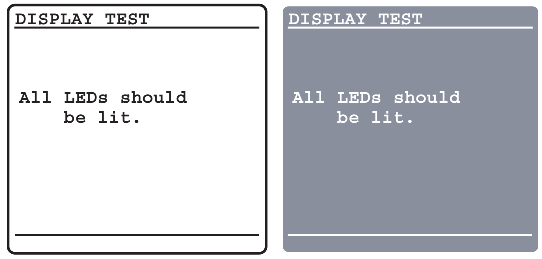


Figure 4.36 DISPLAY TEST Screens

Reset Access Level

The relay uses various passwords to control access to front-panel functions. As you progress through these menus, the relay detects the existing password level and prompts you for valid passwords before allowing you access to levels greater than Access Level 1 (see *Password on page 4.15*). When you want to return the front-panel to the lowest access level (Access Level 1), highlight RESET ACCESS LEVEL item on the MAIN MENU. Pressing **ENT** momentarily displays the screen of *Figure 4.37* and places the front panel at Access Level 1.

The relay automatically resets the access level to Access Level 1 upon front-panel time-out (setting FP_TO is not set to OFF). Use this feature to reduce the front-panel access level before the time-out occurs.

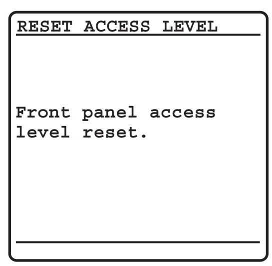


Figure 4.37 RESET ACCESS LEVEL Screen

One-Line Diagram

Most SEL-400 series relays support one-line diagrams on the front-panel LCD. The ONE-LINE DIAGRAM option from the front-panel MAIN MENU displays the one-line diagram that has been selected in the Bay settings class. From this screen, disconnect switch open and close operations, as well as breaker open and close operations can be performed. This screen also displays labels for the different apparatus in the bay configuration and Analog Quantity metering values. The one-line diagram, display labels, and Analog Quantities are settable in the Bay class settings. See *Figure 4.38* for an illustration of the one-line diagram.

For navigation and control operations in the one-line diagram screen, see *Bay Control Front-Panel Operations on page 5.12*.

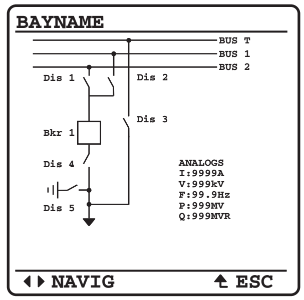


Figure 4.38 One-Line Diagram Screen

Front-Panel Automatic Messages

The relay automatically displays alert messages. Any message generated because of an alert condition takes precedence over the normal ROTATING DISPLAY and the MAIN MENU. Alert conditions include these significant events:

- ➤ Alarm Point asserts
- ➤ Event reports and trips (user-defined)
- ➤ Status warnings
- ➤ Status failures

To display event reports automatically from the ROTATING DISPLAY, you must set front-panel setting DISP_ER to Y. Front-panel setting TYPE_ER allows the user to define which types of event reports will be automatically displayed from the normal ROTATING DISPLAY; ALL will display all event types defined in the relay, and TRIP will display only the event types that include the assertion of the TRIP Relay Word bit.

For alarm point assertions, qualified event reports (including trip events) and status warnings, the relay displays the corresponding full-screen automatic message, only if the front-panel display is in the time-out or standby condition (the relay is scrolling through the default display points/enabled metering screens of the ROTATING DISPLAY or is displaying the MAIN MENU). When a status warning, alarm, or event is triggered, the relay full-screen presentation is similar to the screens of *Figure 4.39*.

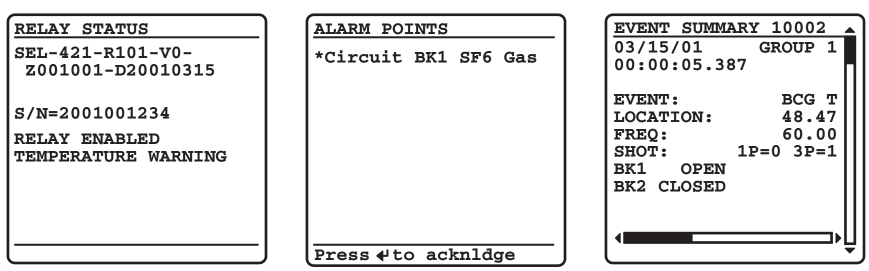


Figure 4.39 Sample Status Warning and Trip EVENT SUMMARY Screens

If you are on site using the relay front panel in menus and screens other than the MAIN MENU and a status warning occurs, an alarm point asserts, or an event report triggers, the relay shows automatic messages at the bottom of the active screen in the message area.

For example, the message area shows RELAY STATUS WARNING for a status warning. *Figure 4.40* is an example of a status warning notification that appears in the message area of a LOCAL CONTROL (local bit) screen. If an alarm point asserts while you are using a front-panel screen, the message area notification reads: ALARM EVENT. If a trip event occurs while you are using a front-panel screen, the message area notification reads RELAY EVENT. When you repeatedly press **ESC** (as if returning to the MAIN MENU) during this warning or trip alert situation, the relay displays the corresponding full-screen automatic message concerning the warning or trip in place of the MAIN MENU. If the front-panel display is at the MAIN MENU and a status warning occurs, the full-screen warning replaces the MAIN MENU. After you view the warning, alarm, or trip screen, pressing **ESC** returns the LCD to the MAIN MENU.

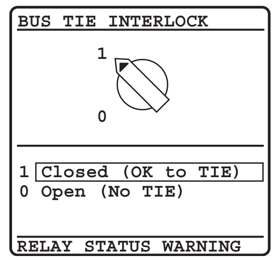


Figure 4.40 Sample Status Warning in the LCD Message Area

For a status failure, the relay immediately displays the full-screen status alert regardless of the present front-panel operating state. The relay displays no further LCD screens until the status failure clears. Should an unlikely status failure event occur, contact your local Technical Service Center or an SEL factory representative (see *Technical Support on page 10.35*).

Operation and Target LEDs

The relay gives you at-a-glance confirmation of relay conditions via operation and target LEDs. These LEDs are located in the middle of the relay front panel. SEL-400 series relays provide either 16 or 24 LEDs depending on ordering option.

You can reprogram all of these indicators except the **ENABLED** and **TRIP** LEDs to reflect other operating conditions than the factory-default programming described in this section. Settings T*n*_LED are SELOGIC control equations that, when asserted during a relay trip event, light the corresponding LED (*n* = 1–24). LED positions are described in parentheses next to each LED in *Figure 4.41*.

Set T*n*LEDL := Y to latch the LEDs during trip events; when you set T*n*LEDL := N, the trip latch supervision has no effect and the LED follows the state of the T*n*_LED SELOGIC control equation. The relay reports these targets in event reports; set the alias name listed in the report (as many as seven characters) by aliasing the T*n*_LED bits with the **SET T** command or with QuickSet. In 12-pushbutton models, the asserted and deasserted colors for the LED are determined with settings T*n*LEDC. Options include red, green, amber, or off. In some SEL-400 series relays, if T*n*LEDL = Y, the relay latches the target on the rising edge of the target bit. In these relays, to cause the bits to latch with trip, modify the equation to include AND R_TRIG TRIP. Refer to the *Target LEDs* section in the relay-specific *Front-Panel Operations* section to determine if the LED latches with the rising edge of TRIP or on the rising edge of T*n*_LED.

After setting the target LEDs, issue the **TAR R** command to reset the target LEDs. For a description of the default LED behavior for a specific relay, see the *Front Panel Operations* section in the relay-specific instruction manual.

Use the slide-in labels to mark the LEDs with custom names. Configurable label templates available to download from selinc.com allow you to customize the front-panel labels.

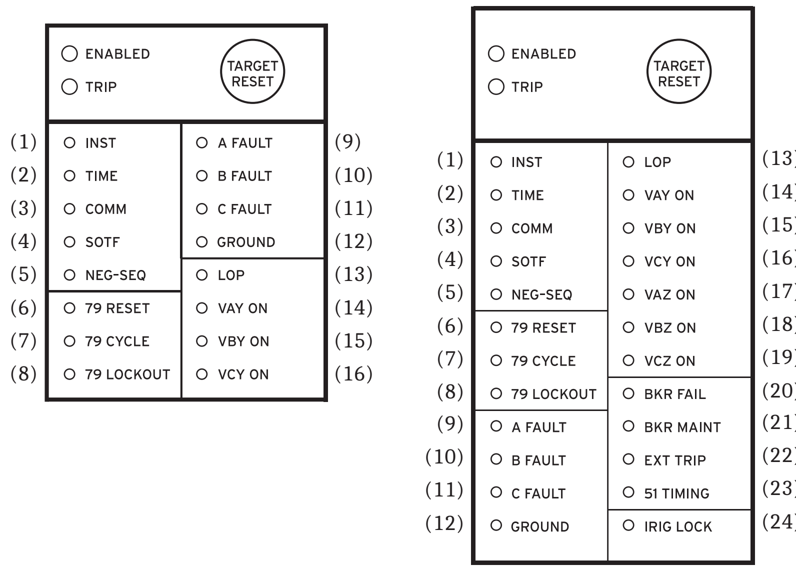


Figure 4.41 SEL-451 Factory-Default Front-Panel Target Areas (16 or 24 LEDs)

Operational

The **ENABLED** LED indicates that the relay is active. Trip events illuminate the **TRIP** LED. The prominent location of the **TRIP** LED in the top target area helps you recognize a trip event quickly. Program settings EN_LEDC and TR_LEDC to determine the color of the respective LED. Options include red or green.

TARGET RESET and Lamp Test

For a trip event, the relay latches the trip-involved target LEDs. Press the **TARGET RESET** pushbutton to reset the latched target LEDs. When a new trip event occurs and you have not reset the previously latched trip targets, the relay clears the latched targets and displays the new trip targets.

Pressing the **TARGET RESET** pushbutton illuminates all the LEDs. Upon releasing the **TARGET RESET** pushbutton, two possible trip situations can exist: the conditions that caused the relay to trip have cleared, or the trip conditions remain present at the relay inputs. If the trip conditions have cleared, the latched target LEDs turn off. If the trip event conditions remain, the relay re-illuminates the corresponding target LEDs. The **TARGET RESET** pushbutton also removes the trip automatic message displayed on the LCD menu screens if the trip conditions have cleared.

Lamp Test Function With TARGET RESET

The **TARGET RESET** pushbutton also provides a front-panel lamp test. Pressing **TARGET RESET** illuminates all the front-panel LEDs, and these LEDs remain illuminated for as long as you press **TARGET RESET**. The target LEDs return to a normal operational state after you release the **TARGET RESET** pushbutton.

Other Target Reset Options

You can reset the target LEDs with the ASCII command **TAR R**; see *TARGET on page 14.63* for more information.

The **TAR R** command and the TARGET RESET pushbutton also control the TRGTR Relay Word bit, which can be used for other functions. TRGTR is the factory-default setting for the unlatch trip SELOGIC control equation, ULTR, in Group settings.

You can reset the targets from the QuickSet **Control** branch of the HMI tree view. Programming specific conditions in the SELOGIC control equation RST-TRGT is another method to reset the relay targets. Access RSTTRGT in the relay Global settings (**Data Reset Control**); to use RSTTRGT, you must enable data reset control with Global setting EDRSTC := Y.

Front-Panel Operator Control Pushbuttons

The relay front panel features large operator control pushbuttons coupled with amber annunciator LEDs for local control. *Figure 4.42* shows this region of the relay front panel with example factory-default configurable front-panel label text. SEL-400 series relays provide either 8 or 12 pushbuttons depending on the product and ordering option.

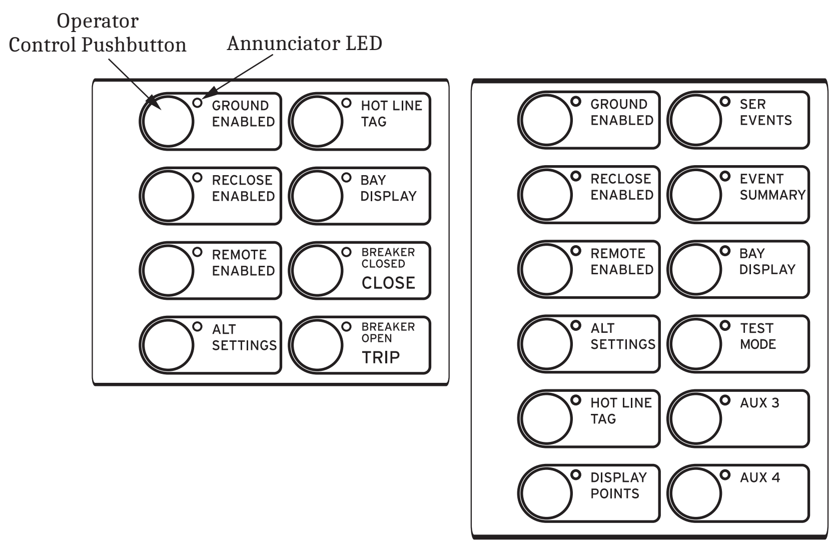


Figure 4.42 SEL-451 Default Operator Control Pushbuttons and LEDs (8 or 12 Pushbuttons)

See *Section 4: Front-Panel Operations* of the product-specific instruction manual for a description of the default configuration of operator control pushbuttons and LEDs.

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SECTION 5

Control

The SEL-400 series relays provide many control features, including circuit breaker controls, disconnect controls, remote bit controls, and bay control. This section describes these control capabilities.

See the specific relay instruction manuals to see how many breakers, disconnects, and remote bits are available and to determine whether or not bay control is supported.

To provide reliable detection of pulsed control bits that assert for one protection logic processing interval within automation logic, conditioning is applied to the control bit to extend the momentary assertion through the automation processing interval. This conditioning ensures the reliable detection of control bit (OC*n*, CC*n*, 89OC*m*, 89CC*m*, 89OCM*m*, 89CCM*m*, and RB01–RB64) assertion in automation logic (where *n* and *m* are product-specific designations). Control bits that assert and deassert multiple times within the same automation logic processing interval will be processed as asserting continuously for the entire automation logic processing interval.

Circuit Breaker Status and Control

SEL-400 series relays include circuit breaker status logic for all supported circuit breakers. The circuit breaker status logic uses the 52A_*k* setting (SELOGIC control equation) and open-phase detection logic to determine the state of Circuit Breaker *k*, and declare Circuit Breaker *k* alarm conditions. See *Section 5: Protection Functions* of the product-specific instruction manual for a description of circuit breaker status logic Relay Word bits and circuit breaker status logic diagrams.

SEL-400 series relays support opening and closing breakers. These operations can be controlled via the terminal commands **OPEN** and **CLOSE**, the binary terminal Fast Operate messages, various supported communications protocols, the front-panel menus, and through the bay control one-line screens. These controls operate the open control (OC*k*) and close control (CC*k*) bits. These bits are used in the relay trip and close logic to integrate these external controls with the relay automatic trip and close behavior. See *Section 6: Protection Application Examples* in the product-specific instruction manual for more information on the trip and close logic.

Disconnect Logic

Disconnect Switch Close and Open Control Logic

NOTE: Disconnect logic is processed four times per power cycle for all products except the SEL-400G. The SEL-400G processes disconnect logic at a rate of 5 ms.

Figure 5.1 and *Figure 5.2* shows the Disconnect Logic that generates open and close output signals necessary to perform the open and close disconnect operations. Use the seal-in timers (89CST*m* and 89OST*m*) to monitor and control disconnect operations. All disconnect control methods (HMI, ASCII, SELOGIC control equations, and Fast Operate) drive the Close and Open Control Logic in the relay.

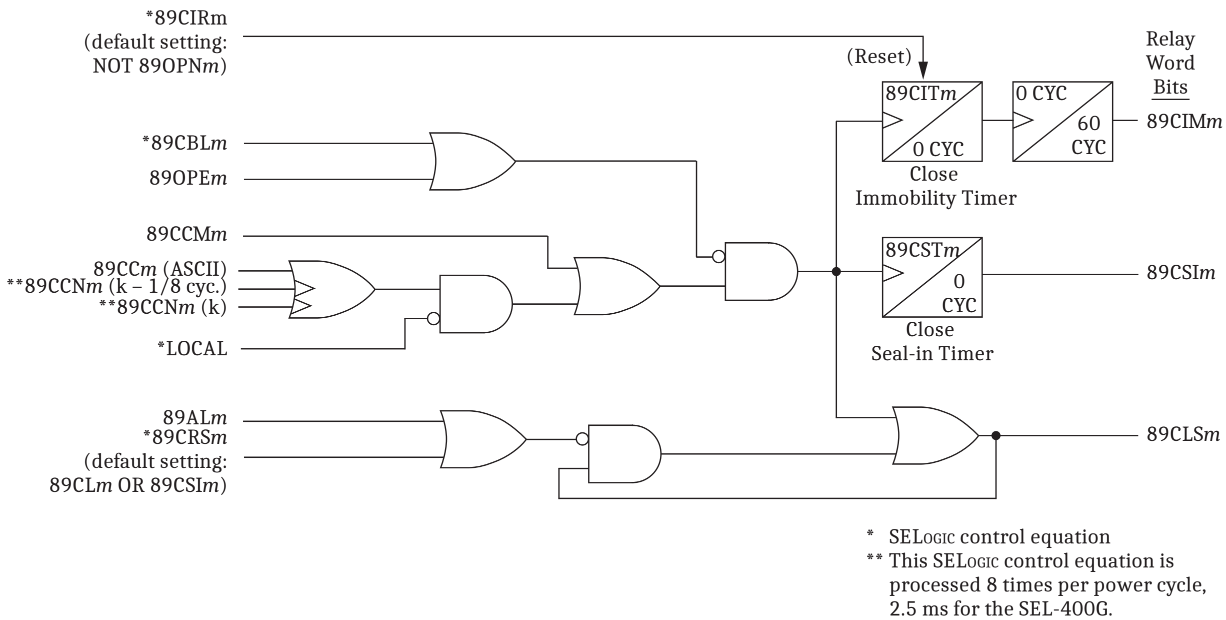


Figure 5.1 Disconnect Switch Close Logic

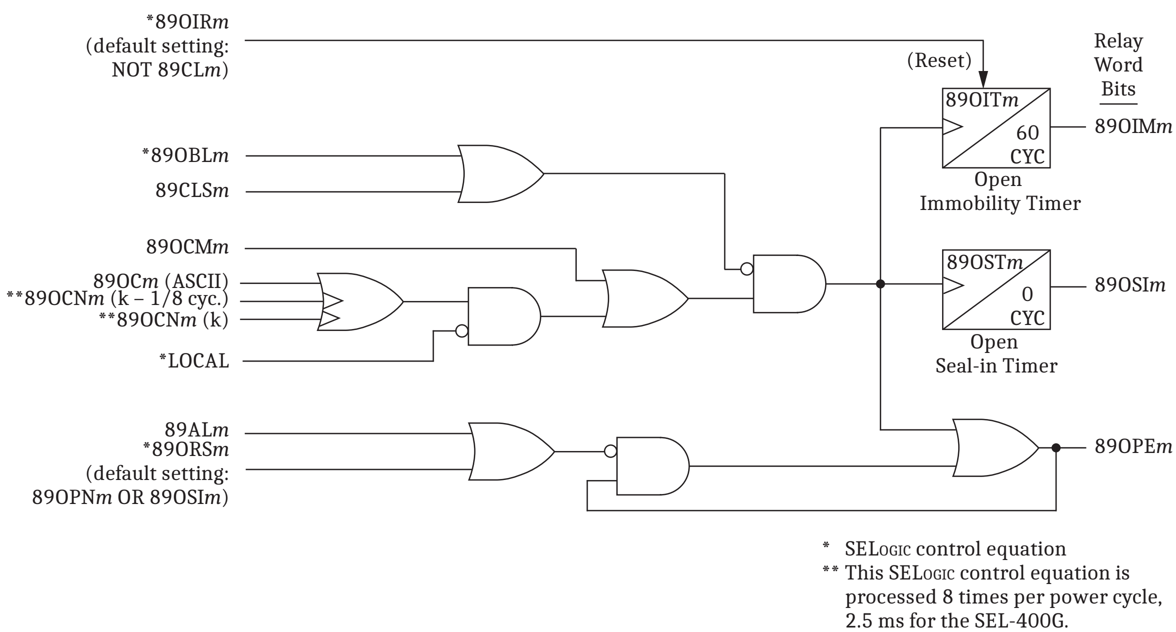


Figure 5.2 Disconnect Switch Open Logic

Disconnect Switch Close and Open Control Logic Status Inputs

89CLSm, 89OPEm

Disconnect Switch Close Logic (*Figure 5.1*) and Open Logic (*Figure 5.2*) generate Relay Word bits 89CLS*m* and 89OPE*m,* which drive the open and close operations. To ensure that an open and close disconnect signal cannot occur at the same time, 89CLS*m* and 89OPE*m* also block operation of the opposing logic. Therefore, Relay Word bit 89CLS*m* is an input to the Disconnect Open Logic, and Relay Word bit 89OPE*m* is an input to the Disconnect Close Logic.

89CBLm, 89OBLm

The 89CBL*m* and 89OBL*m* SELOGIC control equations provide an alternative customizable method for blocking the initiation of a disconnect switch open or close command, respectively.

89CRSm, 89ORSm

The 89CRS*m* and 89ORS*m* SELOGIC control equations provide the flexibility to select the signals that reset the close (89CLS*m*) or open (89OPE*m*) outputs. 89CRS*m* defaults to (89CL*m* OR 89CSI*m*), and 89ORS*m* defaults to (89OPN*m* OR 89OSI*m*).

89CSIm, 89OSIm

Set 89CST*m* and 89OST*m* to seal in the open and close signals for each individual installation. Relay Word bits 89CSI*m* and 89OSI*m* are the outputs of the close and open seal-in timers, and assert after the appropriate timers expire. By default, 89CSI*m* and 89OSI*m* are used in the 89CRS*m* and 89ORS*m* SELOGIC control equations to reset the close and open signals, 89CLS*m* and 89OPE*m*, that drive the disconnect switch motor.

89CLm, 89OPNm

The 89CL*m* and 89OPN*m* Relay Word bits report the state of the disconnect switches. If the disconnect switch is closed, Relay Word bit 89CL*m* is asserted; if the disconnect switch is open, Relay Word bit 89OPN*m* is asserted. See *Figure 5.3* for a description of these inputs. With the default settings, when Relay Word bit 89CL*m* asserts, the close seal-in circuit is blocked, causing 89CLS*m* to deassert. Likewise, with the default settings, when Relay Word bit 89OPN*m* asserts, the open seal-in circuit is blocked, causing 89OPE*m* to deassert.

89ALm

The disconnect switch status and alarm logic in *Figure 5.3* generates the 89ALm Relay Word bit. When Relay Word bit 89ALm asserts, it resets the seal-in circuits, deasserting the 89CLS*m*/89OPE*m* signals.

LOCAL

The LOCAL Relay Word bit asserts when LOCAL SELOGIC control equation asserts to a logical 1. When the LOCAL Relay Word bit asserts, only the HMI commands (89CCM*m* and 89OCM*m*), can initiate close and open operations. When the LOCAL Relay Word bit is deasserted, the 89CLOSE, 89OPEN, SELOGIC disconnect close/open, and Fast Operate disconnect close/open commands can perform disconnect close and open operations. The default value for this setting is NA.

Disconnect Switch Close and Open Control Logic Action Inputs

89CCNm, 89OCNm

89CCN*m* and 89OCN*m* SELOGIC control equations are for programmable close and open disconnect switch operations. The LOCAL Relay Word bit must be deasserted for the close or open SELOGIC equations to initiate a disconnect switch operation. Use care when using SELOGIC control equations for disconnect switch operations; this disconnect operate method is not supervised by the breaker jumper or appropriate relay access levels as is the case with other disconnect operation methods.

89CTLm

This SELOGIC control equation identifies Disconnect *m* as controllable (89CTL*m* := 1) or status-only (89CTL*m* := 0). When controllable, all control functionality is available for Disconnect *m*. When status-only, the disconnect is not selectable when navigating the one-line diagram from the relay front-panel HMI. For three-position disconnects, there is a 89CTL*m* setting for each disconnect position.

89CCMm, 89OCMm

89CCM*m* and 89OCM*m* Relay Word bits pulse for one-quarter cycle when close or open disconnect operations are initiated from the one-line diagram on the front-panel screen. If the LOCAL Relay Word bit is not asserted, then Relay Word bits 89CCM*m* or 89OCM*m* cannot assert.

89CCm, 89OCm

The **89CLOSE** command or Fast Operate disconnect close message, pulses Relay Word bit 89CC*m* for one-quarter cycle. The **89OPEN** command or Fast Operate disconnect open message, pulses Relay Word bit 89OC*m* for one-quarter cycle. The LOCAL Relay Word bit must be deasserted for a disconnect switch operation to be initiated by a Fast Operate message or **89CLOSE** and **89OPEN** commands.

Disconnect Seal-In Timer Settings

89CSTm, 89OSTm

89CST*m* and 89OST*m* settings are for defining the time required for the disconnect switch to complete a close or open operation.

Disconnect Switch Close and Open Control Logic Output

89CLSm, 89OPEm

The 89CLS*m* and 89OPE*m* Relay Word bits are used in SELOGIC output equations to perform close and open disconnect switch operations.

Disconnect Switch Close and Open Control Logic Processing

Figure 5.1 shows the Disconnect Switch Close Logic and *Figure 5.2* shows the Disconnect Switch Open Logic.

Some motor-operated disconnect switches have their own seal-in circuits to seal the closing and opening signals in. Other motor-operated disconnect switches, however, require external sealed-in circuits to maintain the closing and opening signals for the duration of the disconnect operation.

⚠CAUTION
The outputs in the relay are not designed to break the coil current in the disconnect motor. An auxiliary contact with adequate current interrupting capacity must clear the coil current in the disconnect motor before the output on the relay opens. Failure to observe this safeguard could result in damage to the relay output contacts.

With SELOGIC control equations 89CRS*m* and 89ORS*m* set to the default settings (include Relay Word bits 89CSI*m* and 89OSI*m*), the open and close signals remain asserted for the time settings of the Close and Open Seal-In Timers, 89CST*m* and 89OST*m*.

If the 89OBL*m* SELOGIC control equation and the 89OPE*m* and the LOCAL Relay Word bits are deasserted, then any of the relay close disconnect operate methods can assert Relay Word bit 89CLS*m*, and initiate the Close Seal-In Timer, 89CST*m*. Enter Relay Word bit 89CLS*m* into a SELOGIC output equation to drive the motor of the disconnect.

Set the Close Seal-In Timer, 89CST*m*, long enough to keep Relay Word bit 89CLS*m* asserted long enough to complete the disconnect operation.

To account for slow operate times because of cold weather or low battery voltage, set the 89CST*m* time 10 to 15 percent longer than the expected operate time. This guarantees that the disconnect switch has fully operated before the 89CLS*m* signal is removed. When the 89CST*m* seal-in timer expires, 89CSI*m* asserts, or the disconnect switch normally open contact closes (89CL*m* asserted), the 89CLS*m* output deasserts. This completes an open-to-close cycle of the Disconnect Close Logic; the Disconnect Open Logic in *Figure 5.2* behaves in the same manner.

Disconnect switch status and alarm logic in *Figure 5.3* generates Relay Word bit 89AL*m*. When Relay Word bit 89ALm asserts, a disconnect alarm condition exists. The 89AL*m* Relay Word bit ensures that the close or open signal does not remain asserted when a disconnect switch alarm condition exists. When Relay Word bit 89AL*m* asserts or the seal-in timer expires, the 89CLS*m* or 89OPE*m* signals deassert.

When a close operation is inadvertently initiated with the disconnect switch already closed, and the 89CRS*m* SELOGIC control equation is set as defaulted (89CL*m* OR 89CSI*m*), the asserted 89CL*m* Relay Word bit (close status) will block the seal-in circuit before the timer expires. This will deassert the 89CLS*m* Relay Word bit, which drives the disconnect switch motor. In this way, 89CLS*m* asserts for only one processing interval.

If an open command was sent within the 89CSI*m* time, an open and close signal could be sent to the disconnect switch at the same time. The 89CLS*m* Relay Word bit input to the Disconnect Switch Open Logic guarantees that open and close commands are not transmitted to the disconnect switch simultaneously. When the 89CLS*m* Relay Word bit deasserts, an open command can be performed. The 89OBL*m* SELOGIC control equation provides an additional customizable method for blocking the initiation of a close command. The Relay Word bit 89OPE*m*, and 89CBL*m* inputs to the Disconnect Switch Close Logic serves the same purpose.

Disconnect Switch Status and Alarm Logic

The disconnect switch auxiliary contacts are inputs to the Disconnect Switch Status and Alarm Logic as shown in *Figure 5.3*. SELOGIC control equation 89AM*m* is the input for the normally open an auxiliary contact, and SELOGIC control equation 89BM*m* is the input for the normally closed Form B auxiliary contact. For the Status and Alarm Logic to function correctly, wire the Form A and Form B contacts each to separate inputs on the relay. When ordering a relay, consider the number of inputs required for the disconnects being controlled. The number of auxiliary contacts for some systems may require that the relay be configured with additional I/O boards.

Disconnect operations are possible with only one auxiliary contact input, but with this implementation the Status and Alarm Logic will not provide accurate Alarm, Operation in Progress, or Bus-zone protection reporting. When only one auxiliary contact is available for input, set one SELOGIC control equation to the available auxiliary contact input and invert the other SELOGIC control equation:

89AM*m* := **IN102**

89BM*m* := **NOT IN102**

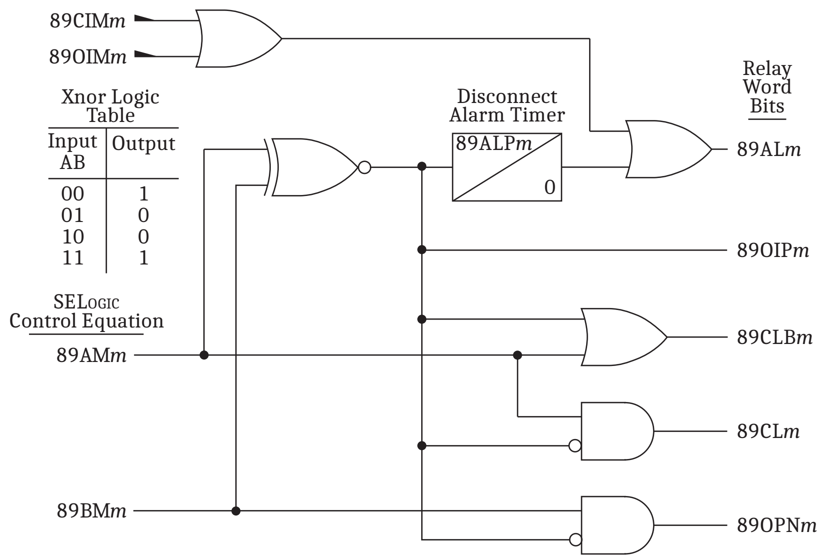


Figure 5.3 Disconnect Switch Status and Alarm Logic

Disconnect Switch Status and Alarm Logic Inputs

89AMm, 89BMm

The 89AM*m* and 89BM*m* SELOGIC control equations represent the normally open and normally closed disconnect switch auxiliary contacts. Typically, these are set to relay inputs that are wired to the auxiliary contacts.

89CIMm, 89OIMm

Input 89CIM*m* asserts for expiration of the close immobility timer, while input 89OIM*m* asserts for expiration of the open immobility timer. Timer expiration indicates one of two conditions. The first is that an open-to-close operation of the disconnect switch failed to move the switch enough to open the normally closed auxiliary contact 89BM*m*. The second is that a close-to-open operation of the disconnect switch failed to move the switch sufficiently to open the normally open auxiliary contact 89AM*m*.

Disconnect Switch Status and Alarm Logic Settings

89ALPm

This setting in the Bay settings class defines the disconnect switch alarm time.

Disconnect Switch Status and Alarm Logic Outputs

89ALm

If a disconnect switch operation initiated from the front panel does not complete, the 89ALP*m* timer expires and the 89AL*m* Relay Word bit asserts. Expiration of the 89ALP*m* timer indicates that an initiated disconnect operation failed to complete and the disconnect switch is in an undetermined state. In addition, the 89CST*m* or 89OST*m* timer also expires to deassert the output signal (89CLS*m* or 89OPE*m*), thus ensuring that there is not a constant signal applied to the disconnect.

89OIPm

When Relay Word bit 89OIP*m* asserts, a disconnect switch operation is in progress. Relay Word bit 89OIP asserts when the states of the 89BM*m* and 89AM*m* Relay Word bits are the same, i.e., both asserted or both deasserted.

89CLBm

This Relay Word bit is used for bus-zone protection and asserts when the disconnect is no longer open (89BM*m* deasserted).

89CLm

When Relay Word bit 89CL*m* asserts, the disconnect switch is closed.

89OPNm

When Relay Word bit 89OPN*m* asserts, the disconnect switch is open.

Disconnect Switch Status and Alarm Logic Processing

Figure 5.3 shows the Disconnect Switch Status and Alarm Logic. Inputs to this logic are the normally open (89AM*m*) and normally closed (89BM*m*) disconnect switch auxiliary contacts.

To understand the logic in *Figure 5.3*, consider an open-to-close operation. The first disconnect operation scenario looks at a successful open-to-close disconnect switch operation; a successful close-to-open operation is similar. In the open state, 89AM*m* is deasserted and 89BM*m* is asserted. Once a close command is initiated in the relay, the disconnect switch starts to move and 89BM*m* deasserts. When 89BM*m* deasserts, the 89ALP*m* pickup timer starts to time. With 89BM*m* deasserted, the state of the disconnect switch cannot be determined, because both disconnect switch auxiliary contacts are deasserted. Set the 89ALP*m* timer longer than the expected undetermined disconnect state time, but less than the 89CST*m* or 89OST*m* seal-in timers. If the 89ALP*m* timer expires, the 89AL*m* Relay Word bit asserts. Relay Word bit 89AL*m* asserts when the disconnect operation does not complete successfully. When the 89ALP*m* timer begins timing, the operation in progress, Relay Word bit 89OIP*m*, and Relay Word bit 89CLB*m* assert. The 89CLB*m* Relay Word bit is for bus-zone protection, this bit asserts when the 89BM*m* input deasserts.

During the disconnect switch operation-in-progress condition, Relay Word bits 89CL*m* and 89OPN*m* are both deasserted because the state of the disconnect switch is undetermined. Once the disconnect switch auxiliary contact Relay Word bit 89AM*m* asserts, the condition has been met to declare the disconnect switch closed. When 89AM*m* asserts, the 89CL*m* Relay Word bit asserts, 89ALP*m* stops timing, Relay Word bit 89OIP*m* deasserts, and Relay Word bit 89CLB*m* remains asserted. This sequence completes a successful open-to-close disconnect switch operation.

The second disconnect operation scenario is for an unsuccessful open-to-close operation, which, until 89ALP*m* starts timing, is identical to the successful operation in the previously discussed first scenario.

During operation of the 89ALP*m* timer, the disconnect switch begins moving. The close disconnect switch output signal 89CLS*m* clears upon expiration of the 89CST*m* seal-in timer. The logic then provides the disconnect switch additional time to complete the close operation, in case some inertia from the motor rotor keeps the disconnect motor in motion. By setting the 89ALP*m* timer longer than the 89CST*m* seal-in timer, you can ensure retention of the close signal until the disconnect switch closes completely. If there is no complete disconnect switch operation during the time 89ALP*m* defines, the relay asserts Relay Word bit 89AL*m* and reports that the disconnect switch is in an undetermined state.

The scenario in which both 89AM*m* and 89BM*m* are asserted simultaneously would occur on a rare disconnect switch failure or a short-circuited auxiliary contact wire connection. When this condition occurs for 89ALP*m* seconds, the 89AL*m* alarm status output will assert.

Disconnect Switch Close and Open Immobility Timer Logic

The Close and Open Immobility Timer Logic detects when a disconnect operation failed to initiate.

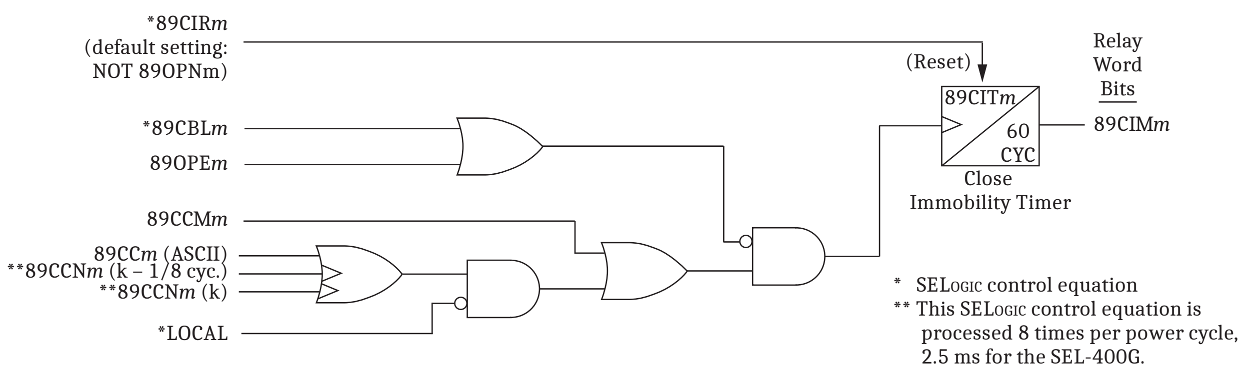


Figure 5.4 Close Immobility Timer Logic

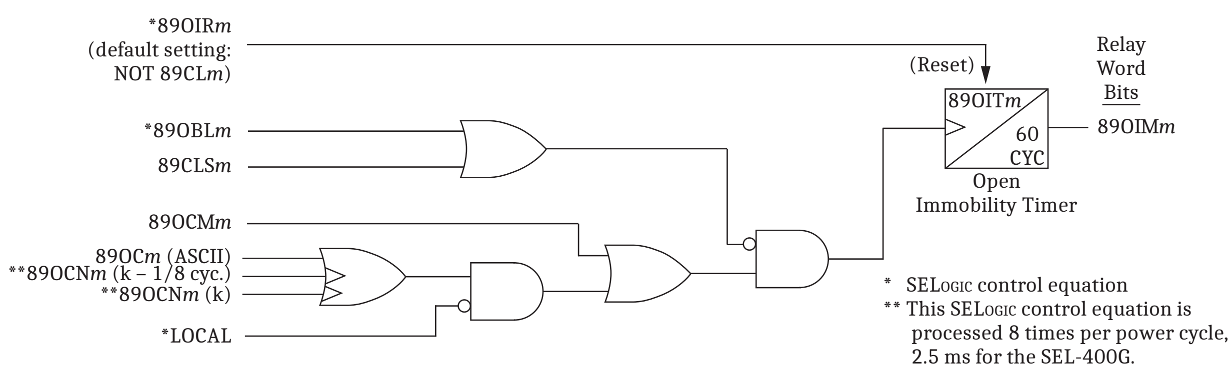


Figure 5.5 Open Immobility Timer Logic

Close and Open Immobility Timer Logic Inputs

LOCAL

The LOCAL Relay Word bit supervises local disconnect control and is based on the LOCAL SELOGIC control equation in the Bay settings class. Disconnect switch operations from the front panel are possible when the LOCAL Relay Word bit is asserted, in other words, the LOCAL Relay Word bit prevents control from the HMI without proper supervision.

89CBLm, 89OBLm

The 89CBL*m* and 89OBL*m* SELOGIC control equations provide an alternative customizable method for blocking the initiation of a disconnect switch open or close command, respectively.

89CIRm, 89OIRm

The 89CIR*m* and 89OIR*m* SELOGIC control equations provide the flexibility to customize resetting the Close and Open Immobility Timers. By default, 89CIR*m* is set to NOT 89OPN*m*, and 89OIR*m* is set to NOT 89CL*m*.

89CLm, 89OPNm

The 89CL*m* and 89OPN*m* Relay Word bits report the state of the disconnect switches. If the disconnect switch is closed, Relay Word bit 89CL*m* is asserted; if the disconnect switch is open, Relay Word bit 89OPN*m* is asserted. See *Figure 5.3* for a description of these inputs.

Disconnect Switch Close and Open Control Logic Action Inputs

89CCNm, 89OCNm

89CCN*m* and 89OCN*m* SELOGIC control equations are for programmable close and open disconnect switch operations. The LOCAL Relay Word bit must be deasserted for the SELOGIC close or open to initiate a disconnect switch operation. Use care when using SELOGIC control equations for disconnect switch operations; this disconnect operate method is not supervised by the breaker jumper or appropriate relay access levels as is the case with other disconnect operation methods.

89CTLm

This SELOGIC control equation identifies Disconnect *m* as controllable (89CTL*m* := 1) or status-only (89CTL*m* := 0). When controllable, all control functionality is available for Disconnect *m*. When status-only, the disconnect is not selectable when navigating the one-line diagram from the relay front-panel HMI. For three-position disconnects, there is a 89CTL*m* setting for each disconnect position.

89CCMm, 89OCMm

89CCM*m* and 89OCM*m* Relay Word bits pulse for one-quarter cycle when close or open disconnect operations are executed from the one-line diagram on the front-panel screen. The LOCAL Relay Word bit must be asserted, for Relay Word bits 89CCM*m* or 89OCM*m* to assert.

89CCm, 89OCm

The **89CLOSE** command or Fast Operate disconnect close message, pulses Relay Word bit 89CC*m* for one-quarter cycle. The **89OPEN** command or Fast Operate disconnect open message, pulses Relay Word bit 89OC*m* for one-quarter cycle. The LOCAL Relay Word bit must be deasserted for a disconnect switch operation to be initiated by a Fast Operate message or **89CLOSE** and **89OPEN** commands.

Disconnect Switch Close and Open Immobility Timer Logic Settings

89CITm, 89OITm

89CIT*m* and 89OIT*m* timer settings in the Bay settings class define the close and open immobility timers.

Disconnect Switch Close and Open Immobility Timer Logic Outputs

89CIMm, 89OIMm

When 89CIM*m* or 89OIM*m* asserts, the close or open immobility timer has expired.

Disconnect Switch Close and Open Immobility Timer Logic Processing

The Close and the Open Immobility Timer Logic detect when one of the close or open disconnect switch methods does not initiate successfully. In other words, it reports when the disconnect switch failed to start moving. The open and close immobility timer logic circuits are similar. When a close operation is initiated, the rising-edge-triggered Close Immobility Timer starts timing. Once the disconnect switch starts to move away from its open position, Relay Word bit 89OPN*m* deasserts (see *Figure 5.3*). If the 89OPN*m* Relay Word bit deasserts, the close immobility timer resets and 89CIM*m* remains deasserted. On the other hand, if the 89OPN*m* Relay Word bit stays asserted, the close immobility timer does not reset. After the close immobility timer expires, 89CIM*m* asserts for one second. When 89CIM*m* asserts, the close operation is considered to have failed to initiate. 89CIM*m* is an input to the disconnect switch status and alarm logic for alarm condition indications.

This logic also uses the LOCAL Relay Word bit to supervise front-panel operations. With the LOCAL Relay Word bit deasserted, no disconnect operations can be initiated from the one-line diagram. With the LOCAL Relay Word bit asserted, Relay Word bit 89CCM*m* asserts for one-quarter cycle when the ENT pushbutton is pressed and a disconnect switch is highlighted in the one-line diagram.

Close, Open, and Undetermined State Indications

This section discusses the way the close and open immobility timers work in conjunction with the disconnect alarm timer to provide disconnect control and alarm indications. When the disconnect switch main contact is stationary (closed or open) the state of the disconnect switch is easily determined.

If the disconnect switch main contact is open:

- Normally closed Form B auxiliary contact (89BM*m* asserted) is closed
- Normally open Form A auxiliary contact (89AM*m* deasserted) is open

If the disconnect switch main contact is closed:

- ➤ Normally closed Form B auxiliary contact (89BM*m* deasserted) is open
- ➤ Normally open Form A auxiliary contact (89AM*m* asserted) is closed

If an operation of the disconnect switch is in progress, the state of the disconnect switch main contact is undetermined:

- ➤ Normally closed Form B auxiliary contact (89BM*m* deasserted) is open
- ➤ Normally open Form A auxiliary contact (89AM*m* deasserted) is open

Any undetermined state of the disconnect switch main contact should be monitored. The relay can be configured to wait for the disconnect switch operation to complete, and issue an alarm if the disconnect switch remains in the undetermined state longer than the 89ALP*m* time. *Figure 5.6* illustrates how the state of the auxiliary contacts change for an open-to-close operation in progress and how the 89CST*m*, 89CIT*m*, and 89ALP*m* timers are configured to manage the undetermined time. The close-to-open scenario would be similar.

With the disconnect switch in the open state, the normally closed Form B auxiliary contact is closed (89BM*m* asserted) and the normally open Form A auxiliary contact is open (89AM*m* deasserted). The 89CST*m* seal-in timer starts timing when a disconnect switch close command is issued. The output of the 89CST*m* seal-in timer keeps the close signal asserted for the duration of the expected disconnect switch operate time. Set the seal-in timer 10 to 15 percent longer than the expected disconnect operate time, to allow for slow disconnect operation times caused by cold temperatures or low battery voltages.

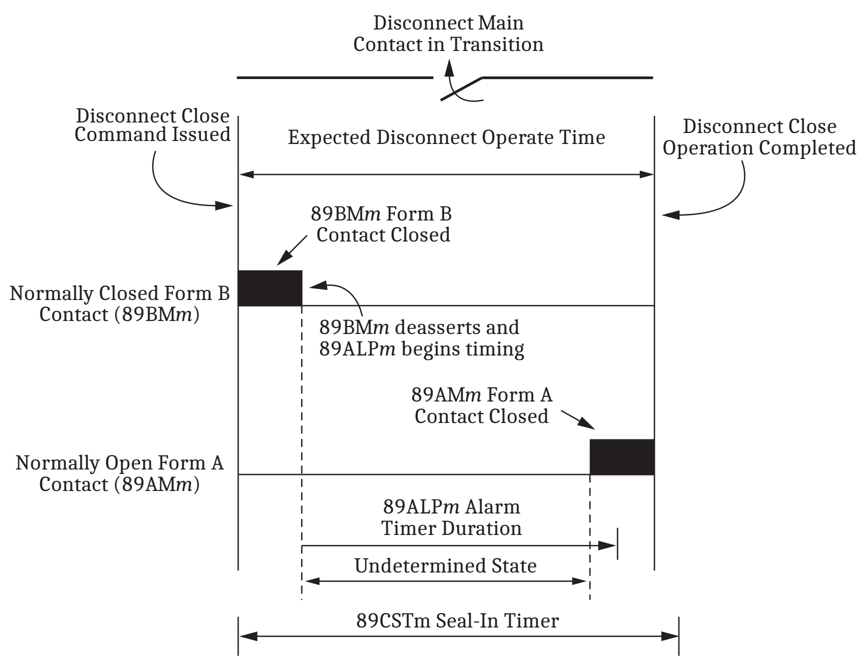


Figure 5.6 Disconnect in Transition

When the normally closed auxiliary contact (SELOGIC input 89BM*m*) deasserts, the disconnect switch is in an undetermined state. No proper position indication from either of the disconnect switch auxiliary contacts (89BM*m* or 89AM*m*) is available. Once the auxiliary normally closed contact (SELOGIC input 89BM*m*) deasserts, the 89ALP*m* timer starts timing. The 89ALP*m* timer monitors the undetermined state of the disconnect switch. For the 89ALP*m* timer to initialize, the disconnect switch has to move a minimum distance to open the normally closed auxiliary contact (open-to-close operation). Set the 89ALP*m* timer longer than the expected undetermined state time, but less than the 89CST*m* seal-in timer. If the normally open auxiliary contact fails to close within the undetermined state time, the 89ALP*m* timer expires and an alarm condition is declared.

The Close Immobility Logic starts the Close Immobility Timer for an operation where the disconnect switch does not move the minimum distance to open the normally closed auxiliary contact (open-to-close operation). When the close immobility timer expires, an alarm condition is declared and Relay Word bit 89AL*m* asserts. If the disconnect moves enough to open the normally closed auxiliary contact, the Close Immobility timer resets and no alarm condition is declared (see *Figure 5.4*).

Remote Bits

Remote bits provide a means for sending remote control commands to relay logic. As indicated in *Table 14.47*, remote bits have three operating states: clear, set, and pulse. It is important to understand the differences between the use of pulsed remote bits in automation and protection SELOGIC control equations. Remote bits can be operated from multiple communications interfaces, including the **CON** command from a terminal (serial or Telnet), Fast Operate messages, and DNP3.

NOTE: The SEL-487E supports 96 remote bits. The SEL-487B supports 96 remote bits and has a processing interval of 1/12 of a power system cycle.

A pulsed remote bit will assert the respective remote bit Relay Word bit (RB*nn*, *nn* = 01–64) for one processing interval (1/8 of a power system cycle). When used in Protection SELOGIC, which also executes at one processing interval, pulsed remote bits provide a momentary means for operating a variety of logic functions, including Protection Latches, Boolean logic expressions, and Protection Logic Counters. Because the pulsed remote bit and Protection processing both operate within the same processing interval, the use of pulsed remote bits is reliable and deterministic.

Bay Control Front-Panel Operations

Each relay has a default one-line diagram. Sometimes these diagrams fit on a single screen and sometimes they require more than one screen that you can pan across. For example, *Figure 5.7* shows the default one-line diagram for the SEL-487E. You can display either of two parts of the diagram by using the **Up Arrow** and **Down Arrow** pushbuttons to pan between an upper screen and a lower screen. The upper screen shows the HV equipment and transformer, while the lower screen shows the transformer and LV equipment. The relay displays the upper screen by default.

NOTE: Not all SEL-400 series relays support bay control operations.

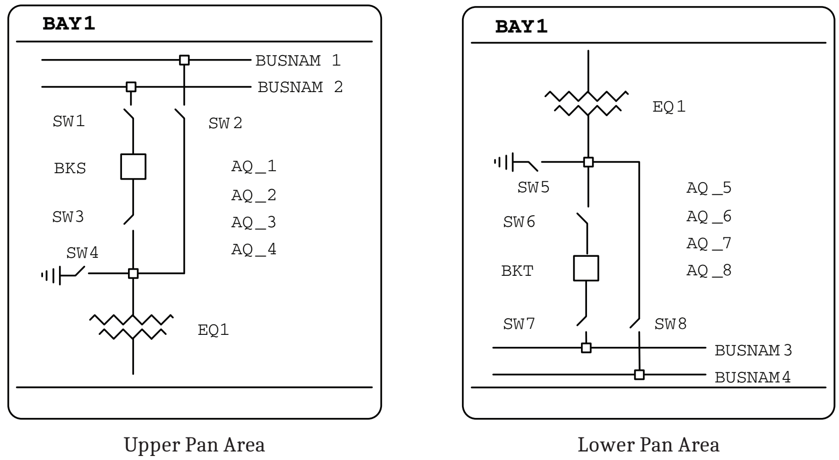


Figure 5.7 SEL-487E Default One-Line Diagram

One-Line Diagram and Labels

Figure 5.8 is an example of a default one-line diagram. The Bay settings class has settings for defining labels and analog quantities. One-line diagrams are comprised of the following:

- Bay Names and Bay Labels
- Busbars and Busbar Labels
- Breakers and Breaker Labels
- Disconnect Switches and Disconnect Switch Labels
- Equipment and Equipment Labels
- Analog Display Points

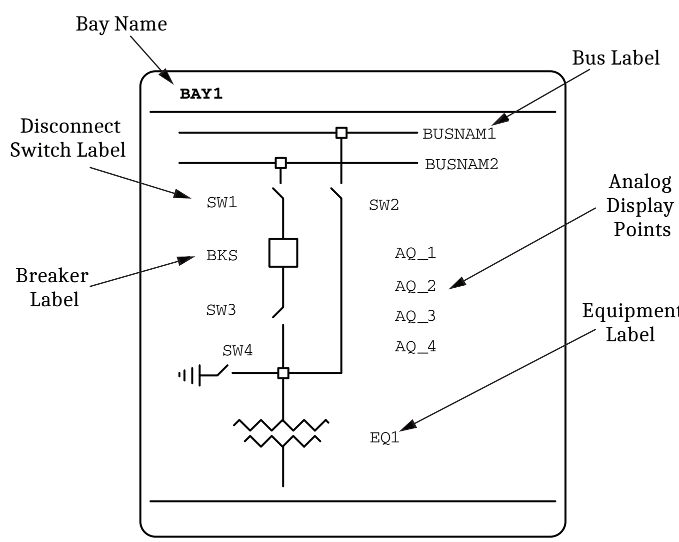


Figure 5.8 Bay Control One-Line Diagram

Front-Panel Pushbutton Navigation Operations in the One-Line Diagram

Navigation within the one-line diagram requires that the front-panel access level be at Breaker Access Level or higher and the Breaker Jumper be installed. If navigation is attempted when:

- ➤ The front panel is not at the Breaker Access Level or higher and passwords are enabled, the relay prompts you to enter the appropriate passwords.
- ➤ The Breaker Jumper is not installed, the `Breaker Control Disabled Please Install the Breaker Jumper` message briefly appears on the screen.

Use the arrow pushbuttons on the front panel to navigate within the one-line diagram. When you first select the one-line diagram, none of the apparatus on the one-line diagram are highlighted. Press the **Left Arrow** or **Right Arrow** pushbutton to enter the one-line diagram and highlight the apparatus. Once you enter the one-line diagram, navigation between the disconnect switch and circuit breaker symbols as follows:

- ➤ Pressing the **Right Arrow** pushbutton highlights the elements from left-to-right and top-to-bottom.
- ➤ When reaching the right-most bottom element, the following **Right Arrow** keystroke "rolls over" and again highlights the left-most top element.
- ➤ The **Left Arrow** pushbutton operates in reverse, i.e., from right-to-left, and bottom-to-top.
- ➤ Pressing the **ENT** pushbutton selects the highlighted symbol.
- ➤ Pressing the **ESC** pushbutton returns you to the previous screen.

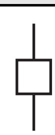
Additionally, if the one-line diagram spans multiple screens, you can pan between the portions of the diagram by using the up and down arrows:

- ➤ Pressing the **Down Arrow** pushbutton while displaying the top bay control screen, displays the bottom bay control screen.
- ➤ Pressing the **Down Arrow** pushbutton while displaying the bottom bay control screen or the **Up Arrow** pushbutton while displaying the top bay control screen, does nothing.
- ➤ Pressing the **Up Arrow** pushbutton while displaying the bottom bay control screen displays the top bay control screen.

Circuit Breaker and Disconnect Definitions and State Representations

Table 5.1 shows the apparatus definitions and symbols displayed on the one-line diagram.

Table 5.1 Circuit Breaker and Disconnect Switch Definitions

Circuit Breaker Open	Circuit Breaker Closed	Disconnect Open	Disconnect Closed
			

NOTE: The intermediate states only apply to disconnect switches because circuit breaker operations have a short duration.

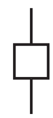
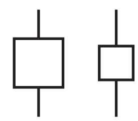
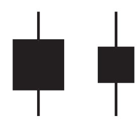
Each apparatus (circuit breaker or disconnect switch) can be in one of the following six states:

- ➤ Open, not highlighted
- ➤ Open, highlighted

- Closed, not highlighted
- Closed, highlighted
- Intermediate, not highlighted (intermediate = transition between open and closed states)
- Intermediate, highlighted

Table 5.2 describes how the one-line diagram represents the different states of the breakers, and how highlighting the breaker affects the display of the symbol.

Table 5.2 Circuit Breaker State Representations

Apparatus Position	Symbol	Asserted Relay Word Bit
Circuit breaker open, not highlighted		NOT 52CLSM*m*
Circuit breaker open, highlighted[a]		NOT 52CLSM*m*
Circuit breaker closed, not highlighted		52CLSM*m*
Circuit breaker closed, highlighted		52CLSM*m*

[a] When the circuit breaker is highlighted, the two symbols shown alternate in the display.

Table 5.3 describes how the one-line diagram represents the different states of the disconnect switches, and how highlighting the disconnect switch affects the display of the symbol. Unlike the fast operation time of the circuit breaker, the disconnect switch operation-in-progress time is longer than the breaker operation time. *Table 5.3* describes how apparatus appear in the one-line diagram when a disconnect operation is in progress.

Table 5.3 Disconnect Switch State Representations (Sheet 1 of 2)

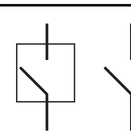
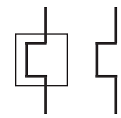
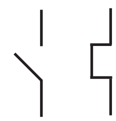
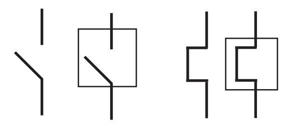
Apparatus Position	Symbol	Asserted Relay Word Bit
Disconnect open, not highlighted		89OPN*m*
Disconnect closed, not highlighted		89CL*m*
Disconnect open, highlighted[a]		89OPN*m*

Table 5.3 Disconnect Switch State Representations (Sheet 2 of 2)

Apparatus Position	Symbol	Asserted Relay Word Bit
Disconnect closed, highlighted[a]		89CL*m*
Disconnect Operation In Progress, not highlighted[b]		89OIP*m*
Disconnect Operation In Progress, highlighted[c]		89OIP*m*

[a] When the disconnect switch is highlighted and no operation is in progress, a square box alternately frames the switch symbol.

[b] For a disconnect switch operation in progress where the disconnect switch is not highlighted, the symbol displayed is the present state symbol and then the opposite state symbol. This sequence repeats until the disconnect switch operation completes.

[c] For a disconnect switch operation in progress where the disconnect is highlighted, the symbol displayed is the present state symbol, then the present state symbol highlighted, then the opposite state symbol, and finally the opposite state symbol highlighted. This sequence repeats until the disconnect switch operation completes.

The one-line diagram indicates highlighted text with a box around the current selection.

Rack-Type Breaker Mosaics

The SEL-400 series relays support the display of three-position rack-type breakers (also referred to as truck-type breakers) in the bay mimic screens on the front-panel LCD. The three positions, (racked out, test, and racked in) are determined by the combination of the 52*n*RACK and 52*n*TEST bay settings (breaker *n* designation depends on the relay model). Navigate to the Mimic Busbar Layout Screen Number setting under Bay Control in the ACSELERATOR QuickSet SEL-5030 Software to identify mimic screens that contain a rack-type breaker.

Figure 5.9 shows the displayed mosaics based on the combination of the 52*n*RACK and 52*n*TEST settings. For non-rack type breakers, the 52*n*RACK and 52*n*TEST settings do not impact any display and control of the non-rack type breakers.

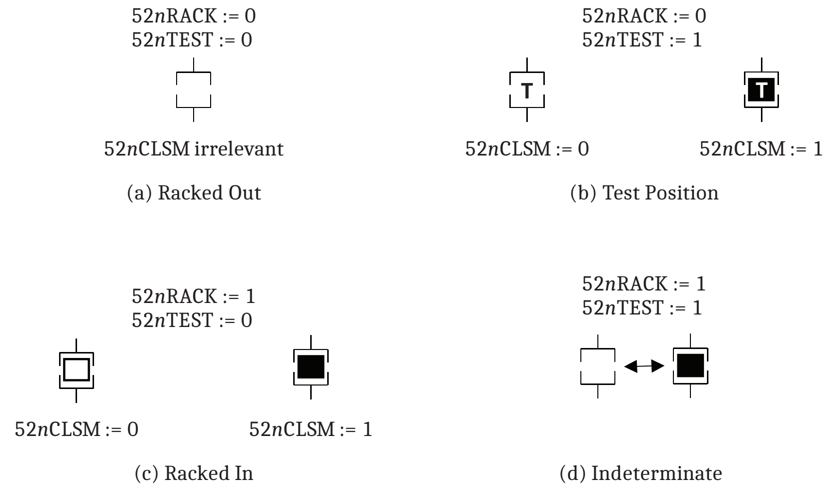


Figure 5.9 Rack-Type Breaker Mosaics

When 52*n*RACK = 52*n*TEST = 0, as shown in *Figure 5.9(a)*, the racked-out breaker mosaic appears. Because the breaker is racked out, the 52*n*CLSM setting is irrelevant for the purposes of the display. When 52*n*TEST = 1 and 52*n*RACK = 0, as shown in *Figure 5.9(b)*, the breaker is in the test position. In this position, the breaker can either be open or closed, depending on the 52*n*CLSM setting. When 52*n*RACK = 1 and 52*n*TEST = 0, as shown in *Figure 5.9(c)*, the breaker is in the racked-in position. While in the racked-in position, the breaker can be open or closed depending on the 52*n*CLSM setting. When 52*n*RACK = 52*n*TEST = 1, as shown in *Figure 5.9(d)*, the display alternates between the mosaics shown to indicate an indeterminate state for the breaker position because the breaker cannot physically be in both the test and racked-in position at the same time.

For relays that support and are set for single-pole breakers (BK*n*TYP := 1), the rack-type breaker mosaics follow functionality similar to non-rack type breaker mosaics, depending on pole status and the EPOLDIS setting. The breaker must also be in the test or racked-in position; if the breaker is in the racked out position, only *Figure 5.9(a)* appears. If the logic declares a pole discrepancy and EPOLDIS := 1, the one-line diagram follows the same alternating pattern as shown in *Figure 5.9(d)*. When you select the breaker on the front-panel HMI, a pole discrepancy screen appears, showing the state (OPENED or CLOSED) for each pole. If EPOLDIS := 0, the one-line diagram still has the alternating pattern shown in *Figure 5.9(d)*, but the pole discrepancy screen does not appear and only shows `STATUS UNKNOWN` for the status field in *Figure 5.9(b)*.

When in the test or racked-in position, the breaker alarm setting, 52*n*_ALM, is checked. If 52*n*_ALM := 1, the displayed breaker alternates between a closed and open breaker in either the test (*Figure 5.9[b]*) or racked-in (*Figure 5.9[c]*) position regardless of breaker contact state. However, for single-pole breakers, if the logic declares a pole discrepancy, the pole discrepancy screen displays when you select the breaker on the front-panel HMI.

You can access breaker control of available breakers regardless of rack position (racked-in, test, racked-out) and breaker state (open, closed). Some breakers in the one-line diagrams are status-only and are not controllable. See *One-Line Diagrams* in *Section 4: Front-Panel Operations* of the product-specific instruction manuals for information on breakers that have control or status-display-only functionality.

Status-Only Disconnects

The SEL-400 series relays can display status-only disconnects. The Disconnect Front Panel Control Enable setting, 89CTL*n*, (see *Section 11: Relay Word Bits* in the product-specific instruction manuals for the number of supported disconnects) applies to both two- and three-position disconnects in the HMI one-line diagram, and it determines whether a selected disconnect can be controlled from the front-panel HMI (89CTL*n* := 1) or cannot (89CTL*n* := 0 or NA). The 89CTL*n* setting differs from the LOCAL setting in that the LOCAL setting is a global local control enable setting and 89CTL*n* is a control enable setting on a per-disconnect level. The LOCAL setting has priority over the 89CTL*n* setting.

The default setting of 89CTL*n* := 1 allows for disconnect control and maintains disconnect front-panel control functionality after a relay firmware upgrade (even when upgrading from a firmware that does not support status-only disconnects). When 89CTL*n* := 1, the relay follows the control functionality outlined in this section. When 89CTLn := 0 or NA, you cannot select the specified disconnect when you are navigating the one-line diagram from the relay front-panel HMI, preventing you from selecting the disconnect for a control function.

Three-position disconnects have a 89CTL*n* disconnect control enable setting for each disconnect position (in-line or ground). The disconnect is selectable for control from the one-line diagram when either 89CTL*n* := 1 and the switch is open, or when either 89CTL*n* := 1 and the switch is closed in the corresponding position to the 89CTL*n* := 1 setting. When in the control window, only control options available based on the 89CTL*n* settings display. For example, if the disconnect is open, and the ground 89CTL*n* := 0 and the in-line 89CTL*n* := 1, the only control option displayed will be to close the in-line disconnect. If the switch is closed to a position whose 89CTL*n* := 0, the switch is not selectable when navigating the one-line diagram. However, should the 89AL*n* Relay Word bit assert for either disconnect position, the disconnect is selectable from the front panel regardless of the 89CTL*n* setting, and a view-only window for the disconnect appears that has no control functions available for the disconnect.

If the corresponding 89CTL*n* disconnect control enable setting transitions from an asserted to a deasserted state while in the control window, the front panel displays `NOT ALLOWED` when you have selected an open or close function.

Circuit Breaker and Disconnect Switch Operations From the Front Panel

Circuit Breaker Open/Close

Figure 5.10 shows the Breaker Control Screens available after pressing the **ENT** pushbutton (`ONELINE` bay control screen), with the circuit breaker highlighted (Only highlighted breakers on the one-line diagram can initiate breaker open or close operations). Pressing the **ENT** pushbutton with the breaker highlighted and the LOCAL Relay Word bit asserted displays the Breaker Control Screen in *Figure 5.10(b)*. If the LOCAL Relay Word bit is not asserted when the **ENT** pushbutton is pressed, the relay displays the screen in *Figure 5.10(c)* for three seconds and then returns to the screen in *Figure 5.10(a)*.

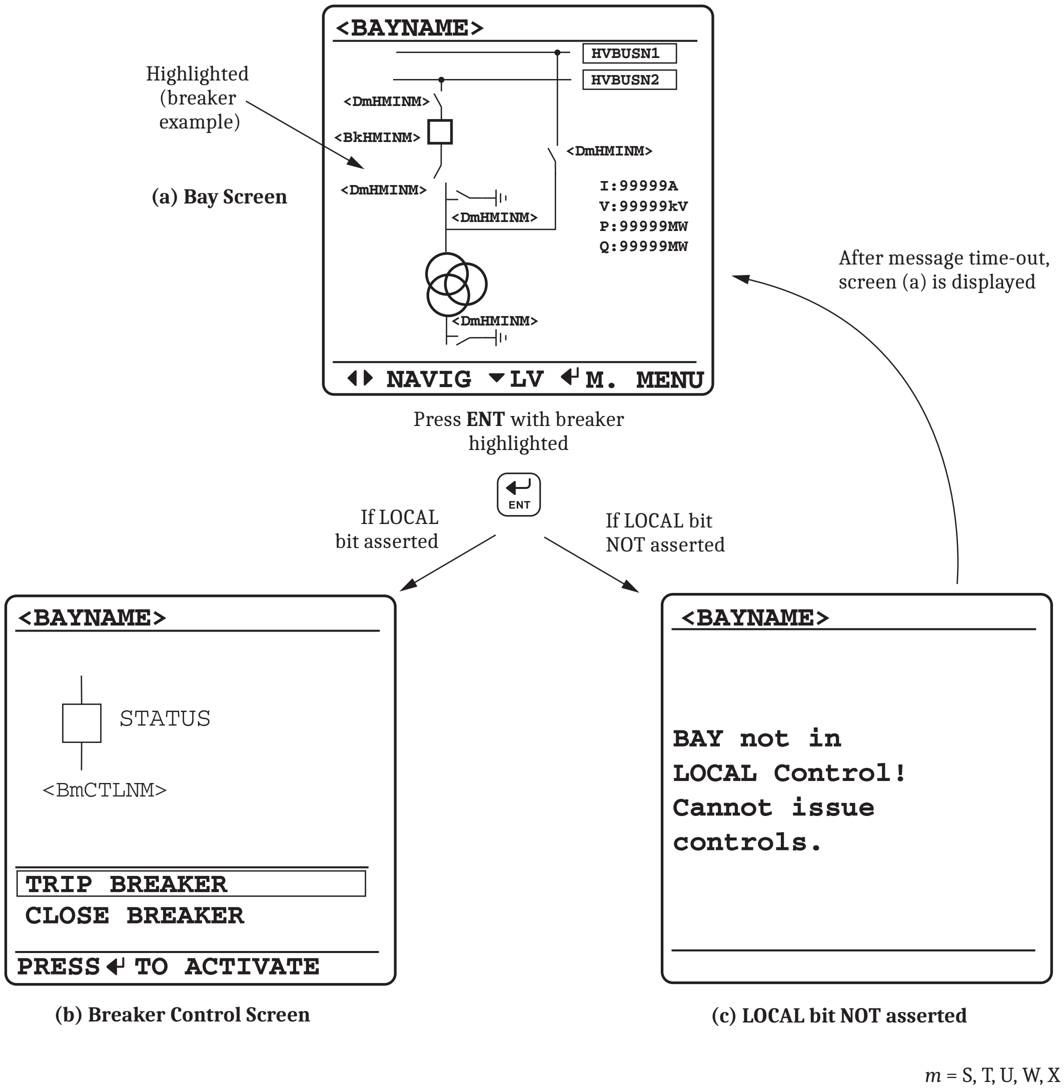


Figure 5.10 Screens for Circuit Breaker Selection

Single-Pole Tripping

With a single-pole breaker, the individual poles operate independently, and normal operation is for one pole to be open for a short period, while the other two poles are closed. However, it is possible that one (or more) poles may fail to complete a particular operation, resulting in a pole-discrepancy condition. For example, if the breaker is issued a **CLOSE** command, two poles may close but one pole may remain open. If this condition lasts for longer than 1.5 seconds, the HMI displays the pole discrepancy screen shown in *Figure 5.11(c)* so that the operator can immediately identify the offending pole. You can operate the breaker from the pole discrepancy screen after the discrepancy has been rectified. All other screens are the same as when you set the relay to three-pole operations.

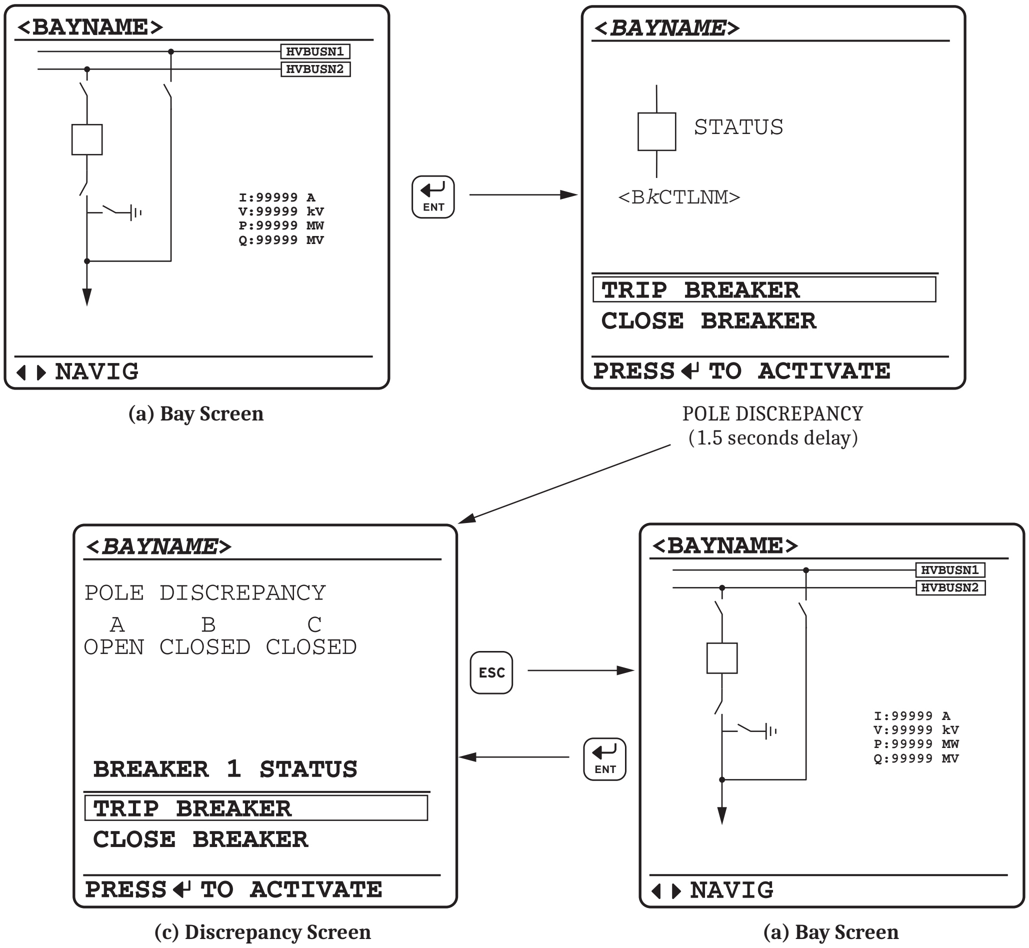


Figure 5.11 Screens During a Pole-Discrepancy Condition

Disconnect Switch Open/Close

Figure 5.12(a) shows the Disconnect Control Screens available when you press the **ENT** pushbutton, in ONELINE bay control screen, with the disconnect switch highlighted. If the LOCAL Relay Word bit is asserted and the disconnect switch is highlighted when you press the **ENT** pushbutton, the Disconnect Control Screen in *Figure 5.12(b)* appears. Use the **Up Arrow** and **Down Arrow** pushbuttons to navigate between the disconnect control functions in *Figure 5.12(b)*. If the LOCAL Relay Word bit is not asserted when the **ENT** pushbutton is pressed, the relay displays screen in *Figure 5.12(c)* for three seconds and then returns to the screen in *Figure 5.12(a)*.

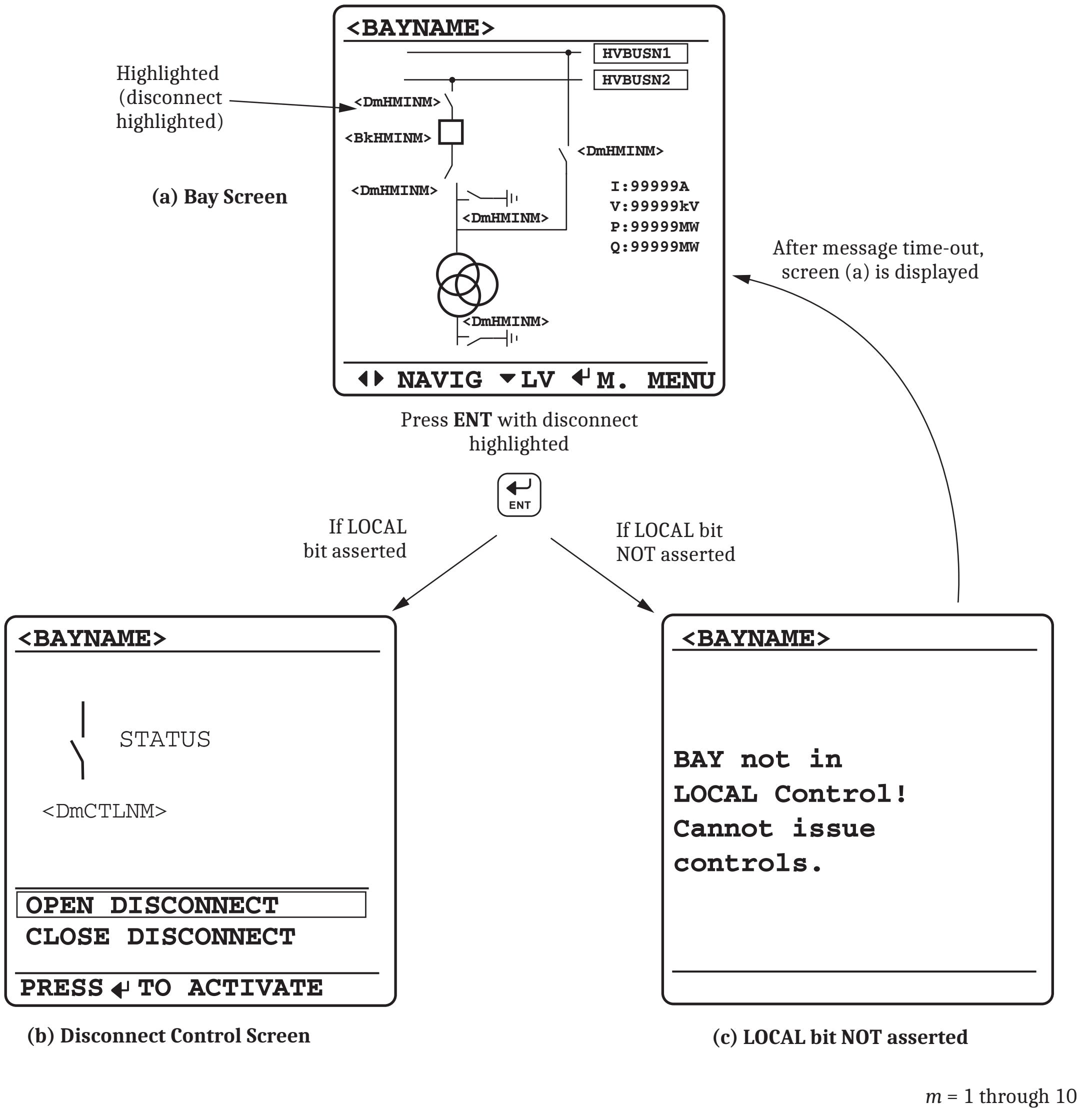


Figure 5.12 Screens for Disconnect Switch Selection

Figure 5.13, *Figure 5.14*, and *Figure 5.15* show all the possible screens during an open-to-close operation of Disconnect 1. Operation of the remaining disconnects is identical. Close-to-open operations are similar, the only difference being that the open Relay Word bits apply instead of the close Relay Word bits. The screen in *Figure 5.13(a)* is displayed after you press the **ENT** pushbutton with Disconnect 1 open and highlighted in the one-line diagram.

When you enter the disconnect screen in *Figure 5.13(a)*, the state that the disconnect switch is in is highlighted, in other words, if Relay Word bit 89OPN1 is asserted, the OPEN DISCONNECT text has a box drawn around it.

To close the disconnect switch, use the **Up Arrow** or **Down Arrow** pushbutton to highlight the CLOSE DISCONNECT text.

If Relay Word bit 89CCM1 asserts after you press the **ENT** key, the relay displays the screen with the caption CLOSE COMMAND ISSUED in *Figure 5.13(c)* for three seconds. While the disconnect operation is in progress, the relay displays the screen with the caption IN PROGRESS in *Figure 5.14(a)* and the disconnect symbol alternately displays the present state symbol and the opposite state symbol. If another disconnect operation attempt is made while a disconnect operation is in progress, the relay displays the screen with the caption *NOT ALLOWED* in *Figure 5.14(b)* for three seconds and then the relay returns to the screen in *Figure 5.14(a)*.

If Relay Word bit 89CCM1 does not assert, the relay displays the *NOT ALLOWED* error message shown in *Figure 5.13(d)* for three seconds and then displays again the screen in *Figure 5.13(b)*.

When Relay Word bit 89CCMD1 asserts, the Close Immobility Timer starts. If Relay Word bit 89CCMD1 asserts, two scenarios are possible: the disconnect fails to close, or the disconnect closes successfully. In the case of a successful close operation, the relay displays the screen in *Figure 5.15(b)*.

Failing to close also has two possible scenarios: the disconnect starts to move, but does not complete the operation, or the disconnect switch operation does not initiate.

When Relay Word bit 89OPN1 deasserts, the Close Immobility timer resets, indicating that the disconnect switch has started to move. If Relay Word bit 89CL1 fails to assert in the expected operation time, the disconnect switch has failed to complete the close operation in the expected time. Failure of the 89CL1 Relay Word bit to assert in the expected disconnect switch operation time causes the 89AL1 Relay Word bit to assert. When Relay Word bit 89AL1 asserts, the relay displays the screen *Figure 5.15(a)* (see *Disconnect Switch Status and Alarm Logic on page 5.5*).

If Relay Word bit 89OPN1 fails to deassert before the Close Immobility Timer expires, Relay Word bit 89ICM1 asserts and the relay displays the screen with the caption STATUS UNKNOWN in *Figure 5.15(a)*. See *Disconnect Switch Close and Open Immobility Timer Logic on page 5.8* for more information regarding the close and open immobility timer logic.

When the disconnect operation completes successfully, the relay displays the screen in *Figure 5.15(b)* until the front-panel timer times out or the **ESC** pushbutton is pressed.

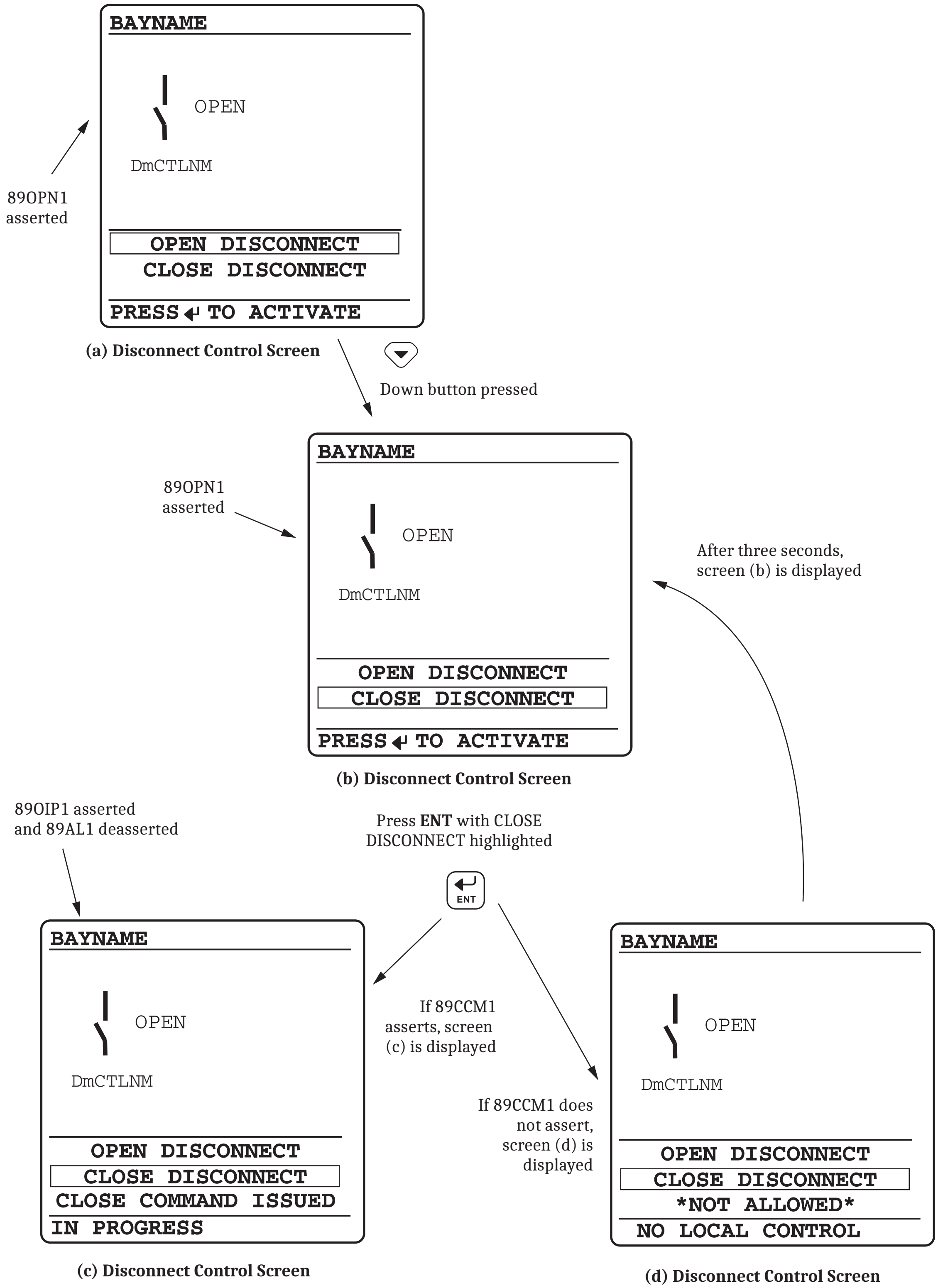


Figure 5.13 HMI Disconnect Operation Initiation

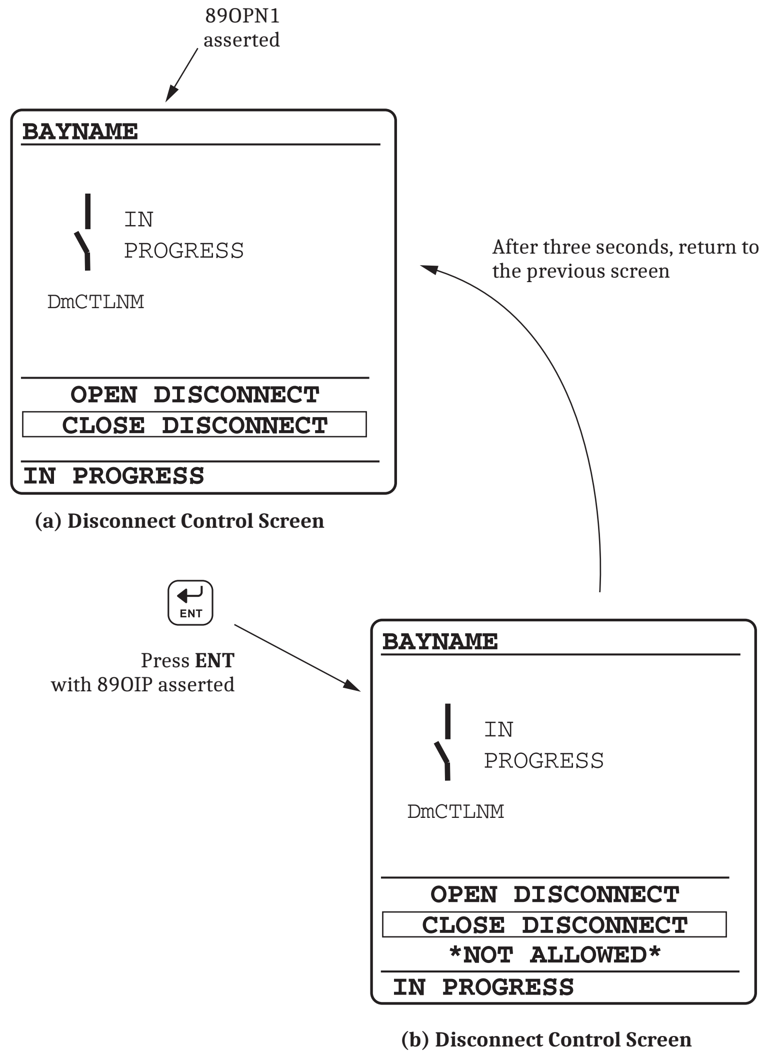


Figure 5.14 HMI Disconnect Operation in Progress

When you initially enter the Disconnect Control Screen, the disconnect switch is in one of four states: disconnect open (89OPN*m*), disconnect closed (89CL*m*), disconnect undetermined without alarm (89OIP*m*), or disconnect undetermined with alarm (89AL*m*). If Relay Word bit 89OIP*m* is asserted, the relay displays the screen in *Figure 5.14(a)*; if Relay Word bit 89AL*m* is asserted, the relay displays the screen in *Figure 5.15(a)*. If both Relay Word bits 89OIP*m* and 89AL*m* are asserted, Relay Word bit 89AL*m* takes priority. If Relay Word bit 89OPN*m* is asserted, the relay displays the screen in *Figure 5.13(a)*. This is the initial screen for an open-to-close operation. If Relay Word bit 89CL*m* is asserted, the relay displays the screen in *Figure 5.15(b)*. This is the initial screen for a close-to-open operation.

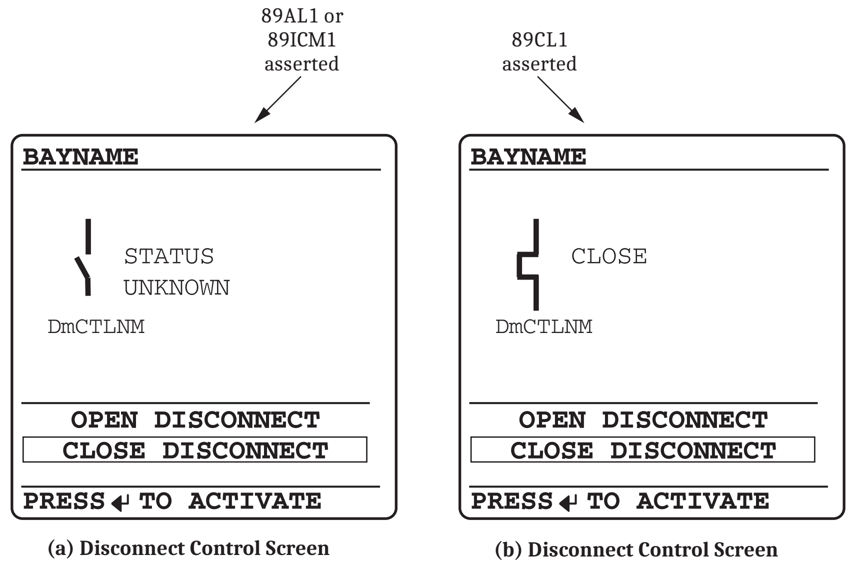


Figure 5.15 HMI Disconnect Operation Completed

Three-Position Disconnect State Representation and Operations From the Front Panel

A three-position disconnect switch consists of two standard disconnects that operate together to form a three-position disconnect. All logic diagrams of the standard disconnect apply to the three-position disconnect, including all settings and Relay Word bits associated with the two individual disconnects. The three-position disconnect has two labels, one for the in-line branch and one for the ground (perpendicular) branch. In the example shown in *Figure 5.16*, the three-position disconnect is made up of Disconnect SW3 and Disconnect SW4. As with the standard disconnect, be sure to correlate the disconnect wiring and settings with the disconnects assigned to the three-position disconnect image on the one-line diagram.

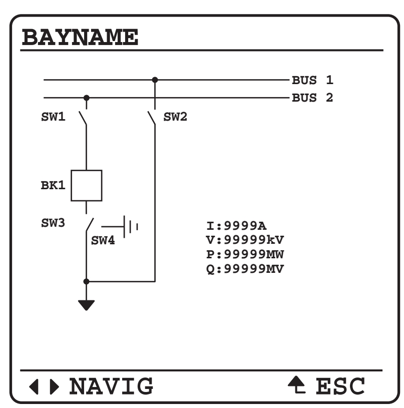
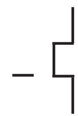
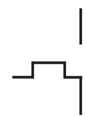
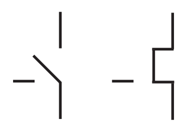
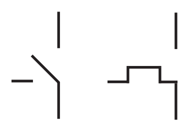
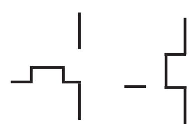


Figure 5.16 Bay Control One-Line Diagram With Three-Position Disconnect Open

Table 5.4 displays how the bay screen one-line diagram represents the different states of the three-position disconnect switch.

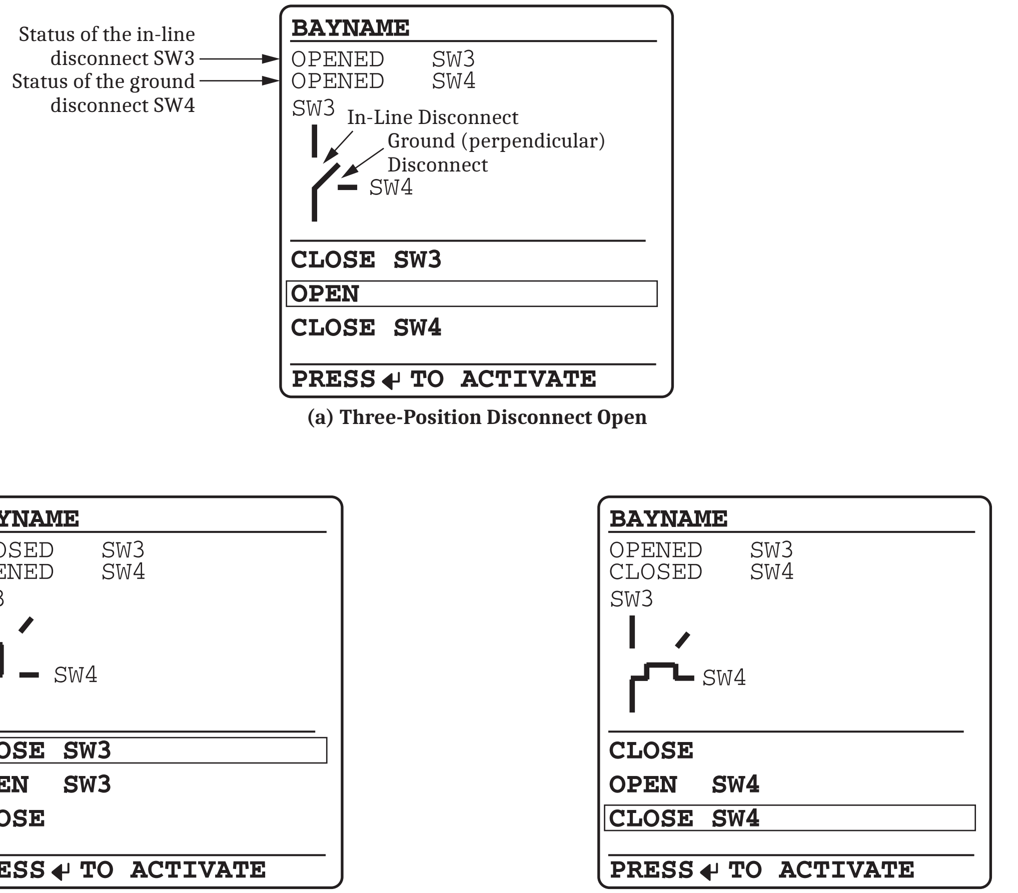
Table 5.4 Three-Position Disconnect Switch State Representations

Apparatus Position	Symbol	Asserted Relay Word Bits
Both disconnects open		89OPN3 and 89OPN4
Disconnect 3 (in-line) closed Disconnect 4 (ground) opened		89CL3 and 89OPN4
Disconnect 3 (in-line) opened Disconnect 4 (ground) closed		89OPN3 and 89CL4
Disconnect 3 (in-line) intermediate[a] Disconnect 4 (ground) opened	 [b]	(89OIP3 or 89AL3) and 89OPN4
Disconnect 3 (in-line) opened Disconnect 4 (ground) intermediate[a]	 [b]	89OPN3 and (89OIP4 or 89AL4)
All other status combinations Disconnect 3 closed, Disconnect 4 closed Disconnect 3 closed, Disconnect 4 intermediate[a] Disconnect 3 intermediate[a], Disconnect 4 closed Disconnect 3 intermediate[a], Disconnect 4 intermediate[a]	 [b]	 89CL3 and 89CL4 89CL3 and (89OIP4 or 89AL4) (89OIP3 or 89AL3) and 89CL4 (89OIP3 or 89AL3) and (89OIP4 or 89AL4)

[a] Intermediate = transition between open and closed states.
[b] The image alternates between the two symbols shown.

Similar to the standard disconnect, if a three-position disconnect is highlighted on the one-line diagram and the **ENT** pushbutton is pressed, a control screen is displayed. The control screen shows the present status of the disconnect based on the disconnect status bits (89CL*m*, 89OPN*m*, 89OIP*m*, and 89AL*m*) from both disconnects that make up the three-position disconnect. The status is shown via the disconnect symbol and the status labels as shown in *Figure 5.17(a)*.

Figure 5.17(a) shows the control screen of a three-position disconnect with both disconnects in the open state. *Figure 5.17(b)* shows the control screen of a three-position disconnect with the in-line disconnect closed and the ground disconnect open. Likewise, *Figure 5.17(c)* shows the control screen of a three-position disconnect with the in-line disconnect open and the ground disconnect closed.



(a) Three-Position Disconnect Open

(b) Three-Position Disconnect Closed In-Line

(c) Three-Position Disconnect Closed to Ground

Figure 5.17 Three-Position Disconnect Control Screens

The three-position disconnect logic is identical to two standard disconnects, but control actions are limited as shown in *Table 5.5*. A control action is only available if the disconnect name is listed next to the action as indicated in the Control Options Displayed column. For example, in the second set of control actions, where Disconnect SW3 is closed and Disconnect SW4 is open, the only control actions available are to open or close Disconnect SW3. *Figure 5.17(b)* shows the control screen for this condition.

Table 5.5 Three-Position Disconnect Switch Control Screen Status and Control Options (Sheet 1 of 2)

State of Disconnects	Status Displayed	Control Options Displayed	Control Actions Available
Disconnect SW3: Open Disconnect SW4: Open	OPENED SW3 OPENED SW4	CLOSE SW3 OPEN[a] CLOSE SW4	CLOSE SW3 NO OPEN CONTROL CLOSE SW4
Disconnect SW3: Closed Disconnect SW4: Open	CLOSED SW3 OPENED SW4	CLOSE SW3[b] OPEN SW3 CLOSE	CLOSE SW3 OPEN SW3 NO CONTROL for SW4
Disconnect SW3: Open Disconnect SW4: Closed	OPENED SW3 CLOSED SW4	CLOSE OPEN SW4 CLOSE SW4[c]	NO CONTROL for SW3 OPEN SW4 CLOSE SW4
Disconnect SW3: Open Disconnect SW4: Alarm	OPENED SW3 UNKNOWN SW4	CLOSE OPEN CLOSE	NO CONTROL for either disconnect

Table 5.5 Three-Position Disconnect Switch Control Screen Status and Control Options (Sheet 2 of 2)

State of Disconnects	Status Displayed	Control Options Displayed	Control Actions Available
Disconnect SW3: Alarm Disconnect SW4: Open	UNKNOWN SW3 OPENED SW4	CLOSE OPEN CLOSE	NO CONTROL for either disconnect
Disconnect SW3: Closed Disconnect SW4: Alarm	CLOSED SW3 UNKNOWN SW4	CLOSE OPEN CLOSE	NO CONTROL for either disconnect
Disconnect SW3: Alarm Disconnect SW4: Closed	UNKNOWN SW3 CLOSED SW4	CLOSE OPEN CLOSE	NO CONTROL for either disconnect
Disconnect SW3: Closed Disconnect SW4: Closed	CLOSED SW3 CLOSED SW4	CLOSE OPEN CLOSE	NO CONTROL for either disconnect
Disconnect SW3: Alarm Disconnect SW4: Alarm	UNKNOWN SW3 UNKNOWN SW4	CLOSE OPEN CLOSE	NO CONTROL for either disconnect

[a] See Figure 5.17(a).
[b] See Figure 5.17(b).
[c] See Figure 5.17(c).

The following example shows the process of changing a three-position disconnect from closed in-line to closed to ground. This process requires that you first open the in-line disconnect before you can close the ground disconnect.

Starting with the one-line diagram in *Figure 5.18*, highlight the three-position disconnect and press the **ENT** pushbutton. If the LOCAL Relay Word bit is asserted, the control screen shown in *Figure 5.17(b)* is displayed on the screen. Note that the only options at this point are to open or close Disconnect SW3. Therefore, use the **Up Arrow** or **Down Arrow** pushbutton to move the highlight box to the OPEN SW3 position. Then press the **ENT** pushbutton to open Disconnect SW3. If Disconnect SW3 successfully opens, the control screen will change as shown in *Figure 5.17(a)*. Note that the control actions changed so that Disconnect SW4 can now be closed. At this point, use the **Up Arrow** or **Down Arrow** pushbutton to move the highlight box to the `CLOSE SW4` position and press the **ENT** pushbutton to close Disconnect SW4. If Disconnect SW4 is successfully closed, the control screen will change as show in *Figure 5.17(c)*.

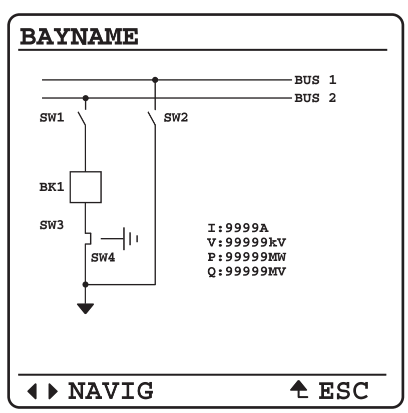


Figure 5.18 Bay Control One-Line Diagram With Three-Position Disconnect Closed In-Line

The relay does not include any default bay mimic screens with three-position disconnects. Should your application require different bay mimic screens with three-position disconnects, contact SEL.

Bay Control Screens

QuickSet and SEL Grid Configurator provide an easy and intuitive way to configure and set the bay control function. The following screenshots show the bay control screens in SEL Grid Configurator; the functionality shown is similar in QuickSet but it does not include the bay screen search tool.

Select the **Bay Control** button from the tree to see the first interactive bay forms in SEL Grid Configurator, as shown in *Figure 5.19*.

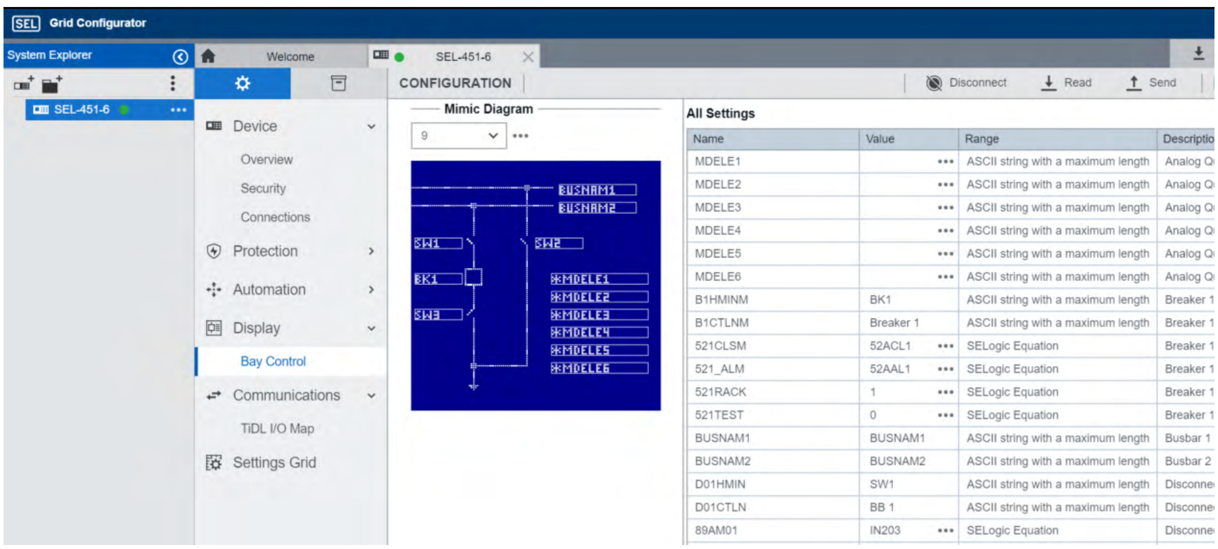


Figure 5.19 Interactive Bay Control Setting Form

Use the bay screen mimic diagram lookup tool to find the mimic diagrams applicable to your application by filtering by the number of displayed breakers and disconnections, as shown in *Figure 5.20*.

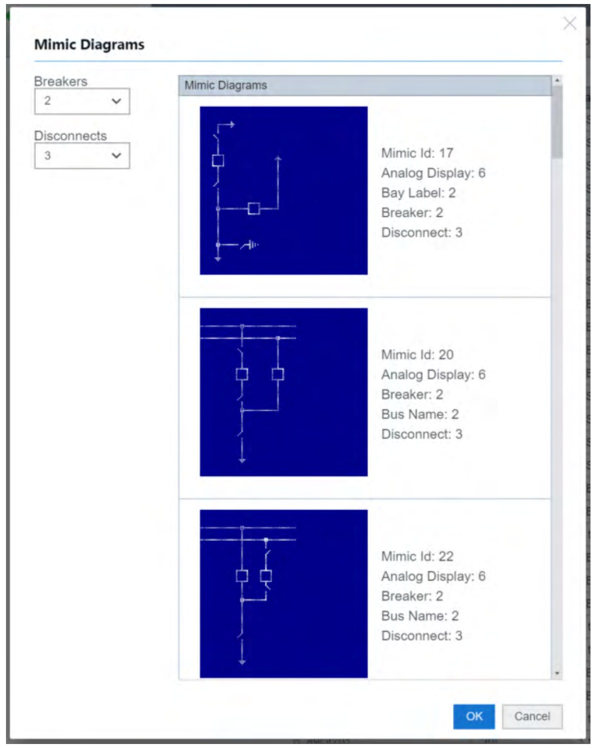


Figure 5.20 Mimic Diagrams

MIMIC

In most SEL-400 series relays, a single one-line diagram needs to be selected. However, in some relays, such as the SEL-487E, multiple screens need to be selected to build up the total composite one-line diagram.

Bay Name

There are 20 characters available for the bay name. This name appears on all the bay control screens.

Local

The LOCAL SELOGIC control equation enables local and remote control of the disconnect switch. This example illustrates how the input contact IN107 can accommodate existing bay controls that use a key to manually change from remote to local control. The key switch is made to actuate a contact when the key is turned, as shown in *Figure 5.21*. With the contact of the switch wired to the input, the key switch provides local and remote control. Make the following setting to enable LOCAL control when IN107 is asserted.

LOCAL := **IN107**

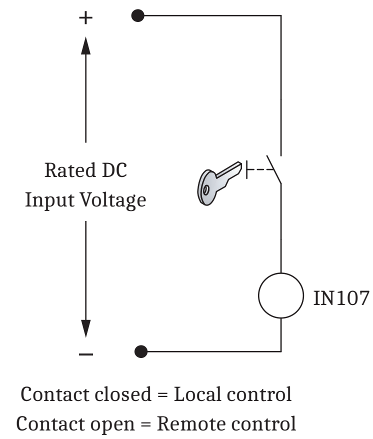


Figure 5.21 Local and Remote Control Logic With Key Control

Bus Names

Figure 5.22 shows the bay screen settings filter automatically to only display settings associated with the item you selected in your mimic diagram. Enter the name of the busbar (e.g., **132 Bus No 1**), and select **OK**.

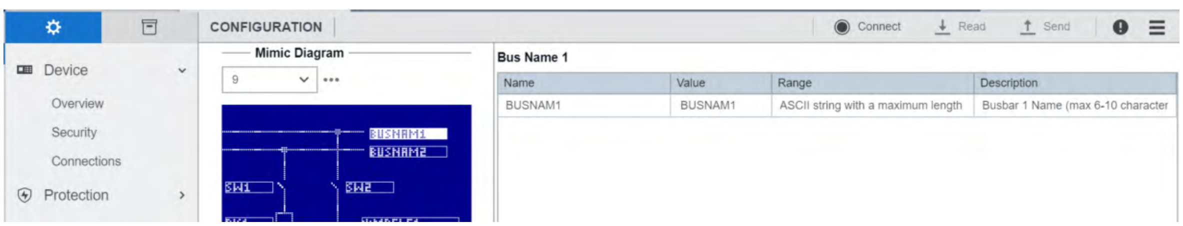


Figure 5.22 Setting Busbar Names in SEL Grid Configurator

Disconnect Assignments

To configure disconnects, select the disconnect switch. The settings filter automatically to only show the selected disconnect settings, as shown in *Figure 5.23*.

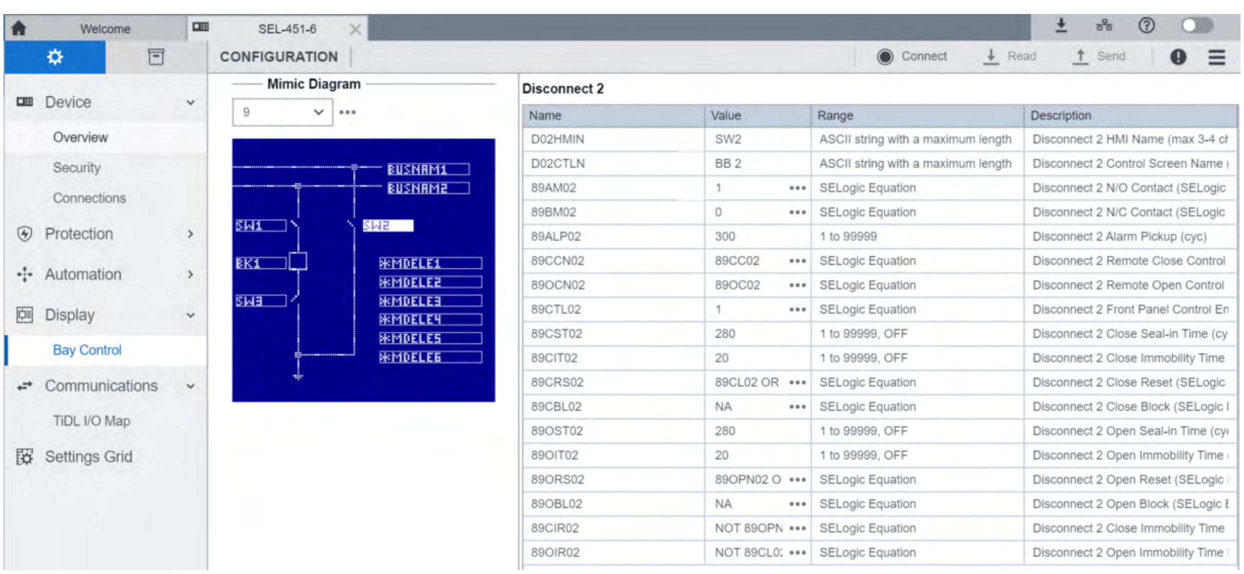


Figure 5.23 Disconnect Assignment Dialog Box, SW1

D01HMIN

Enter a Disconnect 1 label on the HMI (*Figure 5.23*). The number of characters is limited to a maximum string width of 18 pixels (approximately four characters).

D01CTLN

Enter a Disconnect 1 label on the control screen. Enter a descriptive name (there are 15 characters available) that clearly identifies the disconnect.

89AM01, 89BM01

These SELOGIC control equations report the state of Disconnect 1 auxiliary contacts. Both equations must be programmed for the Disconnect Switch Status and Alarm Logic to function correctly.

89ALP01

This timer counts down when both 89AM01 and 89BM01 are in the same state (both asserted or both deasserted). When this disconnect alarm timer expires, an alarm condition exists and the 89AL01 Relay Word bit asserts.

Set the 89ALP01 timer longer than the expected operation (undetermined state) time, but less than the 89CST01 or 89OST01 seal-in timers.

89CCN01, 89OCN01

These SELOGIC control equations close or open Disconnect 1. Take care when programming these equations, because there is no breaker jumper supervision or access level safeguard in place for this disconnect operate method. These settings only work when the LOCAL Relay Word bit is deasserted.

89CTL01

This SELOGIC control equation identifies Disconnect 1 as controllable (89CTL01 := 1) or status-only (89CTL01 := 0). When controllable, all control functionality is available for Disconnect 1. When status-only, the disconnect is not selectable when navigating the one-line diagram from the relay front-panel HMI. For three-position disconnects, there is a 89CTL*n* setting for each disconnect position.

89CST01, 89OST01

These seal-in timers are intended to keep the close or open signal asserted long enough to allow the Disconnect 1 operation to complete. Set the seal-in timers 10 to 15 percent longer than the expected disconnect operate time to give the disconnect switch time to complete the operation.

Cold weather and low battery voltages can impact disconnect switch operation times. Be sure to consider these conditions when setting the seal-in timers.

89CIT01, 89OIT01

The close/open Disconnect 1 immobility timers are triggered at the same time as the seal-in timers. Expiration of these immobility timers indicates that the Disconnect 1 auxiliary contact status failed to change state within the expected time frame.

Set the immobility timers longer than the expected time for the disconnect to leave the initial state (as reported by the 89AM01 and 89BM01 Relay Word bits), but less than the seal-in timer.

Cold weather and low battery voltages can impact disconnect switch operation times. Be sure to consider these conditions when setting the immobility timers.

89CRS01, 89ORS01

These settings reset the seal-in circuit when either the seal-in timer expires or the intended open/close status signal asserts. This is intended to stop driving the Disconnect 1 motor to close or open when the desired state has been reached.

89CBL01, 89OBL01

These SELOGIC control equations provide an optional custom method for blocking all means of close/open control for Disconnect 1.

89CIR01, 89OIR01

These SELOGIC control equations reset the Disconnect 1 close/open immobility timers.

Breaker Assignments

Configure the breaker by selecting the box next to the breakers. The settings filter automatically, as shown in *Figure 5.24*.

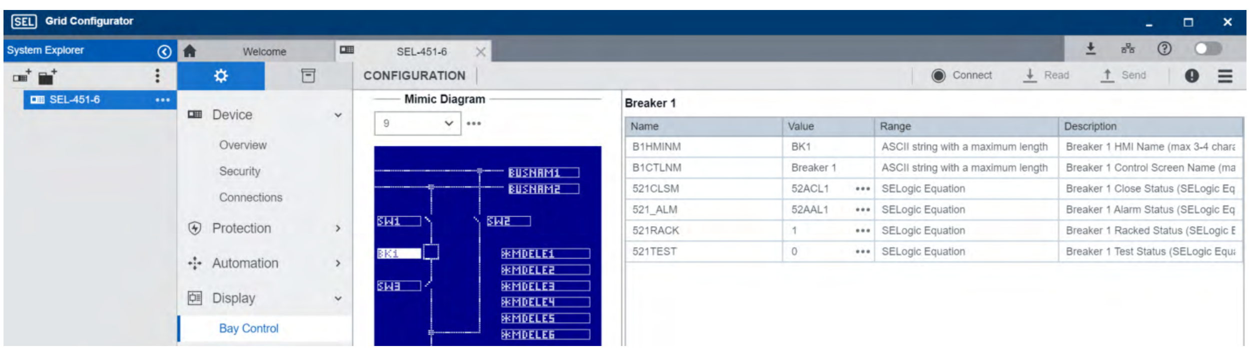


Figure 5.24 Breaker Settings, Breaker S

BKq

In some relays, each numbered breaker (q = 1, 2, 3, 4, or 5) can be assigned to NA or one of the terminals. No terminal can be assigned twice. Unused breaker numbers are forced to NA.

BmHMINM

Enter a Breaker *m* label on the HMI (one-line diagram). The number of characters is limited to a maximum string width of 17 pixels (approximately four characters).

BmCTLNM

Enter a Breaker *m* label on the control screen. Enter a descriptive breaker name (as many as 15 characters).

52mCLSM, 52m_ALM

These SELOGIC control equations report breaker close status and breaker alarm status. Any bit in the Relay Word, as well as logical operators, can be programmed into these SELOGIC control equations.

52mRACK, 52mTEST

These SELOGIC control equations modify the display of rack-type breaker mosaics. The settings are shown for both rack-type and non-rack type breakers, but only impact the display of rack-type breakers. The settings do not have any control functionality impact on any breaker. See *Figure 5.9* for settings impact on the rack-type breaker mosaic display.

Analog Display

If analog display points are not required, leave the setting(s) blank, because the relay displays only the defined display points.

Select analog display label `MDELE1` in the interactive one-line diagram to display the form shown in *Figure 5.25*. Select the Expression Builder button to display the form shown in *Figure 5.26*. The Expression Builder helps build the analog quantity setting string. Press the Expression Builder button on the form shown in *Figure 5.26* to find the Analog or Fixed Element to be displayed.

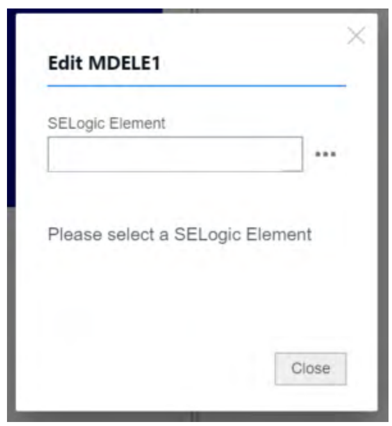


Figure 5.25 Analog Quantity Setting Form

To display fixed text instead of analog quantities, enter the number 1 in the Analog or Fixed Element field.

Figure 5.26 Analog Quantity Setting Form

Select the FREQ System Frequency (see *Figure 5.27*). Enter a Pre-Text, for example 'Frq=', as shown in *Figure 5.27*. Set the numerical display format to 5.2; this displays frequency up to two decimal places. You can scale the numerical value of FREQ to display a scaled value of the analog quantity. For example, a scaling value of 0.5 displays only half the value of FREQ, while a scaling value of 2 displays twice the value of FREQ. Enter text, such as the units of the analog quantity in the Post-Text field. Test the entries by typing a value of 60.51 in the preview analog display field. Select the **Preview** button, and verify that all entries are correct and will fit on the screen.

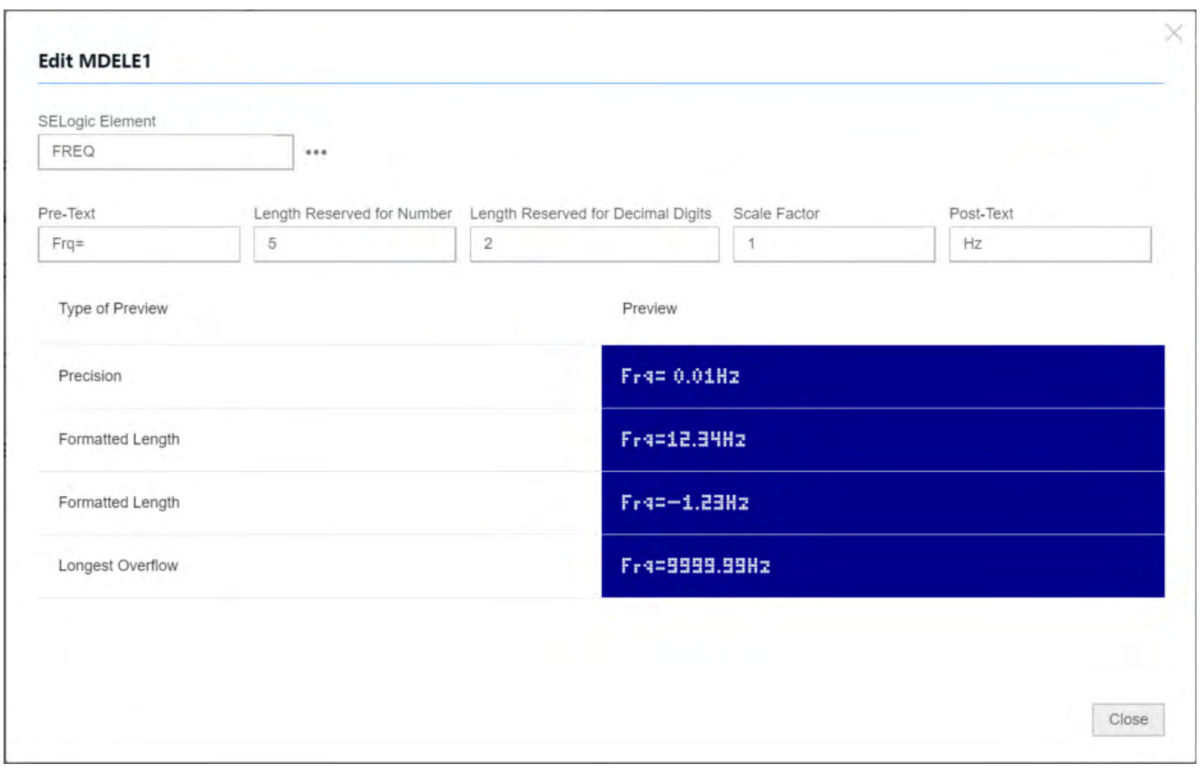


Figure 5.27 Example of an Analog Quantity Expression

SEL recommends that you use the MDELE*n* expression builder within QuickSet or SEL Grid Configurator when creating these settings. However, if you enter the expression from the ASCII command line, the format of the user input is as follows:

Analog Quantity Label,"Pre-Text = {x.y,z} Post-Text"

where:

x = total number of digits of the number to display (includes number of digits following a decimal point)
y = total number of digits to display following a decimal point
z = scaling factor

For example, if you wanted to display the VAZFM analog quantity with 3 total digits with 1 digit following a decimal point and no scaling, enter the following on the command line:

VAZFM,"VAZ = {3.1,1} V"

The setting value reported in QuickSet or SEL Grid Configurator is expected to be reported differently than what is accepted on the ASCII command line.

Customizable Screens

SEL-400 series relays support custom mimic display screens. Custom mimic display screens are developed by the SEL factory by using your requirements, and then added to the QuickSet relay driver. The following images show the breaker and power system variants supported in custom mimic display screens. For a complete list of mimic display screens available in SEL-400 series relays, see selinc.com/app/mimic-diagram/.

Available Circuit Breakers

Figure 5.28 shows the different types of circuit breakers and disconnects available.

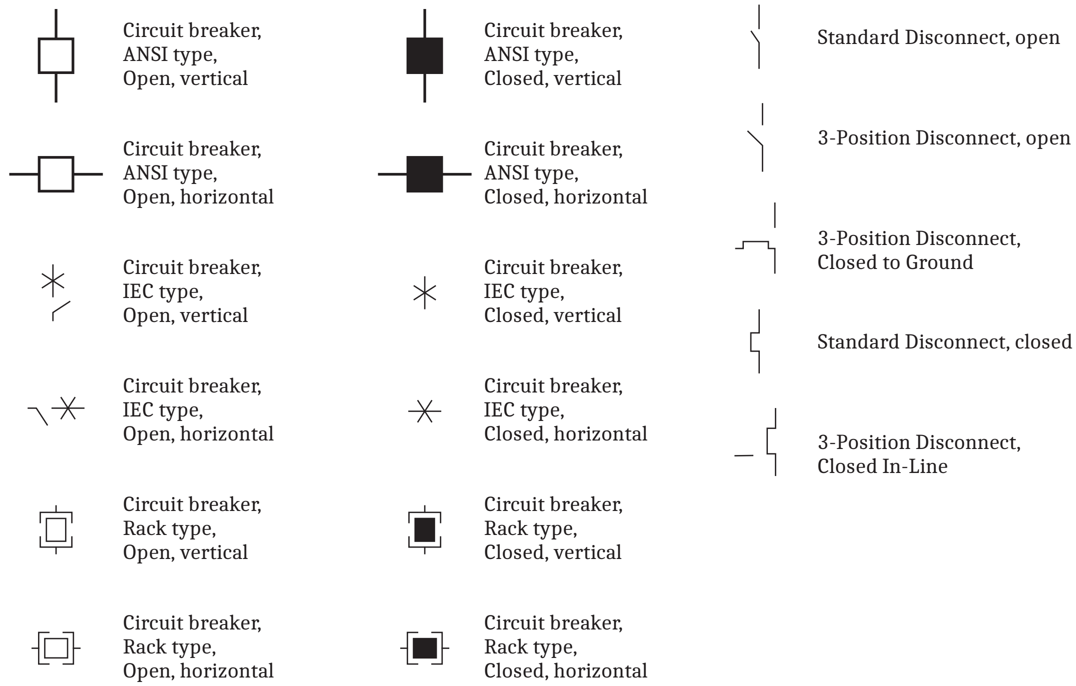


Figure 5.28 Different Types of Circuit Breakers and Disconnects

Available Power System Components

Figure 5.29 shows the different types of power system components available.

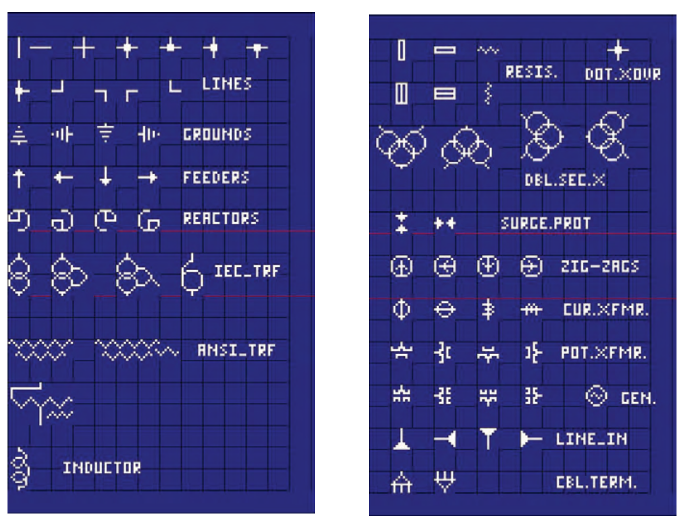


Figure 5.29 Power System Components

Bay Control Example Application

This example demonstrates configuring a bay control screen for an SEL-451. Similar configurations can be done with other SEL-400 series relays.

Bus 1, Bus 2, and Transfer BUS Bay With Ground Switch (MIMIC := 4)

Figure 5.30 illustrates the Bus 1, Bus 2, and Transfer Bus Bay with Ground Switch (MIMIC := 4). The Bay configuration used in this example provides five disconnect switches, one breaker, and the ability to display as many as six Analog Quantities. The labels and Analog Quantities shown in *Figure 5.30* are all a result of the settings entered in this example. See *Table 5.6* for a complete list of Bay settings for this application.

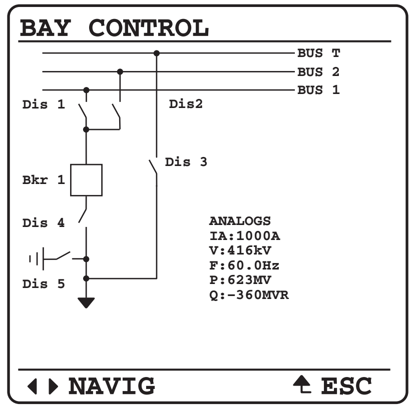


Figure 5.30 Illustration of One-Line Diagram After Entering Example Settings

Bay Control Settings

General One-Line Settings

One-Line Diagram

This setting selects the one-line diagram that defines the bay configuration, and it must exactly match the bay configuration being controlled. Failure to select the exact one-line diagram that describes the bay configuration being controlled could result in misapplications.

MIMIC := **4**

Bay Name

Enter a bay name (as many as 20 characters) that defines the bay being controlled.

BAYNAME := **BAY CONTROL**

Bay Label

As many as two bay labels are available in one-line diagrams 14, 17, 18, and 23. BAYLAB1 and BAYLAB2 settings can accept as many as eight characters, depending on the pixel width of the string.

BAYLAB1 or BAYLAB2 are not required because the MIMIC setting selected in this example does not include bay labels. If MIMIC 14, 17, 18, or 23 had been selected, the relay would have prompted for BAYLAB1 and BAYLAB2 settings.

Busbar Information

Bus-Name Labels

Based on the MIMIC setting, the relay provides as many as nine bus-name labels in the one-line diagram. With MIMIC set to 4, the relay requires three bus-name labels, one for the transfer bus, one for Bus 2, and one for Bus 1. The top-most bus in the one-line diagram is BUSNAM1 and the bottom-most bus in the one-line diagram is the highest number bus available for the selected MIMIC setting, three in this case.

Enter bus-name labels (as many as ten characters) that describe each bus in the one-line diagram.

The actual number of characters accepted depends on the pixel width of the string.

BUSNAM1 := **Bus T**

BUSNAM2 := **Bus 2**

BUSNAM3 := **Bus 1**

Breaker Information

The relay displays breaker information for as many as three breakers. For the bay configuration in this example, the relay displays one. If more breakers were supported, based on the MIMIC setting selected, the settings associated with additional breakers would follow Breaker 1 settings.

Breaker Name Label

Enter a breaker name (as many as six characters) that describes each circuit breaker in the one-line diagram.

The actual number of characters accepted depends on pixel width of the string.

B1HMINM := **Bkr 1**

Breaker Status

This SELOGIC control equation reports breaker close status and breaker alarm status. Any bit in the Relay Word can be programmed into this SELOGIC control equation, as well as logical operators. The equations below return the state of the Bkr 1 status and any Bkr 1 alarm conditions.

521CLSM := **52ACL1**

521_ALM := **52AAL1**

Disconnect Information

The relay provides disconnect switch information for as many as ten disconnect switches. For the bay configuration selected in this example, the relay supports five disconnect switches.

Disconnect Name Label

Enter disconnect labels of as many as six characters in length that describe each disconnect switch in the one-line diagram. The actual number of characters accepted depends on pixel width of the string.

D01HMIN := **Dis 1**

Disconnect Status

Wire the normally open and normally closed auxiliary contacts from the disconnect switch to relay inputs, and program the relay inputs into 89AM01 and 89BM01 SELOGIC control equations. These equations report the state of the disconnect switch auxiliary contacts. Both equations must be programmed for the Disconnect Switch Status and Alarm Logic to function correctly.

89AM01 := **IN103**

89BM01 := **IN104**

Disconnect Alarm Pickup Delay

This setting monitors disconnect open/close operations (the undetermined time) of the disconnect switch. When the disconnect alarm timer expires, an alarm condition exists and the 89AL1 Relay Word bit asserts. Set the 89ALP*m* timer longer than the expected operation (undetermined state) time, but less than the 89CSIT*m* or 89OSIT*m* seal-in timers. The expected disconnect operation time in this example is 250 cycles. 89ALP*m* is entered in cycles and has a range of 1–99999.

89ALP01 := **260**

Disconnect Close/Open Control

Program SELOGIC control equations 89CCN*n* and 89OCN*n* to close or open disconnect switch *n*, respectively. Great care needs to be used when programming these equations because there are no breaker jumper supervision or access level safeguards in place for this disconnect operate method. The settings in this example close the disconnect switch when Remote Bit 1 is set and open the disconnect switch when Remote Bit 1 is cleared. The 89CCN01 SELOGIC example below also includes additional supervision logic where the close operation only operates if Breaker 1 is open (NOT 52CLS1) and the disconnect switch is in the opposite state (89OPN1). When these conditions are met, a close disconnect operation will initiate. Relay Word bit 89CLS1 is the output of the seal-in timer and asserts when Relay Word bit 89CCN01 asserts. Relay Word bit 89OPN1 deasserts as soon as the disconnect switch starts to move. The OR combination of Relay Word bit 89CLS1 and 89OPN1 keeps the close disconnect signal asserted until the disconnect operation has completed. The SELOGIC control equations below demonstrate disconnect lockout control in the relay. The 89OCN01 SELOGIC control equation illustrates the same type of supervision for the disconnect switch open logic.

89CCN01 := **RB01 AND (89OPN1 OR 89CLS1) AND NOT 52CLSM1**

89OCN01 := **NOT RB01 AND (89CL1 OR 89OPEN1) AND NOT 52CLSM1**

Disconnect Front-Panel Control Enable

Program SELOGIC control equation 89CTL*n* to identify a disconnect as controllable (89CTL*n* := 1) or status-only (89CTL*n* := 0). When a disconnect is identified as controllable, the disconnect can be selected when navigating the relay front-panel HMI. When a disconnect is identified as status-only, the disconnect cannot be selected when navigating the relay front-panel HMI. Three-position disconnects have a control equation for each disconnect position. The SELOGIC control equation below identifies the disconnect as controllable.

89CTL01 := **1**

Disconnect Close/Open Seal-in Timers

The seal-in timers assert the close or open signal long enough to allow the disconnect operation to complete. Set the seal-in timer 10 to 15 percent longer than the expected disconnect operate time to give the disconnect switch time to complete the operation. 89CST*m* and 89OST*m* are entered in cycles and have a range of 1–99999. The example shown anticipates a disconnect switch operate time of approximately 250 cycles.

Cold weather and low battery voltages can impact operation times. Be sure to consider these conditions when setting the seal-in timers.

The output contacts must not be used to break the motor coil current. An auxiliary contact with adequate current interrupting capacity must first interrupt current supply to the motor before the relay contact opens. Include the auxiliary contact clearing time when setting the disconnect seal-in timer.

89CST01 := **280**

89OST01 := **280**

Disconnect 2–5

Disconnect switch settings 2–5 are similar to the Disconnect Switch 1 examples above. See *Table 5.6* for a complete list of Bay Class settings for this application.

One-Line Analog Display

One-line diagrams in the relay can contain as many as six Analog Quantity display points. The MIMIC setting selected in this example displays six Analog Display points. See *Display Points on page 4.10* for Display Point programming. The settings below illustrate how to display text and Analog Quantities available in the mimic display. If analog display points are not required to appear in the one-line diagram, leave the setting(s) blank, and the relay will only display the defined display points.

1. 1, “Analogs”
2. IAWM, “IA:(4.0,1)A”
3. VABFM, “V:(3.0,1)kV”
4. FREQ, “F:(4.1,1)Hz”
5. 3P, “P:(3.0,1)MW”
6. 3Q_F, “Q:(3.0,1)MVR”

Control Selection

The LOCAL SELOGIC control equation enables local and remote control of the disconnect switch. This example illustrates how the SEL-451 input contact IN107 can accommodate existing bay controls that use a key to manually change from remote to local control. The key switch is made to actuate a contact when the key is turned, as shown in *Figure 5.31*. With the contact of the switch wired to the SEL-451 input, the key switch provides local and remote control. Make the following setting to enable LOCAL control when IN107 is asserted.

LOCAL := **IN107**

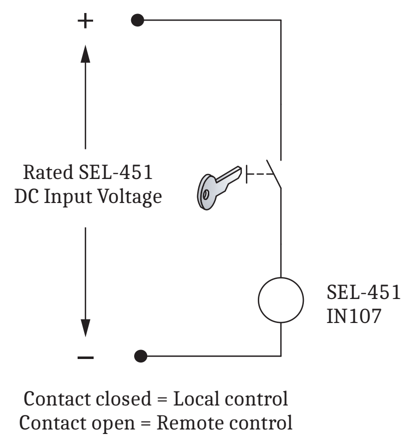


Figure 5.31 Local and Remote Control Logic With Key Control

Front Panel Settings

The one-line diagram is one of the screens that are available for display in the rotating display. To display RMS_V, RMS_I, and ONELINE screens on the rotating display every five seconds, make the following Front Panel settings.

SCROLD := **5**

RMS_V := **Y**

RMS_I := **Y**

RMS_VPP := **N**

RMS_W := **N**

FUNDVAR := **N**

RMS_VA := **N**

RMS_PF := **N**

RMS_BK1 := **N**

RMS_BK2 := **N**

STA_BAT := **N**

FUND_VI := **N**

FUNDSEQ := **N**

FUND_BK := **N**

ONELINE := **Y**

The following settings in the Front Panel settings provide immediate display of the one-line diagram screen when Pushbutton 2 is pressed.

PB2_HMI := **BC**

Output Settings

Output Logic Settings

This illustrates the ability to program disconnect lockout protection for the selected one-line diagram. To eliminate the danger of closing or opening the ground switch on an energized line, the disconnect switch cannot operate unless Breaker 1 is open. When the Disconnect 1 close command is executed (89CLS1), OUT103 only asserts if the state of Breaker 1 is open (NOT 52CLS1). This illustrates disconnect switch lockout protection through SELOGIC control equations. The SELOGIC control equation for OUT104 below illustrates similar lockout protection for the disconnect switch open operation. Wire OUT103 to the disconnect switch closing circuit and OUT104 to the disconnect switch opening circuit.

OUT103 := **89CLS1 AND NOT 52CLSM1**

OUT104 := **89OPEN1 AND NOT 52CLSM1**

⚠CAUTION
The outputs in the relay are not designed to break the coil current in the disconnect motor. An auxiliary contact with adequate current-interrupting capacity must clear the coil current in the disconnect motor before the output opens. Failure to observe this safeguard could result in damage to the output contacts.

Another example of disconnect lockout would be to ensure that Dis 3 never closes when the ground disconnect switch Dis 5 is closed. Enter the SELOGIC control equation below for Dis 3 switch lockout protection. 89CLS3 is the close disconnect switch Relay Word bit for Disconnect 3 and the 89OPN5 Relay Word bit is the status of Disconnect 5. The SELOGIC control equation below will not assert OUT201 unless both conditions are true.

OUT201 := **89CLS3 AND 89OPN5**

These are just a few examples of disconnect lockout control. Use Relay Word bits and SELOGIC programming to design lockout control scenarios required for the configuration being controlled.

The SELOGIC Output settings listed in *Table 5.6* are example close and open disconnect equations with disconnect lockout control for Switches 1–5.

Table 5.6 Application Example Bay Control Settings for Bus 1, Bus 2, and Transfer Bus Bay With Ground Switch Application (Sheet 1 of 3)

Setting	Description	Entry
General One-Line Settings		
MIMIC	One-line Screen Number (1–999)	4
BAYNAME	Bay Name (20 characters)	BAY CONTROL
Busbar Information		
BUSNAM1	Busbar 1 Name (40 pixels, 6–10 characters)	Bus T
BUSNAM2	Busbar 2 Name (40 pixels, 6–10 characters)	Bus 2
BUSNAM3	Busbar 3 Name (40 pixels, 6–10 characters)	Bus 1
Breaker Information		
B1HMINM	Breaker 1 HMI Name (max 3–17 characters)	Bkr 1
B1CTLNM	Breaker 1 HMI Cntl Scr. Name (max. 15 characters)	Bkr 1
521CLSM	Breaker 1 Close Status (SELOGIC Equation)	52ACL1
521_ALM	Breaker 1 Alarm Status (SELOGIC Equation)	52AAL1
Disconnect Information		
D1HMIN	Disconnect 1 HMI Name (max 3–17 characters)	D1
D1CTLN	Disconnect 1 Name (25 pixels, max. 15 characters)	Dis 1
89AM1	Disconnect 1 N/O Contact (SELOGIC Equation)	IN103
89BM1	Disconnect 1 N/C Contact (SELOGIC Equation)	IN104
89ALP1	Disconnect 1 Alarm Pickup Delay (1–99999 cyc)	260
89CCN1	Disconnect 1 Close Control (SELOGIC Equation)	89CC01
89OCN1	Disconnect 1 Open Control (SELOGIC Equation)	89OC01
89CST1	Disconnect 1 Close Seal-in Time (1–99999 cyc)	280
89OST1	Disconnect 1 Open Seal-in Time (1–99999 cyc)	280
D2HMIN	Disconnect 2 HMI Name (max. 3–17 characters)	D2

Table 5.6 Application Example Bay Control Settings for Bus 1, Bus 2, and Transfer Bus Bay With Ground Switch Application (Sheet 2 of 3)

Setting	Description	Entry
D2CTLN	Disconnect 2 Name (25 pixels, 4–6 characters)	Dis 2
89AM2	Disconnect 2 N/O Contact (SELOGIC Equation)	1
89BM2	Disconnect 2 N/C Contact (SELOGIC Equation)	0
89ALP2	Disconnect 2 Alarm Pickup Delay (1–99999 cyc)	260
89CCN2	Disconnect 2 Close Control (SELOGIC Equation)	89CC02
89OCN2	Disconnect 2 Open Control (SELOGIC Equation)	89OC02
89CST2	Disconnect 2 Close Seal-in Time (1–99999 cyc)	280
89OST2	Disconnect 2 Open Seal-in Time (1–99999 cyc)	280
D3HMIN	Disconnect 3 HMI Name (max. 3–17 characters)	D3
D3CTLN	Disconnect 3 Name (25 pixels, 4–6 characters)	Dis 3
89AM3	Disconnect 3 N/O Contact (SELOGIC Equation)	1
89BM3	Disconnect 3 N/C Contact (SELOGIC Equation)	0
89ALP3	Disconnect 3 Alarm Pickup Delay (1–99999 cyc)	260
89CCN3	Disconnect 3 Close Control (SELOGIC Equation)	89CC03
89OCN3	Disconnect 3 Open Control (SELOGIC Equation)	89OC03
89CST3	Disconnect 3 Close Seal-in Time (1–99999 cyc)	280
89OST3	Disconnect 3 Open Seal-in Time (1–99999 cyc)	280
D4HMIN	Disconnect 4 HMI Name (1–99999 cyc)	D4
D4CTLN	Disconnect 4 Name (25 pixels, 4–6 characters)	Dis 4
89AM4	Disconnect 4 N/O Contact (SELOGIC Equation)	1
89BM4	Disconnect 4 N/C Contact (SELOGIC Equation)	0
89ALP4	Disconnect 4 Alarm Pickup Delay (1–99999 cyc)	260
89CCN4	Disconnect 4 Close Control (SELOGIC Equation)	89CC04
89OCN4	Disconnect 4 Open Control (SELOGIC Equation)	89OC04
89CST4	Disconnect 4 Close Seal-in Time (1–99999 cyc)	280
89OST4	Disconnect 4 Open Seal-in Time (1–99999 cyc)	280
D5HMIN	Disconnect 5 HMI Name (1–9999)	D5
89AM5	Disconnect 5 N/O Contact (SELOGIC Equation)	0
89BM5	Disconnect 5 N/C Contact (SELOGIC Equation)	0
89ALP5	Disconnect 5 Alarm Pickup Delay (1–99999 cyc)	260
89CCN5	Disconnect 5 Close Control (SELOGIC Equation)	89CC05
89OCN5	Disconnect 5 Open Control (SELOGIC Equation)	89OC05
89CST5	Disconnect 5 Close Seal-in Time (1–99999 cyc)	280
89OST5	Disconnect 5 Open Seal-in Time (1–99999 cyc)	280
One-Line Analog Display		
1		1, “Analogs”
2		IAWM, “IA:(4.0,1)A”
3		VABFM, “V:(3.0,1)kV”
4		FREQ, “F:(4.1,1)Hz”

Table 5.6 Application Example Bay Control Settings for Bus 1, Bus 2, and Transfer Bus Bay With Ground Switch Application (Sheet 3 of 3)

Setting	Description	Entry
5		3P, "P:(3.0,1)MW"
6		3Q_F, "Q:(3.0,1)MVR"
Control Selection		
LOCAL	Local Control (SELOGIC control equation)	IN107

Table 5.7 Application Example Front Panel Settings

Setting	Description	Entry
Selectable Screens for the Front Panel		
SCROLD	Front Panel Display Update Rate (OFF, 1–15 secs)	5
RMS_V	RMS Line Voltage Screen (Y, N)	Y
RMS_I	RMS Line-Current Screen (Y, N)	Y
RMS_VPP	RMS Line Voltage Phase-to-Phase Screen	N
RMS_W	RMS Active Power Screen	N
FUNDVAR	Fundamental Reactive Power Screen	N
RMS_VA	RMS Apparent Power Screen	N
RMS_PF	RMS Power Factor Screen	N
RMS_BK1	RMS Breaker 1 Currents Screen	N
RMS_BK2	RMS Breaker 2 Currents Screen	N
STA_BAT	Station Battery Screen	N
FUND_VI	Fundamental Voltage and Current Screen	N
FUNDSEQ	Fundamental Sequence Quantities Screen	N
FUND_BK	Fundamental Breaker Currents Screen	N
ONELINE	One-Line Bay Control Diagram	Y
Selectable Operator Pushbuttons		
PB2_HMI	Pushbutton 2 HMI Screen	BC

Table 5.8 Application Example Output Settings, Output SELOGIC Control Equations

Setting	Description	Entry
OUT103	OUT103 SELOGIC control equation	89CLS1 AND NOT 52CLSM1
OUT104	OUT104 SELOGIC control equation	89OPEN1 AND NOT 52CLSM1
OUT105	OUT105 SELOGIC control equation	89CLS2 AND NOT 52CLSM1
OUT106	OUT106 SELOGIC control equation	89OPEN2 AND NOT 52CLSM1
OUT201	OUT201 SELOGIC control equation	89CLS3 AND 89OPN5
OUT202	OUT202 SELOGIC control equation	89OPEN3 AND 52CLSM1
OUT203	OUT203 SELOGIC control equation	89CLS4 AND NOT 52CLSM1
OUT204	OUT204 SELOGIC control equation	89OPEN4 AND NOT 52CLSM1
OUT205	OUT205 SELOGIC control equation	89CLS5 AND NOT 52CLSM1
OUT206	OUT206 SELOGIC control equation	89OPEN5 AND NOT 52CLSM1

SECTION 6

Autoreclosing

This section describes the operation of autoreclose logic in SEL-400 series relays that include an autorecloser. This section covers the following topics:

The relay autoreclose function provides complete control for single circuit breaker and two circuit breaker reclosing schemes. The autoreclose function accommodates both single-pole and three-pole reclosing. Some SEL-400 series relays only support three-pole operations. See the *Features* section in *Section 1: Introduction and Specifications* in the product-specific instruction manual to determine the reclosing capability of each relay. Relays that support single-pole breaker operations can be set for a total of two single-pole reclose shots. Three-pole breaker operations can be set for as many as four three-pole reclose shots.

NOTE: The SEL-487E autoreclose logic is designed to operate as many as six breakers independently, which differs from the rest of the SEL-400 series relays. See the SEL-487E instruction manual for details on SEL-487E autoreclose logic.

You can designate the leader and follower circuit breakers in a two-circuit breaker configuration. The relay recloser can dynamically change leader and follower designations based on settings and operating conditions.

You can program the autoreclose logic to perform one shot of high-speed three-pole reclose. This high-speed three-pole shot replaces one of the four delayed time three-pole shots. There is no difference between a shot of high-speed three-pole reclose and a shot of delayed three-pole autoreclose; simply select the open interval time accordingly.

NOTE: The relay voltage check elements (for bus and line voltages) may be used without the synchronism-check feature, however, for certain voltage connections, some of the synchronism-check settings need to be entered to ensure that the correct voltages are used.

Two autoreclose modes are available when using the relay to control two circuit breakers:

- Combined two-breaker mode (setting E79 := Y)—both circuit breakers must trip before any reclosing can occur.
- Independent two-breaker mode (setting E79 := Y1)—the follower circuit breaker can trip and reclose even when the lead breaker has not operated. This is useful on both ring bus and breaker-and-a-half schemes, where the follower breaker is a tie breaker that can be tripped by protection on either side.

For single circuit breaker applications, use setting E79 := Y.

Autoreclosing States

The autoreclose logic for either circuit breaker can be in one of the following five states (see *Figure 6.1*):

- ➤ Start (common to both circuit breakers) (79STRT)
- ➤ Reset per circuit breaker (BK1RS, BK2RS)
- ➤ Single-pole autoreclose cycle (common to both circuit breakers) (79CY1)
- ➤ Three-pole autoreclose cycle (common to both circuit breakers) (79CY3)
- ➤ Lockout, per circuit breaker (BK1LO, BK2LO)

Start (79STRT)

The autoreclose logic is in the Start state for both circuit breakers during the following conditions:

- ➤ Startup
- ➤ Restart
- ➤ Any relay settings change

The relay stores the previous reclosing state for Relay Word bits 79CY1, 79CY3, BK1LO, BK2LO, BK1RS, and BK2RS when a restart or any relay settings change occurs.

At startup, the recloser logic goes from the start state to the lockout state. For a restart or a settings change, the recloser logic enters the start state, then goes to lockout if the circuit breakers were open before the restart or settings change. If the circuit breakers were previously closed, then the recloser logic proceeds through the 3PMRCD (Manual Close Reclaim Time Delay) time and then goes to the ready state.

Reset (BK1RS, BK2RS)

The autoreclose logic is in the reset or ready state for either circuit breaker when the circuit breaker is ready to begin an autoreclose cycle. There are three reset state timers. After a successful reclose cycle, the relay goes to the reset state after reclaim times SPRCD (Single-Pole Reclaim Time Delay) for single-pole automatic and 3PRCD (Three-Pole Reclaim Time Delay) for three-pole automatic reclosing. If the recloser has been in a lockout condition, the Ready or Reset state cannot occur until the 3PMRCD (Manual Close Reclaim Time Delay) timer has expired. You can only block the reclaim time after a successful reclose cycle. Setting 79BRCT (Block Reclaim Timer) prevents timing of reclaim timers SPRCD, 3PRCD, and 3PMRCD.

Single-Pole Autoreclose (79CY1)

This state does not apply to relays that only support three-pole reclosing. The autoreclose logic is in a single-pole autoreclose cycle for either circuit breaker if all of the following conditions are satisfied:

- ➤ Single-pole trip occurs
- ➤ Condition(s) to initiate a single-pole autoreclose cycle are satisfied
- ➤ Circuit breaker(s) is in service and ready to begin a single-pole autoreclose cycle (that is, reset)

Three-Pole Autoreclose (79CY3)

The autoreclose logic is in a three-pole autoreclose cycle for either circuit breaker if all of the following conditions are satisfied:

➤ Three-pole trip occurs
➤ Condition(s) to initiate a three-pole autoreclose cycle are satisfied
➤ Circuit breaker(s) is in service and ready to begin a three-pole autoreclose cycle (that is, reset)

Lockout (BK1LO, BK2LO)

The lockout state is the default state of any circuit breaker after startup. Other conditions place the recloser in the LO state. The relay recloser has a drive-to-lockout function that you can program for any external or internal condition—use setting 79DTL. A circuit breaker can go to lockout by two methods. The circuit breaker enters the lockout state if either of the following occur:

➤ Supervisory Relay Word bits SP*n*CLS or 3P*n*CLS do not assert within the BK*n*CLSD time
➤ The circuit breaker does not close within the BKCFD time

The timer for both supervisory Relay Word bits SP*n*CLS and 3P*n*CLS is setting BK*n*CLSD. Setting BK*n*CLSD = OFF disables the BK*n*CLSD delay timer, requiring either SP*n*CLS or 3P*n*CLS to assert before transitioning to the next state.

In applications using two circuit breakers, you can designate one circuit breaker as the leader and the other circuit breaker as the follower. The relay freezes the leader/follower decision during an autoreclose cycle unless the autoreclose logic receives another initiation.

If the recloser receives another initiation, the logic reevaluates the leader and follower circuit breakers to determine the number of circuit breakers in a scheme (NBK*n*), the leader circuit breaker (LEADBK*n*), and the follower circuit breaker (FOLBK*n*). This determination is based on the service status of the circuit breakers. The logic considers a circuit breaker out of service if the circuit breaker goes to lockout. The logic considers a circuit breaker to be in service as soon as the circuit breaker closes and is no longer in lockout.

State Diagram

NOTE: The autoreclose function runs once per power-system cycle. To ensure that the logic detects transient element state changes that initiate closing, you should extend the assertion time of transient element states to 1 cycle.

Figure 6.1 illustrates how the autoreclose logic moves from one state to another with respect to Circuit Breaker 1. (This diagram is identical for Circuit Breaker 2; replace the 1 in the Relay Word bits with 2.) The Relay Word bits that correspond to each state are shown (see *Table 6.1*). A solid path between two states indicates that the logic can move in only one direction. Two broken paths between two states indicate the logic can move in either direction between the two states. The dashed vertical line that runs through the center of the figure indicates the states common to both circuit breakers.

Table 6.1 describes each of the five states with respect to Circuit Breaker 1, along with the corresponding Relay Word bits.

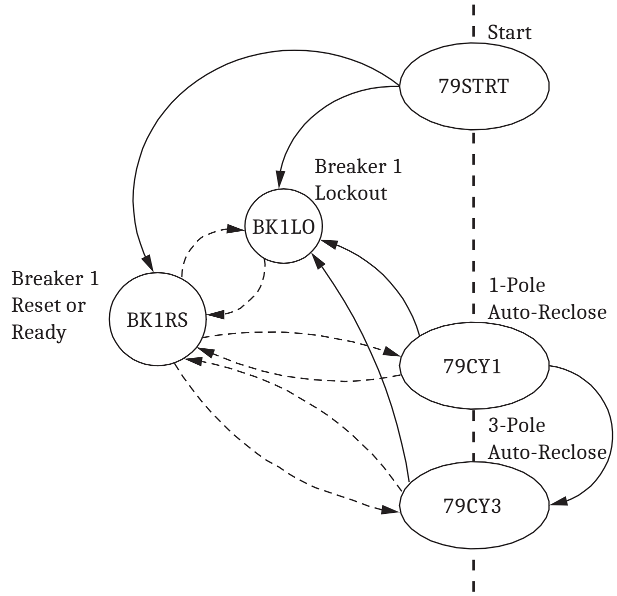


Figure 6.1 Autoreclose State Diagram for Circuit Breaker 1

Table 6.1 Autoreclose Logical States for Circuit Breaker 1

State	Description	Relay Word Bit
Start	Startup, or relay settings change	79STRT
Reset	Circuit Breaker 1 reset	BK1RS
Single-pole autoreclose cycle[a]	Single-pole autoreclose	79CY1
Three-pole autoreclose cycle	Three-pole autoreclose cycle	79CY3
Lockout	Lockout	BK1LO

[a] 79CY1 is only available in relays that support single-pole breaker operations.

One-Circuit-Breaker Autoreclosing

Modes

The autoreclose logic can operate in one of three modes, depending upon the relay autoreclose capabilities:

- Single-pole mode (SPAR)
- Three-pole mode (3PAR)
- Single- and three-pole mode (SPAR/3PAR)

Relay settings ESPR1 (Single-Pole Reclose Enable—BK1) and E3PR1 (Three-Pole Reclose Enable—BK1) determine the autoreclose mode (see *Recloser Mode Enables on page 6.8*). These settings are inputs to the recloser initiation Relay Word bits SPARC (Single-Pole Reclose Initiate Qualified) and 3PARC (Three-Pole Reclose Initiate Qualified); see *Figure 6.8* and *Figure 6.9*. SPARC asserts when all necessary conditions to begin a single-pole autoreclose cycle are satisfied (ESPR1, for example) and the recloser receives a single-pole reclose initiation SPRI (see *Figure 6.8*). Relay Word bit 3PARC asserts when all necessary conditions to begin a three-pole autoreclose cycle are satisfied (E3PR1, for example) and the recloser receives a three-pole reclose initiation 3PRI (see *Figure 6.9*).

Other recloser settings include the initial recloser settings (see *Enable Autoreclose Logic for Two Circuit Breakers on page 6.22*) and the trip logic enable settings E3PT, E3PT1, and E3PT2. When SELOGIC control equations E3PT, E3PT1, and E3PT2 are deasserted, a single-pole reclose follows a single-pole trip; when these SELOGIC control equations are asserted, only three-pole tripping and reclosing result (see *Trip Logic and Reclose Sources for Single-Pole Breaker Applications on page 6.9*).

Single-Pole Mode

NOTE: Single-pole mode is only supported in relays that provide single-pole breaker control.

Figure 6.11 shows the one circuit breaker single-pole autoreclose cycle 79CY1. The cycle starts when Relay Word bit SPARC asserts. The recloser waits as long as 10 cycles for the circuit breaker to open (indicated by Relay Word bit SPO) and then begins timing SPOID (Single-Pole Open Interval Delay) when the circuit breaker opens. After single-pole open interval time SPOID expires, the relay recloses the circuit breaker if supervisory condition SP1CLS (Single-Pole BK1 Reclose Supervision) is satisfied within the duration of timer BK1CLSD (BK1 Reclose Supervision Delay).

At the reclose command, the recloser starts timer BKCFD (Breaker Close Failure Delay). If the circuit breaker fails to close, the recloser goes to lockout (BK1LO) after timer BKCFD expires.

SPRCD Reclaim Timing

If the circuit breaker closes, the recloser starts timer SPRCD (Single-Pole Reclaim Time Delay). The recloser determines subsequent state transitions during reclaim timing according to the status of Relay Word bit SPLSHT (Single-Pole Reclose Last Shot). When SPLSHT is asserted, the recloser forces all subsequent relay trips to three-pole only mode.

SPLSHT Asserted (Last Shot)

The recloser exits the 79CY1 state via one of the following three methods while SPLSHT is asserted:

- If no further trip conditions occur, the recloser goes to the reset state BK1RS after reclaim timer SPRCD expires.
- If a fault occurs during the SPRCD reclaim time, then the recloser asserts Relay Word bit 3PARC if all three-pole reclose conditions are satisfied and proceeds to the autoreclose three-pole cycle state 79CY3.
- If a fault occurs during the SPRCD reclaim time, and the three-pole reclose conditions are not satisfied (E3PR1 is logical 0, for example) the recloser exits the 79CY1 cycle state and goes to the lockout state BK1LO.

SPLSHT Deasserted (Single-Pole Shot Remains)

The recloser exhibits four possible state transitions when SPLSHT is not asserted:

- If no further trip conditions occur, the recloser goes to the reset state BK1RS after timer SPRCD expires.
- If a single-phase fault occurs while the SPRCD reclaim timer is timing, the recloser asserts SPARC for single-pole initiate conditions and returns to the beginning of the 79CY1 cycle state; the recloser increments the shot counter and begins the next open interval timer.

- If a multiphase fault occurs during the SPRCD reclaim time, then the recloser asserts Relay Word bit 3PARC if all three-pole reclose conditions are satisfied (E3PR1 is logical 1, for example) and proceeds to the autoreclose three-pole cycle state 79CY3.
- If a multiphase fault occurs during the SPRCD reclaim time, and the three-pole reclose conditions are not satisfied (E3PR1 is logical 0, for example), the recloser exits the 79CY1 cycle state and goes to the lockout state BK1LO.

Lockout State From 79CY1

The recloser goes to lockout (BK1LO) when any of the following occur:

- The number of trips exceeds the maximum number of shots (NSPSHOT).
- Supervision condition SP1CLS fails to assert in BK1CLSD time.
- Relay Word bit 3POLINE asserts (for a circuit breaker manual opening).
- The circuit breaker fails to close within BKCFD time.
- Any time Relay Word bit 79DTL asserts.

Three-Pole Mode

Figure 6.12 shows the one circuit breaker autoreclose cycle 79CY3. The cycle starts when Relay Word bit 3PARC asserts. The recloser checks SELOGIC control equation 79SKP at this point to determine whether to increment the shot counter. The recloser waits indefinitely for the circuit breaker to open, as indicated by Relay Word bit 3POLINE. The recloser begins timing 3POID1 (Three-Pole Open Interval 1 Delay) when the circuit breaker opens. After the open interval time 3POID1 expires, the relay asserts Relay Word bit BK1CL to reclose the circuit breaker if supervisory condition 3P1CLS (Three-Pole BK1 Reclose Supervision) is satisfied within the duration of timer BK1CLSD (BK1 Reclose Supervision Delay).

At the reclose command, the recloser starts timer BKCFD (Breaker Close Failure Delay). If the circuit breaker fails to close, the recloser goes to lockout (BK1LO) after timer BKCFD expires.

3PRCD Reclaim Timing

If the circuit breaker closes, the recloser starts timer 3PRCD (Three-Pole Reclaim Time Delay). The recloser determines subsequent state transitions during reclaim timing according to the status of Relay Word bit 3PLSHT (Three-Pole Reclose Last Shot).

3PLSHT Asserted (Last Shot)

The recloser exits the 79CY3 state via one of the following two methods while 3PLSHT is asserted:

- If no further trip conditions occur, the recloser goes to the reset state BK1RS after reclaim timer 3PRCD expires.
- If a fault occurs during the 3PRCD reclaim time, then the recloser exits the 79CY3 cycle state and goes to the lockout state BK1LO.

3PLSHT Deasserted (Three-Pole Shot Remains)

The recloser exhibits three possible state transitions when 3PLSHT is not asserted:

- ➤ If no further trip conditions occur, the recloser goes to the reset state BK1RS after timer 3PRCD expires.
- ➤ If a fault occurs during the 3PRCD reclaim time, then the recloser asserts Relay Word bit 3PARC if all three-pole reclose conditions are satisfied (E3PR1 is logical 1, for example) and returns to the beginning of the 79CY3 cycle state; the recloser increments the shot counter and begins the next open interval timer.
- ➤ If a fault occurs during the 3PRCD reclaim time, and the three-pole reclose conditions are not satisfied (E3PR1 is logical 0, for example), the recloser exits the 79CY3 cycle state and goes to the lockout state BK1LO.

Lockout State From 79CY3

The recloser goes to lockout (BK1LO) when any of the following occur:

- ➤ The number of trips exceeds the maximum number of shots (N3PSHOT)
- ➤ Supervision condition 3P1CLS fails to assert in BK1CLSD time
- ➤ Relay Word bit 3POLINE asserts (for a circuit breaker manual opening)
- ➤ The circuit breaker fails to close within BK1CFD time
- ➤ Relay Word bit 79DTL asserts

Single- and Three-Pole Mode

NOTE: Single- and three-pole mode is only supported in breakers that provide single-pole breaker control.

The single- and three-pole mode (SPAR/3PAR) uses elements of both the single-pole mode (SPAR) and the three-pole mode (3PAR). Reclosing begins after a single-pole trip in the single-pole cycle 79CY1 with a valid SPARC as described in *Single-Pole Mode on page 6.5*. The recloser closes the circuit breaker and proceeds to the reclaim timer SPRCD. If a fault occurs during the SPRCD reclaim time and SPLSHT is asserted, then the recloser asserts Relay Word bit 3PARC if all three-pole reclose conditions are satisfied. Upon asserting 3PARC, the recloser exits the 79CY1 cycle state and goes to the beginning of the three-pole autoreclose cycle state 79CY3. The recloser proceeds through the 79CY3 state and exits this state as described in *Three-Pole Mode on page 6.6*.

Three-Pole Priority

If a single-pole autoreclose cycle 79CY1 is in progress and the relay receives an initiation for three-pole reclosing 3PRI, the recloser immediately starts a three-pole autoreclose cycle 79CY3.

Active Circuit Breakers

Two Relay Word bits describe when Circuit Breaker 1 is active for the autoreclose logic:

- ➤ NBK0, No Breaker Active in Reclose Scheme
- ➤ NBK1, One Breaker Active in Reclose Scheme

NBK1 equals logical 1 when Circuit Breaker 1 is closed and the autoreclose logic is reset, or if the autoreclose logic is in an autoreclose cycle (79CY1 or 79CY3). NBK0 equals logical 1 when Circuit Breaker 1 is open and not in an autoreclose cycle (79CY1 or 79CY3), or if the autoreclose logic is locked out (BK1LO).

Enable Autoreclose Logic for One Circuit Breaker

Three-Pole Trip Circuit Breaker

The initial settings necessary to enable autoreclose for a single three-pole trip circuit breaker are shown in *Table 6.2*.

Table 6.2 One-Circuit-Breaker Three-Pole Reclosing Initial Settings

Setting	Description	Entry
General Global Settings (Global)		
NUMBK	Number of Breakers in Scheme	1
Breaker Configuration (Breaker Monitor)		
BK1TYP[a]	Breaker 1 Trip Type	3
Breaker 1 Inputs (Breaker Monitor)		
52AA1	N/O Contact Input—BK1 (SELOGIC control equation)	IN101
Relay Configuration (Group)		
E79	Reclosing	Y

[a] Only applies to relays that support single-pole breaker operations.

Single-Pole Trip Circuit Breaker

The initial settings necessary to enable autoreclose for one single-pole trip circuit breaker are shown in *Table 6.3*.

Table 6.3 One-Circuit-Breaker Single-Pole Reclose Initial Settings

Setting	Description	Entry
General Global Settings (Global)		
NUMBK	Number of Breakers in Scheme	1
Breaker Configuration (Breaker Monitor)		
BK1TYP	Breaker 1 Trip Type	1
Breaker 1 Inputs (Breaker Monitor)		
52AA1	A-Phase N/O Contact Input—BK1 (SELOGIC Equation)	IN101
52AB1	B-Phase N/O Contact Input—BK1 (SELOGIC Equation)	IN102
52AC1	C-Phase N/O Contact Input—BK1 (SELOGIC Equation)	IN103
Relay Configuration (Group)		
E79	Reclosing	Y

Recloser Mode Enables

The SELOGIC control equations E3PR1 and ESPR1 are used to set the relay autoreclose modes. *Table 6.4* illustrates how to enable the autoreclose modes for Circuit Breaker 1.

Table 6.4 One Circuit Breaker Modes of Operation

E3PR1	ESPR1[a]	Result
0	0	Autoreclose disabled
0	1	Single-pole autoreclose only enabled
1	0	Three-pole autoreclose only enabled
1	1	Single- and three-pole autoreclose enabled

[a] ESPR1 only applies to relays that support single-pole reclosing.

E3PR1 is the SELOGIC control equation that enables three-pole autoreclose for Circuit Breaker 1. You can assign this setting to a control input. When E3PR1 equals logical 1, the relay can attempt a three-pole autoreclose cycle for Circuit Breaker 1. If E3PR1 equals logical 0, the relay goes to lockout following a three-pole trip for Circuit Breaker 1.

ESPR1 is the SELOGIC control equation that enables single-pole autoreclose for Circuit Breaker 1. You can assign this setting to a control input. When ESPR1 equals logical 1, the relay can attempt a single-pole autoreclose cycle for Circuit Breaker 1. If ESPR1 equals logical 0, the relay cannot initiate a single-pole autoreclose cycle.

Set either or both E3PR1 and ESPR1 according to your reclosing requirements and relay reclosing capabilities. For single-pole reclosing, set ESPR1 to evaluate to logical 1 and set NSPSHOT to the desired number of single-pole reclose shots. For three-pole reclosing, set E3PR1 to evaluate to logical 1 and set N3PSHOT for the desired number of three-pole shots. For both single-pole and three-pole reclosing, set ESPR1 to evaluate to logical 1, set E3PR1 to evaluate to logical 1, and configure settings NSPSHOT and N3PSHOT for the desired number of reclose shots of each type (see *Recloser Mode Enables on page 6.8*).

Trip Logic and Reclose Sources for Single-Pole Breaker Applications

Internal Recloser

Program the recloser function to drive the trip logic with Relay Word bits R3PTE (recloser three-pole trip enable) and R3PTE1 (recloser three-pole trip enable Circuit Breaker 1) as follows:

E3PT := **R3PTE** Three-Pole Trip Enable (SELOGIC equation)

E3PT1 := **R3PTE1** Breaker 1 3PT (SELOGIC equation)

These settings connect the internal recloser for both three-pole reclosing and single-pole reclosing. Enter enable settings ESPR1 and E3PR1 as appropriate for your application.

Relay Word bits R3PTE and R3PTE1 are logical 1 for either of the following conditions when the setting NUMBK (number of breakers in scheme) is logical 1 and SPLSHT (single-pole last shot) is asserted (see *Figure 6.9*):

- ➤ BK1TYP := 3 (Breaker 1 Trip Type)
- ➤ NSPSHOT := N (Number of Single-Pole Reclosures)

External Recloser

If reclosing is performed by an external relay, assert SELOGIC control equations E3PT and E3PT1 via a control input (for example):

E3PT := **NOT IN104** Three-Pole Trip Enable (SELOGIC equation)

E3PT1 := **NOT IN104** Breaker 1 3PT (SELOGIC equation)

Connect the external recloser single-pole trip output signal to IN104. Other external recloser signals are required; consult the external recloser documentation for interconnection with the relay.

Two-Circuit-Breaker Autoreclosing

Modes

The autoreclose logic can operate in one of three modes, depending upon the relay reclose capabilities:

- Single-pole mode (SPAR)
- Three-pole mode (3PAR)
- Single- and three-pole mode (SPAR/3PAR)

NOTE: In the following discussion, n = 1 or 2 for Circuit Breaker BK1 or BK2.

Relay settings ESPR*n* (Single-Pole Reclose Enable—BK*n*) and E3PR*n* (Three-Pole Reclose Enable—BK*n*) determine the autoreclose mode (see *Recloser Mode Enables on page 6.8*). These settings are inputs to the recloser initiation Relay Word bits SPARC (Single-Pole Reclose Initiate Qualified) and 3PARC (Three-Pole Reclose Initiate Qualified); see *Figure 6.9* and *Figure 6.10*. SPARC asserts when all necessary conditions to begin a single-pole autoreclose cycle are satisfied (ESPR*n*, for example) and the recloser receives a single-pole reclose initiation SPRI (see *Figure 6.9*). Relay Word bit 3PARC asserts when all necessary conditions to begin a three-pole autoreclose cycle are satisfied (E3PR*n*, for example) and the recloser receives a three-pole reclose initiation 3PRI (see *Figure 6.10*).

Single-pole recloser settings also include the initial recloser settings (see *Enable Autoreclose Logic for One Circuit Breaker on page 6.8*) and the trip logic enable settings E3PT, E3PT1, and E3PT2. When SELOGIC control equations E3PT, E3PT1, and E3PT2 are deasserted, a single-pole reclose follows a single-pole trip; when these SELOGIC control equations are asserted, only three-pole tripping and reclosing result (see *Trip Logic and Reclose Sources for Single-Pole Breaker Applications on page 6.24*).

Single-Pole Mode

Figure 6.13 and *Figure 6.14* show the two circuit breaker single-pole autoreclose cycle 79CY1 when E79 := Y and E79 := Y1, respectively. The cycle starts when Relay Word bit SPARC asserts. The recloser freezes calculation of the number of breakers, the leader circuit breaker, and the follower circuit breaker. Depending on the calculation, the recloser asserts the appropriate Relay Word bits NBK0, NBK1, NBK2, LEADBK0, LEADBK1, LEADBK2, FOLBK0, FOLBK1, and FOLBK2.

The recloser checks for an SPO (Single-Pole Open) condition for either the leader or follower, and waits as long as 10 cycles for the circuit breakers to open. If the leader or follower shows a single-pole open inside the 10-cycle window, the recloser proceeds to timing SPOID (Single-Pole Open Interval Delay). The recloser goes to lockout if the circuit breakers fail to open (no close attempts follow). If an evolving fault results in a three-pole trip condition that asserts 3PARC, then the recloser exits the 79CY1 cycle and goes to the three-pole cycle 79CY3. When E79 := Y1, a Single-Pole Open Interval Supervision Condition (SPOISC) must be satisfied before the recloser can proceed to timing SPOID. If the supervisory condition is not met within the duration of timer SPOISD (Single-Pole Open Interval Supervision Delay), the recloser goes to lockout.

After single-pole open interval time SPOID expires, the recloser closes the leader if the single-pole open condition is still in effect and supervisory condition SP*n*CLS (Single-Pole BK*n* Reclose Supervision) is satisfied within the duration of timer BK*n*CLSD (BK*n* Reclose Supervision Delay). If the leader circuit breaker has more than one pole open at the end of the SPOID time, the recloser sends the leader to lockout BK*n*LO.

At the leader close command, the recloser starts timer BKCFD (Breaker Close Failure Delay). If the leader fails to close, the recloser sends the leader to lockout after timer BKCFD expires. If the leader closes within the BKCFD time, the recloser goes to SPRCD (Single-Pole Reclaim Time Delay) reclaim timing if NBK1 is asserted, or prepares to close the follower circuit breaker if NBK2 is asserted.

To close the follower circuit breaker, the recloser checks for two active circuit breakers in the scheme. If NBK2 is asserted, the recloser checks for a single-pole open on the follower and starts timer TBBKD (Time Between Breakers For ARC). If multiple poles of the follower circuit breaker are open, the recloser sends the follower to lockout BK*n*LO. When TBBKD expires, the recloser closes the follower breaker if FBKCEN (Follower Breaker Closing Enable) is asserted and supervisory condition SP*n*CLS is satisfied within the duration of timer BK*n*CLSD. At the follower close command, the recloser starts timer BKCFD (Breaker Close Failure Delay). If the follower fails to close, the recloser sends the follower to lockout after timer BKCFD expires. If the leader circuit breaker is not in lockout, the recloser begins timing SPRCD reclaim time for the leader.

If the follower breaker closes successfully, the recloser starts the SPRCD (Single-Pole Reclaim Time Delay) timer if 79BRCT (Block Reclaim Timer) is not asserted.

SPRCD Reclaim Timing

The recloser determines subsequent state transitions during reclaim timing according to the status of Relay Word bit SPLSHT (Single-Pole Reclose Last Shot). When SPLSHT is asserted, the recloser forces all subsequent relay trips to three-pole only mode.

SPLSHT Deasserted (Single-Pole Shot Remains)

The recloser exhibits four possible state transitions when SPLSHT is not asserted:

- If no further trip conditions occur and timer SPRCD expires, the recloser returns to the reset states BK*n*RS.
- If a single-phase fault occurs while the SPRCD reclaim timer is timing, then the recloser asserts SPARC if all single-pole initiate conditions are satisfied and goes to the beginning of the 79CY1 cycle. The recloser then recalculates and freezes the calculation for the number of active circuit breakers, the leader, and the follower. The recloser then increments the shot counter and begins the next open interval timer.

- If a multiphase fault occurs during the SPRCD reclaim time, then the recloser asserts Relay Word bit 3PARC if all three-pole reclose conditions are satisfied (E3PR*n* is logical 1, for example) and recalculates the number of active circuit breakers, the leader, and the follower before proceeding to the autoreclose three-pole cycle state 79CY3.
- If a multiphase fault occurs during the SPRCD reclaim time, SPLSHT is not asserted, and the three-pole reclose conditions are not satisfied (E3PR*n* is logical 0, for example) and the recloser exits the 79CY1 cycle state and goes to the lockout state BK*n*LO.

SPLSHT Asserted (Last Shot)

The recloser exits the 79CY1 state via three methods while SPLSHT is asserted:

- If no further trip conditions occur and timer SPRCD expires, the recloser returns to the reset states BK*n*RS.
- If a fault occurs during the SPRCD reclaim time, then the recloser asserts Relay Word bit 3PARC if all three-pole reclose conditions are satisfied and proceeds to the autoreclose three-pole cycle state 79CY3.
- If a fault occurs during the SPRCD reclaim time and the three-pole reclose conditions are not satisfied (E3PR*n* is logical 0, for example), then the recloser exits the 79CY1 cycle state and goes to the lockout state Bk*n*LO.

Lockout State From 79CY1

The recloser goes to lockout (BK*n*LO) when the number of trips exceeds the maximum number of shots (NSPSHOT), supervision condition SP*n*CLS fails to assert in BK*n*CLSD time, Relay Word bit 3POLINE asserts (for a circuit breaker manual opening), the circuit breaker fails to close within BKCFD time, or any time Relay Word bit 79DTL asserts.

Three-Pole Mode

Figure 6.15 and *Figure 6.16* show the two circuit breaker three-pole autoreclose cycle 79CY3 when E79 := Y and E79 := Y1, respectively. The cycle starts when Relay Word bit 3PARC asserts. The recloser freezes calculation of the number of breakers, the leader circuit breaker, and the follower circuit breaker. Depending on the calculation, the recloser asserts the appropriate Relay Word bits NBK0, NBK1, NBK2, LEADBK0, LEADBK1, LEADBK2, FOLBK0, FOLBK1, and FOLBK2. The recloser checks SELOGIC control equation 79SKP at this point to determine whether to increment the shot counter.

The recloser waits for 3POLINE to assert:

- if E79 := Y, 3POLINE asserts when both breakers (leader and follower) open (see *Figure 6.15*)
- if E79 := Y1, 3POLINE asserts when at least one breaker (leader or follower) opens (see *Figure 6.16*)

NOTE: The recloser logic is only processed every 1 cycle. To ensure proper timing and to avoid going to lockout unnecessarily, add an additional 1 cycle to the 3PRIH setting to properly account for processing delays.

If 3POLINE asserts within the 3PRIH time delay, the recloser proceeds to timing 3POID1 (Three-Pole Open Interval 1 Delay). If 3POLINE fails to assert within the 3PRIH time-delay setting, the recloser goes to lockout. If the 3PRIH setting = OFF, the recloser will wait indefinitely for 3POLINE to assert before proceeding to timing 3POID1. If SELOGIC control equation 3PFARC (Three-Pole Fast ARC Enable) is asserted, the recloser times the open interval time from setting 3PFOID (Three-Pole Fast Open Interval Delay). When E79 := Y1, a Three-Pole Open Interval Supervision Condition (3POISC) must be satisfied before the recloser can proceed to timing 3POID1. If the supervisory condition is not met within the duration of timer 3POISD (Three-Pole Open Interval Supervision Delay), the recloser goes to lockout.

After three-pole open interval time 3POID or 3PFOID expires.

- and E79 := Y, the recloser attempts to close the leader breaker, as discussed below (first checking the supervisory condition 3P*n*CLS).
- and E79 := Y1, the recloser checks if the leader breaker is open. If open, it attempts to close the leader breaker, as discussed below (first checking the supervisory condition 3P*n*CLS). If the leader breaker is closed (it never opened at the outset), the recloser skips the leader breaker close logic and attempts to close the follower breaker, as discussed further below (first checking for two active breakers and an open follower breaker, before starting timer TBBKD [Time Between Breakers for ARC]).

The recloser closes the leader if supervisory condition 3P*n*CLS (Three-Pole BK*n* Reclose Supervision) is satisfied within the duration of timer BK*n*CLSD (BK*n* Reclose Supervision Delay).

At the leader close command, the recloser starts timer BKCFD (Breaker Close Failure Delay). If the leader fails to close, the recloser sends the leader to lockout BK*n*LO after timer BKCFD expires. If the leader closes within the BKCFD time, the recloser goes to 3PRCD (Three-Pole Reclaim Time Delay) reclaim timing if NBK1 is asserted, or prepares to close the follower circuit breaker if NBK2 is asserted.

To close the follower circuit breaker, the recloser checks for two active circuit breakers in the scheme. If NBK2 is asserted, the recloser checks for a three-pole open on the follower and starts timer TBBKD (Time Between Breakers For ARC). When TBBKD expires, the recloser closes the follower breaker if FBKCEN (Follower Breaker Closing Enable) is asserted and supervisory condition 3P*n*CLS is satisfied within the duration of timer BK*n*CLSD. At the follower close command, the recloser starts timer BKCFD (Breaker Close Failure Delay). If the follower fails to close, the recloser sends the follower to lockout after timer BKCFD expires. If the leader circuit breaker is not in lockout, the recloser begins timing 3PRCD reclaim time for the leader.

If the follower breaker closes successfully, the recloser starts the 3PRCD (Three-Pole Reclaim Time Delay) timer if 79BRCT (Block Reclaim Timer) is not asserted.

3PRCD Reclaim Timing

The recloser determines subsequent state transitions during reclaim timing according to the status of Relay Word bit 3PLSHT (Three-Pole Reclose Last Shot).

3PLSHT Deasserted (Three-Pole Shot Remains)

The recloser exhibits two possible state transitions when 3PLSHT is not asserted:

- If no further trip conditions occur and timer 3PRCD expires, the recloser returns to the reset states BK*n*RS.
- If a fault occurs while the 3PRCD reclaim timer is timing, then the recloser asserts 3PARC if all three-pole initiate conditions are satisfied and goes to the beginning of the 79CY3 cycle. The recloser then recalculates and freezes the number of active circuit breakers, the leader, and the follower. The recloser then increments the shot counter and begins the next open interval timer.

3PLSHT Asserted (Last Shot)

The recloser exits the 79CY3 state via two methods while 3PLSHT is asserted:

➤ If no further trip conditions occur and timer 3PRCD expires, the recloser returns to the reset states BK*n*RS.

➤ If a fault occurs during the 3PRCD reclaim time and 3PLSHT is asserted, then the recloser goes to lockout BK*n*LO.

Lockout State From 79CY3

The recloser goes to lockout (BK*n*LO) when any of the following occur:

➤ The number of trips exceeds the maximum number of shots (N3PSHOT)

➤ Supervision condition 3P*n*CLS fails to assert in BK*n*CLSD time

➤ Relay Word bit 3POLINE asserts for a circuit breaker manual opening (no qualified autoreclose initiation 3PARC)

➤ The circuit breaker fails to close within BKCFD time

➤ SELOGIC equation 79DTL asserts

Single- and Three-Pole Mode

The single- and three-pole mode (SPAR/3PAR) uses elements of both the single-pole mode (SPAR) and the three-pole mode (3PAR). Reclosing begins after a single-pole trip in the single-pole cycle 79CY1 with a valid SPARC as described in *Single-Pole Mode on page 6.10*. The recloser closes the circuit breakers and proceeds to the reclaim timer SPRCD. If a fault occurs during the SPRCD reclaim time and SPLSHT is asserted, then the recloser asserts Relay Word bit 3PARC if all three-pole reclose conditions are satisfied. Upon asserting 3PARC, the recloser exits the 79CY1 cycle state and goes to the beginning of the three-pole autoreclose cycle state 79CY3. The recloser proceeds through the 79CY3 state and exits this state as described in *Three-Pole Mode on page 6.12*.

Three-Pole Priority

If a single-pole autoreclose cycle is in progress (79CY1) and the relay receives an initiation for three-pole reclosing (3PRI), the recloser immediately starts a three-pole autoreclose cycle (79CY3).

Active Circuit Breakers

The following three Relay Word bits describe when Circuit Breaker BK1 and Circuit Breaker BK2 are active for the autoreclose logic:

➤ NBK0, No Breaker Active in Reclose Scheme

➤ NBK1, One Breaker Active in Reclose Scheme

➤ NBK2, Two Breakers Active in Reclose Scheme

Leader and Follower Circuit Breakers

One circuit breaker is the leader and the other is the follower for circuit breaker-and-a-half and ring-bus arrangements. *Figure 6.2* illustrates a multiple circuit breaker arrangement. The leader recloses first. If the leader recloses successfully, the follower also typically recloses.

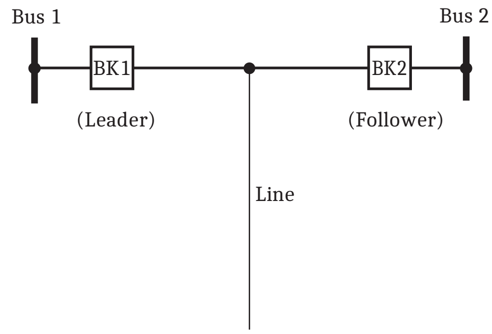


Figure 6.2 Multiple Circuit Breaker Arrangement

Choose Circuit Breaker BK1 as the leader and Circuit Breaker BK2 as the follower. If Circuit Breaker BK1 is out of service (for maintenance, for example), the relay can automatically make Circuit Breaker BK2 the leader.

The relay freezes the leader, follower, and number of active circuit breaker designations during an autoreclose cycle. If the logic receives another reclose initiation, the relay reevaluates the leader, follower, and number of active circuit breaker designations. The logic considers a circuit breaker out of service if the circuit breaker goes to lockout, and declares a circuit breaker to be in service as soon as the circuit breaker closes and is no longer in lockout.

Leader Logic

Relay settings SLBK1 (Leader Breaker = Breaker 1) and SLBK2 (Leader Breaker = Breaker 2) SELOGIC control equations determine the criteria for relay selection of the active leader. Set SLBK1 := 1 to select Circuit Breaker BK1 as the leader; set SLBK2 := 1 to select Circuit Breaker BK2 as the leader. SLBK1 has priority over SLBK2; if you set both settings to 1 or both to 0, Circuit Breaker BK1 is the leader.

Circuit Breaker BK1 is the leader for the following conditions:

- BK1 is the only circuit breaker in service
- BK1 and BK2 are in service and BK1 is selected as the leader (SLBK1 := 1)
- BK1 and BK2 are in service and the setting combination SLBK1 := 0 and SLBK2 := 1 is not in effect

Circuit Breaker BK2 is the leader for the following conditions:

- BK2 is the only circuit breaker in service
- BK1 and BK2 are in service and BK2 is selected as the leader (SLKBK1 := 0 and SLBK2 := 1)
- If neither circuit breaker is in service, there is no leader

The following three Relay Word bits describe which circuit breaker is the leader:

- LEADBK0, No Breaker In Service
- LEADBK1, Leader Breaker = Breaker 1
- LEADBK2, Leader Breaker = Breaker 2

The relay loads the corresponding circuit breaker settings into the leader Relay Word bits (LEADBK0, LEADBK1, and LEADBK2). If there is no leader (no circuit breaker is active), the relay loads a logical 0 into LEADBK1 and LEADBK2, and a logical 1 into LEADBK0.

Follower Logic

The FBKCEN SELOGIC control equation, Follower Breaker Closing Enable, defines the conditions necessary for the follower breaker to reclose.

The relay selects the follower as follows:

- ➤ If Circuit Breaker BK1 is the leader and Circuit Breaker BK2 is not locked out, then Circuit Breaker BK2 is the follower.
- ➤ If Circuit Breaker BK2 is the leader and Circuit Breaker BK1 is not locked out, then Circuit Breaker BK1 is the follower.
- ➤ If fewer than two circuit breakers are in service (NBK0 or NBK1 is asserted), then there is no follower.

The following three Relay Word bits describe which circuit breaker is the follower:

- ➤ FOLBK0, No Follower Breaker
- ➤ FOLBK1, Follower Breaker = Breaker 1
- ➤ FOLBK2, Follower Breaker = Breaker 2

If there is no follower (in the case of only one circuit breaker, for example), the relay loads a logical 0 into the follower SELOGIC control equation FBKCEN.

Dynamic Selection of Leader and Follower Circuit Breakers

The relay dynamically selects the leader and follower circuit breakers during the reclose cycle. The relay calculates the leader in the ready (reset) state. At the start of the reclose cycle, the relay freezes this calculation and sets circuit breaker designations. The leader/follower designation can dynamically change in the cycle if the leader circuit breaker goes to lockout and FBKCEN is asserted.

Set the initial leader/follower designation and follower close conditions with settings SLBK1 (Lead Breaker = Breaker 1), SLBK2 (Lead Breaker = Breaker 2), and FBKCEN (Follower Breaker Closing Enable). *Table 6.5* shows the permutations of these settings.

Table 6.5 Dynamic Leader/Follower Settings

SLBK1	SLBK2	FBKCEN	Comments
0	0	0	BK1 is the leader; BK2 is the leader only if BK1→ LO and BK2 is closed. BK2 will not close as the follower upon successful close of leader BK1.
0	0	1	BK1 is the leader; BK2 is the leader only if BK1→ LO and BK2 is closed. BK2 will close as the follower if BK1→ LO after BKCFD. BK2 will close as the follower upon successful close of the leader BK1.
0	1	0	BK2 is the leader; BK1 is the leader only if BK2→ LO and BK1 is closed. BK1 will not close as the follower upon successful close of leader BK2.
0	1	1	BK2 is the leader; BK1 is the leader only if BK2→ LO. BK1 will close if BK2→ LO after BKCFD. BK1 will close as the follower after TBBKD upon successful close of the leader BK1.
1	0	0	BK1 is the leader; BK2 is the leader only if BK1→ LO and BK2 is closed. BK2 will not close as the follower upon successful close of leader BK1.
1	0	1	BK1 is the leader; BK2 is the leader only if BK1→ LO and BK2 is closed. BK2 will close as the follower if BK1→ LO after BKCFD. BK2 will close as the follower upon successful close of the leader BK1.
1	1	0	Same as 1/0/0.
1	1	1	Same as 1/0/1.
1	0	52AA1	BK1 is the leader; BK2 to LO is the leader if BK1→ LO. BK2 will close as the follower after TBBKD upon successful close of the leader BK1.

Circuit Breaker BK1 is always the leader if SLBK1 is asserted and BK1 is not locked out. Circuit Breaker BK2 is the leader if SLBK2 is asserted, BK2 is not locked out, and SLBK1 is not asserted. The second circuit breaker can become the leader when the leader is locked out.

Setting FBKCEN does not pick the follower, but decides when the second circuit breaker can reclose. If the leader goes to lockout, then the follower goes to lockout if FBKCEN := 0. If, however, the leader is manually opened, the follower breaker can become the leader (after being manually closed) and can close via a reclose cycle if FBKCEN := 1. If you want the follower breaker to close only for specific conditions, use the enable settings to force this close requirement. For example, Circuit Breaker BK2 can dynamically become the leader if BK1 is locked out and BK2 is closed. If you do not want BK2 to become the leader, set FBKCEN := 52AA1. Also see *Example One: No Follower on page 6.17* for another method to prevent BK2 from becoming the leader.

The following examples help illustrate how the relay autoreclose logic dynamically determines the leader and follower circuit breakers. These examples describe a two circuit breaker scheme (such as used in a circuit breaker-and-a-half arrangement) as shown in *Figure 6.3*.

Example One: No Follower

This example describes recloser states when Circuit Breaker BK1 fails to reclose following the first three-pole open interval delay. Set the FBKCEN SELOGIC control equation to prevent Circuit Breaker BK2 from closing as the follower. The leader and follower selection settings are shown in *Table 6.6*.

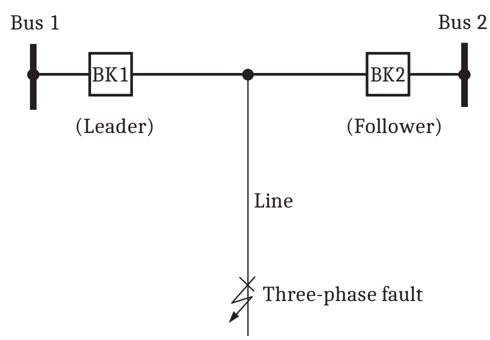


Figure 6.3 Multiple Circuit Breaker Arrangement

Table 6.6 Leader/Follower Selection

Setting Label	Value
SLBK1	1
SLBK2	0
FBKCEN	0

Reset State and 79CY3 Cycle State

Prior to receiving initiation for a three-phase fault, the autoreclose logic resets for both circuit breakers. *Table 6.7* defines the logical state of the autoreclose logic for this example prior to the initiation of an autoreclose cycle.

Table 6.7 Example One: Reset and 79CY3 States

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	0
NBK1	One Breaker Active in Reclose Scheme	0
NBK2	Two Active Breakers in Reclose Scheme	1
LEADBK0	No Leader Breaker	0
LEADBK1	Leader Breaker = Breaker 1	1
LEADBK2	Leader Breaker = Breaker 2	0
FOLBK0	No Follower Breaker	0
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	1

Lockout State

Circuit Breaker BK1 fails to close when the first three-pole open interval expires and goes to lockout. Circuit Breaker BK2 goes to lockout. *Table 6.8* defines the logical state of the autoreclose logic at this point.

Table 6.8 Example One: Lockout State

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	1
NBK1	One Breaker Active in Reclose Scheme	0
NBK2	Two Active Breakers in Reclose Scheme	0
LEADBK0	No Leader Breaker	1
LEADBK1	Leader Breaker = Breaker 1	0
LEADBK2	Leader Breaker = Breaker 2	0
FOLBK0	No Follower Breaker	1
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	0

Reset State After Reclaim Time

Circuit Breaker BK2 is manually closed and now becomes active as the leader after 3PMRCD (Manual Close Reclaim Time Delay). Subsequent reclosing occurs with BK2. *Table 6.9* defines the logical state of the autoreclose logic at this point.

Table 6.9 Example One: Reset State After Reclaim Time (Sheet 1 of 2)

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	0
NBK1	One Breaker Active in Reclose Scheme	1
NBK2	Two Active Breakers in Reclose Scheme	0
LEADBK0	No Leader Breaker	0
LEADBK1	Leader Breaker = Breaker 1	0
LEADBK2	Leader Breaker = Breaker 2	1
FOLBK0	No Follower Breaker	1

Table 6.9 Example One: Reset State After Reclaim Time (Sheet 2 of 2)

Relay Word Bit	Description	Logical State
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	0

Block Reclosing With Enable Settings

To block BK2 as leader use the enable settings; set ESPR2 := NBK2 and E3PR2 := NBK2. With these enable settings BK2 never becomes the leader circuit breaker.

Example Two: BK2 as Successful Follower and Dynamic Leader

Another example is similar to the first with SLBK1/SLBK2/FBKCEN at 1/0/1 (see *Table 6.10*).

Table 6.10 Leader/Follower Selection

Setting Label	Value
SLBK1	1
SLBK2	0
FBKCEN	1

Reset State

Prior to receiving initiation for a three-phase fault, the autoreclose logic resets for both circuit breakers. At the start of the reclose cycle, Relay Word bits LEADBK1, FOLBK2, and NBK2 are asserted (see *Table 6.11*).

Table 6.11 Example Two: Initial Reset State

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	0
NBK1	One Breaker Active in Reclose Scheme	0
NBK2	Two Active Breakers in Reclose Scheme	1
LEADBK0	No Leader Breaker	0
LEADBK1	Leader Breaker = Breaker 1	1
LEADBK2	Leader Breaker = Breaker 2	0
FOLBK0	No Follower Breaker	0
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	1

When BK1 successfully recloses, BK2 closes as the follower after timer TBBKD (Time Between Breakers for ARC).

If BK1 goes to lockout during a reclose cycle (after BKCFD time), then BK2 will close as the follower. After timer 3PRCD (Three-Pole Reclaim Time Delay) expires, the recloser enters the reset state for BK2 (BK2RS). The recloser dynamically recalculates the leader and follower circuit breakers. BK2 becomes the leader with Relay Word bits LEADBK2, FOLBK0, and NBK1 asserted (see *Table 6.12*). When BK2 becomes the leader, the recloser immediately issues the close command to BK2 and does not add any additional SPOID or 3POID interval time.

Table 6.12 Example Two: Final Reset State

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	0
NBK1	One Breaker Active in Reclose Scheme	1
NBK2	Two Active Breakers in Reclose Scheme	0
LEADBK0	No Leader Breaker	0
LEADBK1	Leader Breaker = Breaker 1	0
LEADBK2	Leader Breaker = Breaker 2	1
FOLBK0	No Follower Breaker	1
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	0

Example Three: BK2 as Conditional Follower

One method to program BK2 for closing only after a successful BK1 close is to set SLBK1/SLBK2/FBKCEN as in *Table 6.13*.

Table 6.13 Leader/Follower Selection

Setting Label	Value
SLBK1	1
SLBK2	0
FBKCEN	52AA1

Reset State

Prior to receiving initiation for a three-phase fault, the autoreclose logic resets for both circuit breakers. *Table 6.14* defines the logical state of the autoreclose logic for this example prior to the initiation of an autoreclose cycle.

Table 6.14 Example Three: Reset State

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	0
NBK1	One Breaker Active in Reclose Scheme	0
NBK2	Two Active Breakers in Reclose Scheme	1
LEADBK0	No Leader Breaker	0
LEADBK1	Leader Breaker = Breaker 1	1
LEADBK2	Leader Breaker = Breaker 2	0
FOLBK0	No Follower Breaker	0
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	1

79CY3 Cycle State

The autoreclose logic receives a three-pole initiation. *Table 6.15* defines the logical state of the autoreclose logic for this example during the three-pole autoreclose cycle.

Table 6.15 Example Three: Three-Pole Cycle State

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	0
NBK1	One Breaker Active in Reclose Scheme	0
NBK2	Two Active Breakers in Reclose Scheme	1
LEADBK0	No Leader Breaker	0
LEADBK1	Leader Breaker = Breaker 1	1
LEADBK2	Leader Breaker = Breaker 2	0
FOLBK0	No Follower Breaker	0
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	1

BK2 closes as the follower when BK1 successfully closes (after timer TBBKD).

Lockout State

Circuit Breaker BK1 must close before Circuit Breaker BK2. If Circuit Breaker BK1 fails to close and goes to lockout, then Circuit Breaker BK2 goes to lockout as well because BK2 cannot close as the follower and cannot dynamically become the leader. *Table 6.16* defines the logical state of the autoreclose logic for this example following the unsuccessful reclose attempt.

Table 6.16 Example Three: Lockout State, BK

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	1
NBK1	One Breaker Active in Reclose Scheme	0
NBK2	Two Active Breakers in Reclose Scheme	0
LEADBK0	No Leader Breaker	1
LEADBK1	Leader Breaker = Breaker 1	0
LEADBK2	Leader Breaker = Breaker 2	0
FOLBK0	No Follower Breaker	1
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	0

Example Four: Input Selection of Leader

Figure 6.4 illustrates a circuit breaker-and-a half configuration for this particular example. The leader and follower selection settings are shown in *Table 6.17*. Circuit Breaker BK1 is out of service for maintenance and Disconnect Switch 1 is open.

Table 6.17 Leader/Follower Selection

Setting Label	Setting
SLBK1	IN106 (Disconnect 1 a contacts)
SLBK2	IN107 (Disconnect 2 a contacts)
FBKCEN	0

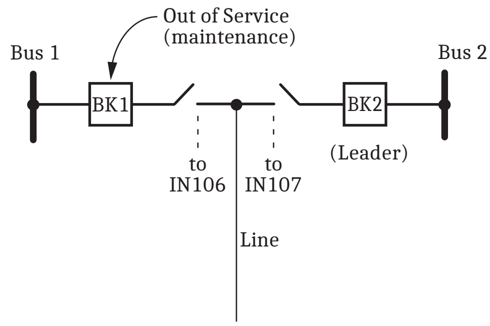


Figure 6.4 Leader/Follower Selection by Relay Input

Table 6.18 defines the logical state of the autoreclose logic for this example prior to the initiation of an autoreclose cycle. These conditions are frozen during an autoreclose cycle. The relay autoreclose logic can unfreeze these conditions if the relay receives another initiation.

Table 6.18 Two Circuit Breakers: Circuit Breaker BK1 Out of Service

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	0
NBK1	One Breaker Active in Reclose Scheme	1
NBK2	Two Active Breakers in Reclose Scheme	0
LEADBK0	No Leader Breaker	0
LEADBK1	Leader Breaker = Breaker 1	0
LEADBK2	Leader Breaker = Breaker 2	1
FOLBK0	No Follower Breaker	1
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	0

Enable Autoreclose Logic for Two Circuit Breakers

Three-Pole Trip Circuit Breakers

The initial settings necessary to enable autoreclose for two three-pole trip circuit breakers are shown in *Table 6.19*.

Table 6.19 Two-Circuit-Breaker Three-Pole Reclose Initial Settings

Setting	Description	Entry
NUMBK	Number of Breakers in Scheme	2
Breaker Configuration (Breaker Monitor)		
BK1TYP[a]	Breaker 1 Trip Type	3
BK2TYP[a]	Breaker 2 Trip Type	3
Breaker 1 Inputs (Breaker Monitor)		
52AA1	N/O Contact Input—BK1 (SELOGIC Equation)	IN101
Breaker 2 Inputs (Breaker Monitor)		
52AA2	N/O Contact Input—BK2 (SELOGIC Equation)	IN102
Relay Configuration (Group)		
E79	Reclosing	Y or Y1

[a] Only applicable to products that support single-pole tripping and reclosing.

Single-Pole Trip Circuit Breakers

The initial settings necessary to enable autoreclose for two single-pole trip circuit breakers are shown in *Table 6.20*.

Table 6.20 Two-Circuit-Breaker Single-Pole Reclose Initial Settings

Setting	Description	Entry
NUMBK	Number of Breakers in Scheme	2
Breaker Configuration (Breaker Monitor)		
BK1TYP	Breaker 1 Trip Type	1
BK2TYP	Breaker 2 Trip Type	1
Breaker 1 Inputs (Breaker Monitor)		
52AA1	A-Phase N/O Contact Input—BK1 (SELOGIC Equation)	IN101
52AB1	B-Phase N/O Contact Input—BK1 (SELOGIC Equation)	IN102
52AC1	C-Phase N/O Contact Input—BK1 (SELOGIC Equation)	IN103
Breaker 2 Inputs (Breaker Monitor)		
52AA2	A-Phase N/O Contact Input—BK2 (SELOGIC Equation)	IN104
52AB2	B-Phase N/O Contact Input—BK2 (SELOGIC Equation)	IN105
52AC2	C-Phase N/O Contact Input—BK2 (SELOGIC Equation)	IN106
Relay Configuration (Group)		
E79	Reclosing	Y or Y1

Recloser Mode Enables

The SELOGIC control equations E3PR*n* and ESPR*n* set the relay for the three autoreclose modes. *Table 6.21* and *Table 6.22* illustrate how to enable the autoreclose modes per circuit breaker.

Table 6.21 Circuit Breaker BK1 Modes of Operation

E3PR1	ESPR1[a]	Result
0	0	Autoreclose disabled
0	1	Single-pole autoreclose only enabled
1	0	Three-pole autoreclose only enabled
1	1	Single- and three-pole autoreclose enabled

[a] Only applicable to relays that support single-pole reclosing.

E3PR1 is the SELOGIC control equation that enables three-pole autoreclose for Circuit Breaker BK1. You can assign this setting to a control input. ESPR1 is the SELOGIC control equation that enables single-pole autoreclose for Circuit Breaker BK1. You can assign this setting to a control input.

When ESPR1 equals logical 1, the relay can attempt a single-pole autoreclose cycle for Circuit Breaker BK1. If ESPR1 equals logical 0, the relay cannot initiate a single-pole autoreclose cycle for Circuit Breaker BK1.

When E3PR1 equals logical 1, the relay can attempt a three-pole autoreclose cycle for Circuit Breaker BK1. If E3PR1 equals logical 0, the relay goes to lockout following a three-pole trip for Circuit Breaker BK1 and the corresponding leader logic transfers automatically to Circuit Breaker BK2.

Table 6.22 Circuit Breaker BK2 Modes of Operation

E3PR2	ESPR2[a]	Result
0	0	Autoreclose disabled
0	1	Single-pole autoreclose only enabled
1	0	Three-pole autoreclose only enabled
1	1	Single- and three-pole autoreclose enabled

[a] Only applicable to relays that support single-pole reclosing.

E3PR2 is the SELOGIC control equation that enables three-pole autoreclose for Circuit Breaker BK2. You can assign this setting to a control input. ESPR2 is the SELOGIC control equation that enables single-pole autoreclose for Circuit Breaker BK2. You can assign this setting to a control input.

When ESPR2 equals logical 1, the relay can attempt a single-pole autoreclose cycle for Circuit Breaker BK2. If ESPR2 equals logical 0, the relay cannot initiate a single-pole autoreclose cycle for Circuit Breaker BK2.

When E3PR2 equals logical 1, the relay can attempt a three-pole autoreclose cycle for Circuit Breaker BK2. If E3PR2 equals logical 0, the relay goes to lockout following a three-pole trip for Circuit Breaker BK2.

Assert one or all SELOGIC control equations E3PR1, E3PR2, ESPR1, and ESPR2 according to your reclosing requirements.

For single-pole reclosing, set ESPR1 := 1 and set NSPSHOT to the desired number of single-pole reclose shots. For three-pole reclosing, set E3PR1 := 1 and set N3PSHOT for the desired number of three-pole shots. For both single-pole and three-pole reclosing, set ESPR1 := 1, E3PR1 := 1, and configure settings NSPSHOT and N3PSHOT for the desired number of reclose shots of each type (see *Recloser Mode Enables on page 6.8*).

Example 6.1 Conditional Three-Pole Tripping for Circuit Breaker BK2

Your system reclosing requirement is that Circuit Breaker BK2 always three-pole trips, unless Circuit Breaker BK2 is the leader. (This occurs when Circuit Breaker BK1 is out of service.) Program SELOGIC control equation ESPR2 as follows:

ESPR2 := **LEADBK2 AND BK1LO** Single-Pole Reclose Enable—BK2 (SELOGIC Equation)

Trip Logic and Reclose Sources for Single-Pole Breaker Applications

Internal Recloser

Program the recloser function to drive the trip logic with Relay Word bits R3PTE (Recloser Three-Pole Trip Enable), R3PTE1 (Circuit Breaker BK1 Recloser Three-Pole Trip Enable) and R3PTE2 (Circuit Breaker BK2 Recloser Three-Pole Trip Enable) as follows:

E3PT := **R3PTE** Three-Pole Trip Enable (SELOGIC Equation)

E3PT1 := **R3PTE1** Breaker 1 Three-Pole Trip (SELOGIC Equation)

E3PT2 := **R3PTE2** Breaker 2 Three-Pole Trip (SELOGIC Equation)

These settings connect the internal recloser for both three-pole reclosing and single-pole reclosing.

Enter enable settings ESPR1 and E3PR1 as appropriate for your application. By default, the relay is a single-pole tripping relay; that is, if E3PT is logical 0 and E3PT1 equals logical 0, the relay can single-pole trip Circuit Breaker BK1. If E3PT1 equals logical 1, the relay can only three-pole trip Circuit Breaker BK1. The same conditions apply to setting E3PT2 and Circuit Breaker BK2.

Table 6.23 summarizes the relay trip logic enable options.

Table 6.23 Trip Logic Enable Options

Enable Condition			Circuit Breaker BK1		Circuit Breaker BK2	
E3PT	E3PT1	E3PT2	Single-Pole Trip	Three-Pole Trip	Single-Pole Trip	Three-Pole Trip
0	0	0	x		x	
0	0	1	x			x
0	1	0		x	x	
0	1	1		x		x
1	0	0		x		x
1	0	1		x		x
1	1	0		x		x
1	1	1		x		x

Relay Word bits R3PTE1 and R3PTE2 both equal logical 1 for any of the following conditions when Global setting NUMBK (Number of Breakers in Scheme) is 2 and SPLSHT (Single-Pole Last Shot) is asserted (see *Figure 6.9*):

- ➤ BK1TYP and BK2TYP equal 3 (Circuit Breaker 1 and Circuit Breaker 2 Trip Type)
- ➤ NSPSHOT := N (Number of Single-Pole Reclosures)

External Recloser

If reclosing is performed by an external relay, assert SELOGIC control equations E3PT, E3PT1, and E3PT2 via control inputs (for example):

E3PT := **IN104** Three-Pole Trip Enable (SELOGIC Equation)

E3PT1 := **IN105** Breaker 1 Three-Pole Trip (SELOGIC Equation)

E3PT2 := **IN106** Breaker 2 Three-Pole Trip (SELOGIC Equation)

Connect the external recloser single-pole trip output signal to IN104, the Circuit Breaker BK1 trip type signal to IN105, and the Circuit Breaker BK2 trip type signal to IN106. Other external recloser signals are required; consult the external recloser documentation for interconnection with the relay.

In installations where the external reclosing relay does not provide three-phase trip control signals, the TOP (Trip during Open-Pole) Relay Word bit can be used in the E3PT setting. This Relay Word bit will assert just after a single- or two-pole trip, and remain asserted until the TOPD timer expires. If a new trip occurs during this time, the E3PT := TOP setting would then cause a three-pole trip.

Autoreclose Logic Diagrams

NOTE: If E79 := N, the autoreclose logic is not processed and the resultant Relay Word Bits are forced to zero.

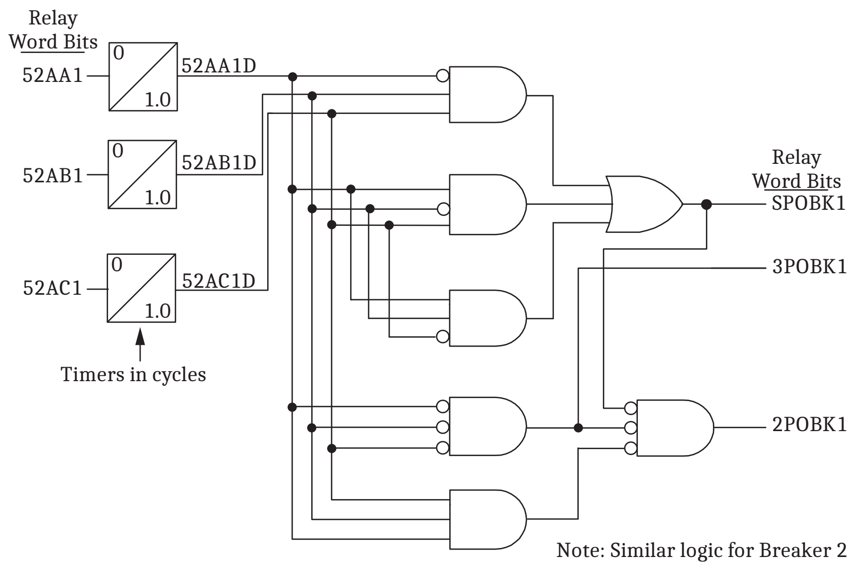


Figure 6.5 Circuit Breaker Pole-Open Logic Diagram—Single-Pole Relays

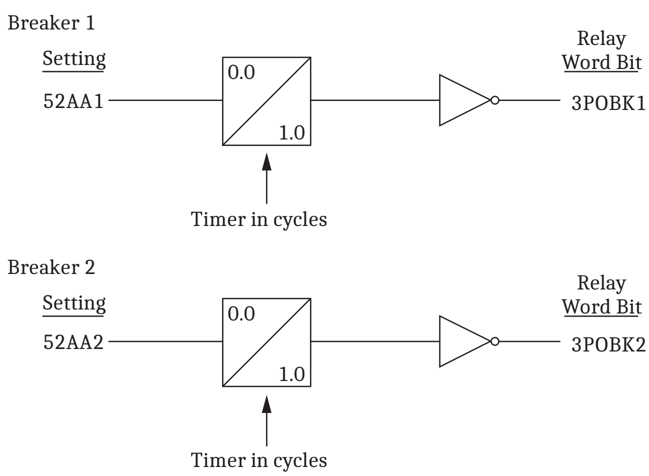


Figure 6.6 Circuit Breaker Pole-Open Logic Diagrams—Three-Pole Relays

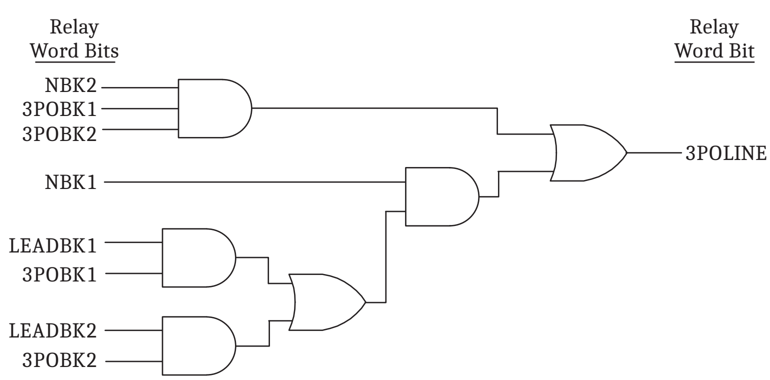


Figure 6.7 Line-Open Logic Diagram When E79 := Y

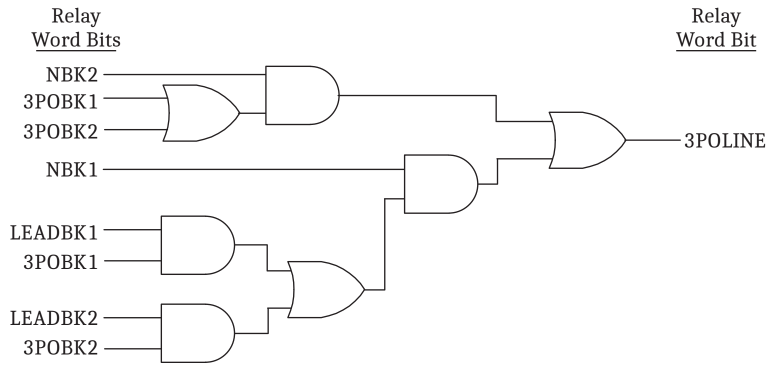


Figure 6.8 Line-Open Logic Diagram When E79 := Y1

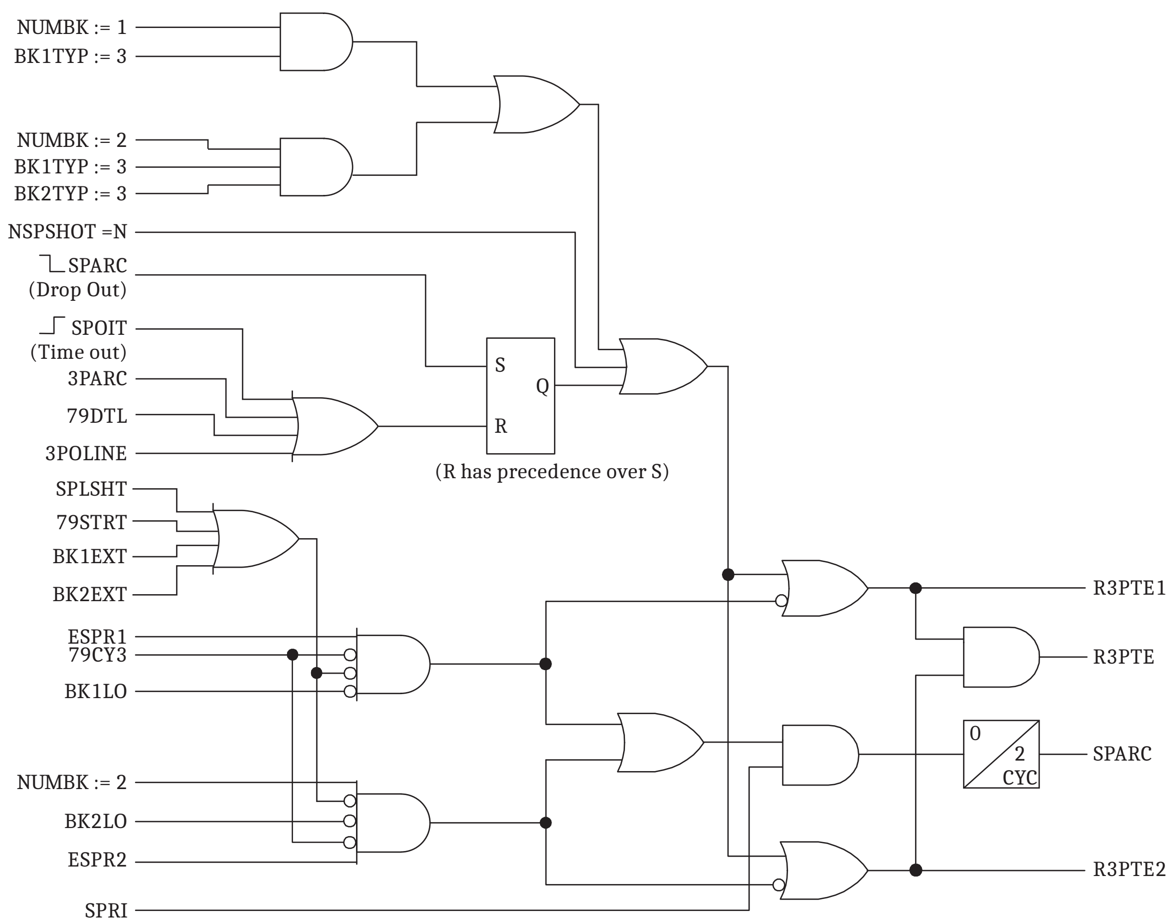


Figure 6.9 Single-Pole Reclose Enable

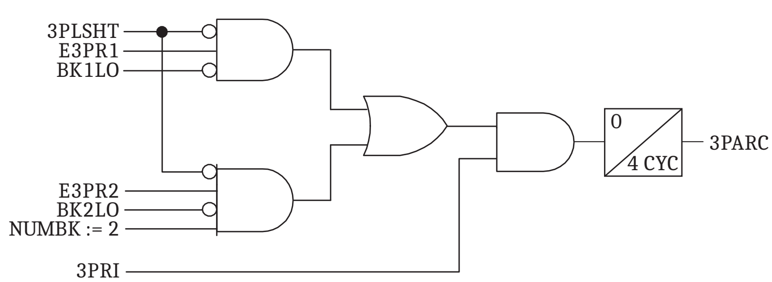


Figure 6.10 Three-Pole Reclose Enable

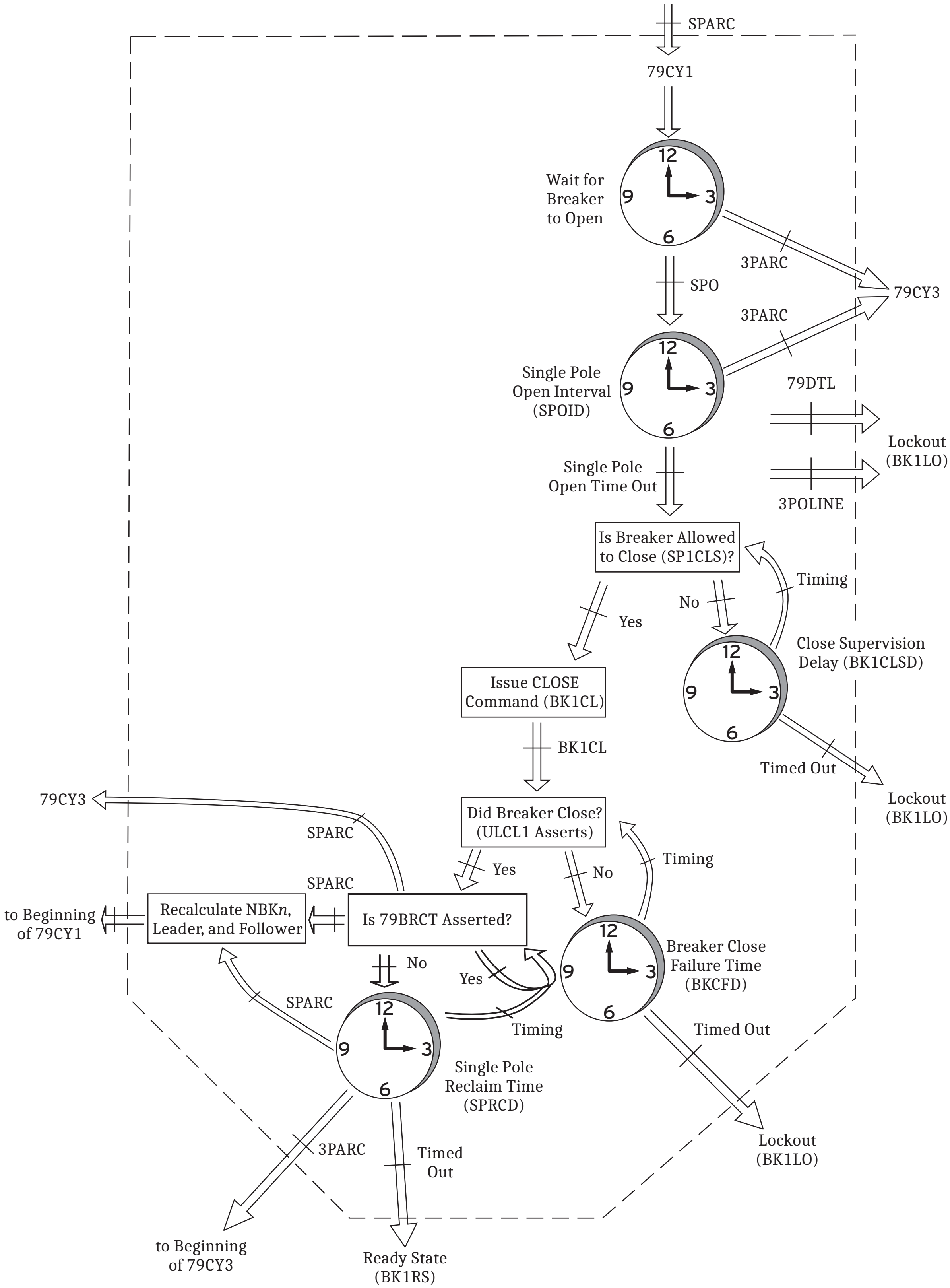


Figure 6.11 One Circuit Breaker Single-Pole Cycle State (79CY1)

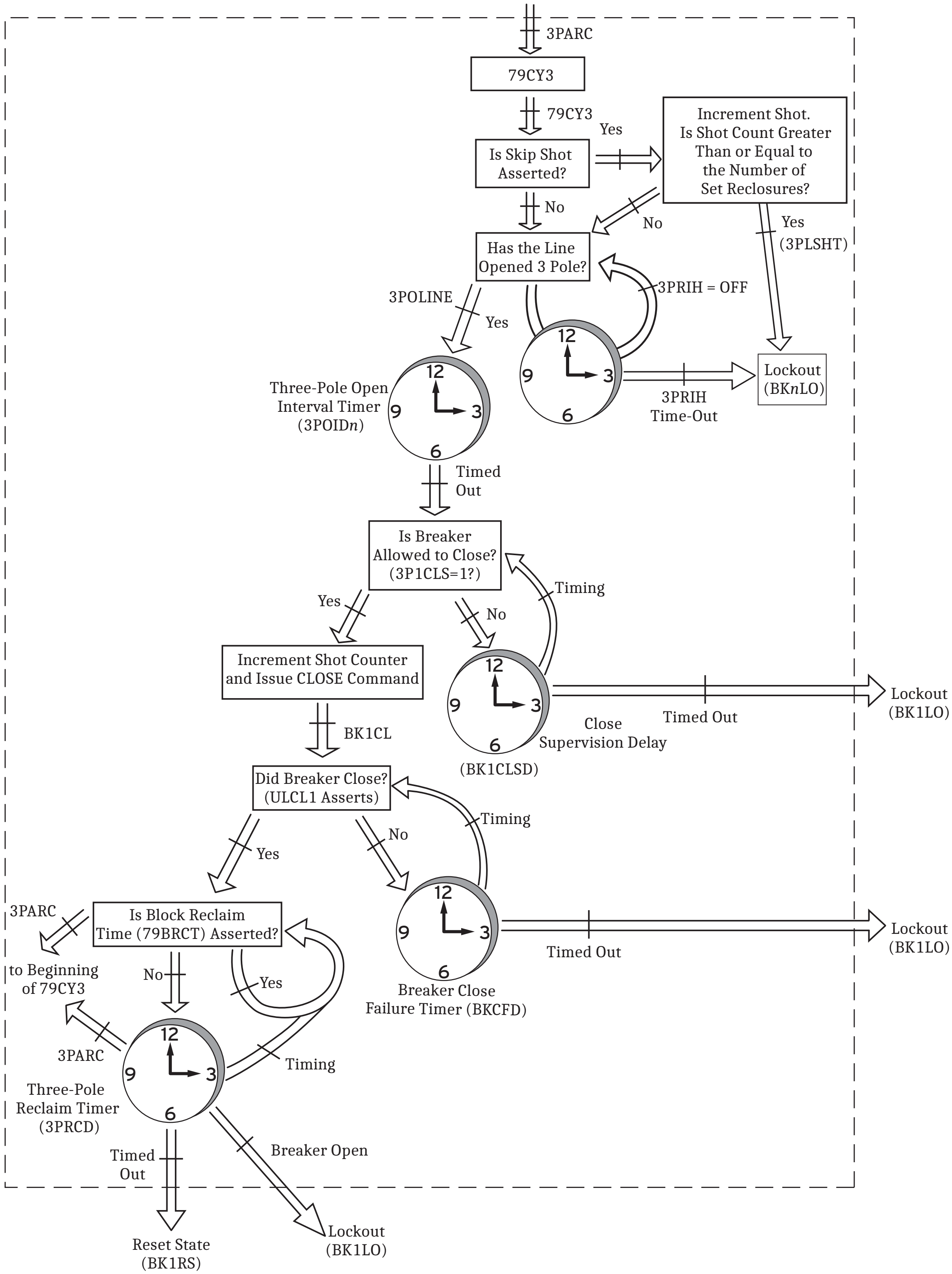


Figure 6.12 One Circuit Breaker Three-Pole Cycle State (79CY3)

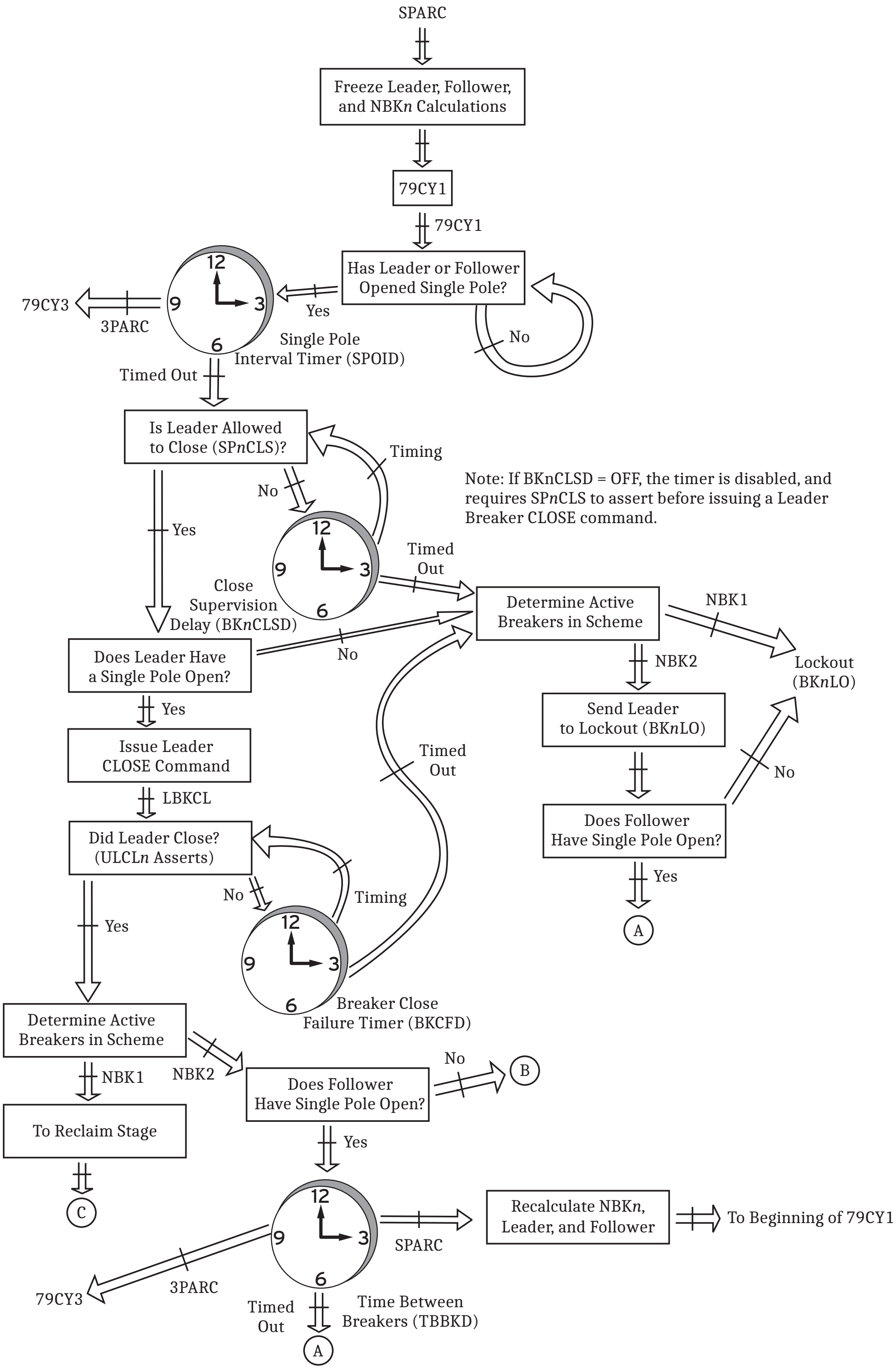


Figure 6.13 Two Circuit Breakers Single-Pole Cycle State (79CY1) When E79 := Y

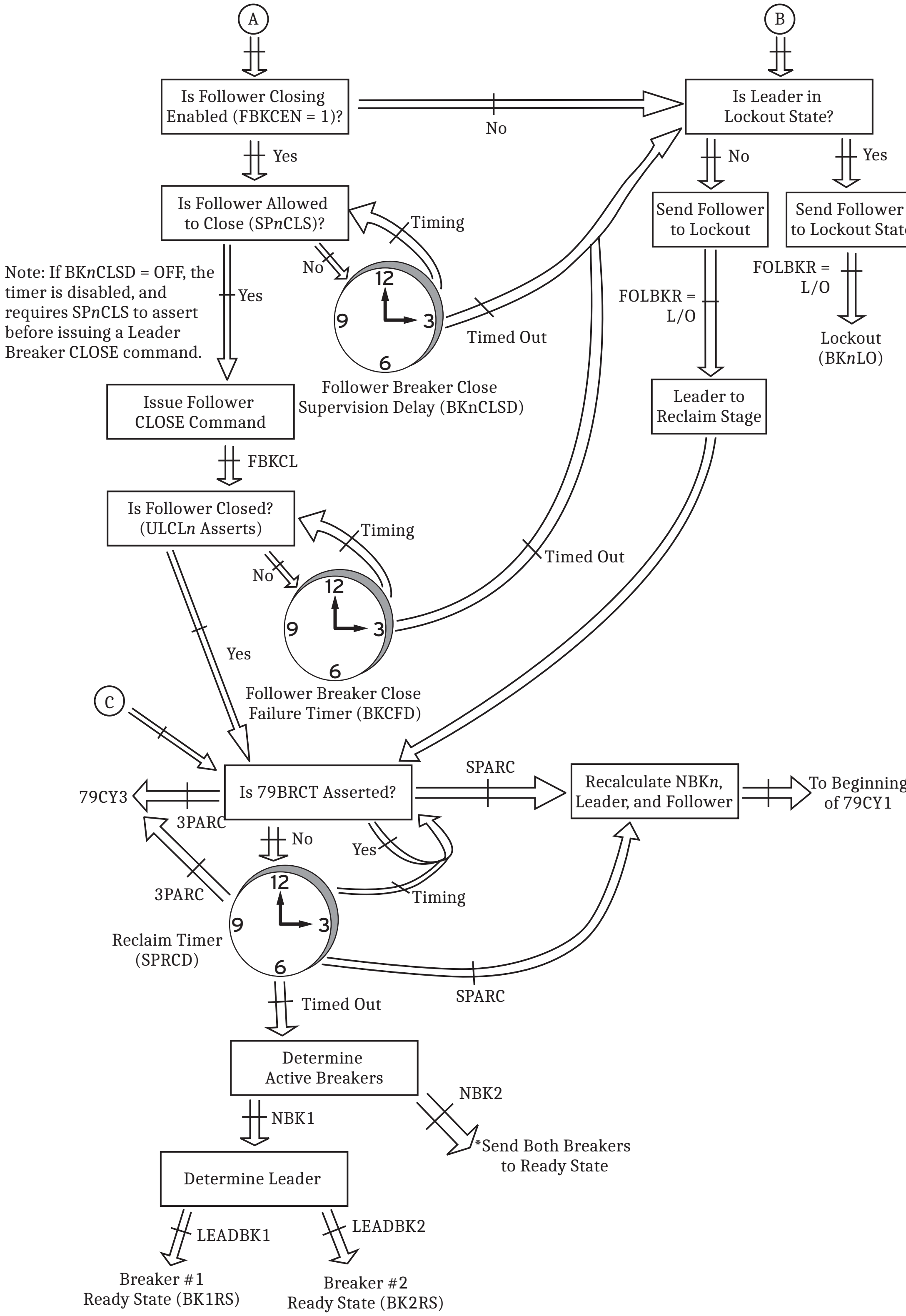


Figure 6.13 Two Circuit Breakers Single-Pole Cycle State (79CY1) When E79 := Y (Continued)

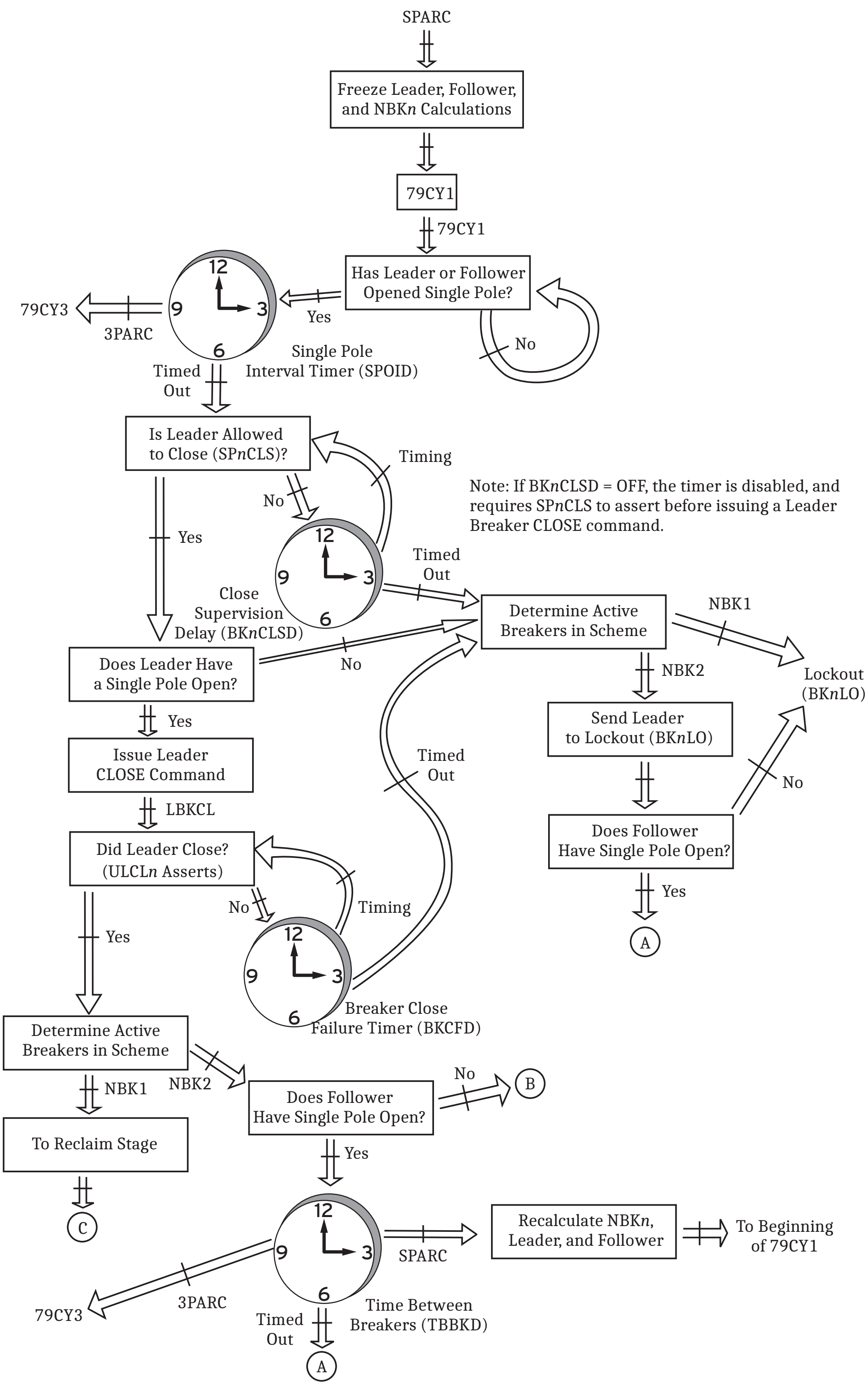


Figure 6.14 Two Circuit Breakers Single-Pole Cycle State (79CY1) When E79 := Y1

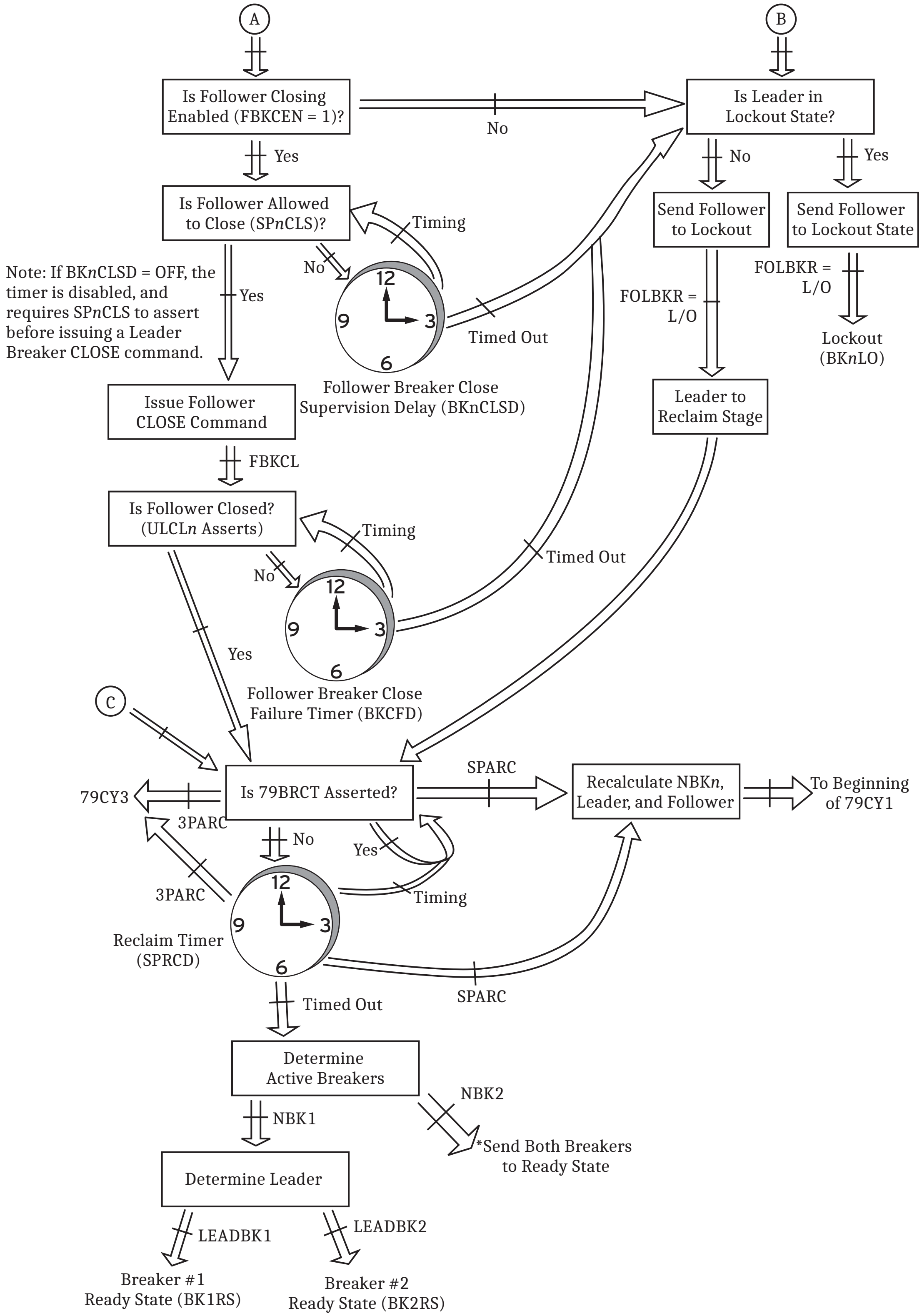


Figure 6.14 Two Circuit Breakers Single-Pole Cycle State (79CY1) When E79 := Y1 (Continued)

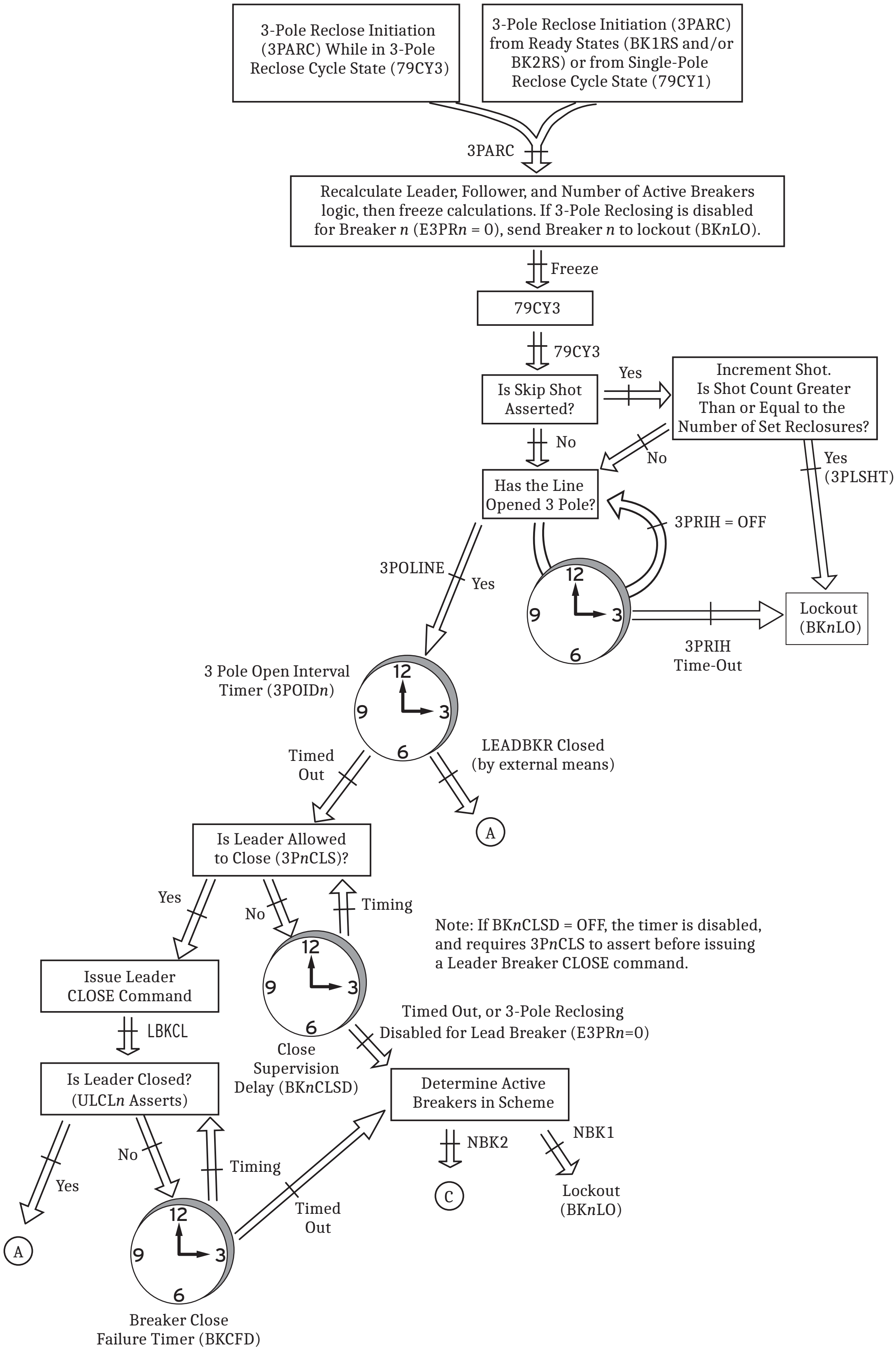


Figure 6.15 Two Circuit Breakers Three-Pole Cycle State (79CY3) When E79 := Y

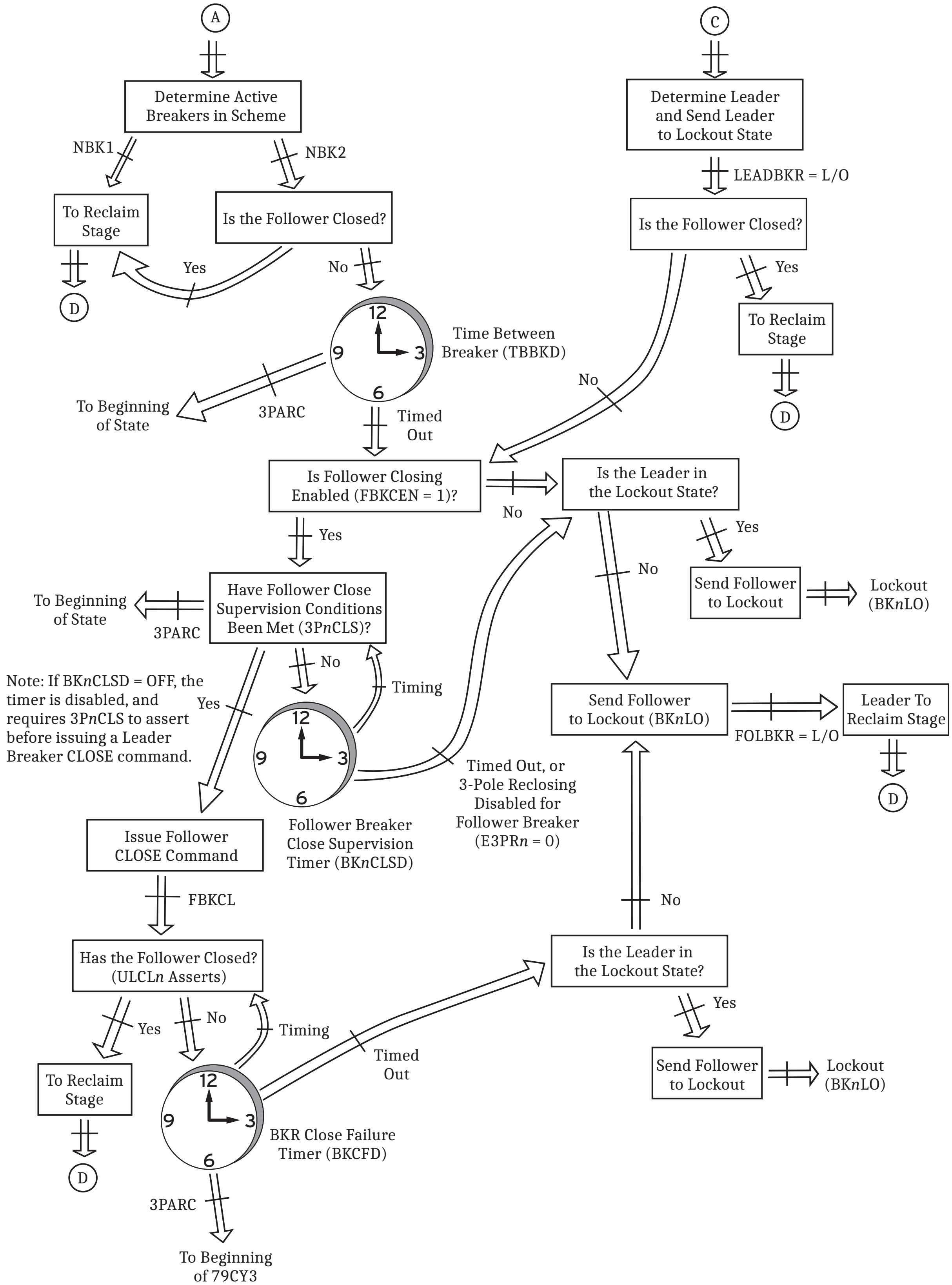


Figure 6.15 Two Circuit Breakers Three-Pole Cycle State (79CY3) When E79 := Y (Continued)

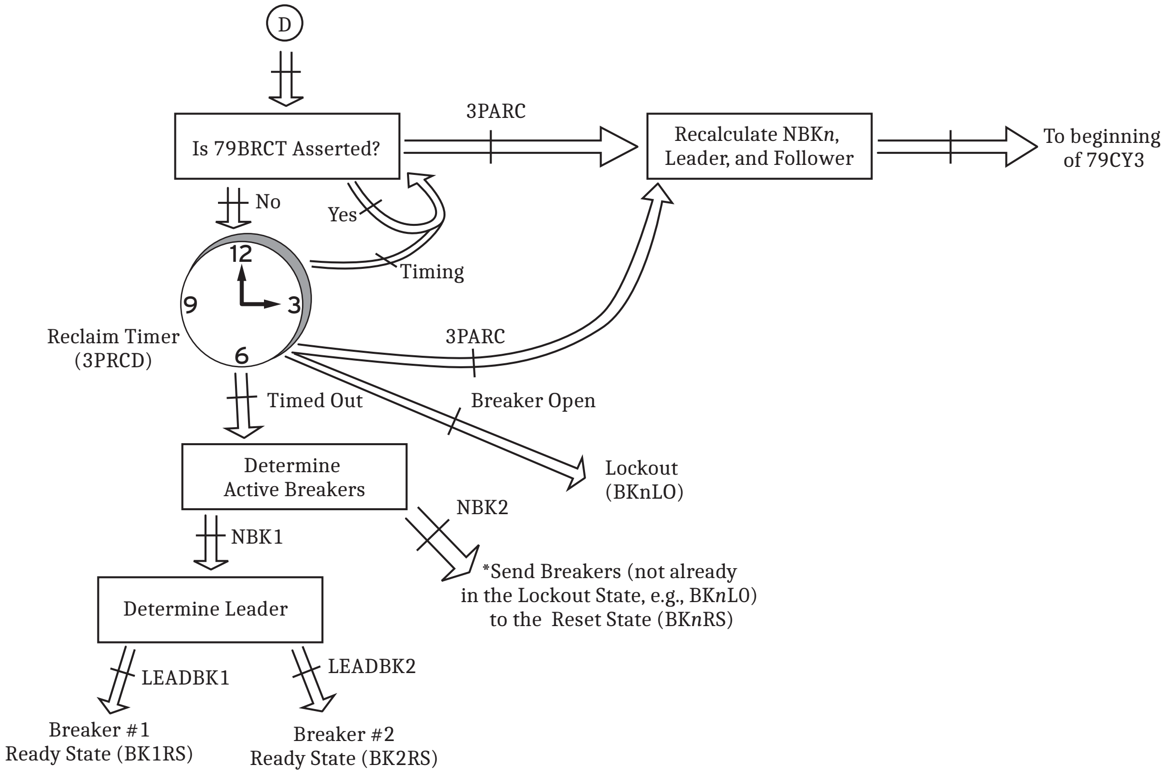


Figure 6.15 Two Circuit Breakers Three-Pole Cycle State (79CY3) When E79 := Y (Continued)

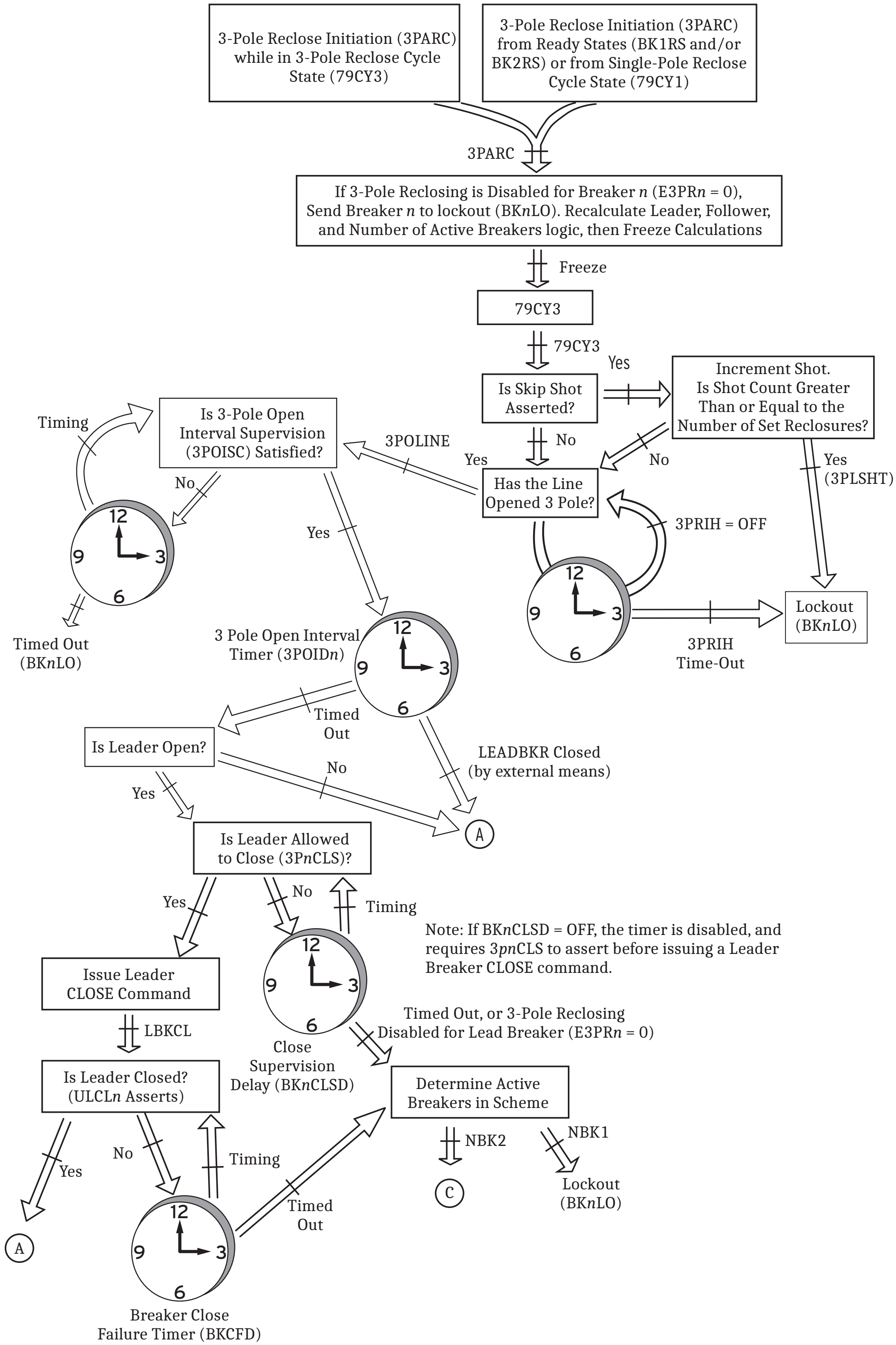


Figure 6.16 Two Circuit Breakers Three-Pole Cycle State (79CY3) When E79 := Y1

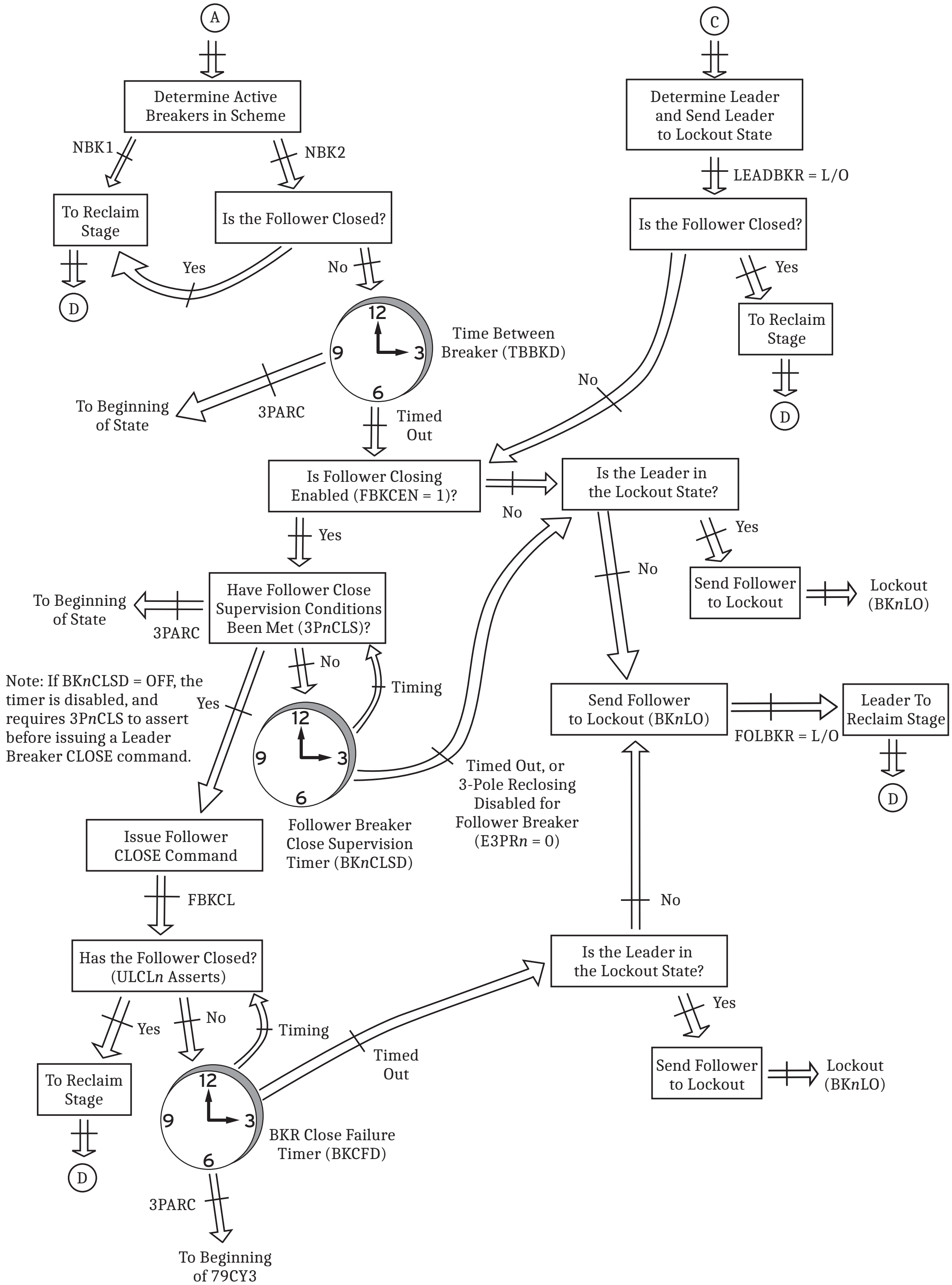


Figure 6.16 Two Circuit Breakers Three-Pole Cycle State (79CY3) When E79 := Y1 (Continued)

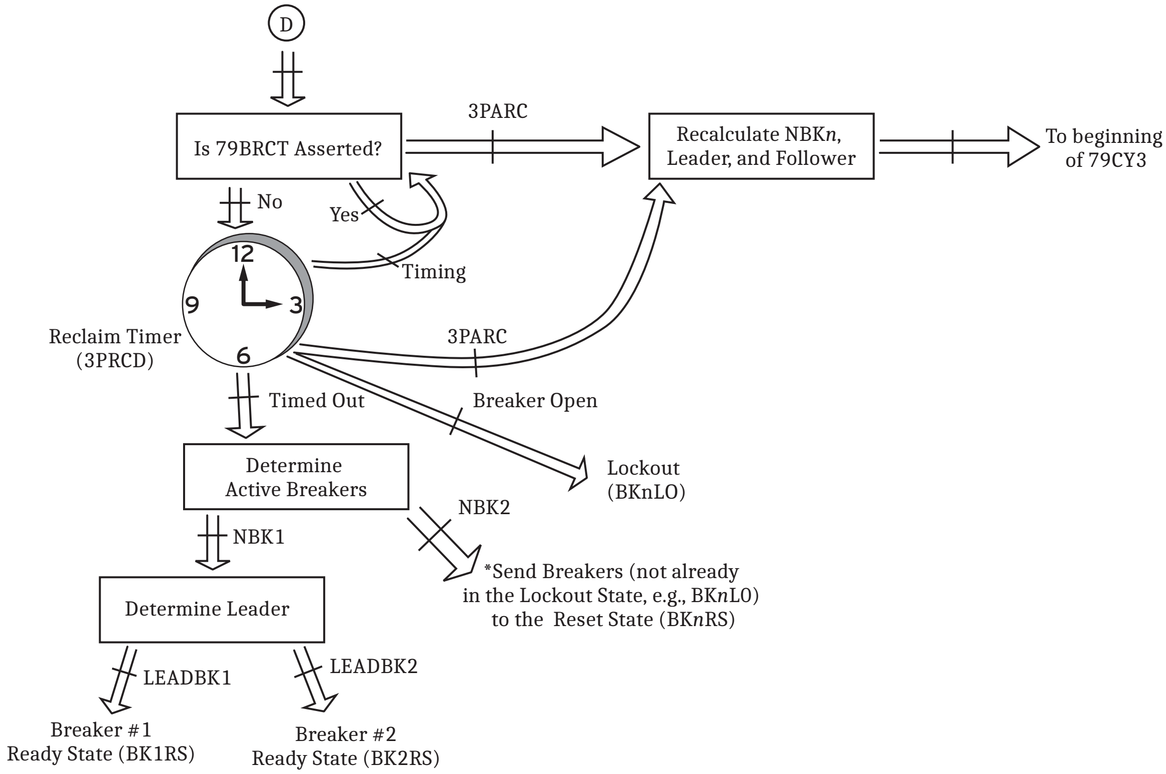


Figure 6.16 Two Circuit Breakers Three-Pole Cycle State (79CY3) When E79 := Y1 (Continued)

Manual Closing

Manual closing is available via the relay to issue a close to the circuit breaker(s) via the same close logic outputs used in autoreclosing (Relay Word bits BK1CL and BK2CL for as many as two circuit breakers). The manual close logic can be user-configured in most any manner with SELOGIC settings BK1MCL and BK2MCL. *Figure 6.17* is a flowchart of the manual close logic. This logic is enabled with Manual Closing enable setting EMANCL := Y.

Figure 6.17 only details the manual close logic for one circuit breaker (breaker BK1). The manual close logic for a second circuit breaker (breaker BK2), if enabled (Global setting NUMBK := 2), is similar. The only difference between the breaker BK1 and breaker BK2 manual close logic in *Figure 6.17* is the substitution of settings and logic outputs (BK2MCL for BK1MCL, ULCL2 for ULCL1, etc.). A manual close is issued for breaker BK1 if all of the following are true:

- A new manual close signal for breaker BK1 is detected (rising-edge assertion of SELOGIC setting BK1MCL)
- No unlatch close conditions are present (SELOGIC setting ULCL1 deasserted)
- No close is presently in progress for breaker BK1 (Relay Word bit output BK1CL is deasserted)

If a manual close is successfully issued for breaker BK1, then:

- Close logic output BK1CL asserts
- The close failure timer starts timing

If breaker BK1 closes successfully, then:

- ➤ The unlatch close condition asserts (indicating breaker closure)
- ➤ Close logic output BK1CL deasserts

If breaker BK1 does not close successfully, then:

- ➤ The close failure timer times out (Relay Word bit BK1CFT asserts momentarily)
- ➤ Close logic output BK1CL deasserts

Note in *Figure 6.17* that if breaker BK1 manual close logic is actively operating (as described in the preceding steps), then breaker BK2 manual close logic cannot be actively operating. Breaker BK2 manual close logic only has a chance to operate if breaker BK1 manual close logic is not actively operating and two breakers are enabled for the scheme (Global setting NUMBK := 2). Thus, manual closing can only be attempted for one breaker at a time.

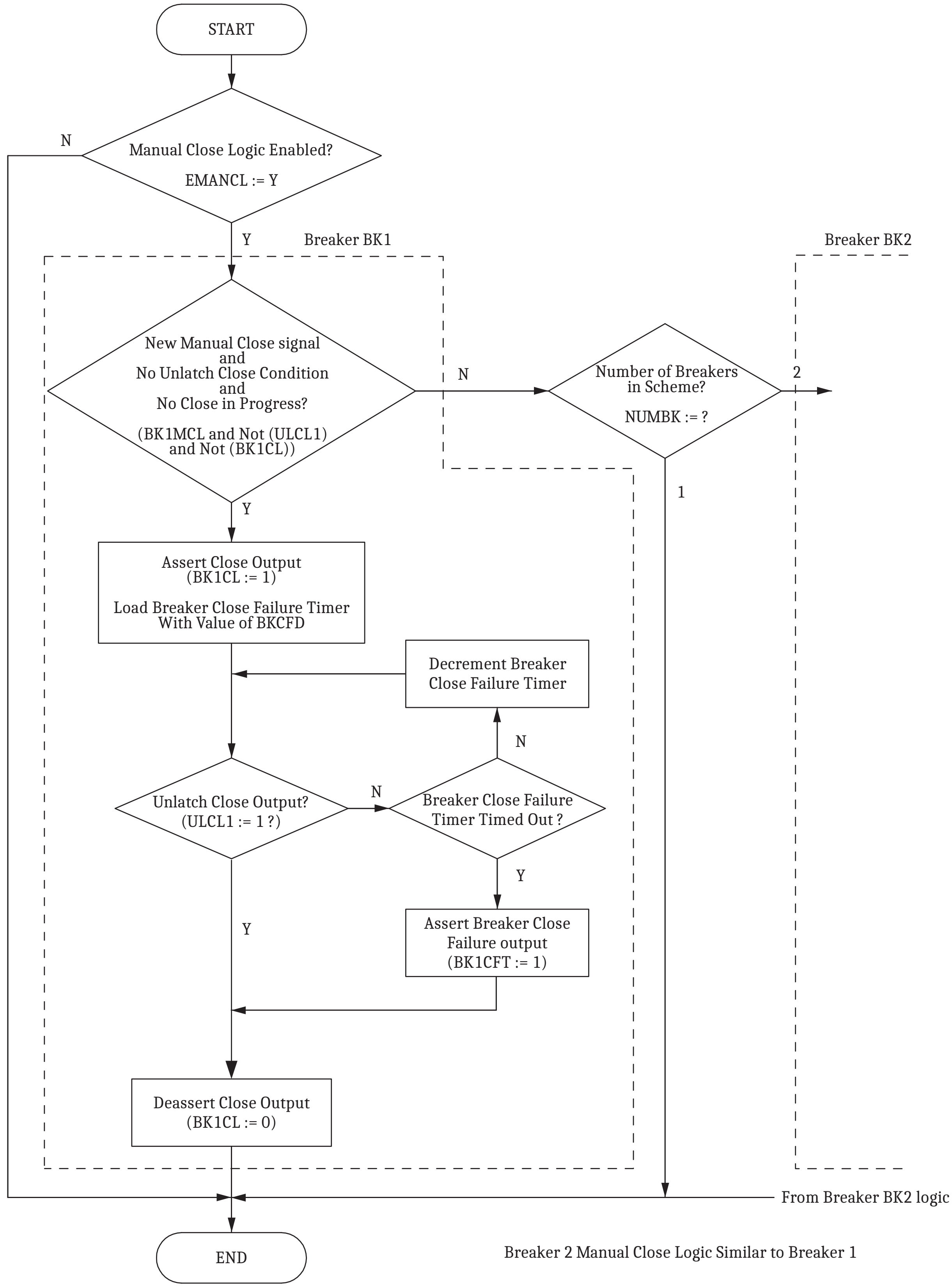


Figure 6.17 Manual Close Logic

Voltage Checks for Autoreclosing and Manual Closing

Voltage elements are available for a final check of line and bus voltages before an autoreclose or manual close is issued. These voltage elements and corresponding pickup settings are enabled with Reclosing Voltage Check enable setting EVCK := Y. *Figure 6.18* shows the application of these voltage elements and *Figure 6.19* and *Figure 6.20* show their implementation. Check voltages for arrangements of as many as two circuit breakers (Global setting NUMBK := 2), as shown in *Figure 6.18*. If the relay is only connected to a single breaker (Global setting NUMBK := 1), then settings 27BK2P and 59BK2P and their associated elements (LLDB2, DLDB2, and DLLB2) are not available.

NOTE: For SV subscriber and TiDL relays, logic that includes the LLDB1, DLLB1, DLDB1, LLDB2, DLLB2, DLDB2 Relay Word bits must be supervised with logic that ensures that the line and bus voltages are OK. For example, LLDB1 AND (NOT(VYBK OR VZBK)).

Voltages VS1 and VS2 in *Figure 6.18*, *Figure 6.19*, and *Figure 6.20* are populated by the synchronism-check settings. For VS1 and VS2, the voltages are determined by the corresponding SYNCS1, ASYNCS1, and ALTS1 settings for VS1, and the SYNCS2, ASYNCS2, and ALTS2 settings for VS2. When EISYNC := N, *Figure 6.19* logic is active and VP is determined by the SYNCP setting. When EISYNC := Y, *Figure 6.20* logic is active and VP1 is the Breaker 1 synchronism-check polarizing voltage determined by the SYNCP1, ASYNP11, ASYNP12, ALTP11, and ALTP12 settings, and VP2 is the Breaker 2 synchronism-check polarizing voltage determined by the SYNCP2, ASYNP21, ASYNP22, ALTP21, and ALTP22 settings. Review details of synchronism checking in the Protection section of the desired product-specific instruction manual.

When EISYNC := N, the pickup settings in *Figure 6.19* are made on the VP voltage base. VP is the voltage reference for voltage angle and magnitude. Only voltage magnitude is of concern for the settings in *Figure 6.19*, not voltage angle.

When EISYNC := Y, pickup settings 27LP and 59LP in *Figure 6.20* are not breaker-independent and must be made to take into account both the VP1 (Breaker 1) and VP2 (Breaker 2) voltage bases. Take into account any compensating factors by using the synchronism-check logic; review details of synchronism checking in *Section 5: Protection Functions* in the product-specific instruction manual for the impact of compensating factors and active, alternative polarizing voltages.

Figure 6.18 implies that three-phase voltage is available from the line PTs. But, resultant voltage VP corresponds to only one phase of this three-phase voltage (e.g., setting SYNCP = VAY; VP is the normalized voltage from voltage input VAY). All the voltage elements in *Figure 6.19* are single-phase voltage elements, detecting live or dead voltage on the bus side with a single-phase voltage element, and likewise on the line side.

Whether or not synchronism-check logic is used, it still has to be enabled for the respective breaker (E25BK1 := Y, Y1, or Y2 and E25BK2 := Y, Y1, or Y2) to allow the corresponding voltage source selection settings to be made.

Live Line/Live Bus

Note in *Figure 6.18* that live line/live bus is not available for either circuit breaker. Voltage elements 59VP, 59VS1, and 59VS2, described in the *Section 5: Protection Functions* of the desired product-specific instruction manual, are available for such a function (e.g., 59VP AND 59VS1 for live line/live bus 1).

Supervising Circuit Breaker Closing with Voltage Checks

Supervising Autoreclosing

For a fault on the line in *Figure 6.18*, both breakers trip open and the lead breaker recloses first. For example, presume the lead breaker closes only if its respective bus is live and the line is dead (dead line/live bus; see *Figure 6.18*). Then, after successful reclose of the lead breaker, the follower breaker closes on synchronism check. Such reclose supervision logic is realized as follows for respective breakers BK1 and BK2:

3P1CLS := **LEADBK1 AND DLLB1 OR FOLBK1 AND 25A1BK1 OR …**

3P2CLS := **LEADBK2 AND DLLB2 OR FOLBK2 AND 25A1BK2 OR …**

Note that the lead breaker and follower breaker supervision (Relay Word bits LEADBK*n* and FOLBK*n*, respectively) provides dynamic control for reclose supervision. One, but not both, of the breakers can reclose for a dead line/live bus condition (lead breaker), while the other then closes for a synchronism-check condition (follower breaker).

Supervising Manual Closing

Voltage checks can also be used to supervise manual closing. For example, presume that manual closing of breaker BK1 (*Figure 6.18*) should not be allowed if the respective bus is dead (dead line/dead bus or live line/dead bus condition):

BK1MCL := **NOT(DLDB1 OR AND LLDB1) AND (…)**

NOTE: This is an example application with EISYNC := N.

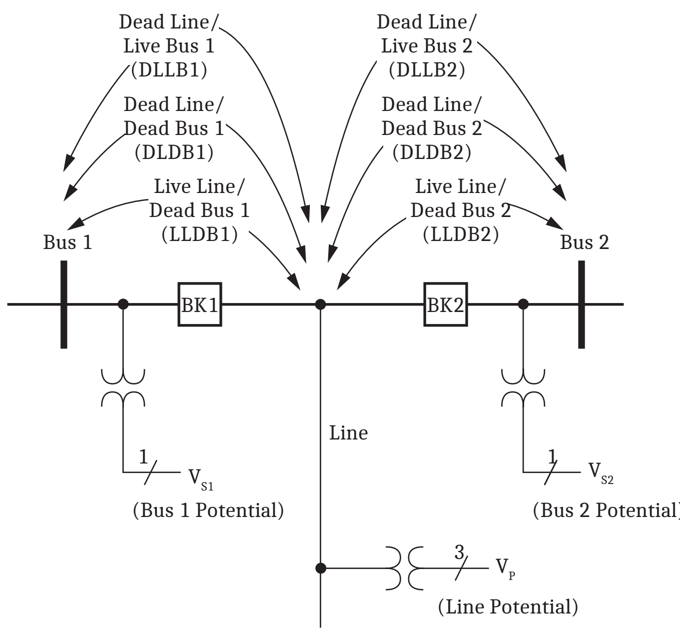


Figure 6.18 Voltage Check Element Applications

NOTE: Active logic when EISYNC := N.

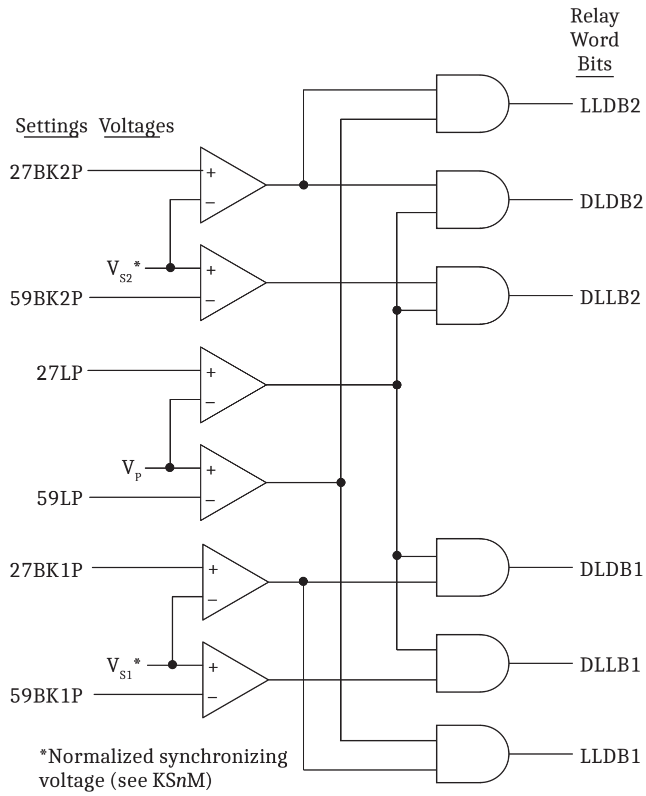


Figure 6.19 Voltage Check Element Logic (EISYNC := N)

NOTE: Active logic when EISYNC := Y.

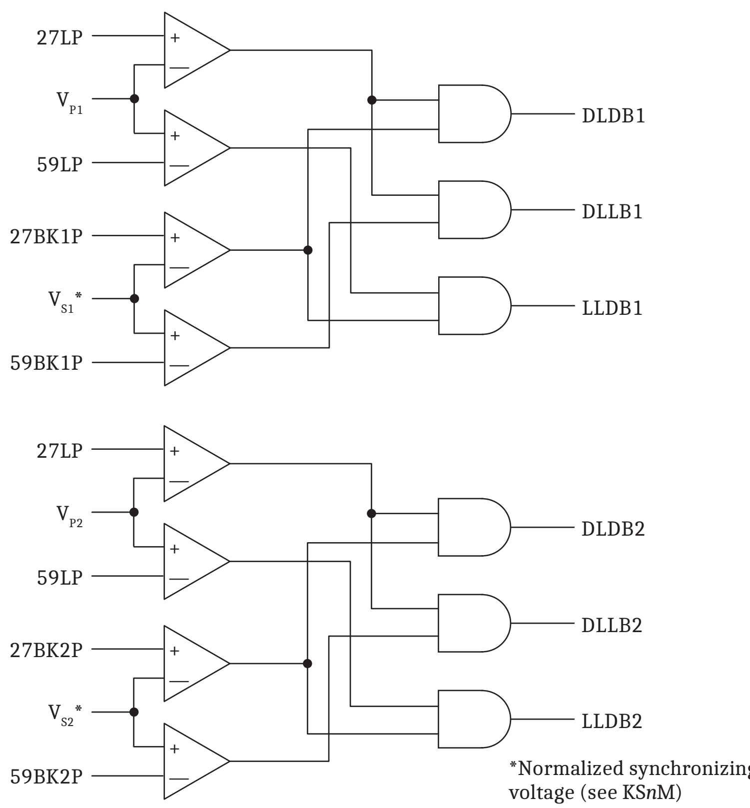


Figure 6.20 Voltage Check Element Logic (EISYNC := Y)

Settings and Relay Word Bits for Autoreclosing and Manual Closing

See the product-specific instruction manual Group Settings tables related to Reclose under the Settings section for a complete list of all autoreclose related settings. *Table 6.24* provides all of the Relay Word bits for autoreclosing.

Table 6.24 Autoreclose Logic Relay Word Bits (Sheet 1 of 2)

Name	Description
BK1RS	Breaker 1 in Reset State
BK2RS	Breaker 2 in Reset State
79CY1[a]	Relay in Single-Pole Reclose Cycle State
79CY3	Relay in Three-Pole Reclose Cycle State
BK1LO	Breaker 1 in Lockout State
BK2LO	Breaker 2 in Lockout State
SPARC[a]	Single-Pole Reclose Initiate Qualified
SPOISC[a]	Single-Pole Open Interval Supervision Condition
SPOI[a]	Single-Pole Open Interval Timing
SPSHOT0[a]	Single-Pole Shot Counter = 0
SPSHOT1[a]	Single-Pole Shot Counter = 1
SPSHOT2[a]	Single-Pole Shot Counter = 2
SPLSHT[a]	Single-Pole Reclose Last Shot
SPRCIP[a]	Single-Pole Reclaim In-Progress
3PARC	Three-Pole Reclose Initiate Qualified
3POISC	Three-Pole Open Interval Supervision Condition
3POI	Three-Pole Open Interval Timing
3PSHOT0	Three-Pole Shot Counter = 0
3PSHOT1	Three-Pole Shot Counter = 1
3PSHOT2	Three-Pole Shot Counter = 2
3PSHOT3	Three-Pole Shot Counter = 3
3PSHOT4	Three-Pole Shot Counter = 4
3PLSHT	Three-Pole Reclose Last Shot
3PRCIP	Three-Pole Reclaim In-Progress
SPOBK1[a]	Single-Pole Open Breaker 1
2POBK1[a]	Two Poles Open Breaker 1
3POBK1	Three-Pole Open Breaker 1
SPOBK2[a]	Single-Pole Open Breaker 2
2POBK2[a]	Two Poles Open Breaker 2
3POBK2	Three-Pole Open Breaker 2
3POBK1	Three-Pole Open Breaker 1
3POLINE	Three-Pole Open Line
R3PTE	Three-Pole Tripping and Reclosing Only
R3PTE1	Recloser Three-Pole Trip Enable -BK1

Table 6.24 Autoreclose Logic Relay Word Bits (Sheet 2 of 2)

Name	Description
R3PTE2	Recloser Three-Pole Trip Enable -BK2
BK1CL	Breaker 1 Close Command
BK2CL	Breaker 2 Close Command
BK1CLST	Breaker 1 Close Supervision Delay Timed Out
BK2CLST	Breaker 2 Close Supervision Delay Timed Out
BK1CFT	Breaker 1 Close Failure Delay Timed Out
BK2CFT	Breaker 2 Close Failure Delay Timed Out
BK1CLSS	Breaker 1 in Close Supervision State
BK2CLSS	Breaker 2 in Close Supervision State
BK1EXT	Breaker 1 Closed Externally
BK2EXT	Breaker 2 Closed Externally
BK1RCIP	BK1 Reclaim in Progress
BK2RCIP	BK2 Reclaim in Progress
79STRT	Relay in Start State
TBBK	Time Between Breakers Timing
LEADBK0	No Leader Breaker
LEADBK1	Leader Breaker = Breaker 1
LEADBK2	Leader Breaker = Breaker 2
FOLBK0	No Follower Breaker
FOLBK1	Follower Breaker = Breaker 1
FOLBK2	Follower Breaker = Breaker 2
NBK0	No Breaker Active in Reclose Scheme
NBK1	One Breaker Active in Reclose Scheme
NBK2	Two Breakers Active in Reclose Scheme
LLDB1	Live Line—Dead Bus 1 (59L AND 27BK1)
DLLB1	Dead Line—Live Bus 1 (27L AND 59BK1)
DLDB1	Dead Line—Dead Bus 1 (27L AND 27BK1)
LLDB2	Live Line—Dead Bus 2 (59L AND 27BK2)
DLLB2	Dead Line—Live Bus 2 (27L AND 59BK2)
DLDB2	Dead Line—Dead Bus 2 (27L AND 27BK2)

[a] Only applicable to products that support single-pole reclosing.

SECTION 7

Metering

The relay provides extensive capabilities for metering important power system parameters.

This section provides basic information about metering capabilities in typical SEL-400 series relays. Not all SEL-400 series relays support every metering feature described in this section. See *Section 7: Metering, Monitoring, and Reporting* of the product-specific instruction manual for information on the specific metering capabilities of a specific relay.

The SEL-400 series relays typically provide the following metering modes for measuring power system operations:

- *Instantaneous Metering on page 7.2*
- *Maximum/Minimum Metering on page 7.5*
- *Demand Metering on page 7.6*
- *Energy Metering on page 7.10*
- *Synchrophasor Metering on page 7.10*
- *Battery Metering on page 7.11*
- *RTD Metering on page 7.12*
- *Protection Math Variable Metering on page 7.12*
- *Automation Math Variable Metering on page 7.13*
- *MIRRORED BITS Remote Analog Metering on page 7.13*

Monitor present power system operating conditions with instantaneous metering. Maximum/Minimum metering displays the largest and smallest system deviations since the last reset. Demand metering includes either thermal or rolling analysis of the power system and peak demand metering. Energy metering displays the megawatt-hours imported, megawatt-hours exported, and total megawatt-hours. Time-synchronized metering displays the line voltage and current synchrophasors.

The relay processes various sets of currents and voltages, depending on the specific relay.

Use the **MET** command to access the metering functions. Issuing the **MET** command with no options returns fundamental measurement quantities. The **MET** command followed by a number, **MET *k***, specifies the number of times the command will repeat (*k* can range from 1–32767). This is useful for troubleshooting or investigating uncharacteristic power system conditions.

Table 7.1 lists some common **MET** command variants.

Table 7.1 MET Command (Sheet 1 of 2)

Name	Description
MET	Display fundamental line metering information
MET RMS	Display rms line metering information

Table 7.1 MET Command (Sheet 2 of 2)

Name	Description
MET M	Display line maximum/minimum metering information
MET RM	Reset line maximum/minimum metering information
MET D	Display demand line metering information
MET RD	Reset demand line metering information
MET RP	Reset peak demand line metering information
MET E	Display energy line metering information
MET RE	Reset energy line metering information
MET BAT	Display dc battery monitor information
MET RBM	Reset battery monitor min/max measurements
MET PM	Display phasor measurement (synchrophasor) metering information
MET RTD	Display SEL-2600 temperature quantities
MET PMV	Display protection math variable values
MET AMV	Display automation math variable values
MET ANA	Display remote analogs received from MIRRORED BITS

Instantaneous Metering

Use instantaneous metering to monitor power system parameters in real time. The relay typically provides these fundamental frequency readings:

- Fundamental frequency phase voltages and currents
- Phase-to-phase voltages
- Sequence voltages and currents
- Fundamental real, reactive, and apparent power
- Displacement power factor

NOTE: After startup, automatic restart, or a warm start, including settings change and group switch, in the beginning period of 20 cycles, the 10-cycle average values are initialized with the latest calculated 1-cycle average values.

You can also typically monitor these real-time rms quantities (with harmonics included):

- RMS phase voltages and currents
- Real and apparent rms power
- True power factor

Power

The instantaneous power measurements are derived from 10-cycle averages that the relay reports by using the generator condition of the positive power flow convention; for example, real and reactive power flowing out (export) is positive, and real and reactive power flowing in (import) is negative (see *Figure 7.1*).

NOTE: The SEL-487B does not include power and power factor in its metering reports.

For power factor, LAG and LEAD refer to whether the current lags or leads the applied voltage. The reactive power Q is positive when the voltage angle is greater than the current angle ($\theta V > \theta I$), which is the case for inductive loads where the current lags the applied voltage. Conversely, Q is negative when the voltage angle is less than the current angle ($\theta V < \theta I$); this is when the current *leads* the voltage, as in the case of capacitive loads.

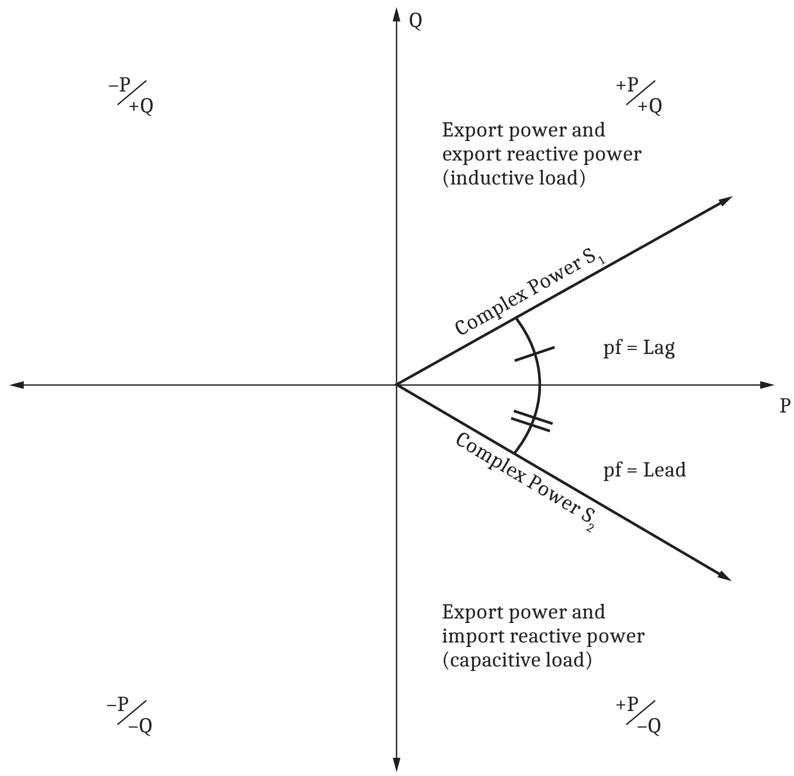


Figure 7.1 Complex Power (P/Q) Plane

Some products include Relay Word bits to indicate the leading or lagging power factor (see *Section 11: Relay Word Bits* in the product-specific instruction manual). In the case of a unity power factor or loss of phase or potential condition, the resulting power factor angle would be on this axis of the complex power (P/Q) plane shown in *Figure 7.1*. This would cause the power factor Relay Word bits to rapidly change state (chatter). Be aware of expected system conditions when monitoring the power factor Relay Word bits. It is not recommended to use chattering Relay Word bits in the SER or anything that will trigger an event.

High-Accuracy Instantaneous Metering

The relay is a high-accuracy metering instrument. *Table 7.2* and *Table 7.3* show the metering accuracy for the relay instantaneous metering quantities at nominal power system frequency and at 20°C. Use a method similar to that in *Example 7.1* to compute exact error coefficients.

NOTE: The SEL-487B does not provide frequency metering because it does not support frequency tracking.

Table 7.2 Instantaneous Metering Accuracy—Voltages, Currents, and Frequency

Quantity	Magnitude Accuracy		Phase Accuracy
	Range	Specification	
Vϕ, Vϕϕ	33.5 – 200 $V_{L–N}$	± 0.1%	±0.5°
3V0, V1, 3V2	33.5 – 200 $V_{L–N}$	± 0.15%	±0.1°
Iϕ	(0.5 – 3)• I_{NOM}	±0.2% ± (0.8 mA) • I_{NOM}	±0.2°
3I0, I1, 3I2	(0.5 – 3)• I_{NOM}	± 0.3% ± (1.0 mA) • I_{NOM}	±0.3°
FREQ	40–65 Hz	±0.01 Hz	

Table 7.3 Instantaneous Metering Accuracy—Power

Quantity	Description	Power Factor	Accuracy (%)[a]
At 0.1 • I_{NOM}			
3P	Three-phase rms real power	Unity	±0.40
		–0.5 or +0.5	±0.70
$3Q_1$	Reactive power	–0.5 or +0.5	±0.50
At 1.0 • I_{NOM}			
3P	Three-phase fundamental real power	Unity	±0.40
		–0.5 or +0.5	±0.40
$3Q_1$	Reactive power	–0.5 or +0.5	±0.40

[a] Power accuracy is valid for applied currents in the range (0.1–1.2) • I_{NOM}, and applied voltages from 33.5–75 V.

Example 7.1 Calculating Exact Error Coefficients

Consider the case of a 5 A relay during normal operating conditions. The secondary current in the CT is 1.0 A for nominal system operation. Noting that this current is greater than 10 percent of I_{NOM} (1 A > 0.5 A), calculate the error coefficient:

$$
\begin{aligned}
\text{error} &= \pm(0.2\% \bullet 1.0\ \text{A}) \pm (0.8\ \text{mA} \bullet I_{NOM}) \\
&= \pm(0.002 \bullet 1.0\ \text{A}) \pm (0.0008\ \text{A} \bullet 5) \\
&= \pm(0.002\text{A} \pm 0.004\text{A}) \\
&= +0.002\ \text{A to } +0.006\ \text{A} \\
&\quad \text{and} \\
&= -0.006\ \text{A to } -0.002\ \text{A}
\end{aligned}
$$

Equation 7.1

Figure 7.2 represents the calculated accuracy range. The error is very small, indicating that the relay measures normal operating currents accurately.

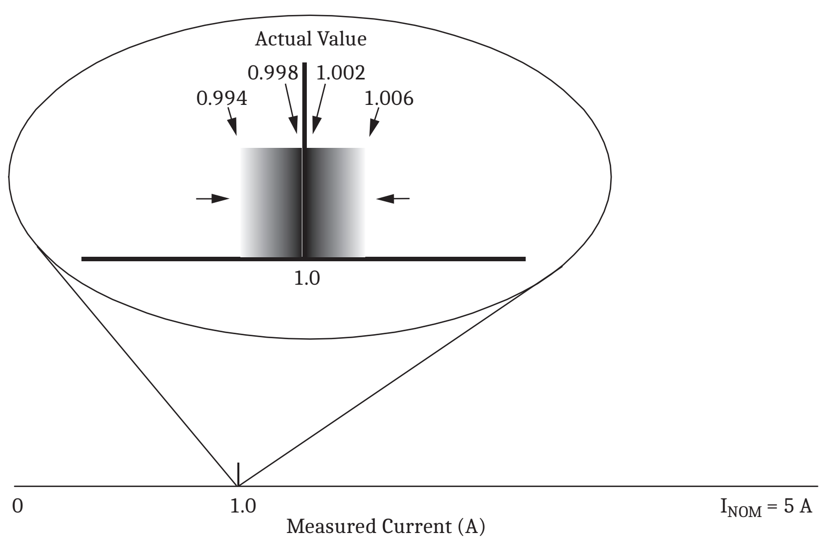


Figure 7.2 Typical Current Measuring Accuracy

Example 7.1 Calculating Exact Error Coefficients (Continued)

When you use *Equation 7.1*, you add an error amount related to the nominal current rating of the relay, I_{NOM}. Use just the numeric portion of I_{NOM}, either “5” for a 5 A relay or “1” for a 1 A relay; do not use the unit (A). The errors in *Equation 7.1* are very small and qualify the relay as a high-accuracy meter.

Maximum/Minimum Metering

The relay measures and retains the deviations of the power system since the last maximum/minimum reset. Knowing these maximum and minimum quantities can help you operate your power system more effectively in a variety of ways. For example, you can benefit from maximum/minimum metering information by using it to track power flow for troubleshooting, planning future expansion, and scheduling maintenance.

NOTE: Not all SEL-400 series relays support maximum/minimum metering.

The relay provides maximum/minimum metering for a variety of line and breaker quantities, as well as for dc battery voltage. The relay also records the maximum values of the sequence voltages and sequence currents.

View or Reset Maximum/Minimum Metering Information

The relay shows time-stamped maximum/minimum quantities when you use a communications port or ACSELERATOR QuickSet SEL-5030 Software to view these quantities. In addition, you can read the maximum/minimum quantities on the relay front-panel LCD screen.

To reset the maximum/minimum values, use the **MET RM** command from a communications terminal, or use the RESET button in the QuickSet **HMI > Meter and Control > Maximum/Minimum** window, or answer Y and press ENT at the Maximum/Minimum submenu reset prompt on the front-panel LCD screen. You can also reset maximum/minimum metering with Global settings (typically RST-MML, RSTMMB1, and RSTMMB2).

Maximum/Minimum Metering Updating and Storage

The relay updates maximum/minimum values once per power system cycle. The relay stores maximum/minimum values and the corresponding dates and times to nonvolatile storage once per day. If greater than a previously stored maximum or less than a previously stored minimum, the new value overwrites the previous value. Should the relay lose control power, it will restore the maximum/minimum information saved at 23:50 hours on the previous day.

The relay updates maximum/minimum values under the following conditions:

- DFAULT is deasserted (equals logical 0)
- The metering value is greater than the previous maximum, or less than the previous minimum, for 2 cycles
- Voltage input is greater than 13 V secondary
- Current input is greater than $0.05 \cdot I_{NOM}$ (in secondary amperes)

Megawatt and megavar maximum/minimum values are subject to the above voltage thresholds, current thresholds, and conditions.

FAULT SELOGIC Control Equation

The relay suspends updating maximum/minimum metering when SELOGIC control equation FAULT asserts to logical 1. If there is a fault, the elements programmed in FAULT pick up and assert Relay Word bit DFAULT (Delayed FAULT Suspend). This Relay Word bit remains asserted for one minute after SELOGIC control equation FAULT deasserts. While DFAULT is asserted, the relay does not record maximum/minimum data.

In addition, the relay also suspends demand metering during the time that Relay Word bit DFAULT is asserted.

Demand Metering

Economic operation of the power system involves the proper allocation of the load demand among the available generating units. By knowing the demand requirements at different points in the system and at different times of the day you can optimize your system generation resources or your consumption of electric power. The relay provides you this demand information and enables you to operate your power system with an effective economic strategy.

NOTE: Not all SEL-400 series relays support demand metering.

The relay uses longer-term accumulations of the metering quantities for reliable demand data.

Thermal Demand and Rolling Demand

Two methods exist for measuring power system current and power demand. These methods are thermal demand metering and rolling demand metering. *Figure 7.3* and *Figure 7.4* illustrate the step input response of the two demand measuring methods with setting DMTC (demand meter time constant) at 15 minutes.

Thermal Demand

Thermal demand is a continuous exponentially increasing or decreasing accumulation of metered quantities. Thermal demand measurement is similar to parallel RC network integration. Thermal demand metering response is at 90 percent (0.9 per unit) of the full applied value after a period equal to the DMTC setting (15 minutes in *Figure 7.3*).

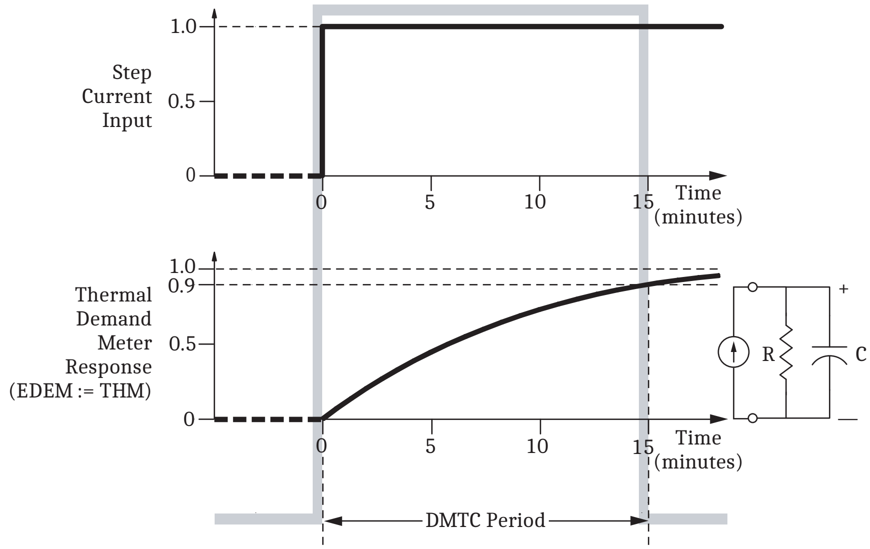


Figure 7.3 Thermal Demand Metering

Rolling Demand

Rolling demand is a sliding time-window arithmetic average. Rolling demand measurement is similar to a step-sampled A/D conversion system. *Figure 7.4* shows the rolling demand response for a step input for a demand meter time constant of 15 minutes (DMTC := 15). The relay divides the DMTC period into three 5-minute intervals and averages the three DMTC subinterval samples every DMTC period. *Table 7.4* lists the rolling demand response for four DMTC periods shown in *Figure 7.4*. Rolling demand metering response is at 100 percent (1.0 per unit) of the full applied value after a time equal to the fourth DMTC period (see *(d)* in *Figure 7.4*).

Table 7.4 Rolling Demand Calculations

DMTC Period (see Figure 9.18)	1/3 DMTC Interval (minutes)	Interval Sample (per unit)	Rolling Demand Total	Rolling Demand Calculation	Rolling Demand Response (per unit)
(a)	–5 to 0	0	0	0 / 3	0
(b)	0 to 5	1	1	1 / 3	0.33
(c)	5 to 10	1	2	2 / 3	0.67
(d)	10 to 15	1	3	3 / 3	1.00

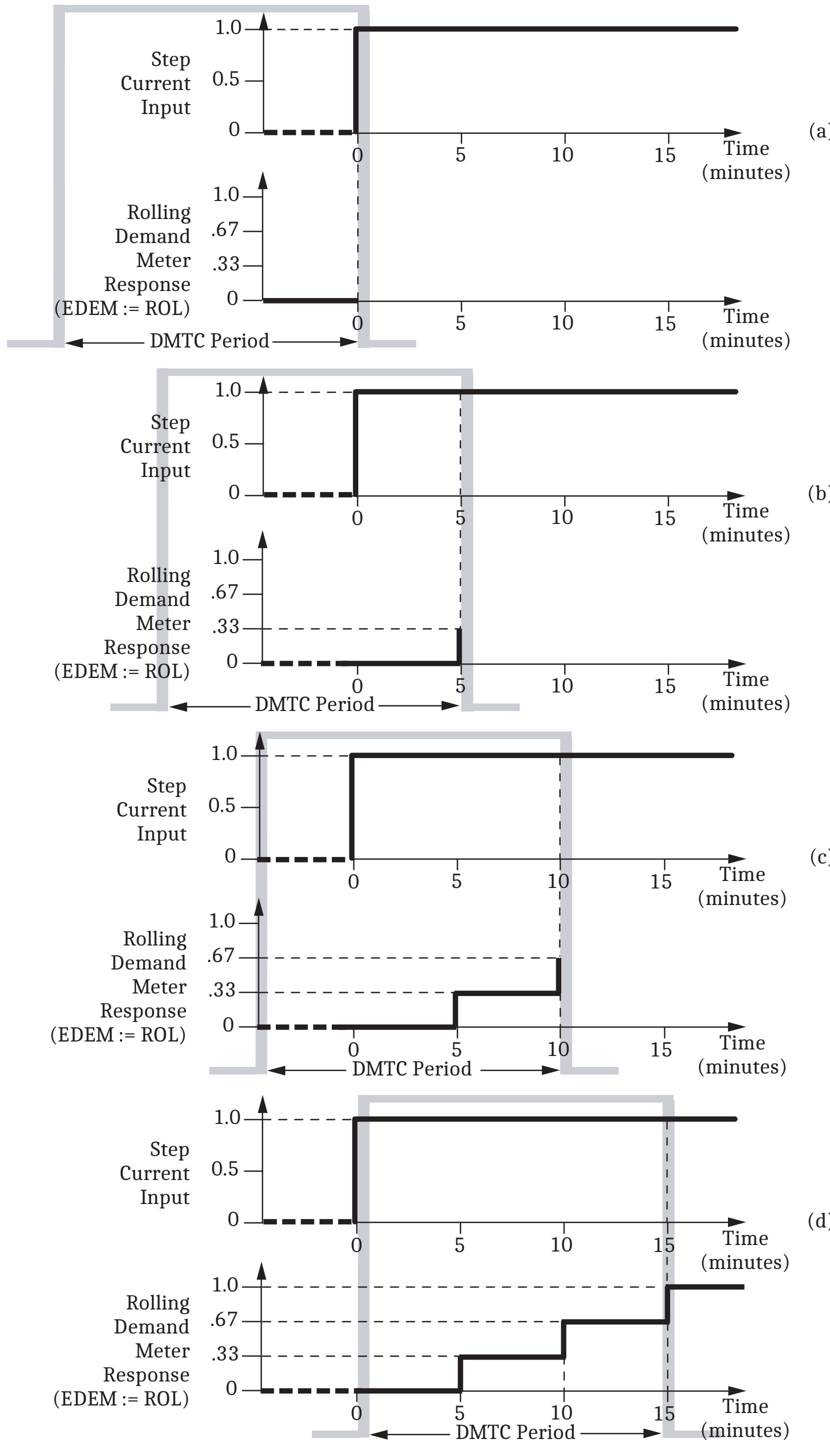


Figure 7.4 Rolling Demand Metering

Demand Metering Settings

Use the demand metering enable setting EDEM to select the demand metering type (thermal or rolling) appropriate to your needs. Use demand pickup settings (typically PDEMP, QDEMP, and GDEMP) to set alarm thresholds to notify you when demand currents exceed preset operational points.

NOTE: Changing EDEM or DMTC resets the demand meter values to zero. This also applies to changing the active settings group where either setting EDEM or DMTC is different in the new active settings group. (Changing demand current pickup settings PDEMP, GDEMP, and QDEMP will not affect the demand meters.)

Figure 7.5 shows how the relay applies the demand current pickup settings over time. When residual-ground demand current IG(DEM) exceeds the corresponding demand pickup setting GDEMP, Relay Word bit GDEM asserts to logical 1. Use these demand current logic outputs (PDEM, GDEM, and QDEM) for control or alarm for high loading or unbalance conditions.

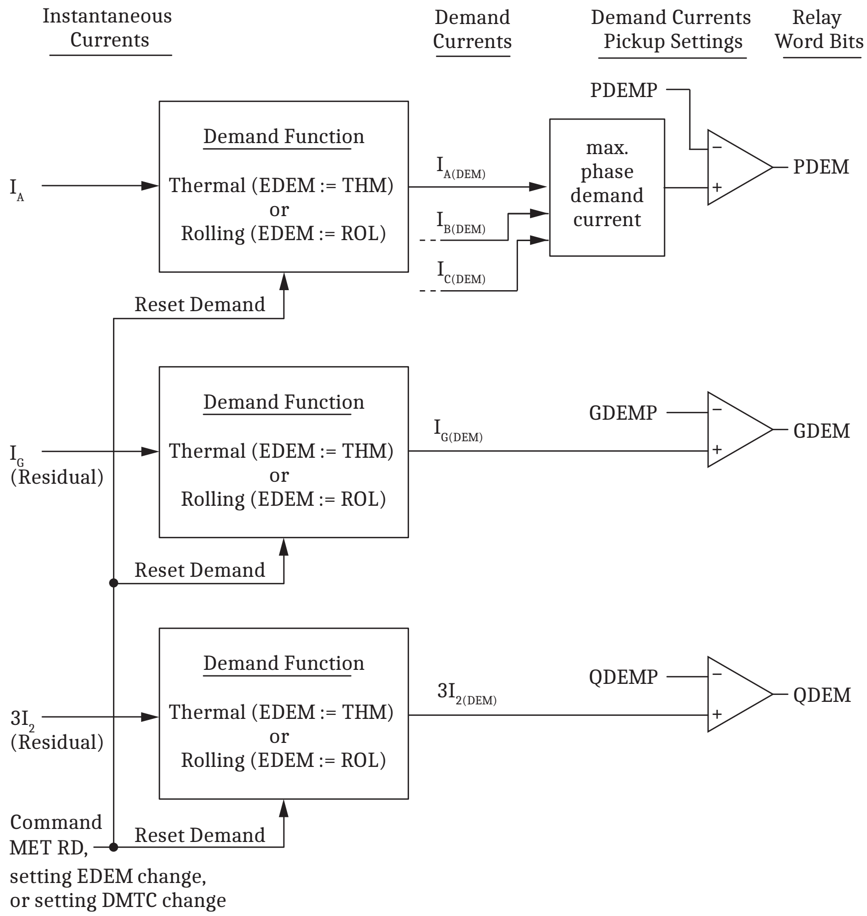


Figure 7.5 Demand Current Logic Outputs

View or Reset Demand Metering Information

The relay shows demand metering quantities and time-stamped peak demand quantities when you use a communications port or QuickSet to view these quantities. In addition, you can read the demand and peak demand quantities on the relay front-panel LCD screen.

To reset the demand metering values use the **MET RD** command from a communications terminal, or use the RESET button in the QuickSet **HMI > Meter and Control > Demand/Peak** window, or answer `Y` and press ENT at the `Demand Submenu` reset demand prompt on the front-panel LCD screen. The relay begins the demand meter sampling period from the time of the demand meter reset.

To reset the peak demand metering values, enter the **MET RP** command from a communications terminal, or use the RESET button in the QuickSet **HMI > Meter and Control > Demand/Peak** window, or answer `Y` and press ENT at the `Demand Submenu` reset peak demand prompt on the front-panel LCD screen. You can also reset demand metering with Global settings RST_DEM and RST_PDM (for demand and peak demand) when EDRSTC (Data Reset Control) is Y.

Demand Metering Updating and Storage

The relay updates demand and peak demand values once per second. The relay also stores peak demand values and the date and time these occurred to nonvolatile storage once per day (it overwrites the previous stored value if it is exceeded). Should the relay lose control power, it will restore the peak demand information saved at 23:50 hours on the previous day.

Demand metering updating and peak recording is suspended during the time that SELOGIC control equation FAULT asserts Relay Word bit DFAULT (Delayed FAULT Suspend).

Energy Metering

Energy is the power consumed or developed in the electric power system measured over time. You can use accurate accounting of power system energy flow to manage billing revenues, whether your system is a net energy producer or consumer. Time-synchronized demand and energy measurements make demand and energy metering information even more useful for power system status applications.

NOTE: Not all SEL-400 series relays support energy metering. The SEL-487E performs energy calculations using fundamental active and reactive power quantities.

The relay integrates energy imported and exported on a per-phase basis every second. As in demand metering, the relay uses the longer-term accumulations of rms or true real power for reliable energy data.

View or Reset Energy Metering Information

You can read the energy metering quantities by using a communications port, QuickSet, or the relay front-panel LCD screen.

To reset the energy values, use the **MET RE** command from a communications terminal, or use the **RESET** button in the QuickSet **HMI > Meter and Control > Energy** window, or answer `Y` and press **ENT** at the `Energy Meter` submenu reset prompt on the front-panel LCD screen. You can also reset energy metering with Global setting RST_ENE when EDRSTC (Data Reset Control) is Y.

Energy Metering Updating and Storage

The relay updates energy values once per second. The relay also stores energy values to nonvolatile storage once every four hours, referenced from 23:50 hours (it overwrites the previously stored value if it is exceeded). Should the relay lose control power, it restores the energy values saved at the end of the last four-hour period.

Synchrophasor Metering

The relay provides synchrophasor measurement with an angle reference according to IEEE C37.118. The relay calculates the phasor measurement quantities 50 or 60 times per second, depending on the nominal system frequency contained in Global setting NFREQ.

NOTE: Not all SEL-400 series relays support synchrophasor measurements.

When you issue the **MET PM** ***time*** command, the relay captures the time-synchronized data for the given trigger time (specify ***time*** in 24-hour format). The relay displays the synchrophasor data immediately after the time trigger.

The synchrophasor measurements are only valid when a suitable high-accuracy IRIG-B or Precision Time Protocol (PTP) time source is connected to the relay, as indicated by Relay Word bit TSOK = logical 1.

The **MET PM** command is only available when the relay is configured for phasor measurement functions (Global settings) and the relay is in high-accuracy time-keeping mode.

Battery Metering

The relay monitors battery system voltages and records time stamps for voltage excursions. In addition, the relay records maximum and minimum battery voltages. *Figure 7.6* shows a sample dc battery monitor meter report. Use the **MET BAT** command from a communications terminal to obtain this report.

```
=>>MET BAT <Enter>

Relay 1                                      Date: 06/07/2008  Time: 22:51:47.067
Station A                                    Serial Number: 2008030645

Station Battery        VDC      VDCPO     VDCNE      VAC
   VDC1 (V)            115.86    57.32    -58.54     0.01

             VDC1(V)    Date       Time
Minimum       105.86 04/07/2008  22:43:04.022
Enter L-Zone         04/07/2008  22:40:14.162
Exit L-Zone          04/07/2008  22:44:09.223


Maximum       125.86 04/09/2008  12:34:14.321
Enter H-Zone         04/09/2008  12:31:32.543
Exit H-Zone          04/09/2008  12:35:12.657

LAST DC RESET:  01/15/2008  20:10:31.427

=>>
```

Figure 7.6 Battery Metering: Terminal

Any battery voltage between setting DCLWP and the dc battery monitor low limit of 15 Vdc is in the L-Zone. Battery voltages in the H-Zone are voltages higher than the DCHWP setting.

Use the **MET RBM** command from a communications terminal to reset the dc battery monitor. You can program a SELOGIC control equation RST_BAT (in Monitor settings) to control dc battery monitor reset.

RTD Metering

Use the **MET RTD** command to display the resistance temperature detector (RTD) values, as shown in *Figure 7.7*.

```
=>>MET RTD <Enter>

Relay 1                                     Date: 04/12/2008  Time: 06:06:31.366
Station A                                   Serial Number: 2008030645


RTD Input Temperature Data (deg. C)
RTD  1 = -50
RTD  2 = 250
RTD  3 = 0
RTD  4 = 45
RTD  5 = 34
RTD  6 = 65
RTD  7 = -23
RTD  8 = 39
RTD  9 = 23
RTD 10 = 11
RTD 11 = 54
RTD 12 = 78

=>>
```

Figure 7.7 RTD Report

Protection Math Variable Metering

Use the **MET PMV** command to display all 64 PMV values, as shown in *Figure 7.8*.

```
=>>MET PMV <Enter>

Relay 1                                     Date: 04/07/2008  Time: 21:03:40.451
Station A                                   Serial Number: 2008030645

Protection Analog Quantities
  PMV01 =      0.000        PMV02 =      0.000        PMV03 =      0.000
  PMV04 =      0.000        PMV05 =      0.000        PMV06 =      0.000
  PMV07 =      0.000        PMV08 =      0.000        PMV09 =      0.000
  PMV10 =      0.000        PMV11 =      0.000        PMV12 =      0.000
  PMV13 =      0.000        PMV14 =      0.000        PMV15 =      0.000
  PMV16 =      0.000        PMV17 =      0.000        PMV18 =      0.000
  PMV19 =      0.000        PMV20 =      0.000        PMV21 =      0.000
  PMV22 =      0.000        PMV23 =      0.000        PMV24 =      0.000
  PMV25 =      0.000        PMV26 =      0.000        PMV27 =      0.000
  PMV28 =      0.000        PMV29 =      0.000        PMV30 =      0.000
  PMV31 =      0.000        PMV32 =      0.000        PMV33 =      0.000
  PMV34 =      0.000        PMV35 =      0.000        PMV36 =      0.000
  PMV37 =      0.000        PMV38 =      0.000        PMV39 =      0.000
  PMV40 =      0.000        PMV41 =      0.000        PMV42 =      0.000
  PMV43 =      0.000        PMV44 =      0.000        PMV45 =      0.000
  PMV46 =      0.000        PMV47 =      0.000        PMV48 =      0.000
  PMV49 =      0.000        PMV50 =      0.000        PMV51 =      0.000
  PMV52 =      0.000        PMV53 =      0.000        PMV54 =      0.000
  PMV55 =      0.000        PMV56 =      0.000        PMV57 =      0.000
  PMV58 =      0.000        PMV59 =      0.000        PMV60 =      0.000
  PMV61 =      0.000        PMV62 =      0.000        PMV63 =      0.000
  PMV64 =      0.000
=>>
```

Figure 7.8 PMV Report

Automation Math Variable Metering

Use the **MET AMV** command to display all 256 AMV values, as shown in *Figure 7.9*.

```
=>>MET AMV <Enter>

Relay 1                                    Date: 04/07/2008  Time: 21:04:33.579
Station A                                  Serial Number: 2008030645

Automation Analog Quantities
 AMV001 =      0.000       AMV002 =      0.000       AMV003 =      0.000
 AMV004 =      0.000       AMV005 =      0.000       AMV006 =      0.000
 AMV007 =      0.000       AMV008 =      0.000       AMV009 =      0.000
 AMV010 =      0.000       AMV011 =      0.000       AMV012 =      0.000

 AMV013 =      0.000       AMV014 =      0.000       AMV015 =      0.000
 .
 .
 .

 AMV238 =      0.000       AMV239 =      0.000       AMV240 =      0.000
 AMV241 =      0.000       AMV242 =      0.000       AMV243 =      0.000
 AMV244 =      0.000       AMV245 =      0.000       AMV246 =      0.000
 AMV247 =      0.000       AMV248 =      0.000       AMV249 =      0.000

 AMV250 =      0.000       AMV251 =      0.000       AMV252 =      0.000
 AMV253 =      0.000       AMV254 =      0.000       AMV255 =      0.000
 AMV256 =      0.000
=>>
```

Figure 7.9 AMV Report

MIRRORED BITS Remote Analog Metering

Use the **MET ANA** command to display the analog values used with MIRRORED BITS communications, as shown in *Table 7.5*.

Table 7.5 Information Available With the MET ANA Command

Command	Information
MET ANA	Analog value in channel A Analog value in channel B

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SECTION 8

Monitoring

The relay provides extensive capabilities for monitoring substation components. Most SEL-400 series relays provide the following useful features:

- *Circuit Breaker Monitor on page 8.1*
- *Station DC Battery System Monitor on page 8.21*

This section describes monitoring capabilities that are common to many SEL-400 series relays. Some relays include additional monitoring capabilities that are not common to other SEL-400 series relays. See the relay-specific instruction manuals to determine the specific monitoring features available in each relay.

Circuit Breaker Monitor

The relay features advanced circuit breaker monitoring. *Figure 8.1* shows that the relay processes phase currents, circuit breaker auxiliary contacts, and the substation dc battery voltages to detect out-of-tolerance and maximum life circuit breaker parameters. These parameters include current interrupted, operating times, and contact wear. By using relay monitoring, maintenance personnel can determine the extent of a developing circuit breaker problem and select an appropriate response to correct the problem. These monitoring features are available online in real-time; you can detect impending problems immediately. The result is better power system reliability and improved circuit breaker life expectancy.

NOTE: This section lists settings for Circuit Breaker 1. The number of circuit breakers and the circuit breaker references vary between relays. See the product-specific instruction manual for the specific breakers available for circuit breaker monitoring.

One of the many circuit breaker monitor features is the circuit breaker contact wear monitor. The relay tracks the number of circuit breaker close-open operations and respective fault interrupting levels for each of two circuit breakers. The relay uses data from the circuit breaker manufacturer to compare the recorded operational data with the manufacturer's recommended maintenance requirements. The relay notifies you when each set of circuit breaker pole contacts exceeds preset wear thresholds. Using this information, you can operate your substation more economically by accurately scheduling circuit breaker maintenance.

You can also collect the following data on these circuit breaker parameters:

- Circuit breaker wear
- Electrical operating time
- Mechanical operating time
- Circuit breaker inactivity time
- Interrupted current
- Pole scatter (for single-pole breakers only)
- Pole discrepancy (for single-pole breakers only)
- Motor run time

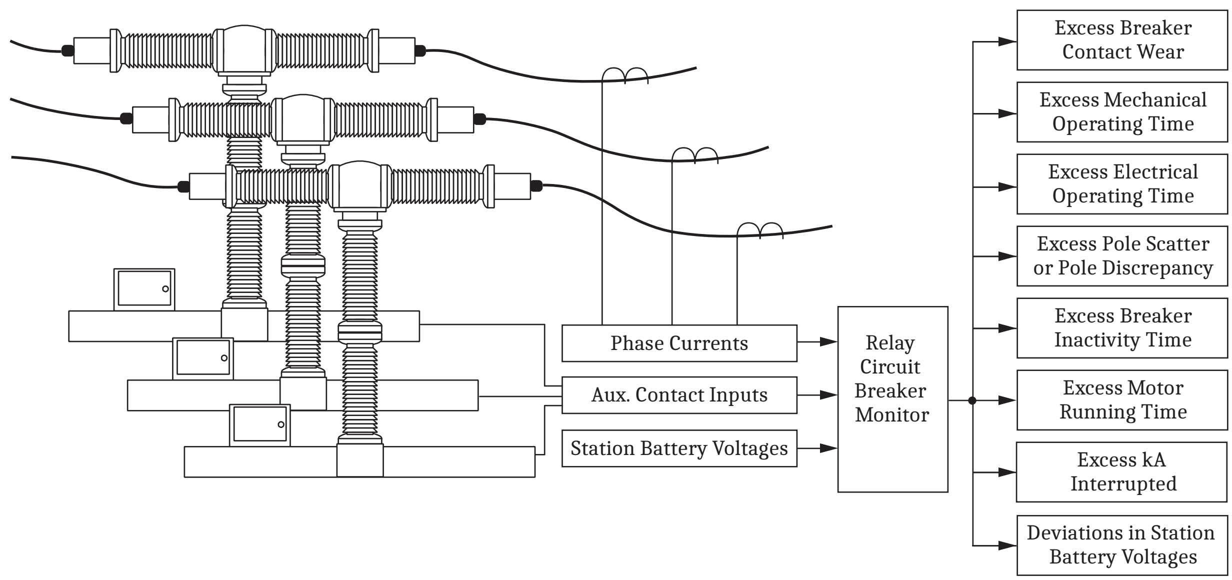

Figure 8.1 Intelligent Circuit Breaker Monitor

You can program the relay to alarm when any of the above quantities exceed a preset threshold. In addition, the relay stores a 128-event circuit breaker history in nonvolatile memory. The circuit breaker history report includes circuit breaker mechanical operation times, electrical operation times, interrupted currents, and other important parameters. The alarm and reporting features help you operate your substation safely and reliably.

Enabling the Circuit Breaker Monitor

NOTE: Some SEL-400 series relays do not support single-pole tripping breakers. In these cases, the corresponding BKnTYP setting is not available and only information related to three-pole breakers will be available.

NOTE: Some SEL-400 series relays use a BK_SEL setting to list enabled breakers, rather than the EBnMON settings shown here.

Enable and configure the relay circuit breaker monitor by using the settings listed in *Table 8.1* for each of two possible circuit breakers. Power system circuit breakers are either single-pole tripping or three-pole tripping circuit breakers; set the relay for the circuit breaker type that the relay controls. For a single-pole tripping circuit breaker, set BK1TYP := 1, and for a three-pole tripping circuit breaker, set BK1TYP := 3. The factory-default setting is BK1TYP := 1. Be sure to configure the relay with the settings that match your circuit breakers.

Table 8.1 Circuit Breaker Monitor Configuration

Name	Description	Range
EB1MON	Enable Circuit Breaker 1 monitoring	Y, N
BK1TYP	Circuit Breaker 1 type	1, 3
EB2MON	Enable Circuit Breaker 2 monitoring	Y, N
BK2TYP	Circuit Breaker 2 type	1, 3

Circuit Breaker Contact Wear Monitor

The circuit breaker contact wear monitor in the relay provides information that helps you schedule circuit breaker maintenance. This monitoring function accumulates the number of close-open operations and integrates the per-phase current during each opening operation. The relay compares this information to a predefined circuit breaker maintenance curve to calculate the percent contact wear on a per-pole basis.

The circuit breaker maintenance curve also incorporates the accumulated fault current arcing time ($\Sigma I^2 t$), assuming an identical arcing time for each trip. You can obtain the one-cycle arcing time from circuit breaker manufacturer data.

The relay updates and stores the contact wear information and the number of trip operations in nonvolatile memory. You can view this information through any communications port.

Any phase wear percentage that exceeds the threshold setting B1BCWAT asserts the alarm Relay Word bit, B1BCWAL, for Circuit Breaker 1. You can use this Relay Word bit in a SELOGIC control equation to alert operations personnel, or you can control other functions such as blocking reclosing. The relay limits the maximum reported circuit breaker wear percentage to 150 percent.

NOTE: In the following discussion, three elements are specified, one for each phase: ϕ = A, B, and C.

The relay integrates currents and increments the trip counters for the contact wear monitor each time the SELOGIC control equation BM1TRPϕ asserts. Set the logic for this function from a communications port with the **SET M** ASCII command, with the ACSELERATOR QuickSet SEL-5030 software program **Breaker Monitor Settings** tree view, or by using the front-panel `SET/SHOW` menu. (See *Making Simple Settings Changes on page 3.15* for information on setting the relay by using these methods.) The default settings cause the contact wear monitor to integrate and increment each time the relay trip logic asserts.

Perform the following specific steps to use the circuit breaker contact wear monitor:

Step 1. Enable the circuit breaker monitor.

Step 2. Load the manufacturer's circuit breaker maintenance data.

Step 3. Preload any existing circuit breaker wear (if setting up the contact wear monitor on a circuit breaker with preexisting service time).

Step 4. Program the SELOGIC control equations for trip and close conditions.

Enable the Circuit Breaker Monitor

You must enable the circuit breaker monitor before you load the manufacturer's data, preload any existing circuit breaker wear, and set the trip initiate and close initiate SELOGIC control equations. Set the circuit breaker monitor enable setting EB*x*MON to Y (for Yes) for Breaker *x*.

Load Manufacturer Circuit Breaker Maintenance Data

Load the maintenance data supplied by the circuit breaker manufacturer. Circuit breaker maintenance information lists the number of permissible operating cycles (close/open operations) for a given current interruption level. *Table 8.2* shows typical circuit breaker maintenance information from an actual SF6 circuit breaker. The *Figure 8.2* log/log plot is the circuit breaker maintenance curve, produced from the *Table 8.2* data.

Table 8.2 Circuit Breaker Maintenance Information—Example (Sheet 1 of 2)

Current Interruption Level (kA)	Permissible Close/Open Operations
0.00–1.2	10000
2.00	3700
3.00	1500
5.00	400
8.00	150

Table 8.2 Circuit Breaker Maintenance Information—Example (Sheet 2 of 2)

Current Interruption Level (kA)	Permissible Close/Open Operations
10.00	85
20.00	12

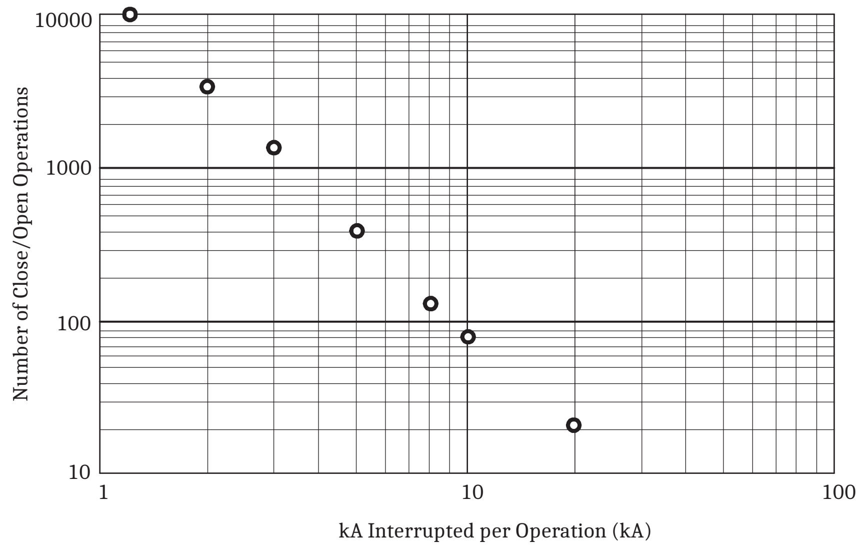

Figure 8.2 Circuit Breaker Maintenance Curve (Manufacturer's Data)

The three set points necessary to reproduce this circuit breaker maintenance curve in the relay are listed in *Table 8.3* for Circuit Breaker 1. *Figure 8.3* shows how to determine these three set points from the maintenance curve shown in *Figure 8.2*.

Table 8.3 Contact Wear Monitor Settings—Circuit Breaker 1

Setting	Definition	Range
B1COSP1	Close/open set point 1—max	0–65000 close/open operations
B1COSP2	Close/open set point 2—mid	0–65000 close/open operations
B1COSP3	Close/open set point 3—min	0–65000 close/open operations
B1KASP1[a]	kA interrupted set point 1—min	1.0–999 kA in 0.1-kA steps
B1KASP2	kA interrupted set point 2—mid	1.0–999 kA in 0.1-kA steps
B1KASP3[a]	kA interrupted set point 3—max	1.0–999 kA in 0.1-kA steps

[a] The ratio of settings B1KASP3/B1KASP1 must be in the range: 5 ≤ B1KASP3/B1KASP1 ≤ 100.

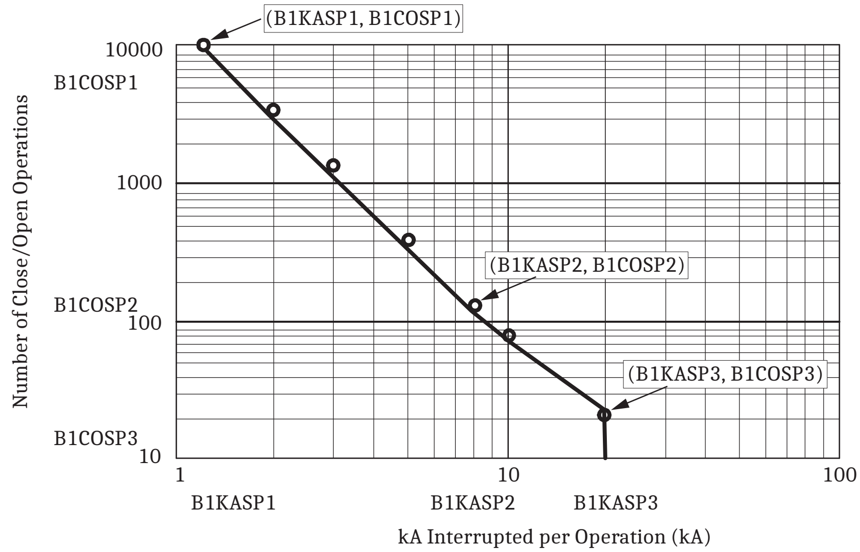

Figure 8.3 Circuit Breaker Contact Wear Curve With Relay Settings

Circuit Breaker Contact Wear Curve Details

Circuit breaker maintenance information from the two end values of *Table 8.2* or *Figure 8.2* determine set point (B1KASP1, B1COSP1) and set point (B1KASP3, B1COSP3) for the contact wear curve of *Figure 8.3*. Set point (B1KASP2, B1COSP2) is the middle maintenance point in these data. There are two philosophies for selecting the middle set point. One method places the middle set point to provide the best "curve-fit" for your plot of the manufacturer's circuit breaker maintenance data (shown in *Figure 8.2*). Another philosophy is to set the middle point based on actual experience or fault studies of the typical system faults.

Example 8.1 Creating the Circuit Breaker Contact Wear Curve

Acquire the manufacturer's maintenance information (this example uses the data of *Table 8.2* for Circuit Breaker 1). If you receive the data in tabular form, plot the manufacturer's maintenance information on log/log paper in a manner similar to *Figure 8.2*.

Choose the left and right set points from the extremes of the curve you just plotted. Select the left set point on the contact wear curve corresponding to (B1KASP1, B1COSP1) by setting B1KASP1 := 1.2 and B1COSP1 := 10000. Plot the right set point (B1KASP3, B1COSP3) by setting B1KASP3 := 20.0 and B1COSP3 := 12.

Choose the midpoint of the contact wear curve based on your experience and system fault studies. The majority of operations for a typical circuit breaker are to interrupt single-line-to-ground faults. Therefore, plot the midpoint (B1KASP2, B1COSP2) by setting B1KASP2 at or slightly greater than the expected single-line-to-ground fault current: B1KASP2 := 8.0 and B1COSP2 := 150.

There are two other notable portions of the circuit breaker contact wear curve in *Figure 8.3*. The curve is horizontal below the left set point (B1KASP1, B1COSP1). This is the close/open operation limit regardless of interrupted current value (for the *Example 8.1* circuit breaker, this is at B1COSP1 := 10000). Some manufacturers call this point the mechanical circuit breaker service life.

Another part of the circuit breaker maintenance curve falls vertically at the right set point (B1KASP3, B1COSP3). This is the maximum interrupted current limit (for the *Example 8.1* circuit breaker, this is at B1KASP3 := 20.0). If the interrupted current exceeds setting B1KASP3, the relay sets contact wear at 105 percent.

Example 8.2 I^2t Criteria Application

Some circuit breaker manufacturers do not provide a circuit breaker maintenance curve, but specify the accumulated fault current arcing time (ΣI^2t) for circuit breaker maintenance. For example, manufacturer's data specify ΣI^2t per phase at 750 kA^2 seconds for a particular circuit breaker, at a rated arcing duration for each trip of 1 cycle. The circuit breaker maximum interrupting current rating is 40 kA, and the continuous load current rating is 2 kA.

You can construct the contact wear curve for this circuit breaker from the specified ΣI^2t. Choose B1KASP1 := 2.0 (the continuous current rating) and B1KASP3 := 40.0 (the maximum interrupting current rating). Choose the middle of the contact wear curve based on experience and system fault studies. The majority of faults a typical circuit breaker interrupts are single-line-to-ground faults. Therefore, set B*n*KASP2 at or slightly greater than the expected single-line-to-ground fault current (B1KASP2 := 10.0 kA in this example). Using the following equations, calculate these settings points to obtain the number of close/open operations:

$$\text{B1COSP1} = \frac{\sum I^2 t}{(\text{B1KASP1})^2 \bullet t_{arc}} = \frac{750}{2^2 \bullet (0.01667 \bullet 1)} := 11250$$

Equation 8.1

$$\text{B1COSP2} = \frac{\sum I^2 t}{(\text{B1KASP2})^2 \bullet t_{arc}} = \frac{750}{10^2 \bullet (0.01667 \bullet 1)} := 450$$

Equation 8.2

$$\text{B1COSP3} = \frac{\sum I^2 t}{(\text{B1KASP3})^2 \bullet t_{arc}} = \frac{750}{40^2 \bullet (0.01667 \bullet 1)} := 28$$

Equation 8.3

In these equations, t_{arc} is the arcing time in seconds; $t_{arc} = (1/f_{NOM}) \bullet$ (arc duration in cycles); f_{NOM} is the nominal power system frequency (50 Hz or 60 Hz). These calculations show the number of close/open operations rounded to the nearest unit.

Preloading Contact Wear Data

Upon the first commissioning of the relay, the associated circuit breakers can already have some wear. You can preload a separate amount of wear for each pole of each circuit to preload existing contact wear data. The relay accepts integer values of percentage wear as great as 100 percent. The relay adds the incremental contact wear at the next circuit breaker monitor initiation (and at all subsequent initiations) to the preloaded value to obtain a total wear value. The limit for reporting circuit breaker contact wear is 150 percent for each pole.

Program the SELOGIC Control Equations for Trip and Close Conditions

Circuit Breaker Monitor Trip Initiation Settings: BM1TRPϕ

NOTE: In the following discussion, three elements are specified. There is one element for each phase: ϕ = A, B, and C. With three-pole breakers, only phase A is used to represent the entire breaker. Some three-pole relays include A in the names and others disregard it.

The relay employs SELOGIC control equations to initiate the circuit breaker monitor. For Circuit Breaker 1, this setting is BM1TRPϕ. These SELOGIC control equations use Relay Word bits to determine when the circuit breaker monitor accumulates circuit breaker operating parameters from phases A, B, and C. When detecting a rising edge (a transition from logical 0 to logical 1) of the initiation settings, the relay accumulates the interrupted rms currents and advances the trip counter by one count. There are separate current accumulators and trip counters for each circuit breaker pole. *Table 8.4* shows the factory-default settings for circuit breaker monitor initiation.

NOTE: Factory defaults differ for single-pole tripping and three-pole tripping. Three-pole tripping uses the single setting BM1TRPA for all three poles.

Table 8.4 Circuit Breaker Monitor Initiate SELOGIC Control Equations

Name	Description	Comment[a]
BM1TRPA	BK1 monitor initiate equation	If BK1TYP := 3
BM1TRPA	A-Phase BK1 monitor initiate equation	If BK1TYP := 1
BM1TRPB	B-Phase BK1 monitor initiate equation	If BK1TYP := 1
BM1TRPC	C-Phase BK1 monitor initiate equation	If BK1TYP := 1

[a] See Table 8.1.

Initiation settings can include both internal and external tripping conditions. To capture trip information initiated by devices other than the relay, you must program the SELOGIC control equation BM1TRPϕ to sense these trips.

Example 8.3 Circuit Breaker Monitor External Trip Initiation

Connect external trip signals to the relay control inputs. This example uses input IN201; you can use any control inputs that are appropriate for your installation. Control Input IN201, an optoisolated input, is located on the relay I/O Interface Board #1.

If you want Circuit Breaker Monitor 1 to initiate for the trip elements TPA1, TPB1, and TPC1, or for external trips, set these SELOGIC control equations from the **SET M** ASCII command or the QuickSet **Breaker Monitor Settings** tree view:

BK1TYP := **1** Breaker 1 Trip Type (Single Pole = 1, Three Pole = 3)

BM1TRPA := **TPA1 OR IN201** Breaker Monitor A-Phase Trip Initiate—BK1

BM1TRPB := **TPB1 OR IN202** Breaker Monitor B-Phase Trip Initiate—BK1

BM1TRPC := **TPC1 OR IN203** Breaker Monitor C-Phase Trip Initiate—BK1

Example 8.4 Using a Control Input to Capture External and Internal Trip Commands

You can also capture all trip information for circuit breaker trips by using a relay control input to monitor the trip bus for the given circuit breaker. *Figure 8.4* shows an illustration of this method in which IN206 connects to the Circuit Breaker 1 A-Phase trip bus (via a parallel connection across the trip bus), and asserts for any trip from any source. This example uses inputs IN206; you can use any control inputs that are appropriate for your installation. Vdc for this example is 125 Vdc.

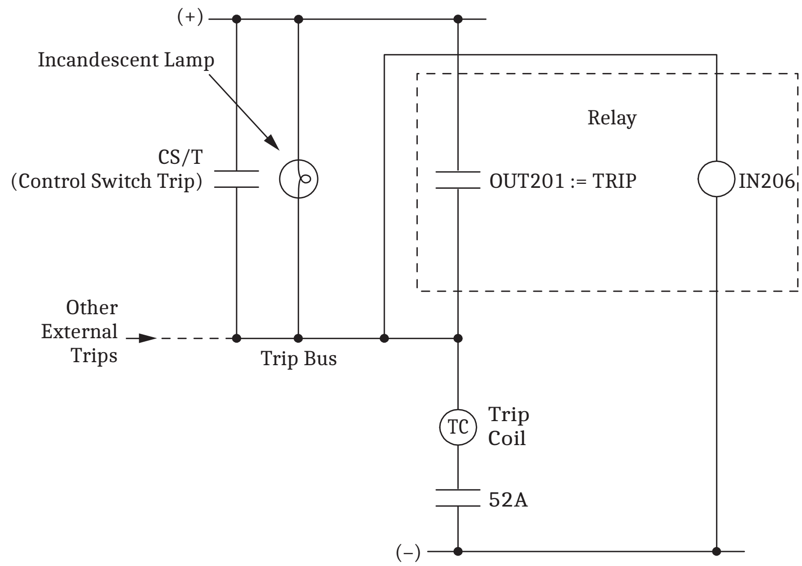

Figure 8.4 Trip Bus Sensing With Relay Input IN206

Many U.S. substation trip bus configurations have an incandescent trip indicator lamp from the battery + terminal to the trip bus. This lamp presents an impedance that can provide sufficient "pull-up" on the trip bus to falsely assert the control input. The worst case for this condition occurs when the circuit breaker is open (auxiliary circuit breaker (52A) contact in *Figure 8.4* is open). You can change the input debounce time IN206PU for slow or noisy mechanical switches; the default debounce time of 1/8 cycle should be sufficient for most trip bus arrangements.

Use the **SET G** (GLOBAL) command or the QuickSet **Global > Control Inputs Settings** tree view to confirm that the debounce time (settings IN206PU and IN206DO) are correct for your trip bus control voltage. You must enable independent control input conditioning by using Global setting EICIS. Enter these settings:

EICIS := **Y** Independent Control Input Settings (Y, N)

IN206PU := **0.1250** Input IN206 Pickup Delay (0.0000–5 cyc)

IN206DO := **0.1250** Input IN206 Dropout Delay (0.0000–5 cyc)

BM1TRPA := **IN206** Breaker Monitor Trip—BK1 (SELOGIC Equation)

Use this procedure to cause the circuit breaker monitor to initiate for either external or internal Circuit Breaker 1 A-Phase trips.

Circuit Breaker Monitor Close Initiation Settings: BM1CLSϕ

NOTE: In the following discussion, three elements are specified. There is one element for each phase: ϕ = A, B, and C. With three-pole breakers, only phase A is used to represent the entire breaker. Some three-pole relays include A in the names and others drop it.

The relay employs SELOGIC control equations to initiate the circuit breaker monitor duration timers for close functions. For Circuit Breaker 1, this setting is BM1CLSϕ. These SELOGIC control equations use Relay Word bits to determine when the circuit breaker monitor times mechanical closing, electrical closing, and pole scatter. *Table 8.5* shows the factory-default settings for circuit breaker monitor close initiation.

Table 8.5 Circuit Breaker Monitor Close SELOGIC Control Equations

Name	Description	Comment[a]
BM1CLSA	Breaker Monitor 1 close equation	If BK1TYP := 3
BM1CLSA	Breaker Monitor 1 A-Phase close equation	If BK1TYP := 1
BM1CLSB	Breaker Monitor 1 B-Phase close equation	If BK1TYP := 1
BM1CLSC	Breaker Monitor 1 C-Phase close equation	If BK1TYP := 1

[a] See Table 8.1.

As in *Example 8.4* (connection of the trip bus to a control input), you can also capture the circuit breaker close information by using a relay input to monitor the close bus for the given circuit breaker.

Other Circuit Breaker Monitor Functions

kA Interrupt Monitoring

The relay monitors the amount of phase current that each pole of the circuit breaker interrupts at each trip operation. The relay records the interrupted current as a percentage of the circuit breaker maximum interrupting rating specified by the manufacturer. Set the maximum interruption current with setting B1MKAI (Maximum kA Interrupt Rating—BK1). If the percent of current interrupt that the relay records exceeds threshold setting B1KAIAT (kA Interrupt Capacity Alarm Threshold—BK1), the relay asserts breaker monitor alarm Relay Word bit B1KAIAL.

Mechanical Operating Time

The mechanical operating time is the time between trip initiation or close initiation and the associated phase circuit breaker 52A normally open contact status change. (Assertion of 52Aϕ1 indicates that a particular circuit breaker phase has closed). The relay measures the tripping times for each phase from the assertion of the respective BM1TRPϕ Relay Word bit to the dropout of the respective 52Aϕ1 Relay Word bit. Similarly, for mechanical closing time, the relay measures the closing times for each phase from the assertion of the BM1CLSϕ Relay Word bit to the pickup of the 52Aϕ1 Relay Word bit. The relay compares these tripping or closing times to the mechanical slow operation time thresholds for tripping and closing, B1MSTRT and B1MSCLT, respectively. The relay issues a mechanical slow operation alarm, B1MSOAL, for 5 seconds when trip or close times exceed these thresholds. See *Figure 8.5* for a Circuit Breaker 1 A-Phase timing diagram.

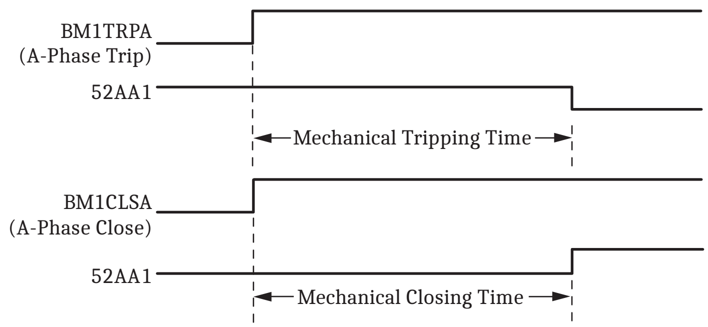

Figure 8.5 Mechanical Operating Time for Circuit Breaker 1 A-Phase

Example 8.5 Mechanical Operating Time Settings

Use Circuit Breaker 1, a single-pole tripping circuit breaker, for this example. Connect the circuit breaker normally open 52A contacts through station battery power to IN201, IN202, and IN203. This example uses inputs IN201, IN202, and IN203 for A-, B-, and C-Phases, respectively; you can use any control inputs that are appropriate for your installation. The control voltage for this example is 125 Vdc.

Control Inputs IN201–IN203 are direct-coupled inputs.

Set the Relay Word bits to respond to these inputs.

52AA1 := **IN201** A-Phase N/O Control Input—BK1 (SELOGIC Equation)

52AB1 := **IN202** B-Phase N/O Control Input—BK1 (SELOGIC Equation)

52AC1 := **IN203** A-Phase N/O Control Input—BK1 (SELOGIC Equation)

Connect external trip signals to IN301, IN302, and IN303, and external close signals to IN304, IN305, and IN306 for the A-, B-, and C-Phases, respectively. Use the default settings for input conditioning (debounce time and assertion level), as with inputs IN201 to IN203 above.

Set the mechanical operating time threshold for the slow trip alarm (B1MSTRT) to 30 ms, and the slow close alarm threshold (B1MSCLT) to 70 ms. Use your company standard practices to determine these settings for your application. For this example, enter the following settings:

B1MSTRT := **30** Mechanical Slow Trip Alarm Threshold—BK1 (1–999 ms)

B1MSCLT := **70** Mechanical Slow Close Alarm Threshold—BK1 (1–999 ms)

EB1MON := **Y** Breaker 1 Monitoring (Y, N)

BK1TYP := **1** Breaker 1 Trip Type (Single Pole = 1, Three Pole = 3)

BM1TRPA := **TPA1 OR IN301** Breaker Monitor A-Phase Trip—BK1 (SELOGIC Equation)

BM1TRPB := **TPB1 OR IN302** Breaker Monitor B-Phase Trip—BK1 (SELOGIC Equation)

BM1TRPC := **TPC1 OR IN303** Breaker Monitor C-Phase Trip—BK1 (SELOGIC Equation)

Example 8.5 Mechanical Operating Time Settings (Continued)

BM1CLSA := **BK1CL OR IN304** Breaker Monitor A-Phase Close—BK1 (SELOGIC Equation)

BM1CLSB := **BK1CL OR IN305** Breaker Monitor B-Phase Close—BK1 (SELOGIC Equation)

BM1CLSC **:= BK1CL OR IN306** Breaker Monitor C-Phase Close—BK1 (SELOGIC Equation)

Assertion of the Relay Word bit B1MSOAL indicates any one of the following four conditions:

- The mechanical operating time for a trip operation exceeds 30 ms (the slow trip alarm setting)
- The mechanical operating time for a close operation exceeds 70 ms (the slow close setting)
- No 52Aϕ1 status change occurred during the time B1MSTRT plus approximately 100 ms after trip initiation (a trip time-out condition)
- No 52Aϕ1 status change occurred during the time B1MSCLT plus approximately 100 ms after close initiation (a close time-out condition)

The relay makes a further check on the auxiliary circuit breaker (52A) contacts by testing whether these circuit breaker contacts have changed state within approximately 100 ms after the end of the trip or close threshold times. Thus, this additional check serves as the trip time-out and close time-out condition. This check verifies that the circuit breaker actually closed or opened, and it alerts you if maintenance is required on the circuit breaker mechanical linkages or auxiliary (52) contacts.

Electrical Operating Time

The electrical operating time is the time between trip or close initiation and an open-phase status change. For both circuit breakers, the relay measures the tripping time for each phase from the assertion of the BM1TRPϕ Relay Word bit to the time the relay detects an open-phase condition. Similarly, the relay measures electrical operating time for closing each phase from the assertion of BM1CLSϕ to the restoration of phase quantities. The relay compares these tripping or closing times to the electrical slow operation time thresholds for tripping and closing, B1ESTRT and B1ESCLT, respectively. The relay issues an electrical slow operation alarm, B1ESOAL, for 5 seconds when trip or close times exceed these thresholds. *Figure 8.6* shows the timing diagram for the A-Phase pole of Circuit Breaker 1.

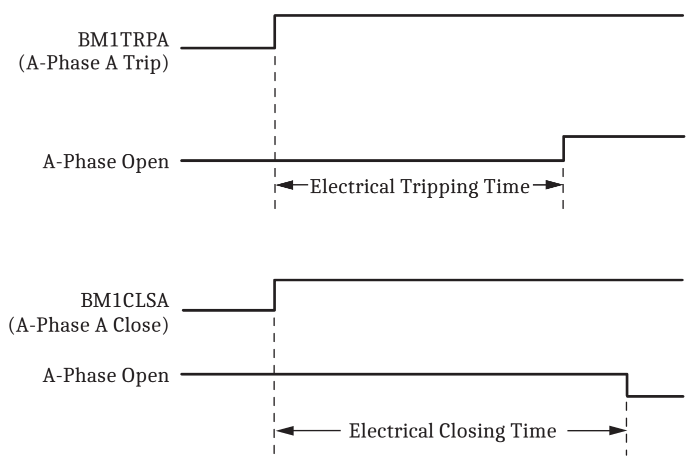

Figure 8.6 Electrical Operating Time for Circuit Breaker 1 A-Phase

Primary load/fault current can indicate contact closing, contact opening, and arc extinction, depending upon the actual circuit breaker monitor setup. You can detect problems within the circuit breaker arcing chamber by timing the interval from trip/close initiation to electric arc extinction.

Example 8.6 Electrical Operating Time Settings

Use Circuit Breaker 1, a single-pole tripping circuit breaker, for this example. Connect external trip signals to IN201, IN202, and IN203, and external close signals to IN204, IN205, and IN206 for the A-, B-, and C-Phases, respectively. This example uses control inputs IN201–IN206; you can use any control inputs that are appropriate for your installation. The control voltage for this example is 125 Vdc.

Control Inputs IN201–IN206 are located on the relay I/O Interface board #1.

Set the electrical operating time threshold for the slow trip alarm (B1ESTRT) at 25 ms, and the slow close alarm threshold (B1ESCLT) at 65 ms. Use your company standard practices to determine these settings for your application. For this example, enter the following settings.

B1ESTRT := **25** Electrical Slow Trip Alarm Threshold—BK1 (1–999 ms)

B1ESCLT := **65** Electrical Slow Close Alarm Threshold—BK1 (1–999 ms)

EB1MON := **Y** Breaker 1 Monitoring (Y, N)

BK1TYP := **1** Breaker 1 Trip Type (Single Pole = 1, Three Pole = 3)

BM1TRPA := **TPA1 OR IN201** Breaker Monitor A-Phase Trip—BK1 (SELogic Equation)

BM1TRPB := **TPB1 OR IN202** Breaker Monitor B-Phase Trip—BK1 (SELogic Equation)

BM1TRPC := **TPC1 OR IN203** Breaker Monitor C-Phase Trip—BK1 (SELogic Equation)

BM1CLSA := **BK1CL OR IN204** Breaker Monitor A-Phase Close—BK1 (SELogic Equation)

Example 8.6 Electrical Operating Time Settings (Continued)

BM1CLSB := **BK1CL OR IN205** Breaker Monitor B-Phase Close—BK1 (SELOGIC Equation)

BM1CLSC := **BK1CL OR IN206** Breaker Monitor C-Phase Close—BK1 (SELOGIC Equation)

Assertion of the Relay Word bit B1ESOAL indicates any one of the following four conditions:

- The electrical operating time for a trip operation exceeds 25 ms (the slow trip alarm setting)
- The electrical operating time for a close operation exceeds 65 ms (the slow close setting)
- No pole-open logic status change occurred during the time B1ESTRT plus approximately 100 ms after trip initiation (a trip time-out condition)
- No pole-open logic status change occurred during the time B1ESCLT plus approximately 100 ms after close initiation (a close time-out condition)

The relay further checks the circuit breaker by testing whether the circuit breaker has interrupted or restored current within 100 ms after the end of the trip or close threshold times. Thus, this additional check serves as the trip time-out and close time-out condition. This verifies that the circuit breaker actually closed or opened, and alerts you if maintenance is required on circuit breaker mechanical linkages.

Pole Scatter

The relay records and compares the operation time of each circuit breaker pole to detect time deviations between pairs of circuit breaker poles when tripping and closing all three poles simultaneously on single-pole-capable circuit breakers. The relay measures the differences in operating times resulting from auxiliary circuit breaker (52A) contact status changes. The logic compares the operation time of each individual circuit breaker pole against the time for each of the other poles. The relay triggers an alarm, B1PSAL, for any time deviation greater than the preset time threshold settings B1PSTRT and B1PSCLT for Circuit Breaker 1.

NOTE: Pole scatter applies only to single-pole mechanism circuit breakers (BK1TYP := 1). These circuit breakers have an auxiliary circuit breaker (52A) contact for each phase.

Figure 8.7 shows the operating time for each pole (A, B, and C) of Circuit Breaker 1. TAB represents the operating time deviation between poles A and B. TBC is the time between B and C, and TCA is the time between C and A. Once activated, the pole scatter alarm remains asserted for five seconds.

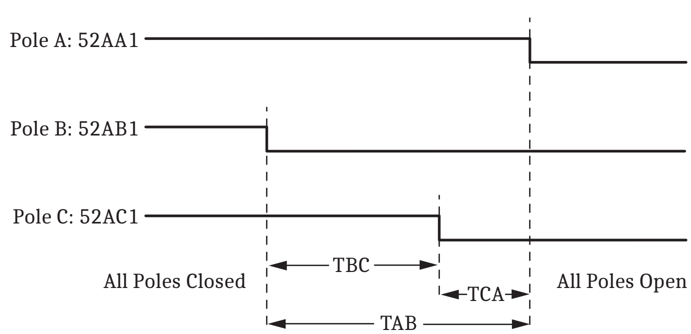

Figure 8.7 Timing Illustration for Pole Scatter at Trip

Example 8.7 Pole Scatter Settings

Use Circuit Breaker 1, a single-pole tripping circuit breaker, for this example. This example uses control inputs IN301, IN302, and IN303 for the A-, B-, and C-Phases, respectively; you can use any control inputs that are appropriate for your installation.

The control voltage for this example is 125 Vdc. Control Inputs IN301–IN303 are located on I/O Board #3. Connect the circuit breaker normally open auxiliary circuit breaker (52A) contacts through station battery power to IN301, IN302, and IN303.

Set the relay to respond to these inputs by using the QuickSet **Breaker Monitor (SET M)** settings:

52AA1 := **IN301** A-Phase Normally Open Control Input—BK1 (SELOGIC Equation)

52AB1 := **IN302** B-Phase Normally Open Control Input—BK1 (SELOGIC Equation)

52AC1 := **IN303** C-Phase Normally Open Control Input—BK1 (SELOGIC Equation)

Connect external trip signals to IN201, IN202, and IN203, and external close signals to IN204, IN205, and IN206 for the A-, B-, and C-Phases, respectively. This example uses control inputs IN201–IN206; you can use any control inputs that are appropriate for your installation.

Set the pole scatter trip alarm time threshold (B1PSTRT) at 4 ms, the pole scatter close alarm time threshold (B1PSCLT) at 6 ms, and the pole discrepancy time delay (B1PDD) at 1400 ms. Use your company standard practices to determine these settings for your application. For this example, enter the following settings:

B1PSTRT := **4** Pole Scatter Trip Alarm Threshold—BK1 (1–999 ms)

B1PSCLT := **6** Pole Scatter Close Alarm Threshold—BK1 (1–999 ms)

B1PDD := **1400** Pole Discrepancy Time Delay—BK1 (1–9999 ms)

EB1MON := **Y** Breaker 1 Monitoring (Y, N)

BK1TYP := **1** Breaker 1 Trip Type (Single Pole = 1, Three Pole = 3)

BM1TRPA := **TPA1 OR IN201** Breaker Monitor A-Phase Trip—BK1 (SELOGIC Equation)

BM1TRPB := **TPB1 OR IN202** Breaker Monitor B-Phase Trip—BK1 (SELOGIC Equation)

BM1TRPC := **TPC1 OR IN203** Breaker Monitor C-Phase Trip—BK1 (SELOGIC Equation)

BM1CLSA := **BK1CL OR IN204** Breaker Monitor A-Phase Close—BK1 (SELOGIC Equation)

BM1CLSB := **BK1CL OR IN205** Breaker Monitor B-Phase Close—BK1 (SELOGIC Equation)

BM1CLSC := **BK1CL OR IN206** Breaker Monitor C-Phase Close—BK1 (SELOGIC Equation)

Example 8.7 Pole Scatter Settings (Continued)

If any of the pole-open times (TAB, TBC, and TCA in *Figure 8.7*) exceed 4 ms, or if any of the pole close times exceed 6 ms, the relay asserts the Relay Word bit B1PSAL. Assertion of B1PSAL indicates any one of the following four conditions:

- ➤ The pole scatter time for trip operation exceeds the alarm setting time (4 ms)
- ➤ The pole scatter time for close operation exceeds the alarm setting time (6 ms)
- ➤ One phase auxiliary circuit breaker (52A) contact status change exceeds B1PSTRT plus approximately 5 ms after the trip initiation
- ➤ One phase auxiliary circuit breaker (52A) contact status change exceeds B1PSCLT plus approximately 5 ms after the close initiation

Note that the relay provides a time out of approximately 200 ms after the trip or 300 ms after the close threshold to end detection of pole scatter alarms.

Pole Discrepancy

The relay continuously monitors the status of each circuit breaker pole to detect open or close deviations among the three poles. In addition, at tripping and closing, the relay measures the differences in operating times during the auxiliary circuit breaker (52A) contact status changes or open-phase logic operation. The relay triggers an alarm Relay Word bit, B1PDAL, if the status of any pole compared to another pole exceeds the time window setting B1PDD for the circuit breaker.

NOTE: Pole discrepancy applies only to single-pole mechanism circuit breakers (BK1TYP := 1). These circuit breakers have an auxiliary circuit breaker (52A) contact output for each phase.

You can set the relay to use the current flowing through the circuit breaker to supervise pole discrepancy timing of the auxiliary circuit breaker (52A) contacts. Enable this supervision by setting E1PDCS to Y for Circuit Breaker 1.

Pole discrepancy setting B1PDD should be longer than the single-pole reclosing dead time.

$$\text{B1PDD} := (\text{SPOID} + \text{circuit breaker pole operating time} + \text{contact latency}) \bullet 1.2$$

Equation 8.4

where:

SPOID is the single-pole open interval time and the factor 1.2 is a safety factor.

Round this time to the next higher hundreds of milliseconds value to give the pole discrepancy setting.

Figure 8.8 shows a Circuit Breaker 1 operation where Pole B closes first, followed by Pole C; Pole A closes slowly. If the time from a change in 52AB1 to the change in 52AA1 exceeds the pole discrepancy time threshold setting B1PDD, then the relay asserts the B1PDAL alarm. Once activated, the relay asserts the pole discrepancy alarm for five seconds.

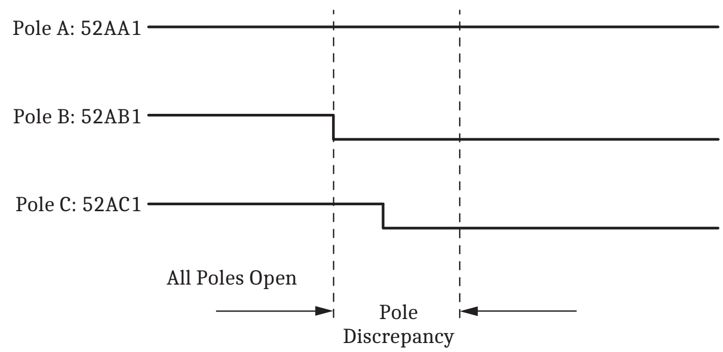

Figure 8.8 Pole Discrepancy Measurement

Example 8.8 Pole Discrepancy Alarm for Circuit Breaker 1—No Other Circuit Breaker Monitor Functions

Use Circuit Breaker 1, a single-pole tripping circuit breaker, for this example. This example uses control inputs IN301, IN302, and IN303 for the A-, B-, and C-Phases, respectively; you can use any control inputs that are appropriate for your installation.

The control voltage for this example is 125 Vdc. Control Inputs IN301–IN303 are located on I/O Board #2. Connect the circuit breaker normally open auxiliary circuit breaker (52A) contacts through station battery power to IN301, IN302, and IN303.

Set the relay internal Relay Word bits to respond to these inputs by using the QuickSet **Breaker Monitor (SET M)** settings:

52AA1 := **IN301** A-Phase Normally Open Control Input—BK1 (SELOGIC Equation)

52AB1 := **IN302** B-Phase Normally Open Control Input—BK1 (SELOGIC Equation)

52AC1 := **IN303** C-Phase Normally Open Control Input—BK1 (SELOGIC Equation)

Connect external trip signals to IN301, IN302, and IN303, and external close signals to IN304, IN305, and IN306 for the A-, B-, and C-Phases, respectively. This example uses control inputs IN301–IN306; you can use any control inputs that are appropriate for your installation.

Set the pole discrepancy time delay (B1PDD) at 1400 ms. This time delay assumes a dead time of 1000 ms plus a pole closing time of 100 ms (including contact latency), plus 20 percent (for security), rounded to the next higher hundreds of milliseconds value. This pole discrepancy time is longer than the single-pole open interval time default of 900 ms; confirm that this is the case for your application settings.

Enter the following settings:

B1PDD := **1400** Pole Discrepancy Time Delay—BK1 (1–9999 ms)

EB1MON := **Y** Breaker 1 Monitoring (Y, N)

BK1TYP := **1** Breaker 1 Trip Type (Single Pole = 1, Three Pole = 3)

The pole discrepancy timing window is B1PDD := 1400 (ms). Assertion of the Relay Word bit B1PDAL indicates that the status of the three Circuit Breaker 1 poles disagrees for 1400 ms or longer.

Circuit Breaker Inactivity Time Elapsed

The relay circuit breaker inactivity time monitor detects the elapsed time (measured in days) since the last trip or close operation of a circuit breaker. Use setting B1ITAT to set the circuit breaker inactivity time. An alarm Relay Word bit, B1BITAL, asserts if the elapsed time exceeds a predefined setting. This alarm is useful to detect circuit breakers that are not operated on a regular basis. These circuit breakers can fail to operate when needed to perform a protection trip. If a breaker operation occurs after the alarm asserts, the alarm resets at time 00:00:00.000.

Example 8.9 Inactivity Time Settings

Use Circuit Breaker 1 for this example. To assert an alarm if Circuit Breaker 1 has not operated within the last 365 days, enter the following settings:

EB1MON := **Y** Breaker 1 Monitoring (Y, N)

B1ITAT := **365** Inactivity Time Alarm Threshold—BK1 (N, 1–9999 days)

Assertion of the Relay Word bit B1BITAL indicates that it has been more than 365 days since the last Circuit Breaker 1 operation.

When testing the inactivity timer, you must measure actual relay clock transitions across time 00:00:00.000 (to increment the day counter). If you set the relay to a specific date, enable the circuit breaker monitor (EB1MON := Y), then advance the date setting to a new date, the inactivity timer shows only one day of elapsed time.

Motor Running Time

The relay circuit breaker monitor measures circuit breaker motor running time. Depending on your circuit breaker, you can use the motor running time to monitor the charge time of the circuit breaker springs or the running time of the compressed air motor. An alarm asserts if the elapsed motor running time exceeds the predefined threshold setting B1MRTAT.

Setting B1MRTIN is a SELOGIC control equation to activate the motor running timer. The rising edge of B1MRTIN indicates the motor starting time; a falling edge indicates the motor stop time. The motor running time logic asserts the alarm Relay Word bit, B1MRTAL, for 5 seconds when the motor running time exceeds the predefined threshold. Setting B1MRTIN to logical 0 disables the motor running time feature of the circuit breaker monitor.

Example 8.10 Motor Running Time Settings

Use Circuit Breaker 1 for this example.

Connect the motor control contact to IN207. This example uses control input IN207; you can use any control inputs that are appropriate for your installation.

To determine the motor run time value, take the circuit breaker out of service by using your company standard circuit breaker maintenance policy. Issue a trip and close command while you measure the time that the circuit breaker motor requires for recharging the spring or reestablishing the return air pressure to normal. Add 20 percent to this time measurement to avoid false alarms. Use the resulting time value for the motor running time alarm setting B1MRTAL.

Example 8.10 Motor Running Time Settings (Continued)

The control voltage for this example is 125 Vdc. Control Input IN207 is located on the relay I/O Interface board #1.

The recharge time measurement for this circuit breaker was 20 seconds; add 20 percent (4 seconds) to give an alarm time of 24 seconds. To set the motor running time alarm threshold at 24 seconds, enter the following settings:

EB1MON := **Y** Breaker 1 Monitoring (Y, N)

B1MRTIN := **IN207** Motor Run Time Control Input—BK1 (SELOGIC Equation)

B1MRTAT := **24** Motor Run Time Alarm Threshold—BK1 (1–9999 seconds)

Assertion of the Relay Word bit B1MRTAL indicates the following condition: motor running time exceeds 24 seconds because IN207 was asserted for more than 24 seconds.

BREAKER Command

Use the **BRE** command to access vital information about the condition of substation circuit breakers and preset or reset circuit breaker monitor data. The relay monitors two separate circuit breakers; you must specify Circuit Breaker 1 and Circuit Breaker 2 for most **BRE** commands. *Table 8.6* shows the **BRE** commands. For more information on the **BRE** command, see *BREAKER on page 14.4*.

Table 8.6 BRE Command

Command	Description	Access Level
BRE C A	Clear all circuit breaker monitor data to zero.	B, P, A, O, 2
BRE *n* C[a]	Clear Circuit Breaker *n* data to zero.	B, P, A, O, 2
BRE *n*[a]	Display the breaker report for the most recent Circuit Breaker *n* operation.	1, B, P, A, O, 2
BRE *n* H[a]	Display history data for the last 128 Circuit Breaker *n* operations.	1, B, P, A, O, 2
BRE *n* P[a]	Preload previously accumulated Circuit Breaker *n* data.	B, P, A, O, 2

[a] n is the breaker reference.

The **BRE *n* C** command resets the accumulated circuit breaker monitor data for Circuit Breaker *n*. The clear command **BRE C A** clears all data for both circuit breakers.

The **BRE *n*** command displays the circuit breaker report for the most recent Circuit Breaker *n* operation.

You can also reset the circuit breaker report with Global SELOGIC setting RST_BK*n* for the Circuit Breaker *n* report. You must first set EDRSTC (Data Reset Control) to Y to access these Global settings.

The relay also displays the operation summary and the circuit breaker alarms. When the circuit breaker maintenance curve reaches 150 percent for a particular pole, the percentage wear for this pole remains at 150 percent (even if additional current is interrupted) until reset. However, the relay continues to advance the operation counter to as many as 9999999 operations per pole until reset. Accumulated circuit breaker wear/operations data are retained if the relay loses power or if the circuit breaker monitor is disabled (EB*n*MON := N).

Circuit Breaker Report

Figure 8.9 shows a sample breaker report (with typical data). The relay reports dc battery monitor voltages for the minimum dc voltage during a 20-cycle period at circuit breaker monitor trip initiation (BM1TRPϕ) and for a 30-cycle window at circuit breaker monitor close initiation (BM1CLSϕ). The circuit breaker report contains data only for options that you have enabled.

```
=>BRE 1 <Enter>

Relay 1                                   Date: 03/20/2001  Time: 17:21:42.577
Station A                                 Serial Number: 2001001234
Breaker 1
Breaker 1 Report
                                Trip A  Trip B  Trip C   Cls A   Cls B   Cls C
Avg Elect Op Time (ms)                                     5.8     7.5     8.4
Last Elect Op Time (ms)          18.2    20.0    17.9      8.4    10.4     8.4
Avg Mech Op Time (ms)
Last Mech Op Time (ms)           25.8    24.4    26.5     30.1    26.3    34.2
Inactivity Time (days)              1       1       1        1       1       1
                                     3 Pole Trip            3 Pole Close
                                   AB      BC      CA      AB      BC      CA
Max Pole Scatter (ms)             5.1     3.1     5.0     6.3     4.1     2.1
Last Pole Scatter (ms)            2.1     1.0     3.1     4.1     2.1     2.1

                              Pole A  Pole B  Pole C
Accum Pri Current (kA)       3.13657 0.43533 0.41785
Accum Contact Wear (%)           0.5     0.5     0.5
Max Interrupted Current (%)      1.6     0.2     0.2
Last Interrupted Current(%)      1.6     0.2     0.2
Number of Operations               5       5       5

                              Alarm   Total Count
Mechanical Operating Time     MSOAL       4
Electrical Operating Time     ESOAL       3
Breaker Inactivity Time       BITAL       0
Pole Scatter                   PSAL       2
Pole Discrepancy               PDAL       1
Current (kA) Interrupted      KAIAL       0
LAST BREAKER MONITOR RESET   03/15/2001   07:21:31.067

=>
```

Figure 8.9 SEL-411L Breaker Report (for the Most Recent Operation)

Breaker History

The relay displays the circuit breaker history report when you issue the **BRE *n* H** command. The report consists of as many as 128 circuit breaker monitor events stored in nonvolatile memory. These events are determined by settings BM*n*TRPϕ and BM*n*CLSϕ. The breaker history report is similar to that shown in *Figure 8.10* (shown with typical data).

NOTE: If the breaker electrical or mechanical operating time exceeds a closing or tripping setting, the relay flags the data as overflowed by appending the + symbol to the corresponding operating time.

```
=>BRE 1 H <Enter>
Breaker 1 History Report
Relay 1                                   Date: 03/15/2001  Time: 07:19:27.156
Station A                                 Serial Number: 2001001234

No.    Date         Time        Bkr.Op Op Time(ms)   Pri I   VDC1   VDC2
                                       Elect Mech     (A)    (V)    (V)
1    06/01/2000  12:24:36.216   Trp A   26  28       5460    119    118
2    06/01/2000  12:24:36.216   Trp B   26  28       5260    119    118
3    06/01/2000  12:24:36.216   Trp C   26  28       5160    119    119
4    09/26/1999  16:24:36.214   Cls A   39  35       1020    118    118
5    09/26/1999  16:24:36.214   Cls B   39  35       990     118    118
6    09/26/1999  16:24:36.214   Cls C   39  35       1010    118    118
7    03/26/1999  11:24:36.218   Cls C   39  35       1100    117    115
8    03/26/1999  11:24:31.218   Trp C   26  28       3460    116    112
128
=>
```

Figure 8.10 Breaker History Report

Preload Breaker Wear

You can preload a separate contact wear value for each pole of each circuit breaker by using the command **BRE *n* P** for Circuit Breaker *n*. The relay adds the incremental contact wear at all subsequent circuit breaker monitor initiations to your preloaded value to obtain a total wear value. You can enter integer values of percentage wear from 1 to 100 percent. In addition to preloading contact wear data, you can enter values for previous operations and accumulated currents. The maximum number of operations or accumulated primary current (in kA) you can enter is 9999999. The circuit breaker preload terminal screen is similar to *Figure 8.11* for both the terminal and QuickSet.

```
=>BRE 1 P <Enter>
Accum Contact Wear (%)           A-phase % :=  5 ? 12 <Enter>
                                 B-phase % := 10 ? 15 <Enter>
                                 C-phase % :=  7 ? 10 <Enter>
Accum Num of Operations:         A-phase := 25 ? 11 <Enter>
                                 B-phase := 25 ? 11 <Enter>
                                 C-phase := 25 ? 11 <Enter>

Accum Pri Current (kA)           Trip A := 99.0 ? 299 <Enter>
                                 Trip B := 98.0 ? 254 <Enter>
                                 Trip C := 98.0 ? 257 <Enter>
                                   Pole A      Pole B      Pole C
Accum Contact Wear (%)               12          15          10
Accum Num of Operations              11          11          11
Accum Pri Current (kA)              299         254         257
```

Figure 8.11 Circuit Breaker Preload Data

When performing circuit breaker testing, capture the **BRE *n* P** information (write the date or use a terminal screen capture) before testing. Test the circuit breaker, then enter the previously recorded preload data with the **BRE *n* P** command. Using this method, you can eliminate testing operations from actual usage data in the circuit breaker monitor.

SEL Compressed ASCII Circuit Breaker Report

You can retrieve a Compressed ASCII circuit breaker report by using the **CBR** command from any communications port.

The relay arranges items in the Compressed ASCII circuit breaker report in a special order. For the purpose of improving products and services, SEL sometimes changes the items and item order.

The information presented below explains the message and serves as a guide to the items in a Compressed ASCII configuration circuit breaker report.

The format of the Compressed ASCII **CBR** message is the following.

```
"RID","SID","FID","yyyy"
relayid,station,fidstring,"yyyy"
"BID","yyyy"
breakerid,"yyyy"
"AVG_TR_ELE","LST_TR_ELE","AVG_TR_MEC","LST_TR_MEC","LST_TRmDC1",
   "LST_TRmDC2","TR_INAC(d)","MAX_TR_SCA","LST_TR_SCA", "AVG_CL_ELE",
   "LST_CL_ELE","AVG_CL_MEC","LST_CL_MEC","LST_CLmDC1",
   "LST_CLmDC2","CL_INAC(d)","MAX_CL_SCA","LST_CL_SCA", "ACC_I(kA)",
   "ACC_WEAR(%)","MAX_INT_I(%)","LAST_INT_I(%)","NUM_OPS","yyyy"
fff,fff,fff,fff,fff,fff,iii,fff,fff,fff,fff,fff,fff,fff,fff,iii,fff,fff,
   fff,fff,fff,fff,iii,"yyyy"
fff,fff,fff,fff,fff,fff,iii,fff,fff,fff,fff,fff,fff,fff,fff,iii,fff,fff,
   fff,fff,fff,fff,iii,"yyyy"
fff,fff,fff,fff,fff,fff,iii,fff,fff,fff,fff,fff,fff,fff,fff,iii,fff,fff,
   fff,fff,fff,fff,iii,"yyyy"
"AVG_MOT_RT","LST_MOT_RT","RST_MONTH","RST_DAY","RST_YEAR","RST_HOUR","RST_MIN",
  "RST_SEC","yyyy"
iii,iii,iii,iii,iii,iii,iii,iii,"yyyy"
```

Definitions for the items and fields in the Compressed ASCII configuration are the following:

- yyyy is the checksum
- iii is an integer value
- fff is a floating-point value

The relay reports the data as A-Phase in the first line, B-Phase in the second line, and C-Phase in the third line. Pole scatter data are slightly different: TAB is in the first line, TBC is in the second line, and TCA is in the third line.

Station DC Battery System Monitor

NOTE: This section lists settings for Station DC Battery Monitor 1; settings for Station DC Battery Monitor 2 are similar; replace 1 in the setting with 2.

The relay automatically monitors station battery system health by measuring the dc voltage, ac ripple, and voltage between each battery terminal and ground. SEL-400 series relays provide either one or two dc monitor channels. See the product-specific instruction manual to see how many breaker monitor channels the relay supports. Four voltage thresholds give you the ability to create five sensing zones (low failure, low warning, normal, high warning, and high failure) for the dc voltage.

The ac ripple quantity indicates battery charger health. When configuring the ac ripple setting DC1RP, we can define the ripple content of a dc supply as the peak-to-peak ac component of the output supply waveform.

The relay also makes measurements between the battery terminal voltages and station ground to detect positive and negative dc ground faults. *Figure 8.12* shows a typical dual-battery dc system.

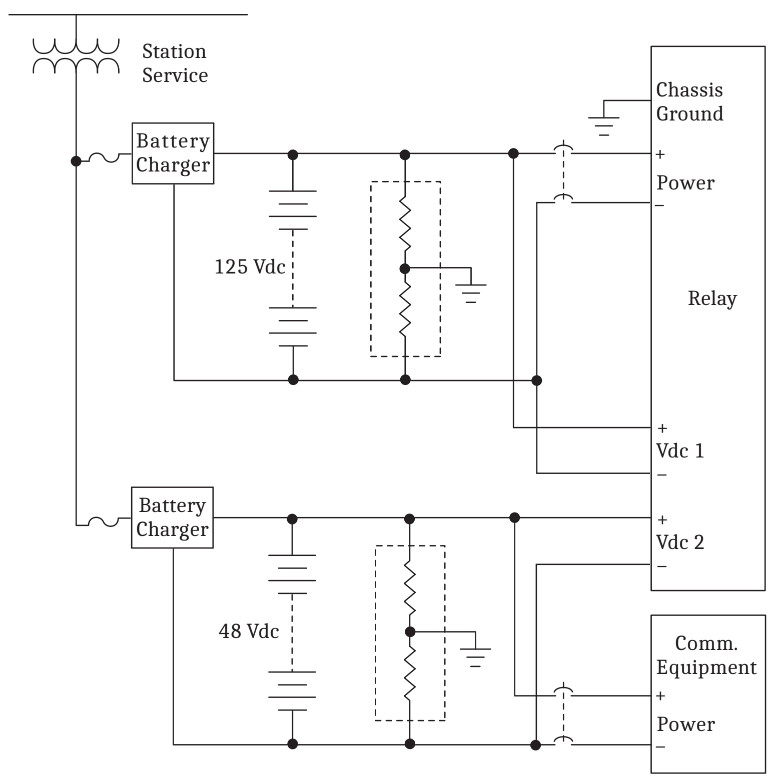

Figure 8.12 Typical Station DC Battery System

The dc battery monitor measures the station battery voltage applied at the rear-panel terminals labeled Vdc1 (+ and –) and Vdc2 (+ and –). Monitoring dc voltage during circuit breaker operation gives a quick test of the battery system, which includes wiring and junctions from the batteries to the circuit breaker. In the breaker report and in the breaker history report, the relay displays the minimum value of station battery voltage during circuit breaker operation on a per-pole basis.

NOTE: First enable Station DC Monitoring (with the Global setting EDCMON) to access station dc battery monitor settings.

Table 8.7 lists the station dc battery monitor settings and the corresponding Relay Word bits that assert when battery quantities exceed these settings thresholds. Use the **SET G** ASCII command from a terminal or use the QuickSet **Global > Station DC Monitoring** branch of the Settings tree view to access the DC Monitor settings.

Table 8.7 DC Monitor Settings and Relay Word Bit Alarms

Setting[a]	Definition	Relay Word Bit[a]
DC1LFP	Low Level Fail Pickup (OFF, 15–300 Vdc)	DC1F
DC1LWP	Low Level Warn Pickup (OFF, 15–300 Vdc)	DC1W
DC1HWP	High Level Warn Pickup (OFF, 15–300 Vdc)	DC1W
DC1HFP	High Level Fail Pickup (OFF, 15–300 Vdc)	DC1F
DC1RP	Peak-to-Peak AC Ripple Pickup (1–300 Vac)	DC1R
DC1GF	Ground Detection Factor (1.00–2.00) (advanced setting)	DC1G

[a] For DC2 Monitor Settings and Relay Word bit alarms, substitute 2 for 1 in the setting names and Relay Word bit names.

Station DC Battery System Monitor Application

In addition to providing a view of how much the station dc battery voltage dips when tripping, closing, and when other dc control functions occur, the dc monitor also alarms for under- or overvoltage dc battery conditions in five sensing regions. The following describes how to apply the dc battery monitor to a typical 125 Vdc protection battery system with a 48 Vdc communications equipment battery system. Adjust the values used here to meet the specifications of your company.

Battery Voltage

When setting the station dc battery monitor, you must determine the minimum and maximum dc levels in the battery system. In addition, you must also establish the threshold levels for different battery system states or conditions. The following voltage levels describe these battery system conditions:

- Trip/Close—the lowest dc voltage point at which circuit breaker trip and close operations occur
- Open-circuit—the dc battery voltage when all cells are fully charged and not connected to the battery charger
- Float low—the lowest charging voltage supplied by the battery charger
- Float high—the highest charging voltage supplied by the battery charger
- Equalize mode—a procedure during which the batteries are overcharged intentionally for a preselected time to bring all cells to a uniform output

Set the low end of the allowable dc battery system voltage according to the recommendations of C37.90–1989 (R1994) IEEE Standard for Relays and Relay Systems Associated with Electric Power. Section 6.4 in this standard is titled Allowable Variation from Rated Voltage for Voltage Operated Auxiliary Relays. This section calls for an 80 percent low-end voltage and 28, 56, 140, or 280 Vdc high-end voltages for the popular nominal station battery voltages. *Table 8.8* lists expected battery voltages under various conditions that use commonly accepted per-cell voltages.

Table 8.8 Example DC Battery Voltage Conditions

Condition	Calculation	Battery Voltage (Vdc)
Trip/Close	80% • 125 Vdc	100.0
Open-Circuit	60 (cells) • 2.06 (volts/cell)	123.6
Float Low	60 (cells) • 2.15 (volts/cell)	129.0
Float High	60 (cells) • 2.23 (volts/cell)	133.8
Equalize Mode	60 (cells) • 2.33 (volts/cell)	139.8
Trip/Close	80% • 48 Vdc	38.4
Open-Circuit	24 (cells) • 2.06 (volts/cell)	49.4
Float Low	24 (cells) • 2.15 (volts/cell)	51.6
Float High	24 (cells) • 2.23 (volts/cell)	53.5
Equalize Mode	24 (cells) • 2.33 (volts/cell)	55.9
Trip/Close	80% • 24 Vdc	19.2
Open-Circuit	12 (cells) • 2.06 (volts/cell)	24.7
Float Low	12 (cells) • 2.15 (volts/cell)	25.8
Float High	12 (cells) • 2.23 (volts/cell)	26.8
Equalize Mode	12 (cells) • 2.33 (volts/cell)	28.0

Use the expected battery voltages of *Table 8.9* to determine the relay station dc battery monitor threshold settings. *Table 8.9* shows these threshold settings for a nominal 125-Vdc battery system (the Vdc1 input) and a nominal 48-Vdc battery system (the Vdc2 input).

Table 8.9 Example DC Battery Monitor Settings—125 Vdc for Vdc1 and 48 Vdc for Vdc2

Setting	Description	Indication	Value (Vdc)
DC1LFP	Low-fail threshold, Mon. 1	Poor battery performance	100
DC1LWP	Low-warning threshold, Mon. 1	Charger malfunction	127
DC1HWP	High-warning threshold, Mon. 1	Equalization	137
DC1HFP	High-fail threshold, Mon. 1	Charger malfunction	142
DC2LFP	Low-fail threshold, Mon. 2	Poor battery performance	38
DC2LWP	Low-warning threshold, Mon. 2	Charger malfunction	50
DC2HWP	High-warning threshold, Mon. 2	Equalization	55
DC2HFP	High-fail threshold, Mon. 2	Charger malfunction	57

AC Ripple

Another method for determining whether the substation battery charger has failed is to monitor the amount of ac ripple on the station dc battery system. The IEEE C37.90-1989 standard also identifies an “Allowable AC Component in DC Control Voltage Supply” (Section 6.5) as an alternating component (ripple) of 5 percent peak or less. (This definition is valid if the minimum instantaneous voltage is not less than 80 percent of the rated voltage.) The relay measures ac ripple as a peak-to-peak waveform, consequently, DC1RP and DC2RP should be set at or greater than 10 percent (2 • 5% peak) of the equalizing voltage. *Table 8.10* shows the ac ripple threshold settings for this example.

Table 8.10 Example DC Battery Monitor Settings—AC Ripple Voltages

Setting	Description	Indication	Value (Vac)
DC1RP	AC ripple threshold, Mon. 1	Charger malfunction	14
DC2RP	AC ripple threshold, Mon. 2	Charger malfunction	6

DC Ground

If a battery system is centered around chassis ground, then the magnitude of the voltage measured from the positive terminal-to-ground and from the negative terminal of the battery to ground should be approximately one-half of the nominal battery system voltage. The ratio of the positive-to-ground battery voltage to the negative-to-ground battery voltage is 1 to 1, or 1.00. *Equation 8.5* is the balanced (no grounding) ratio for a 125-Vdc battery system.

$$k = \frac{Vdc1_{pos}}{Vdc1_{neg}} = \frac{62.50\ V}{62.50\ V} = 1.00$$

Equation 8.5

If either terminal is partially or completely shorted to chassis ground, then the terminal voltage will be less than the nominal terminal-to-ground voltage. This causes the ratio of positive voltage to negative voltage to differ from 1.00. *Equation 8.6* is an example of the unbalanced (grounding) ratio for a partial short circuit to ground on the negative side of a 125-Vdc battery system.

$$k = \frac{Vdc1_{pos}}{Vdc1_{neg}} = \frac{62.50\ V}{59.10\ V} = 1.06$$

Equation 8.6

The relay uses this voltage ratio to calculate a ground detection factor. *Figure 8.13* shows a graphical representation of the ground detection factor setting and battery system performance.

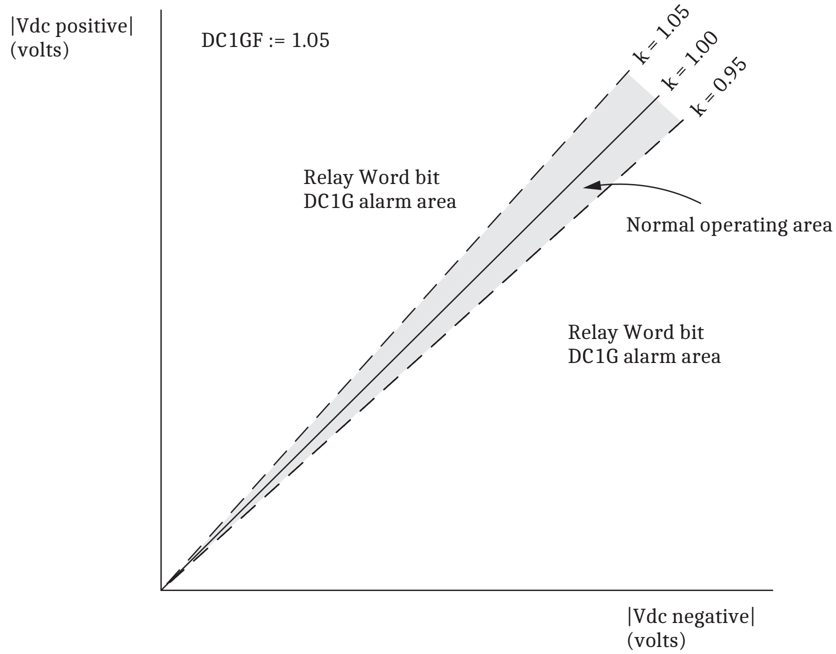

Figure 8.13 Ground Detection Factor Areas

NOTE: Only the upper ground detection factor in Figure 8.12 is entered as a setting. The relay calculates the lower factor by taking the reciprocal of the upper factor: 1/1.05 = 0.952 in this case.

If the ground detection factor ratio exceeds a setting threshold, the relay asserts the DCIG Relay Word bit. To set the ground detection factor threshold, enable the advanced Global settings (set EGADVS := Y), and set the DC1GF and the DC2GF thresholds at a value close to 1.05 (the factory-default setting) to allow for some slight battery system unbalance of around 5 percent. *Table 8.11* lists the ground detection factor threshold settings for this example.

Table 8.11 Example DC Battery Monitor Settings—Ground Detection Factor (EGADVS := Y)

Setting	Description	Indication	Value
DC1GF	Ground detection factor, Mon. 1	Battery wiring ground(s)	1.05
DC2GF	Ground detection factor, Mon. 2	Battery wiring ground(s)	1.05

DC Battery Monitor Alarm

You can use the battery monitor Relay Word bits to alert operators for out-of-tolerance conditions in the battery systems. Add the appropriate Relay Word bit to the SELOGIC control equation that drives the relay control output you have selected for alarms. For example, use the Form B contact of control output OUT214. Set the SELOGIC control equation to include the battery monitor thresholds.

OUT214 := **NOT (HALARM OR SALARM OR DC1F OR DC1W OR DC1R OR DC1G)** (Output SELOGIC Equation)

This is one method; you can implement many other methods as well.

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SECTION 9

Reporting

The relay features comprehensive power system data analysis capabilities. The relay provides these useful analysis tools:

An event is a representation of the operating conditions of the power system at a specific time. Events include instances such as a relay trip, an abnormal situation in the power system that triggers a relay element, or an event capture command.

Information from oscillograms, relay event reports, SER, and signal profiling data are very valuable if you are responsible for outage analysis, outage management, or relay settings coordination.

The relay accepts high-accuracy timing, such as IRIG-B. When a suitable external clock is used (such as the SEL-2407 Satellite-Synchronized Clock), the relay synchronizes the data acquisition system to the received signal. Knowledge of the precise time of sampling allows comparisons of data across the power system. Use a coordinated network of time-synchronized relays to create moment-in-time "snapshots" of the power system. These data are useful for determining power system dynamic voltage and current phasors, impedances, load flow, and system states.

Data Processing

SEL-400 series relays are numeric, or microprocessor-based, relays that sample power system conditions. The relay converts analog inputs received via CT and PT inputs to digital information for processing to determine relaying quantities for protection and automation. *Figure 9.1* shows a general overview of the input processing diagram for the relay. *Figure 9.2* shows a general overview of the input processing for a relay with Sampled Values (SV).

The relay outputs two types of analytical data: high-resolution raw data and filtered data. *Figure 9.1* shows the path a power system VT and CT signals take through relay input processing. A CT or PT analog input begins at hardware acquisition and sampling, continues through software filtering, and progresses to protection and automation processing. The initial hardware low-pass filter half-power or –3 dB point is 3.0 kHz. Next, the relay samples the power system voltage or current with an 8000 samples/second A/D (analog to digital) converter. This is the tap point for high-resolution raw data captures. You can select 8000 samples/second, 4000 samples/second, 2000 samples/second, and 1000 samples/

second effective sampling rates for presentation and storage of the high-resolution raw data COMTRADE format (see *Oscillography on page 9.9*). From the same 8 kHz downsampled data, a dashed lined showing SV data packet creation is provided and only occurs on SEL-400 series SV publisher devices.

Figure 9.2 shows the path a power system signal received via DSS technology takes through relay processing. The received data streams are first filtered, decoded, scaled, and resampled. The resampled data then continues through software filtering and progresses to protection and automation processing. The relay resamples incoming data to 8 kHz analog samples. This is the tap point for high-resolution raw data captures.

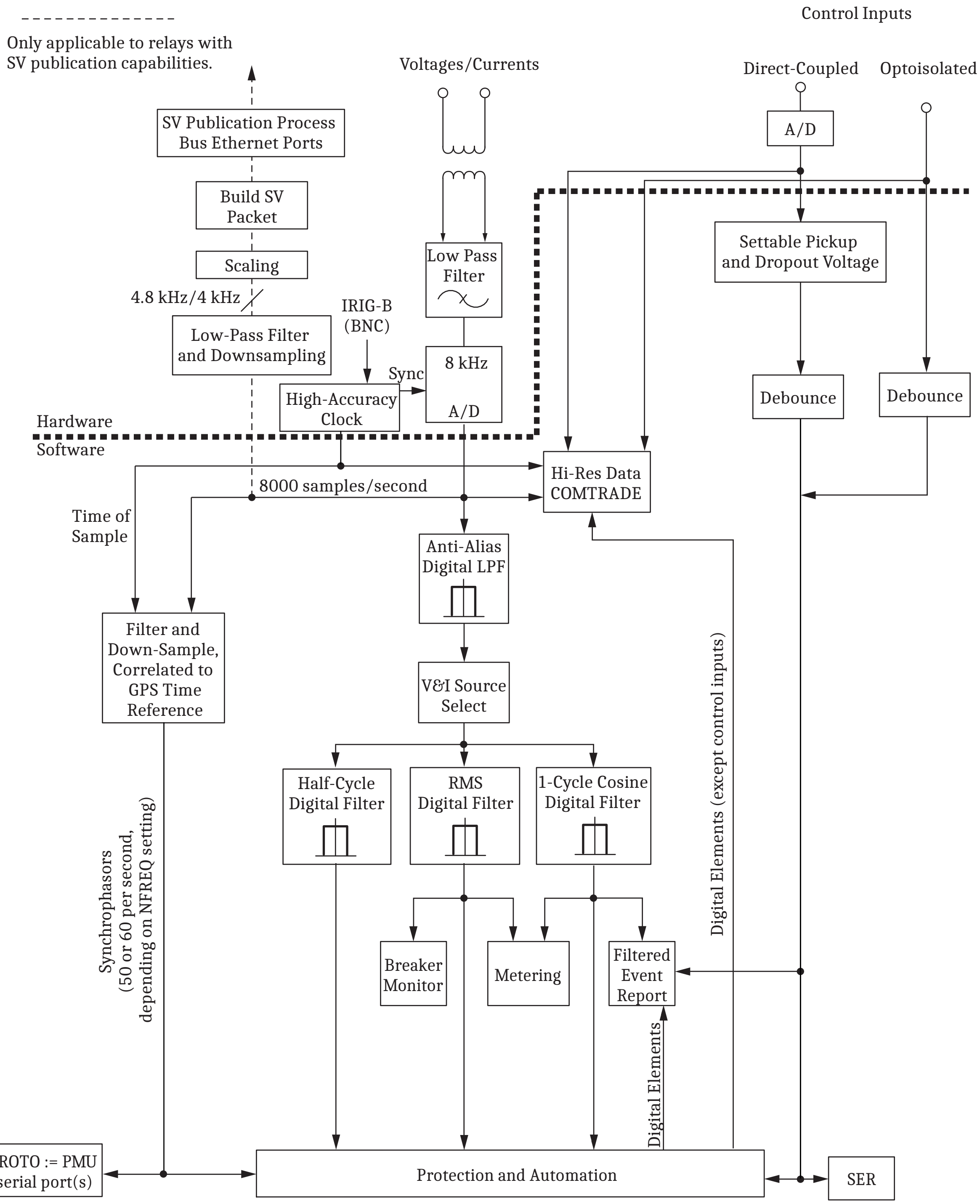


Figure 9.1 Input Processing

The software portion of input signal processing receives the high-resolution raw data sampled quantities and passes these to the Anti-Aliasing Digital Filter. The half-power or –3 dB point of the anti-aliasing filter is 640 Hz. Subsequent processing decimates the sampled data to the processing interval by using additional digital filtering. This information is the filtered data for event reports and other relay functions. The relay downsamples the filtered data to present 4-samples/cycle event reports.

The relay samples the control inputs at a rate of 2 kHz. The raw input digital status is available in high-resolution (COMTRADE) data files. Contact bounce may be visible when the raw data are viewed.

The relay filters both types of control inputs with settable debounce timers, and updates the resulting Relay Word bits every processing interval. Event reports can include the filtered control input Relay Word bits.

Control input state changes will appear to occur faster in COMTRADE oscillography files than in event reports (**EVE** command) or Sequential Events Recorder reports (**SER** command) because of the control input debounce time delays.

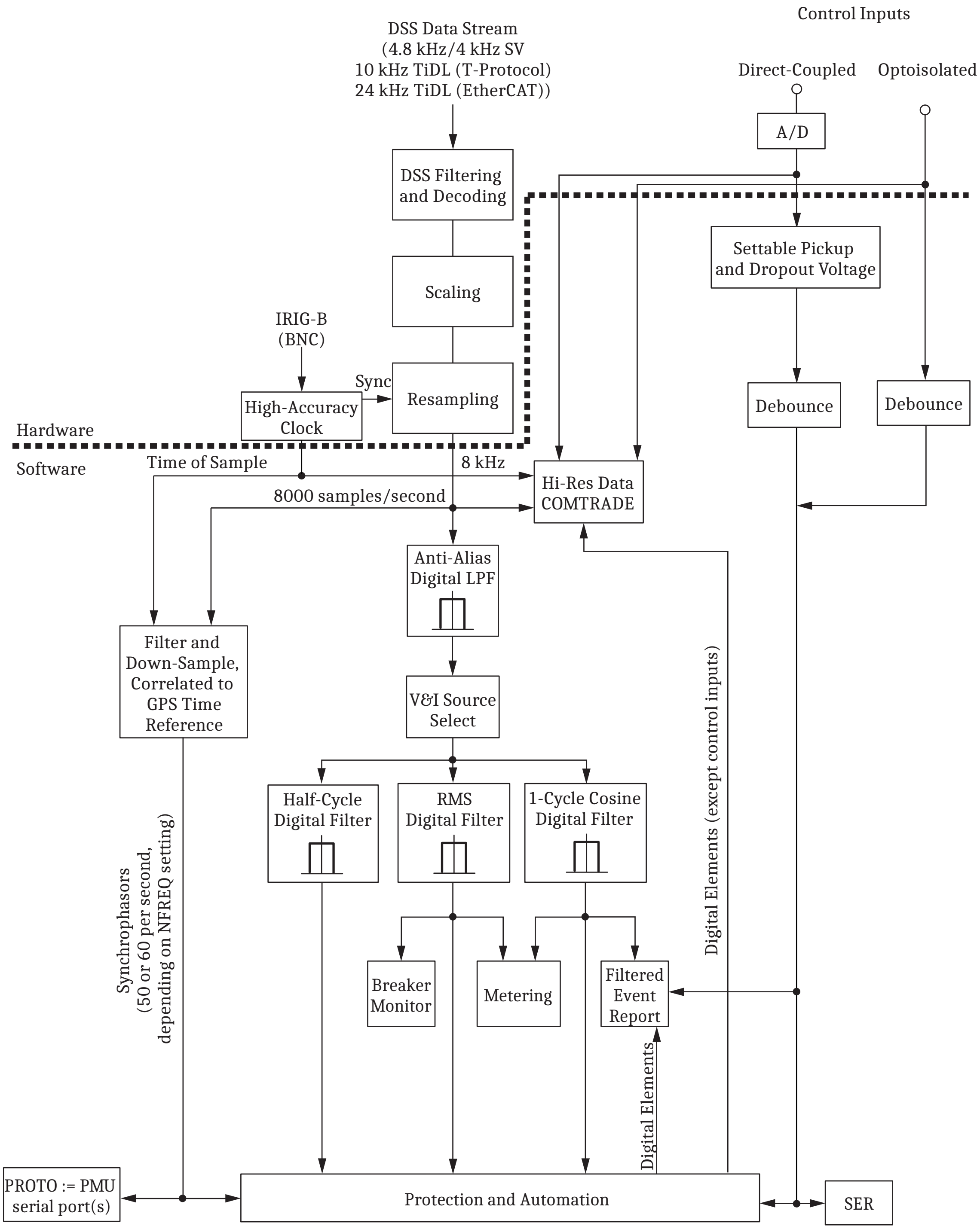


Figure 9.2 Input Processing of SEL-400 Series Relays Supporting DSS Technology

Effect of Full-Cycle Cosine Filtering on Protection Speed

Most of the protection elements within an SEL-400 series relay use data that have been processed through a full-cycle cosine filter (see *Figure 9.1*). This digital filter removes harmonic content and removes the decaying dc component that is present during a fault. To accomplish this, the relay maintains a data buffer for each of the input analog channels (e.g., VAY, IAW), containing a full-power system cycle of data. The oldest data sample in the buffer is from one power system cycle in the past, and the newest data sample is from the present. The output of the filter is a weighted sum of these buffered data samples, with the weights being points from a cosine function (hence the name cosine filter).

When a fault occurs, the cosine filter is initially full of pre-fault data. It takes a full-power system cycle for the filter buffer to completely fill up with fault data. It takes an additional quarter cycle for the phasor magnitudes to fully stabilize at their new values because the relay calculates phasor magnitudes by using two samples separated by a quarter cycle. Consequently, the full-cycle cosine filtered protection quantities take as long as 1.25 power system cycles to reach a new steady state after the onset of a fault.

Figure 9.3 illustrates this behavior. At time $t = 0$, the relay sees a step change in secondary current from 5 A to 15 A rms secondary. The full-cycle filtered current magnitude reaches the new steady-state value of 15 A after approximately 1.25 power system cycles. To illustrate the effect on protection speed, consider three hypothetical overcurrent elements within the relay, each with a different pickup value. The pickup values are PU1 = 6 A, PU2 = 10 A, and PU3 = 14 A, respectively, and these are plotted on the graph alongside the filtered current magnitude. It is evident from the graph that the overcurrent elements with the smaller pickup values operate more quickly. Element 1 operates in 0.125 cycles, Element 2 operates in 0.625 cycles, and Element 3 operates in 1.125 cycles. The smaller the pickup threshold is relative to the applied current, the faster the element operates. This is a direct consequence of the fact that it takes approximately a cycle for the cosine filter to fully charge.

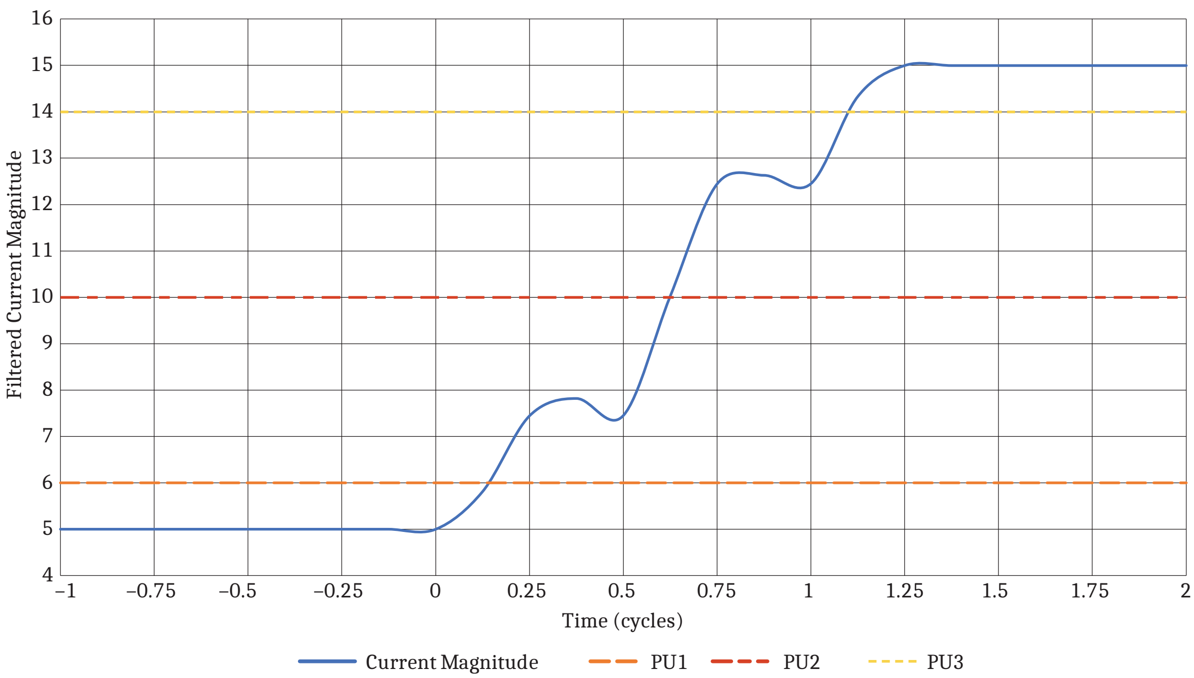


Figure 9.3 Filtered Current Magnitude With Overcurrent Pickups

The processing rate of the protection logic combines with the cosine filter delay to influence protection speed. Most SEL-400 series protection elements run at either 8 samples/cycle or 4 samples/cycle. When the applied current is very large relative to the pickup threshold (e.g., PU1 for Element 1), the processing rate is very influential in determining the protection speed. This is because the effective cosine filter delay is only around one processing interval in that case. When the applied current is barely over the pickup (e.g., PU3 for Element 3), the protection speed is mostly determined by the cosine filter delay because a full cycle is a considerably longer time than one processing interval.

Triggering Data Captures and Event Reports

Oscillograms and event reports are triggered both internally and externally depending on the event trigger that you program in the relay.

Use an event trigger to initiate capturing power system data. High-resolution raw data oscillography and event reports use the same triggering methods. The trigger for data captures comes from four possible sources:

- Relay Word bit TRIP assertions
- SELOGIC control equation ER (Event Report Trigger)
- **TRI** command
- SEL Grid Configurator (see *Section 2: PC Software*)

In some SEL relays, the **PUL** command initiated event recording. If you want the **PUL** command to initiate data capture, add the Relay Word bit TESTPUL to the SELOGIC control equation ER.

Relay Word Bit TRIP

If Relay Word bit TRIP asserts, the relay automatically generates a data capture event trigger on the rising edge of the TRIP Relay Word bit state change. In every instance, TRIP causes the relay to begin recording data. You therefore do not have to enter any condition that causes a trip in the ER SELOGIC control equation.

SELOGIC Control Equation ER

Program the SELOGIC control equation ER to trigger high-resolution raw data oscillography, traveling-wave data oscillography, and standard event reports for conditions other than TRIP conditions. When ER asserts, the relay begins recording data if the relay is not already capturing data initiated by another trigger.

Example 9.1 Triggering Event Report/Data Capture by Using the ER SELOGIC Control Equation

This example shows how the elements in the ER SELOGIC control equation initiate relay data capture.

An example of a factory-default setting for Group setting SELOGIC control equation ER in the SEL-411L is:

ER := **R_TRIG Z2P OR R_TRIG Z2G OR R_TRIG 51S01 OR R_TRIG Z3P OR R_TRIG Z3G** Event Report Trigger Equation (SELOGIC Equation)

Example 9.1 Triggering Event Report/Data Capture by Using the ER SELOGIC Control Equation (Continued)

The element transitions in this setting are from the following Relay Word bits:

- ➤ Z2P, Z3P: Zone 2 phase distance element, Zone 3 phase distance element
- ➤ Z2G, Z3G: Zone 2 ground distance element, Zone 3 ground distance element
- ➤ 51S01: Instantaneous output of Inverse-Time Overcurrent Element 1

The rising-edge operator, R_TRIG, occurs in front of each of the elements in the factory-default ER equation. Rising-edge operators are especially useful for generating an event report at fault inception. The triggering element causes ER to assert, then clears the way for other elements to assert ER because the relay uses only the beginning of a long element assertion. The starting element in a continuously occurring fault does not mask other possible element triggers. This allows another rising-edge sensitive element to generate another event report later in that same continuously occurring fault (such as an overcurrent situation with the R_TRIG 51S01 element).

In the example factory-default ER SELOGIC control equation, if the Z3G element remains asserted for the duration of the ground fault, the rising-edge operator, R_TRIG, in front of Z3G causes ER to assert for only one processing interval (a 1/8-cycle pulse). Other elements in the ER SELOGIC control equation can trigger event reports while the Z3G element remains asserted throughout the fault duration.

You can also use the falling-edge operator, F_TRIG, to initiate data captures.

Example 9.2 Including PUL Command Triggering in the ER SELOGIC Control Equation

This example shows you how to add the effect of the PUL command to emulate previous SEL relays. The relay asserts Relay Word bit, TESTPUL, when any output is pulsed via the PUL command.

Program the Group settings SELOGIC control equation ER as follows:

ER := **R_TRIG Z2P OR R_TRIG Z2G OR R_TRIG 51S01 OR R_TRIG Z3P OR R_TRIG Z3G OR TESTPUL** Event Report Trigger Equation (SELOGIC Equation)

TRI (Trigger Event Report) Command

Use the **TRI** command from any communications port to trigger the relay to begin recording high-resolution raw data, traveling-wave data, and event report data. When testing with the **TRI** command, you can gain information on power system operating conditions that occur immediately after you issue the **TRI** command.

Duration of Data Captures and Event Reports

The relay stores unfiltered, high-resolution raw data (sampled at either 8 kHz, 4 kHz, 2 kHz, or 1 kHz) and filtered event reports. The number of stored high-resolution raw data captures and event reports is a function of the amount of data contained in each capture. You can configure the relay to record long data captures at high sampling rates, although this reduces the total number of stored events you can retrieve from the relay.

To use the data capture functions, select the effective sampling rate and data capture times. Relay setting SRATE determines the number of data points the relay records per second. You can set SRATE to 8 kHz, 4 kHz, 2 kHz, and 1 kHz.

The length of the data capture/event report (setting LER) and the pre-trigger or pre-fault time (setting PRE) are related, as shown in *Figure 9.4*. The LER setting is the overall length of the event report data capture; the PRE setting determines the time reserved in the LER period when the relay records pre-trigger (pre-fault) data. Typically, you set the PRE time to 20 percent of the total LER period. Traveling-wave records have a fixed sampling rate of 1.5625 MHz and a fixed event length of 7.5 ms.

NOTE: PRE has a dynamic range based on the current value of LER. The upper range of PRE = LER – 0.05.

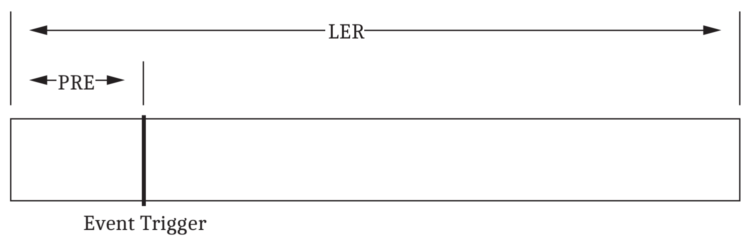


Figure 9.4 Data Capture/Event Report Times

The relay stores all data captures to volatile RAM and then moves these data to nonvolatile memory storage. There is enough volatile RAM to store one maximum length capture (maximum LER time) for a given SRATE. No data captures can be triggered while the volatile RAM is full; the relay must move at least one data capture to nonvolatile storage to re-enable data capture triggering. Thus, to record sequential events, you must set LER to half or less of the maximum LER setting. The relay stores more sequential data captures as you set LER smaller.

See *Section 7: Metering, Monitoring, and Reports* in the product-specific instruction manual, to determine the event storage capacity for any specific relay. The relay automatically overwrites the oldest events with the newest events when the nonvolatile storage capacity is exceeded.

Oscillography

NOTE: Relays with DSS technology adjust COMTRADE files automatically by the channel delay associated with the DSS technology used. This allows for comparison with COMTRADE files gathered from traditional, non-DSS relays. CEV files, however, retain the channel delay because those files show how the relay operated based on the received signals.

The relay features the following types of oscillography:

- ➤ Raw data oscillography—effective sampling rate as fast as 8000 samples/second
- ➤ Event report oscillography from filtered data

Use high-resolution raw data oscillography to view transient conditions in the power system. You can set the relay to report these high-resolution oscillograms at 8000 samples/second, 4000 samples/second, 2000 samples/second, and 1000 samples/second effective sampling rates. The high-resolution raw data and traveling-wave data oscillograms are available as files through the use of Ymodem file transfer and File Transfer Protocol (FTP) in the binary COMTRADE file format output (IEEE Std C37.111-1999 and C37.111-2013, Common Format for Transient Data Exchange (COMTRADE) for Power Systems).

NOTE: The SEL-400G provides both filtered and raw high-resolution oscillograms by using the IEEE C37.111-2013 COMTRADE file format.

The filtered data oscillograms give you accurate information on the relay protection and automation processing quantities. The relay outputs filtered event reports through a terminal or as files in ASCII format and Compressed ASCII format, through FTP and Ymodem file transfers. *Figure 9.5* shows a sample filtered-data oscillogram.

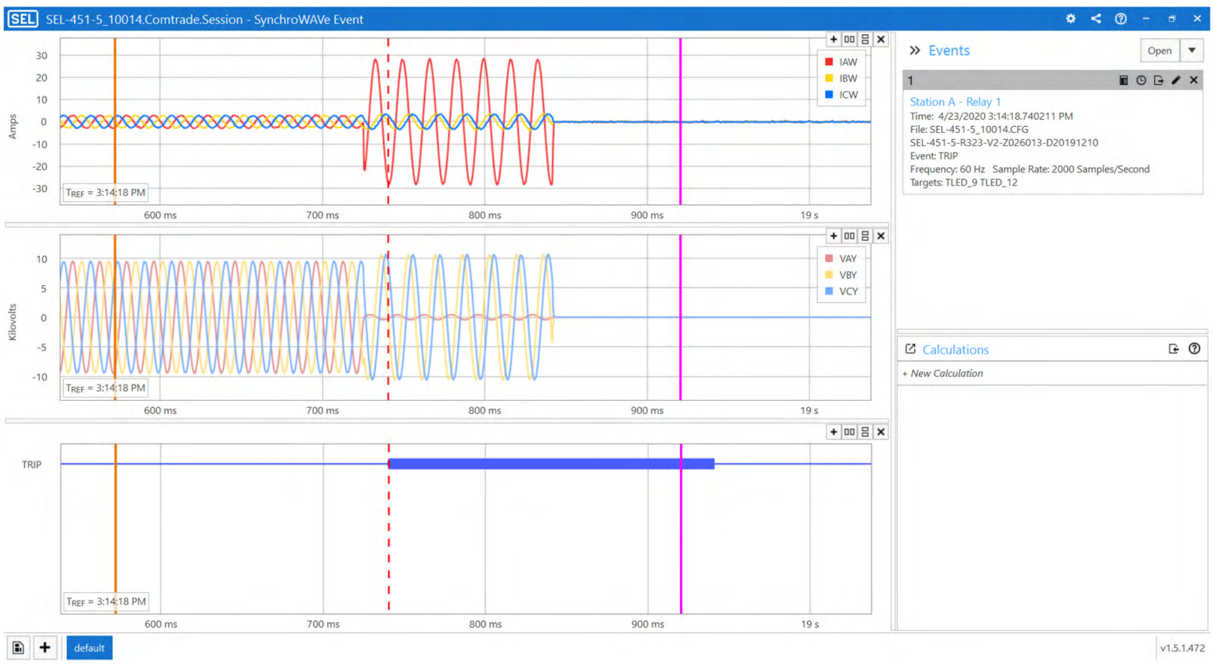


Figure 9.5 Sample Oscillogram

Raw Data Oscillography

Raw data oscillography produces oscillograms that track power system anomalies that occur outside relay digital filtering.

COMTRADE files always include all eight Relay Word bits from each row of the Relay Word used as the base set for the relay (see *Section 7: Metering, Monitoring, and Reporting* in the product-specific instruction manual for a list of these bits). Additionally, it includes the rows containing those Relay Word bits configured for inclusion by the ERDG setting.

The relay stores high-resolution raw data oscillography in binary format and uses COMTRADE file types to output these data:

- .HDR—header file
- .CFG—configuration file
- .DAT—high-resolution raw data file

The .HDR file contains summary information about the event in ASCII format. The .CFG file is an ASCII configuration file that describes the layout of the .DAT file. The .DAT file is in binary format and contains the values for each input channel for each sample in the record. These data conform either to the IEEE C37.111-1999 or C37.111-2013 COMTRADE standard, depending on the relay report settings.

.HDR File

The .HDR file contains the summary and relay settings information that appears in the event report for the data capture (see *Event Summary Section of the Event Report on page 9.23* and *Settings Section of the Event Report on page 9.24*). The settings portion is as illustrated in *Figure 9.6*.

Summary Event Information

```
Relay 1                                 Date: 02/02/2011  Time: 14:11:21.000
Station A                               Serial Number: 2010265004

Event: ABG T   Location: 59.61 (mi)   From: LOCAL   FLM: TW   Time Source: HIRIG
Event Number: 10121      Shot 1P: 0   Shot 3P: 0        Freq: 59.99     Group: 1
Targets:
Breaker 1: CLOSED
Breaker 2: OPEN
PreFault:     IA     IB     IC     IG    3I2       VA       VB       VC    V1mem
MAG(A/kV)    200    200    200      1      1  133.946  133.938  133.941  133.935
ANG(DEG)    -0.7 -120.5  119.4  -51.7  -88.7      0.0   -119.9    120.2      0.1

Fault:
MAG(A/kV)   2200   2200   2200      7    376  133.937  133.926  133.957  133.933
ANG(DEG)    -0.7 -120.6  119.5 -102.0  -83.5      0.0   -119.9    120.2      0.1

                 87 Differential Currents
PreFault:     IA     IB     IC     IQ     IG
MAG(pu)     0.00   0.00   0.00   0.00   0.00
ANG(DEG)     0.0    0.0    0.0    0.0    0.0

Fault:
MAG(pu)     0.00   0.00   0.00   0.00   0.00
ANG(DEG)     0.0    0.0    0.0    0.0    0.0
```

Relay Settings

```
SET_G1.TXT
[INFO]
RELAYTYPE=SEL-411L
FID=SEL-411L-X136-V0-Z001001-D20110114
BFID=SLBT-4XX-R205-V0-Z001002-D20100128
PARTNO=0411L0X6X1B6BCXH5C4E4XX
[IOBOARDS]
INT4_E, , , 24, 8, 0, 0, 1
CFSINT8, , , 8, 8, 0, 0, 2
[G1]
"SID","Station A"
"RID","Relay 1"
"NUMBK",2
"BID1","Breaker 1"
"BID2","Breaker 2"
"NFREQ",60
.
.
.
"AR197",
"AR198",
"AR199",
"AR200",
```

Figure 9.6 Sample COMTRADE .HDR Header File

.CFG File

The .CFG file contains data such as sample rates, number of channels, line frequency, channel information, and transformer ratios (see *Figure 9.7*). A <CR><LF> follows each line. If control inputs or control outputs are not available because of board loading and configuration, the relay does not report these inputs and outputs in the analog and digital sections of the .CFG file. *Figure 9.7* shows a typical C37.111-1999 COMTRADE file format. C37.111-2013 COMTRADE file formats are also provided.

Station A,FID=SEL-411L-1-R100-V0-Z001001-D20110311,1999	Relay Information (1999 = COMTRADE Standard)
398,14A,384D	398 = sum of analogs and digitals 14A = total number of analog channels 384D = total number of digital points[a]
1,IAW,A,,A,0.324059,0,0,-32767,32767,200.0,1,P 2,IBW,B,,A,0.324059,0,0,-32767,32767,200.0,1,P 3,ICW,C,,A,0.324059,0,0,-32767,32767,200.0,1,P 4,IAX,A,,A,0.324059,0,0,-32767,32767,200.0,1,P 5,IBX,B,,A,0.324059,0,0,-32767,32767,200.0,1,P 6,ICX,C,,A,0.324059,0,0,-32767,32767,200.0,1,P 7,VAY,A,,kV,0.032406,0,0,-32767,32767,2000.0,1,P 8,VBY,B,,kV,0.032406,0,0,-32767,32767,2000.0,1,P 9,VCY,C,,kV,0.032406,0,0,-32767,32767,2000.0,1,P 10,VAZ,A,,kV,0.032406,0,0,-32767,32767,2000.0,1,P 11,VBZ,B,,kV,0.032406,0,0,-32767,32767,2000.0,1,P 12,VCZ,C,,kV,0.032406,0,0,-32767,32767,2000.0,1,P 13,VDC1,,,V,0.011178,-0.000000,0,-32767,32767,1,1,P 14,VDC2,,,V,0.011178,-0.000000,0,-32767,32767,1,1,P	14 Analog Channels
1,87USAFE,,,0 2,UNUSED2,,,0 3,UNUSED3,,,0 4,UNUSED4,,,0 5,OC1,,,0 6,CC1,,,0 7,OC2,,,0 8,CC2,,,0 9,87LA,,,0 10,87LB,,,0 11,87LC,,,0 12,87LQ,,,0 13,87LG,,,0 14,87FLSOK,,,0 15,87DTTRX,,,0 . . . 382,PCT06Q,,,0 383,PCT07Q,,,0 384,PCT08Q,,,0	384 Digital Points
60	Nominal System Frequency (INFREQ Setting)
1	
2000,1000	2000 = Sample Rate (SRATE setting) 1000 = Length of the Report x Sample Rate (LER x SRATE)
17/03/2011,08:36:38.697687	Time Stamp of the First Data Point
17/03/2011,08:36:38.799850	Time Stamp of the Trigger Point
BINARY	
1	

Figure 9.7 COMTRADE .CFG Configuration File Data

[a] If ERDIG is set to S, the digital points are all the Relay Word bits set in ERDG as well as the Relay Word bits that are always included in the event report. If ERDIG is set to A, the digital points are all the Relay Word bits in the device.

The configuration file has the following format:

- Station name, device identification, COMTRADE standard year
- Number and type of channels
- Channel name units and conversion factors
- Line frequency
- Sample rate and number of samples
- Date and time of first data point
- Date and time of trigger point
- Data file type
- Time stamp multiplication factor

.DAT File

NOTE: The analog data are time-aligned to when the data changed on the input terminals. Similarly, the contact inputs are time-aligned to when the data changed on the input terminals. All other digital data are time-aligned to when the value changed in the relay.

The .DAT file follows the COMTRADE binary standard. The format of the binary data files is sample number, time stamp, data value for each analog channel, and grouped status channel data for each sample in the file. There are no data separators in the binary file, and the file contains no carriage return/line feed characters. The sequential position of the data in the binary file determines the data translation. Refer to the IEEE Std C37.111-1999 or C37.111-2013, Common Format for Transient Data Exchange (COMTRADE) for Power Systems for more information.

Generating Raw Data Oscillograms

To use high-resolution raw data oscillography, select the type of triggering event and use a trigger event method described in *Triggering Data Captures and Event Reports on page 9.7*. Use the settings SRATE, LER, and PRE to set the relay for the appropriate data sampling rate and data capture time (see *Duration of Data Captures and Event Reports on page 9.9*).

Retrieving Raw Data Oscillograms

Use a computer terminal emulation program and the **FILE** commands at any communications port to retrieve the stored high-resolution raw data capture from the relay file structure. If the relay has an Ethernet port, you can also use FTP to retrieve these files. You can also use QuickSet.

Event Report Oscillography

Use a terminal or SEL-supplied PC software to retrieve filtered event report files stored in the relay and transfer these files to your computer. SYNCHROWAVE Event can be used to view the compressed event files that the relay generates for an event.

Event Reports, Event Summaries, and Event Histories

Event reports simplify post-fault analysis and help you improve your understanding of protection scheme operations. Event reports also aid in testing and troubleshooting relay settings and protection schemes because these reports contain detailed data on voltage, current, and relay element status. For further analysis assistance, the relay appends the active relay settings to each event report. The relay stores event reports in nonvolatile memory, and you can clear the event report memory on a port-by-port basis.

You decide the amount of information and length in an event report (see *Duration of Data Captures and Event Reports on page 9.9*).

The relay records the filtered power system data that the relay uses in protection and automation processing. You can view filtered information about an event in one or more of the following forms.

- Event report
- Event summary
- Event history

Alias Names

NOTE: If Alias names were changed after an event was recorded, the relay uses the present alias names in subsequent event reports.

To customize your event report, rename any Relay Word bit or analog quantity with more meaningful names to improve the readability of fault analysis and customized programming. After renaming the primitive quantities, the alias names rather than the primitive names appear in the event reports for the user-selectable analog and digital channels. The primitive names of the analog channels still appear in the event reports.

Event Report

The relay generates event reports to display analog data, digital data (control inputs, control outputs, and the state of Relay Word bits), and relay settings. The event report is a complete description of the data that the relay recorded in response to an event trigger. Each event report includes these components:

- Report header and analog section—Currents and voltages, sometimes including calculated quantities such as differential currents
- Digital section—Relay Word bit elements, control outputs, control inputs
- Event summary
- Settings
  - Group settings
  - Global settings
  - Output settings
  - **PORT 5** settings[1]
  - SELOGIC control equations protection logic

Viewing the Event Report

Access event reports from the communications ports and communications cards at Access Level 1 and higher. (You cannot view event reports at the front panel, although you can view event summary information at the front-panel display.) You can independently acknowledge the oldest event report at each communications port (**EVE ACK** command) so that you and users at other ports (SCADA, Engineering, etc.) can retrieve complete sets of event reports. To acknowledge the oldest event report, you must first view that event report at a particular port by using the **EVE N(EXT)** command.

You can use the **EVE** command and a terminal to retrieve event reports by event order or by event serial number. (The relay labels each new event with a unique serial number as reported in the **HIS** command history report [see *Event History on page 9.27*].)

Events are referenced two ways: by relative reference or by event serial number. Relative references are in the range 1–9999, where 1 refers to the most recent event, 2 to the next most recent, and so on. Event serial numbers are in the range 10000–42767. You can find the event serial number in the event history report. With the **EVE** and **CEV** commands, you can retrieve events by using either type of reference. Event files are names based on the event serial number.

[1] The following **PORT 5** settings are available in COMTRADE .HDR files: EPORT, E61850, EGSE, EMMSFS, E850MBC, SVRXEN (SV subscribers), SVTXEN (SV publishers), CH_DLY, EPTP, PTPPRO, PTPTR, DOMNUM, PTHDLY, PDINT, BUSMODE, NETMODE, and NETPORT.

By applying modifiers to the **EVE** command, you can retrieve only analog or digital information, and you can exclude the summary or settings portions of the report. The default **EVE** command event report data resolution is 4 samples/cycle and the default report length is 0.5 seconds (30 cycles at 60 Hz or 25 cycles at 50 Hz) with the factory-default setting for LER.

See the **EVE** command description in *Section 9: ASCII Command Reference* in the product-specific instruction manual for a complete list of options.

You can retrieve event reports with the QuickSet **Tools > Events > View Event Files** menu. The **Analysis > View Event Files** menu gives you oscillogram/element displays, phasor displays, harmonic analysis, and an event summary for each event you select in the **Event History** dialog box.

You can also download event report files from the relay by using a terminal emulation program with file transfer capability. At an Access Level 1 prompt or higher, type **FILE READ EVENTS E8_*nnnnn*.TXT <Enter>** for the 8-samples/cycle event report and type **FILE READ EVENTS E4_*nnnnn*.TXT <Enter>** for the 4-samples/cycle event report (*nnnnn* is the event serial number). Start the terminal download routine to store the file on your computer. If you want the Compressed ASCII file, use the C8_*nnnnn*.TXT and C4_*nnnnn*.TXT file names for the 8-samples/cycle and 4-samples/cycle Compressed ASCII event reports, respectively.

The following discussion shows sample portions of an event report that you download from the relay by using a terminal and the **EVE** command. An event report contains analog, digital, summary, and settings sections without breaks.

Inverse Polarity in Event Reports

In COMTRADE event reports, terminals that have EINVPOL enabled do not show the polarity as inverted. The COMTRADE must display the values as they are applied to the CT and PT inputs of the measuring device. This also ensures that when you use an event playback, the setting applies to the signals coming in the back of the relay and recreates the event properly.

Compressed event reports (CEV), show the polarity as inverted. The CEV displays the analogs as the relay uses them in processed logic; therefore, the relay displays the inverted polarity. See *Section 5: Protection Functions* in the product-specific instruction manual for information on inverting polarity on current and voltage inputs.

Report Header and Analog Section of the Event Report

The first portion of an event report is the report header and the analog section. Some relays have more than one analog section. See *Section 7: Metering, Monitoring, and Reports* in the product-specific instruction manual for details on what the event reports look like in each relay. See *Figure 9.8* for an example of a SEL-421 event report.

The report header is the standard relay header listing the relay identifiers, date, and time. Report headers help you organize report data. Each event report begins with information about the relay and the event. The report lists the RID setting (Relay ID) and the SID setting (Station ID). The FID string identifies the relay model, flash firmware version, and the date code of the firmware. The relay reports a date and time stamp to indicate the internal clock time when the relay triggered the event. The relay reports the firmware checksum as Configured IED Description (CID).

The event report column labels follow the header. The data underneath the analog column labels contain samples of power system voltages and currents.

```
Relay 1                                          Date: 03/15/2001  Time: 23:30:49.026
Station A                                        Serial Number: 2001001234
FID=SEL-421-R101-V0-Z001001-D20010315            Event Number = 10007      CID=0x3425
```

Header
Firmware ID in bold

```
Currents (Amps Pri)             Voltages (kV Pri)
    IA     IB     IC     IG     VA     VB     VC    VS1    VS2  V1mem

[1]
  -267    167     44    -56 -288.0  337.7  -47.8  215.3  144.9 -287.9
   -76   -203    241    -37 -223.7 -138.4  361.3 -290.5  331.3 -223.7
   266   -166    -45     55  288.2 -337.5   47.5 -215.2 -145.0  288.1
    76    202   -242     36  223.4  138.7 -361.4  290.5 -331.2  223.5
```

1 Cycle of Data
See *Figure 9.9* and *Figure 9.10* to calculate phasors for the data in bold.

```
                                        •
                                        •
                                        •
[6]
  -269    167     46    -56 -289.3  336.9  -45.8  215.5  144.7 -289.4
   -74   -202    240    -35 -222.2 -140.2  361.5 -290.2  331.4 -221.8
   268   -165    -45     57  289.4 -336.7   45.6 -215.4 -144.6  289.5
    93    151   -888   -643  221.1  133.5 -335.0  290.2 -331.4  220.8
[7]
  -208   2701  -3760  -1267 -288.7  293.7  -24.1  215.5  144.5 -286.3
  -146   2941    173   2968 -219.6  -87.6  261.6 -290.1  331.4 -214.0>
   134  -5748   8310   2696  286.9 -232.4    3.5 -215.6 -144.4  273.3
   179  -6677   1811  -4688  219.8   47.4 -214.2  290.0 -331.5  202.8
```

Trigger

```
[8]
  -125   5661  -8506  -2971 -286.1  213.6   -3.8  215.8  144.2 -256.5
  -177   6857  -1950   4730 -220.8  -46.9  214.2 -289.9  331.6 -193.2*
   129  -5508   8382   3003  286.9 -213.8    3.6 -216.0 -144.0  243.9
   174  -6726   1839  -4712  220.4   47.2 -214.2  289.8 -331.6  185.9
```

Largest Current (to Event Summary)

```
[9]
  -128   5623  -8479  -2984 -287.1  213.9   -3.5  216.1  143.8 -234.5
  -173   6821  -1924   4724 -219.8  -47.3  214.0 -289.7  331.7 -180.4
   126  -5540   8404   2990  286.6 -213.7    3.5 -216.3 -143.7  227.3
   177  -6749   1860  -4713  220.0   47.4 -212.9  289.6 -331.8  176.2
[10]
  -126   4616  -6204  -1714 -282.9  178.6   41.9  216.4  143.5 -222.1
  -106   4288  -1047   3135 -231.6  -64.5   95.3 -289.4  331.9 -162.6
    65  -1722   1878    221  140.2  -72.1  -43.6 -216.6 -143.3  194.6
    16   -807      4   -786  105.1   41.3   10.5  289.2 -332.0  130.7
```

Circuit Breaker Open

```
[11]
    -1     -1     -2     -5   13.8    1.1    0.3  216.8  143.1 -147.1
     2      3      4      9   54.8   -0.7   -0.3 -289.1  332.1  -93.5
     1      1      2      5   -8.1   -1.6   -1.1 -217.0 -142.8  109.8
    -2     -2     -3     -8  -58.2    0.2    0.2  289.0 -332.2   65.3
```

Figure 9.8 Fixed Analog Section of an Example SEL-421 Event Report

Within an event report, there are bracketed numbers at the left of the report (for example, [11]) that indicate the cycle number.

The trigger row is indicated by a > character following immediately after the last analog data column. This is the dividing point between the pre-fault or PRE time and the fault or remainder of the data capture.

The relay indicates which row has the largest current magnitudes, which are reported in the event summary, with an asterisk (*) character immediately after the last analog data column. The (*) takes precedence over the > if both occur on the same row in the analog section of the event report.

ERAQc (Analog Quantities)

NOTE: Analog quantities programmed in the Event Reporting Analog Quantities (ERAQc) are only added to the filtered event reports. These added analog quantities will not be visible in COMTRADE files.

To supplement the fixed analog quantities in the event report, select as many as 20 additional analog quantities in the event report. For example, say you programmed a function in the relay by using Protection Math Variables PMV01–PMV06, and you want to include these six PMVs in the event report. Enter the six PMVs in the Event Reporting Analog Quantities as shown below.

```
Event Reporting Analog Quantities
(Maximum 20 Analog Quantities)
1: PMV01
2: PMV02
3: PMV03
4: PMV04
5: PMV05
6: PMV06
```

The relay correlates the freeform line number chronologically with the ERAQ*c* quantities. In this example, ERAQ01 = PMV01, ERAQ02 = PMV02, etc.

In the event report, the ERAQ quantities follow the fixed analog quantities.

```
PMV01      PMV02      PMV03      PMV04      PMV05      PMV06
[1]
    20.000     25.000    102.000     34.000     67.000     54.000
    20.000     25.000    102.000     34.000     67.000     54.000
    20.000     25.000    102.000     34.000     67.000     54.000
    20.000     25.000    102.000     34.000     67.000     54.000
[2]
    20.000     25.000    102.000     34.000     67.000     54.000
    20.000     25.000    102.000     34.000     67.000     54.000
    20.000     25.000    102.000     34.000     67.000     54.000
    20.000     25.000    102.000     34.000     67.000     54.000
```

Obtaining RMS Phasors From 4-Samples/Cycle Event Reports

Use the column data in an event report to calculate rms values. You can use a calculator to convert rectangular data to phasor data, or use hand-calculations to separately determine the magnitude and angle of the rms phasor.

Hand Calculation Method

The procedure in the following steps explains a method for obtaining a current phasor from the IA channel data in the event report of *Figure 9.8*. You can process voltage data columns similarly. The drawings in *Figure 9.9* and *Figure 9.10* show 1 cycle of A-Phase current in detail. *Figure 9.9* shows how to relate the event report ac current column data to the sampled waveform and rms values. *Figure 9.10* shows how to find the phasor angle. If you use the larger 8-samples/cycle event report, take every other sample and apply those values in this procedure.

This examples assumes you have captured an event report and are prepared to calculate phasors from it.

Step 1. Calculate the phasor magnitude:

a. Select a cycle of data from the IA column of the event report.

Figure 9.8 Cycle [1] data for this example are shown in *Figure 9.9*.

There are three pairs of scaled instantaneous current samples from Cycle [1].

Compute phasor magnitude by using the following expression:

$$\sqrt{X^2 + Y^2} = |\text{Phasor}|$$

Equation 9.1

b. In *Equation 9.1*, Y is the first row of IA column current of a data pair, and the next row is X, the present value of the pair.

For this example, the computation shown in *Figure 9.9* yields 277.0 A.

c. Compute phasor magnitudes from the remaining data pairs for Cycle [1].

d. Confirm that all values are similar.

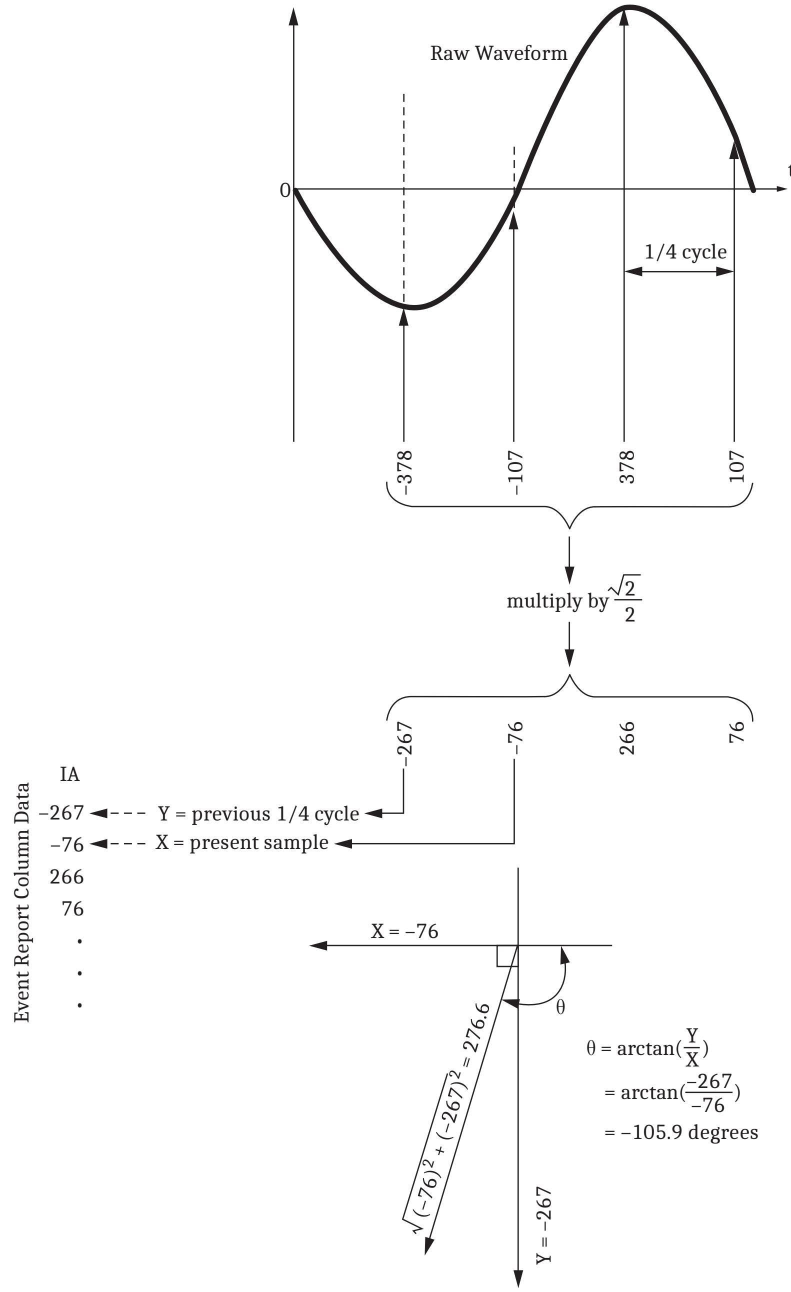


Figure 9.9 Event Report Current Column Data and RMS Current Magnitude

Step 2. Calculate the immediate phase angle.

a. Select the same cycle of data from the IA column of the event report as you did when finding the magnitude (Cycle [1] data for this example).

b. Compute phasor angle by using the following expression:

$$\theta = \arctan\left(\frac{Y}{X}\right) = \angle\text{Phasor}$$

Equation 9.2

In *Equation 9.2*, Y is the first (or previous value) IA column current of a data pair, and X is the present value of the pair.

For this example, the computation shown in *Figure 9.10* yields –105.9 degrees.

c. Compute phasor angles from the remaining data pairs for Cycle [1].

NOTE: The arctan function of many calculators and computing programs does not return the correct angle for the second and third quadrants (when X is negative). When in doubt, graph the X and Y quantities to confirm that the angle that your calculator reports is correct.

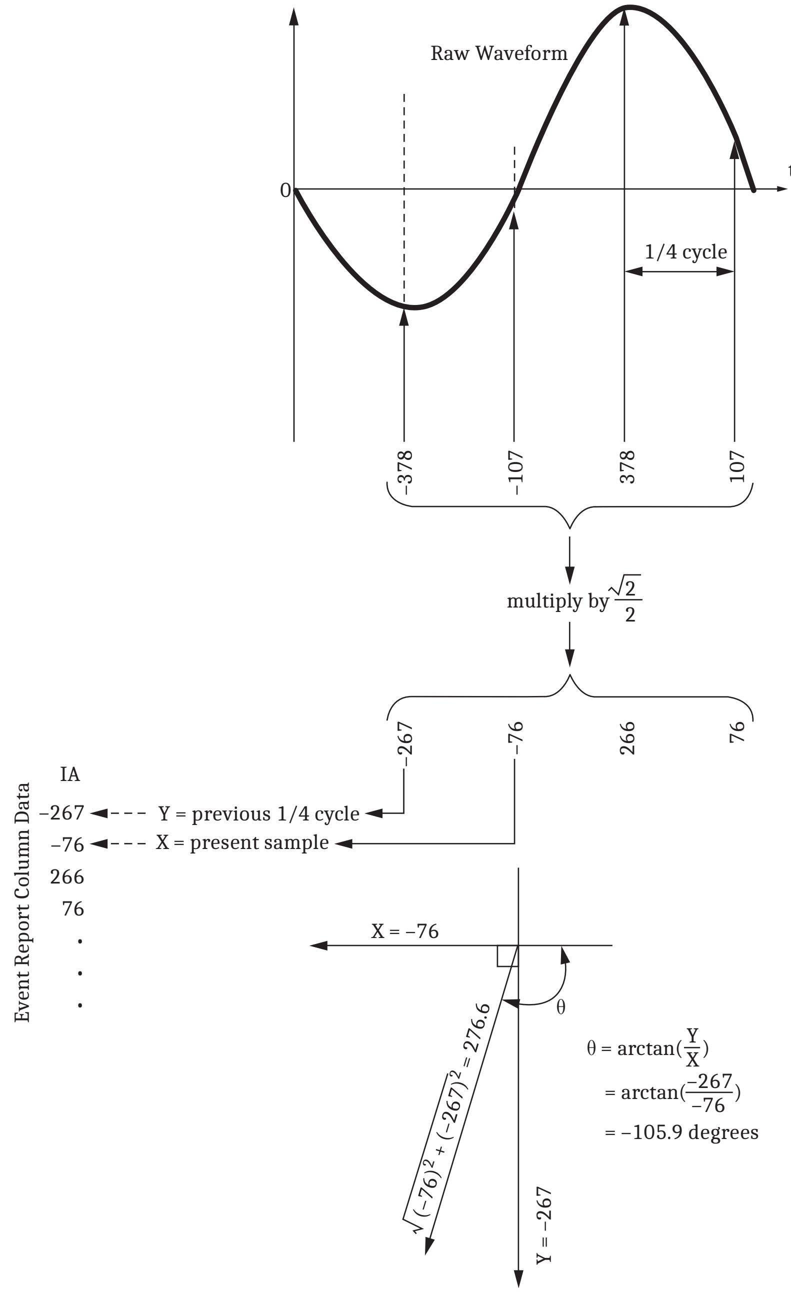


Figure 9.10 Event Report Current Column Data and RMS Current Angle

Step 3. Calculate the reference phase angle. Usually, you compare power system angles to a reference phasor (positive-sequence A-Phase voltage, for example):

Repeat *Step 2* for the row data in the VA column that correspond to the IA column data values you used in *Step 2*.

The angle calculation for the VA data is the following:

$$\begin{aligned}\theta &= \angle \mathrm{VA} \\ &= \arctan\left(\frac{\mathrm{Y}}{\mathrm{X}}\right) \\ &= \arctan\left(\frac{-288.0}{-223.7}\right) \\ &= -127.8^\circ\end{aligned}$$

Equation 9.3

(This is an example of an arctan calculation that yields the incorrect answer from some calculators and math programs.)

Step 4. Calculate the absolute phase angle:

Subtract the IA angle from the VA angle to obtain the A-Phase-referenced phasor angle for IA.

$$\angle \mathrm{VA} - \angle \mathrm{IA} = -127.8^\circ - (-105.9^\circ) = -21.9^\circ$$

Equation 9.4

IA leads VA; thus, the rms phasor for current IA at the present sample is 277.0 A $\angle 21.9^\circ$, referenced to VA.

In the procedure above, you use two rows of current data from the event report to calculate an rms phasor current. At the first sample pair of Cycle [1], the rms phasor is $I_A = 277.0\ \mathrm{A}\ \angle{-105.9^\circ}$.

The present sample of the sample pair (X = –76) is a scaled instantaneous current value (not an rms quantity) that relates to the rms phasor current value by the expression.

$$\mathrm{X} = -76 = 277.0 \bullet \cos(-105.9^\circ)$$

Equation 9.5

Polar Calculator Method

A method for finding the phasor magnitude and angle from event report quarter-cycle data pairs is to use a polar-capable calculator or computer program. Many calculators and computer programs convert Cartesian (X and Y) coordinate data to polar data. Key or enter the X value (present value or lower value of a column pair) and the Y value (later value or upper value in a column pair) as Cartesian (rectangular) coordinates. Perform the keystrokes necessary for your calculator or computing program to convert to polar coordinates. This is the phasor value for the data pair.

Digital Section of the Event Report

The second portion of an event report is the digital section. Inspect the digital data to evaluate relay element response during an event. See *Figure 9.11* for an example from the SEL-411L. If you want to view only the digital portion of an event report, use the **EVE D** command. In the digital portion of the event report, the relay indicates deasserted elements with a period (.) and asserted elements with an asterisk (*) character.

The element and digital information labels are single character columns. Read these columns from top to bottom. The trigger row includes a > character following immediately after the last digital element column to indicate the trigger point. The relay marks the row used to report the maximum fault current with an asterisk (*) character at the right of the last digital element column. Event reports that are 4-samples/cycle reports show the OR combination of digital elements in the two 8-samples/cycle rows to make the quarter-cycle entry.

The digital report arranges the event report digital settings into 79 column pages. For every 79 columns, the relay generates a new report that follows the previous report.

The report displays the digital label header for each column in a vertical fashion, aligned on the last character. For example, if the first digital section elements are IN201, #, RMBA5, Z2P, LBOKA, #, OUT203, OUT204, and HALARM, the header appears as in *Figure 9.12*. If the Relay Word bits included in the header were assigned aliases, the alias names appear in the report.

```
                                                                    22 B B
                                                             C        55 F F
                      VZ             S      66     66  55    O BBBBBB AA T T
         MMM      ZZZ PL        3333 05 666 77 666 77 511  Z M KKKKKK 11 RFRF      Digital Column Labels
TTT MMMM 234 ZZZZ 234 OOL OO 3S 2222 T0 777 GG 777 QQ 1SS  3KP 121212 BB IBIB
PPP 1234 PPP 1234 GGG LAO SS PP QQGG FP GGG 23 QQQ 23 S11 PRER RRLLCC KK PFPF
ABC PPPP TTT GGGG TTT VDP BT OO FRFR T1 123 TT 123 TT 1TR TBYM SSOOLL 12 1122

[1]

... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....      1 Cycle of Data
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....

                                       •
                                       •
                                       •

[6]
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
[7]
*** **.. ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....

*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....>     Trigger

*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
[8]
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....

*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....*     Values used in the Event Summary

*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
[9]
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
[10]
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** .... ... .... ... *.. .. .* .... .. ... .. ... .. ... .... ...... .. ....
*** .... ... .... ... *.. .. *. .... .. ... .. ... .. ... .... ...... .. ....

[11]                                                                               Circuit Breaker Open

*** .... ... .... ... *.. .. *. *.*. .. ... .. ... .. ... .... ...... .. ....
*** .... ... .... ... *.. .. *. .... .. ... .. ... .. ... .... ...... .. ....
*** .... ... .... ... *.. .. *. .... .. ... .. ... .. ... .... ...... .. ....
*** .... ... .... ... *.. .. *. .... .. ... .. ... .. ... .... ...... .. ....
```

Figure 9.11 Digital Section of the SEL-411L Event Report

```
                IN201
                #
                RMBA5
                Z2P
                LBOKA
                #
                OUT203
                OUT204
                HALARM

      OOH
I R   UUA
N M L TTL
2 BMO 22A
0 A2K OOR
1 5PA 34M

. ... ...
   .. ...
* ..* ...
* ..* ...
```

Figure 9.12 Sample Digital Portion of the Event Report

Selecting Event Digital Elements

NOTE: The compressed event reports and COMTRADE files from the relay may contain additional digital elements as compared to standard (ASCII) event reports (see CEVENT on page 9.25).

Specify the digital elements in the digital section of the event report by using the Event Reporting Digital Elements settings found in the Report settings (the **SET R** command from a terminal or the **Report** branch of the Settings tree view of SEL Grid Configurator or QuickSet). You can enter as many as 800 Relay Word bits from a maximum of 100 target rows. The # symbol places a blank column in the digital report. Use the # symbol to organize the digital section of the event report.

Digital Section INnnn Times

Reported assertion times for input digital elements differ, although these elements have the same name in both high-resolution raw data reports and in the filtered event reports. When you enter an input (IN*nnn*) in the event digitals list, the relay displays the filtered input with time latency in the event report and the Compressed ASCII event report. However, in the binary COMTRADE file event report, the relay reports the actual high-sample rate capture time for relay inputs.

Event Summary Section of the Event Report

The third portion of an event report is the summary section. See *Figure 9.13* for the locations of items included in an example summary section of an event report. The specific values available depend on the specific relay. See *Section 7: Metering, Monitoring, and Reports* in the product-specific instruction manual to see what specific data are reported in the summary of a relay. If you want to exclude the summary portion from an event report, use the **EVE NSUM** command.

The information in the summary portion of the event report is the same information in the event summary, except that the report header does not appear immediately before the event information when you view a summary in the event report.

```
Event: TRIP   Location: $$$$.$$      From: LOCAL     FLM: SE  Time Source: OTHER
Event Number: 10030      Shot 1P: 0   Shot 3P: 0        Freq: 60.00     Group: 1
Targets: INST COMM 87L
Breaker 1: CLOSED       Trip Time: 11:18:49.016
Breaker 2: NA

PreFault:     IA     IB     IC     IG    3I2       VA       VB       VC    V1mem

MAG(A/kV)    426    426    427      1      0  286.420  286.638  286.302  286.453

 ANG(DEG)     1.3 -118.7  121.3  130.6  -99.2      0.0   -120.0    120.0      0.0

 Fault:

MAG(A/kV)    426    426    427      1      1  286.397  286.632  286.298  286.450

ANG(DEG)     1.3 -118.7  121.3  106.1  -92.6      0.0   -120.0    120.0      0.0

                 87 Differential Currents

PreFault:     IA     IB     IC     IQ     IG
MAG(pu)     0.36   0.35   0.36   0.00   0.00
ANG(DEG)     1.4 -118.9  120.9   92.9   59.5

Fault:
MAG(pu)     0.00   0.00   0.00   0.00   0.00
ANG(DEG)   -20.6  -20.6  -20.6  -20.6  -20.6
```

Event Information

Pre-Fault Data

Fault Data

Line-Current Differential Status

Figure 9.13 Example Summary Section of the SEL-411L Event Report

Settings Section of the Event Report

The final portion of an event report is the settings section. See *Figure 9.14* for the locations of items included in a sample settings section of an event report. If you want to exclude the settings portion from an event report, use the **EVE NSET** command.

The settings portion of the event report lists important relay settings at the time the relay event triggered. The event report shows Group, Global, Output, protection SELOGIC control equation settings, Alias settings, and some Port 5 settings. For the Group settings and the protection SELOGIC settings, the relay reports only the active group. The settings order in the event report is the same order as when you issue a **SHOW** command from a terminal.

```
Group 1
Line Configuration
CTRW    := 400      CTRX    := 400      PTRY    := 3636     VNOMY   := 115
PTRZ    := 3636     VNOMZ   := 115      Z1MAG   := 4.72     Z1ANG   := 82.60
Z0MAG   := 14.50    Z0ANG   := 75.70    EFLOC   := Y
  •
  •
  •

Global
General Global Settings
SID     := "Station A"
RID     := "Relay 1"
NUMBK   := 2
BID1    := "Breaker 1"
BID2    := "Breaker 2"
NFREQ   := 60       PHROT   := ABC      DATE_F  := MDY
FAULT   := NA
  •
  •
  •
```

Active Group Settings

Global Settings

Figure 9.14 Settings Section of the Event Report

Output Interface Board #1 OUT201 := 3PT OUT202 := BK1CL OUT203 := BK2CL OUT204 := NA OUT205 := NA OUT206 := NA OUT207 := NA OUT208 := NA • • •	Output Settings
Remote Analog Outputs RA001 := NA RA002 := NA • • • RA061 := NA RA062 := NA RA063 := NA RA064 := NA	Remote Analog Settings
Mirrored Bits Transmit Equations TMB1A := NA • • • TMB8B := NA	MIRRORED BITS Settings
Protection 1 Freeform Protection SELOGIC 1: ### PROTECTION FREEFORM AUTOMATION EXAMPLE 2: ### 3: ### SET CONTROL VARIABLE 1 4: ### ASSERTS WHEN PRIMARY POSITIVE SEQUENCE IS 5: ### GREATER THAN 90% OF 230 KV DIVIDED BY SQRT 3 6: PSV01 := V1M >= 119.5 #90% OF 230 KV DIVIDED BY SQRT 3	Active Protection Logic Settings
Alias Relay Aliases (Relay Word Bit or Analog Quantity name, 7 Character Alias [0-9 A-Z _]) 1: EN,"REL_EN"	Alias Settings

Figure 9.14 Settings Section of the Event Report (Continued)

CEVENT

The relay provides a Compressed ASCII event report for SCADA and other automation applications. QuickSet uses Compressed ASCII commands to gather event report data. If you want to view the Compressed ASCII event report data, use a terminal to issue ASCII command **CEV**. This is a comma-delimited ASCII file. The relay appends a four-digit hex checksum at the end of the lines in the Compressed ASCII report.

Items included in the Compressed ASCII event report are similar to the event report, although the relay reports the items in a special order. CEV files (like COMTRADE files) include all eight Relay Word bits from each row of the Relay Word used as the base set for the relay (see *Section 7: Metering, Monitoring, and Reporting* in the product-specific instruction manual for a list of these bits). Additionally, it includes the rows containing those Relay Word bits configured for inclusion by the ERDG setting. For the purpose of improving products and services, SEL sometimes changes the items and item order.

Event Summary

You can retrieve a summary version of stored event reports as event summaries. These short-form reports present vital information about a triggered event. The relay generates an event in response to power system faults and other trigger events (see *Triggering Data Captures and Event Reports on page 9.7*). The summary information available depends on the specific relay. See *Section 7: Metering, Monitoring, and Reports* in the product-specific instruction manual for the details of the summary event report for a specific relay.

The relay can be configured to automatically send an event summary on serial ports (see *Automatic Messages on page 15.33*).

Viewing the Event Summary

Access the event summary from the communications ports and communications cards. View and download event summaries from Access Level 1 and higher. You can independently acknowledge a summary (with the **SUM ACK** command) at each communications port so that you and users at other ports (SCADA, Engineering, etc.) can retrieve a complete set of summary reports. To acknowledge and remove a summary, you must first use the **SUM N(EXT)** command to view that summary.

You can use the **SUM** command to retrieve event summaries by date or date range, and by event number. (The relay labels each new event with a unique number as reported in the **HIS** command history report; see *Event History on page 9.27*.)

Table 9.1 lists the **SUM** commands. See *SUMMARY on page 14.62* for complete information on the **SUM** command.

Table 9.1 SUM Command

Command	Description
SUM	Return the most recent event summary (with header).
SUM *n*	Return a particular *n*[a] event summary (with header).
SUM ACK	Acknowledge the event summary on the present communications port.
SUM N	View the oldest unacknowledged event summary (**N** = next).

[a] The parameter n indicates event order or serial number.

You can also view event summaries by using SYNCHROWAVE Event.

CSUMMARY

The relay outputs a Compressed ASCII summary report for SCADA and other automation applications. Issue ASCII command CSU to view the Compressed ASCII summary report. This is a comma-delimited ASCII file. The relay appends a four-digit hex checksum at the end of the lines in the Compressed ASCII report.

Items included in the Compressed ASCII summary report are similar to those included in the summary report, although the relay reports the items in a special order. For the purpose of improving products and services, SEL sometimes changes the items and item order.

Event History

The event history gives you a quick look at recent relay activity. The relay labels each new event with a unique number from 10000 to 42767. (At 42767 the relay returns to 10000 for the next event number and then continues to increment.) See *Figure 9.15* for a sample event history.

The event history typically contains the following:

- Standard report header
  - Relay and terminal identification
  - Date and time of report
- Event number
- Event date and time
- Event type
- Location of fault (if applicable)
- Maximum phase current from summary fault data
- Active group at the trigger instant
- Targets

Figure 9.15 is a sample event history from a terminal.

```
Relay 1                                       Date: 03/16/2001  Time: 11:57:27.803
Station A                                     Serial Number: 2001001234
#        DATE         TIME      EVENT  LOCAT   CURR GRP TARGETS
10007 03/15/2001 23:30:49.026 BCG T   48.17   8892  1  INST TIME ZONE_1 B_PHASE
10006 03/15/2001 07:15:00.635 ABC T   22.82   8203  1  INST ZONE_1 A_PHASE bk1rs
10005 03/15/2001 06:43:53.428  TRIG  $$$$.$$     0  1
```

Event Number | Event Type | Fault Location | Active Group

Figure 9.15 Sample SEL-411L Event History

The event types in the event history are the same as the event types in the event summary.

The event history report indicates events stored in relay nonvolatile memory. The relay places a blank row in the history report output; items that are above the blank row are available for viewing (use the **EVE** and **CEV** commands). Items that are below the blank row are no longer in relay memory; these events appear in the history report to indicate past power system performance. The relay does not ordinarily modify the numerical or time order in the history report. However, if an event report is corrupted (power was lost during storage, for example), the relay lists the history report line for this event after the blank row.

Viewing the Event History

Access the history report from the communications ports and communications cards. View and download history reports from Access Level 1 and higher. You can also clear or reset history data from Access Levels 1 and higher. You can independently clear/reset history data at each communications port so that you and users at other ports (SCADA, Engineering, etc.) can retrieve complete history reports. You can also clear all history data from all ports (with the **HIS CA** command).

Use the **HIS** command from a terminal to obtain the event history. You can view event histories by date or by date range, or you can specify the number of the most recent events that the relay returns. See *HISTORY on page 14.41* for information on the **HIS** command. *Table 9.2* lists the **HIS** commands.

Table 9.2 HIS Command

Command	Description
HIS	Return event histories with the oldest at the bottom of the list and the most recent at the top of the list.
HIS *k*	Return the *k* most recent event summaries with the oldest at the bottom of the list and the most recent at the top of the list.
HIS *date1*	Return the event summaries on date *date1*[a].
HIS *date1 date2*	Return the event summaries from date1 to date2, with date1 at the bottom of the list and date2 at the top of the list.
HIS C	Clear all event data on the present port.
HIS R	Clear all event data on the present port.
HIS CA	Clear event data for all ports.
HIS RA	Clear event data for all ports.

[a] Use the same date format as Global setting DATE_F.

You can use QuickSet to retrieve the relay event history. Use the **Tools > Events > Get Event Files** menu to view the Event History dialog box. See *Analyze Events on page 2.33* for information and examples.

CHISTORY

The relay outputs a Compressed ASCII history report for SCADA and other automation applications. Issue the **CHI** command to view the Compressed ASCII history report. This is a comma-delimited ASCII file. The relay appends a four-digit hex checksum at the end of each history in the Compressed ASCII history report.

Items included in the Compressed ASCII history report are similar to those included in the history report, although the relay reports the items in a special order. For the purpose of improving products and services, SEL sometimes changes the items and item order.

History File Download

You can also download the history report file from the relay. Use a terminal emulation program with file transfer capability. At an Access Level 1 prompt or higher type **FILE READ REPORTS HISTORY.TXT <Enter>**. Start the terminal download routine to store the file on your computer. If you want the Compressed ASCII file, type **FILE READ REPORTS CHISTORY.TXT <Enter>**. In addition, you can use QuickSet to download history files.

Sequential Events Recorder (SER)

The Sequential Events Recorder (SER) gives you detailed information on relay states and relay element operation. The SER captures and time-tags state changes of Relay Word bit elements and relay conditions. These conditions include power-up, relay enable and disable, group changes, settings changes, memory overflow, diagnostic restarts, SER autoremoval/reinsertion, and Ethernet firmware upgrade attempts. The relay stores the latest 1000 SER entries to nonvolatile memory. *Figure 9.16* is a sample SER report.

The SER report contains the following:

- ➤ Standard report header
  - ➢ Relay and terminal identification
  - ➢ Date and time of report
- ➤ SER number
- ➤ SER date and time
- ➤ Relay element or condition
- ➤ Element state
- ➤ TiDL commissioning statuses. (Applies only to TiDL [T-Protocol] relays.)

```
Relay 1                                     Date: 03/16/2001  Time: 13:09:29.341
Station A                                   Serial Number: 2001001234
FID=SEL-411L-R101-V0-Z001001-D20010315
#      DATE        TIME          ELEMENT              STATE
6    03/15/2001  00:00:00.004  Power-up             Group 1
5    03/15/2001  00:00:00.022  Relay                Enabled
4    03/15/2001  00:30:00.021  GROUND O/C 1 LINE 1  51S1 PICKED UP
3    03/15/2001  00:30:03.221  GROUND O/C 1 LINE 1  51S1 TIMEOUT
2    03/15/2001  00:32:00.114  GROUND O/C 1 LINE 1  51S1 RESET
1    03/15/2001  00:32:00.114  GROUND O/C 1 LINE 1  51S1 DROPOUT
```

SER Number

Relay Element or Condition

Figure 9.16 Sample SER Report

In the SER report, the oldest information has the highest number. The newest information is always #1. When using a terminal, you can order the positions of the SER records in the SER report.

Viewing the SER Report

The relay displays the SER records in ASCII and binary formats.

Access the SER report from the communications ports and communications cards in Access Level 1 and higher. You can independently clear/reset already viewed SER data at each communications port (with the **SER CV** or **SER RV** command) so that users at other ports (SCADA, Engineering, for example) can retrieve complete SER reports. The **SER CV** or **SER RV** command will not clear any SER data that has been recorded, but not viewed, on a particular serial port. To clear all SER data on a serial port, use the **SER C** or **SER R** command.

To clear all SER data from all serial ports, use the **SER CA** or **SER RA** command, available only from Access Levels P, A, O, and 2. This procedure would normally be used after relay commissioning or testing.

Use an ASCII terminal, SEL Grid Configurator, or QuickSet to examine SER records. You can use the **SER** command to view the SER report by date, date range, SER number, or SER number range. The relay labels each new SER record with a unique number.

Table 9.3 SER Commands

Command	Description
SER	Return the 20 most recent records from the SER, with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list.
SER *k*	Return the *k* most recent records from the SER, with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list.
SER *m n*[a]	Return the SER records from *m* to *n*. If *m* is greater than *n*, records appear with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list. If *m* is less than *n*, records appear with the most recent (lowest number) at the top of the list and the oldest (highest number) at the bottom of the list.
SER *date1*[b]	Return the SER records on date *date1*.
SER *date1 date2*	Return the SER records from *date1* at the top of the list to *date2* at the bottom of the list.
SER C or **SER R**	Clear SER records on the present port.
SER CA or **SER RA**	Clear SER data for all ports.
SER CV or **SER RV**	Clear viewed SER records on the present port.
SER D	List chattering SER elements that the relay is removing from the SER records.

[a] The parameters m and n indicate SER numbers that the relay assigns at each SER trigger.
[b] Use the same date format as Global setting DATE_F.

You can retrieve SER records with QuickSet. The **HMI > Meter and Control** menu item gives you the SER report. The latest 200 SER events are viewable on the front-panel display through the front-panel EVENTS MENU.

CSER

The relay outputs a Compressed ASCII SER report for SCADA and other automation applications. Issue the CSE command to view the Compressed ASCII SER report. A sample of the SER report appears in *Figure 9.17*; this is a comma-delimited ASCII file. The relay appends a four-digit hex checksum at the end of the lines in the Compressed ASCII report.

Items included in the Compressed ASCII SER report are similar to the SER report, although the relay reports the items in a special order. For the purpose of improving products and services, SEL sometimes changes the items and item order.

```
"RID","SID","FID","03e2"
"Relay 1","Station A","SEL-411L-R101-V0-Z001001-D20010315","0dfc"
```
Report Header

```
"#","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","ELEMENT","STATE","0FC8"
1,3,15,2001,00,32,00,114,"GROUND_O/C_1_LINE_1","51S1_DROPOUT","09D2"
2,3,15,2001,00,32,00,114,"GROUND_O/C_1_LINE_1","51S1_RESET","08E7"
3,3,15,2001,00,30,03,221,"GROUND_O/C_1_LINE_1","51S1_TIMEOUT","09B0"
4,3,15,2001,00,30,00,021,"GROUND_O/C_1_LINE_1","51S1_PICK_UP","097B"
5,3,15,2001,00,00,00,222,"Relay","Enabled","09BA"
6,3,15,2001,00,00,00,004,"Power-up","Group 1","0A0A"
```
SER Data (six records)

Figure 9.17 Sample Compressed ASCII SER Report

SER File Download

You can also download the SER data as a file from the relay. Use a terminal emulation program with file transfer capability. At an Access Level 1 prompt or higher type **FILE READ REPORTS SER.TXT <Enter>**. Start the terminal download routine to store the file on your computer. If you want the Compressed ASCII file, type **FILE READ REPORTS CSER.TXT <Enter>**.

Setting SER Points

NOTE: The relay is limited to storing SER points at a rate of approximately 6000 per hour. Be careful to select points that will not lead to this rate being exceeded.

You program the relay elements that trigger an SER record. You can select as many as 250 elements. These triggers, or points, can include control input and control output state changes, element pickups and dropouts, recloser state changes, and so on. Use the **SET R** command from a terminal, or use the SEL Grid Configurator or QuickSet **Report** branch of the Settings tree view to enter **SER Points**.

Use the text-edit line mode settings method to enter or delete SER elements. To set an SER element, enter the five items of this comma-delimited string (all but the first parameter are optional): Relay Word Bit, Reporting Name, Set State Name, Clear State Name, HMI Alarm.

The relay defaults to the element name when you do not provide a reporting name. The default names for the set and clear states are Asserted and Deasserted, respectively. By default, SER Points are not configured for HMI alarm display. The relay always creates an SER record for power-up, relay enable and relay disable, any group change and settings change, diagnostic restart, and memory overflow.

Automatic Deletion and Reinsertion

The SER also includes an automatic deletion and reinsertion function. The relay automatically deletes oscillating SER items from SER recording. This function prevents overfilling the SER buffer with “chattering” information. Set Report setting ESERDEL (Enable SER Delete) to Y to enable this function, and select values for the setting SRDLCNT (SER Delete Count) and the setting SRDLTIM (SER Delete Time) that mask the chattering SER element. The relay removes an item from all SER recordings once a point has changed state more than SRDLCNT times in an SRDLTIM period. Once deleted from SER recording, the relay ignores the item for a 10 • SRDLTIM period. At the end of this period, the relay checks the chatter criteria and, if the point does not exceed the criteria, the relay automatically reinserts the item into SER recording. To see a list of deleted SER points, use the **SER D** command.

Signal Profiling

Use the analog signal profiling function to record and track values of as many as 20 analog quantities. This function provides data in CASCII that is compatible to import directly into applications like spreadsheets. Specify the specific analog quantities for profiling with the SPAQ Report settings. At the data acquisition rate of 5 minutes, the relay stores at least 10 days of all analog signals selected for profiling in nonvolatile memory. The report includes the time of acquisitions and the magnitude of each selected analog quantity. By defining conditions in the signal profiling enable SELOGIC variable setting (SPEN), you can record analog values at particular periods or conditions of interest.

SPAQgg (Analog Quantities for Signal Profiling)

Enter any analog quantity available in the relay from the Analog Quantity list in this freeform setting.

SPAR (Signal Profile Acquisition Rate)

Although you can select as many as 20 analog quantities, the signal acquisition rate is the same for all analog quantities. Select an acquisition rate of 1, 5, 15, 30, or 60 minutes.

SPEN (Signal Profile Enable)

Use this SELOGIC control equation to specify conditions under which the profiling must take place. If there are no conditions, be sure to set SPEN = 1, or else no data are recorded (default value of NA disables the function).

SECTION 10

Testing, Troubleshooting, and Maintenance

This section address the philosophy of relay testing, general approaches to testing and troubleshooting, troubleshooting common problems, and a few maintenance items. This section begins with guidelines for determining and establishing test routines for SEL-400 series relays. Follow the standard practices of your company in choosing testing philosophies, methods, and tools. The relay incorporates self-tests to help you diagnose potential difficulties should they occur. The section Relay Troubleshooting contains a quick-reference table for common relay operation problems.

Topics presented in this section include the following:

All SEL-400 series relays are factory-calibrated; this section contains no calibration information. If you suspect that the relay is out of calibration, contact your Technical Service Center or the SEL factory.

Testing Philosophy

Protective relay testing generally consists of three categories: acceptance testing, commissioning testing, and maintenance testing. The categories differ in testing complexity and according to when these activities take place in the life of the relay.

Each testing category includes particular details as to when to perform the test, the testing goals at that time, and the relay functions that you need to test. This information is a guide to testing SEL-400 series relays; be sure to follow the practices of your company for relay testing.

Acceptance Testing

SEL performs detailed acceptance testing on all new relay models and versions. We are certain that your relay meets published specifications. Even so, you can perform acceptance testing on a new relay model to become familiar with the relay operating theory and settings; this familiarity helps you apply the relay accurately and correctly. A summary of acceptance testing guidelines is presented in *Table 10.1*.

Table 10.1 Acceptance Testing

Details	Description
Time	Test when qualifying a relay model for use on the utility system.
Goals	a) Confirm that the relay meets published critical performance specifications such as operating speed and element accuracy. b) Confirm that the relay meets the requirements of the intended application. c) Gain familiarity with relay settings and capabilities.
Test	Test all protection elements and logic functions critical to your intended application.

Commissioning Testing

SEL performs a complete functional check and calibration of each SEL-400 series relay before shipment so that your relay operates correctly and accurately. You should perform commissioning tests to verify proper connection of the relay to the power system and all auxiliary equipment. Check control signal inputs and outputs. Check breaker auxiliary inputs, SCADA control inputs, and monitoring outputs. Use an ac connection test to verify that the relay current and voltage inputs are the proper magnitude and phase rotation.

Brief fault tests confirm that the relay settings and protection scheme logic are correct. You do not need to test every relay element, timer, and function in these tests.

At commissioning, use the relay **METER** command to verify the ac current and voltage magnitude and phase rotation (see *Examining Metering Quantities on page 3.34*).

Use the **PUL** command to pulse relay control output operation. Use the **TAR** command to view relay targets and verify that control inputs are operational. Use **TEST DB**, **TEST DB2**, and **TEST FM** to check SCADA interfaces. (See *TEST DB on page 14.65*, *TEST DB2 on page 14.66*, and *TEST FM on page 14.68* for information on these relay commands.)

Table 10.2 lists guidelines for commissioning testing. For further discussion of these tests, see *Checking Relay Operation* in *Section 3: Testing* of the product-specific instruction manual.

Table 10.2 Commissioning Testing

Details	Description
Time	Test when installing a new protection system.
Goals	a) Validate all system ac and dc connections. b) Confirm that the relay functions as intended using your settings. c) Check that all auxiliary equipment operates as intended. d) Check SCADA interface.
Tests	Test all connected/monitored inputs and outputs, and the polarity and phase rotation of ac connections. Make simple checks of protection elements. Test communications interfaces.

TiDL System Commissioning

See *Section 19: Digital Secondary Systems* for information on commissioning a TiDL system.

Maintenance Testing

All SEL-400 series relays use extensive self-testing routines and feature detailed metering and event reporting functions. These features reduce your dependence on routine maintenance testing. When you want to perform maintenance testing, follow the recommendations in *Table 10.3*.

Table 10.3 Maintenance Testing

Details	Description
Time	Test at scheduled intervals or when there is an indication of a problem with the relay or power system.
Goals	a) Confirm that the relay is measuring ac quantities accurately. b) Check that scheme logic and protection elements function correctly. c) Verify that auxiliary equipment functions correctly.
Tests	Test all relay features/power system components that did not operate during an actual fault within the past maintenance interval.

You can use the relay reporting features as maintenance tools. Periodically compare the relay **METER** command output to other meter readings on a line to verify that the relay measures currents and voltages correctly and accurately. Use the circuit breaker monitor, for example, to detect slow breaker auxiliary contact operations and increasing or varying breaker pole operating times. For details on these features, see *Circuit Breaker Monitor on page 8.1*.

Each occurrence of a fault tests the protection system and relay application. Review relay event reports in detail after each fault to determine the areas needing your attention. Use the event report current, voltage, and relay element data to determine that the relay protection elements and communications channels operate properly. Inspect event report input and output data to determine whether the relay asserts outputs at the correct times and whether auxiliary equipment operates properly.

At each maintenance interval, the only items to be tested are those that have not operated (via fault conditions and otherwise) during the maintenance interval. The basis for this testing philosophy is simple: you do not need to perform further maintenance testing for a correctly set and connected relay that measures the power system properly and for which no relay self-test has failed.

SEL-400 series relays are based on microprocessor technology; the relay internal processing characteristics do not change over time. For example, if time-overcurrent element operating times change, these changes occur because of alterations to relay settings and/or differences in the signals applied to the relay. You do not need to verify relay element operating characteristics as a part of maintenance checks.

SEL recommends that you limit maintenance tests on SEL relays according to the guidelines listed in *Table 10.3*. You will spend less time checking relay operations that function correctly. You can use the time you save to analyze event data and thoroughly test systems needing more attention.

Testing Features and Tools

All SEL-400 series relays provide the following features that can assist you during relay testing:

- ➤ Metering
- ➤ High-resolution oscillography
- ➤ Event reports
- ➤ Event summary reports
- ➤ Sequential Events Recorder (SER) reports
- ➤ IEC 61850 Mode/Behavior*
- ➤ IEC 61850 Simulation Mode*

*Only available on IEC 61850-enabled relays.

Certain relay commands are useful in confirming relay operation. The following commands, for example, aid you in testing the relay:

- ➤ **TAR**
- ➤ **PUL**
- ➤ **TEST DB**
- ➤ **TEST DB2**
- ➤ **TEST FM**
- ➤ **TEST SV**

In addition, the relay incorporates a low-level test interface where you can interrupt the connection between the relay input transformers and the input processing module. Use the low-level test interface to apply reduced-scale test quantities from the SEL-4000 Relay Test System; you do not need to use large power amplifiers to perform relay testing.

You can use the **TEST SV** and **COM SV** commands to verify Sampled Values (SV) communications

Metering

NOTE: Some relays support a single dc battery monitor. See the relay-specific instruction manual to determine whether one or two dc battery monitors are supported.

The specific metering data available depends on the relay model. See *Section 7: Metering, Monitoring, and Reporting* in the product-specific instruction manual for detailed information. In general, the metering data show the ac currents and voltages (magnitude and phase angle) connected to the relay in primary values. In addition, metering shows many other quantities including the power system frequency (FREQ) and the voltage input to the station dc battery monitors (Vdc1 and Vdc2). Compare these quantities against quantities from other devices of known accuracy. The metering data are available at the serial ports, from the ACSELERATOR QuickSet SEL-5030 Software HMI, and at the front-panel LCD METER menu. See *METER on page 14.47*, *Meter on page 4.16*, *QuickSet HMI on page 2.30*, and *Examining Metering Quantities on page 3.34* for more information.

High-Resolution Oscillography

NOTE: Control Inputs are sampled at 2 kHz, and the raw binary data (prior to debounce timer conditioning) is available in high-resolution oscillography. The COMTRADE data labels for raw control input data are IN101–IN107, IN201–IN2nn, IN301–IN3nn,IN401–IN4nn, IN501–IN5nn, based on installed hardware, where nn = 01–08 or 01–24.

The relay takes an unfiltered data snapshot of the power system at each event trigger or trip. The relay samples power system data at high sample rates from 1 kHz to 8 kHz. You can use SEL-5601-2 SYNCHROWAVE Event Software or other COMTRADE viewing program to export and view these raw data in a binary COMTRADE file format. Use high-resolution oscillography to capture fast power system transients or to examine low-frequency anomalies in the power system. See *Raw Data Oscillography on page 9.10* for more information.

Event Reports

NOTE: Control Inputs are sampled at 2 kHz, and then conditioned by a debounce timer. The resulting Relay Word bits are updated 8 times/cycle and are available in standard event report files.

The relay also generates a filtered-quantities event report in response to faults or disturbances. Each event report contains information on current and voltage, relay element states, control inputs, and control outputs. If you are unsure of the relay response or your test method, the event report provides you with information on the operating quantities that the relay used at the event trigger. The relay provides oscillographic displays of the filtered event report data, which give you a visual tool for testing relay operating quantities. You can use the serial ports and QuickSet to view event reports. See *Event Reports, Event Summaries, and Event Histories on page 9.13* for a complete discussion of event reports.

Event Summary Reports

The relay generates an event summary for each event report; use these event summaries to quickly verify proper relay operation. With event summaries, you can quickly compare the reported fault current and voltage magnitudes and angles against the reported fault location and fault type. If you question the relay response or your test method, you can obtain the full event report and the high-resolution oscillographic report for a more detailed analysis. See *Event Summary on page 9.26* for more information on the event summary.

SER Reports

The relay provides an SER report that time tags changes in relay elements, control inputs, and control outputs. Use the SER for convenient verification of the pickup and dropout of any relay element. For a complete discussion of the SER, see *Sequential Events Recorder (SER) on page 9.28*.

IEC 61850 Mode/Behavior and Simulation Mode

An IEC 61850 technology-based substation differs from traditional substations in that analog and binary signals are exchanged between process-level, bay-level, and substation-level IEDs via Ethernet messaging. The IEC 61850 standard supports various types of testing via IEC 61850 Mode/Behavior and Simulation mode. Refer to *IEC 61850 Testing on page 10.10*.

Test Commands

TAR Command

Use the **TAR** command to view the state of relay control inputs, relay outputs, and relay elements individually during a test. You can see relay targets at the serial ports, and from the front-panel LCD (see *TARGET on page 14.63* and *Operation and Target LEDs on page 4.33*).

PUL Command

Use the **PUL** command to test the control output circuits. The specified output closes if open, or opens if closed. You can use the **PUL** command at the serial ports, in the QuickSet HMI, and from the front-panel LCD (see *PULSE on page 14.55*, *QuickSet HMI on page 2.30*, and *Operation and Target LEDs on page 4.33*).

TEST DB Command

Use the **TEST DB** command for testing the relay database, which is used for Fast Message Data Access. The **TEST DB** command can be used to override any value in the relay database. Use the **MAP 1** command and the **VIEW 1** command to inspect the relay database (see *MAP on page 14.46*). You must be familiar with the relay database structure to use the **TEST DB** command effectively; see *Section 10: Communications Interfaces* in the product-specific instruction manual for more information.

TEST DB2 Command

Use the **TEST DB2** command to test the DNP3 and IEC 61850 interfaces. Values you enter are "override values." For more information on DNP3, see *Section 16: DNP3 Communication*. For more information on IEC 61850, see *Section 17: IEC 61850 Communication*.

TEST FM Command

Use the **TEST FM** command to override normal Fast Meter quantities for testing purposes. You can only override "reported" Fast Meter values (per-phase voltages and currents). You cannot directly test Fast Meter values that the relay derives from the reported values (power, sequence components, etc.). For more information on Fast Meter, see *SEL Fast Meter, Fast Operate, Fast SER Messages, and Fast Message Data Access on page 15.34*.

TEST SV Command

NOTE: The **TEST SV** command is not supported in the SEL-487E-5 SV Publisher.

Use the **TEST SV** command on SEL merging unit, e.g., SEL-401 to enter SEL TEST SV mode. While in this mode, the merging unit publishes fixed secondary quantities scaled by the CTR and PTR ratios.

When you use the **TEST SV** command on the SEL SV subscriber, the SV relay enters the SEL TEST SV mode. The relay accepts SV messages from a merging unit that is also in TEST SV mode. Refer to *TEST SV on page 14.69* for more details.

Test Methods

Use the following methods to conveniently test the pickup and dropout of relay elements and other relay functions:

- Target indications (element pickup/dropout)
- Control output closures
- SER reports

The tests and procedures in the following sections are for 5 A relays. Scale values appropriately for 1 A relays.

Once you have completed a test, return the relay settings that you modified for the test to default or operational values.

Testing With Relay Word Bits

Use the communications port **TAR** command or the front panel to display the state of relay elements, control inputs, and control outputs. Viewing a change in relay element (Relay Word bit) status is a good way to verify the pickup settings you have entered for protection elements. See *Examining Relay Elements on page 3.42* for more information on examining relay elements by using a terminal and from the front panel.

Testing With Control Outputs

You can set the relay to operate a control output to test a single element. Set the SELOGIC control equation for a particular output (OUT101–OUT108, for example) to respond to the Relay Word bit for the element under test. See *Operating the Relay Inputs and Outputs on page 3.55* for configuring control inputs and control outputs. *Section 11: Relay Word Bits* in the product-specific instruction manual lists the names of the relay element logic outputs.

Example 10.1 Testing the 50P1 Element With a Control Output

This procedure shows how to set control output OUT105 to test the SEL-451 50P1 Phase Instantaneous Overcurrent element.

For this test, you must have a variable current source for relay testing and a control output closure indicating device such as a test set or a digital multimeter (DMM).

In this example, use Grid Configuator or QuickSet to configure the relay (see *Section 2: PC Software*).

Step 1. Establish communication with the relay through either SEL Grid Configurator or QuickSet, then read settings.

Step 2. Navigate to Main Board Outputs contact settings in the settings tree structure.

Example 10.1 Testing the 50P1 Element With a Control Output (Continued)

Step 3. Set OUT105 to respond to the 50P1 element pickup.

The software checks the validity of the setting you entered.

An invalid setting (you could have mistyped the element name) results in an error.

Step 4. Upload the new settings to the SEL-451.

If you see no error message, the new settings are loaded in the relay.

Step 5. Connect an indicating device to OUT105 on the relay rear panel.

A DMM measuring resistance can show an open circuit (open contact) or a low-resistance short (closed contact).

Step 6. Connect a test source to the relay.

a. Set the current output of a test source to zero output level.

b. Connect a single-phase current output of the test source to the IAW analog input.

Step 7. Increase the current source to produce a current magnitude greater than 15.00 A secondary in the relay (to test the element).

When the 50P1 element picks up, the relay changes the 50P1 Relay Word bit to logical 1 and closes the output contacts of control output OUT105.

The indicating device operates.

Testing With SER

You can set the relay to generate a report from the SER to test relay elements; include the element that you want to test in the SER **Points and Aliases** list. Set aliases for the element name, set state, and clear state in the relay SER to simplify reading the SER report. See *Sequential Events Recorder (SER) on page 9.28* for complete information on the SER.

Example 10.2 Testing the SEL-451 51S1 Element by Using the SER

The SER gives exact time data for testing time-overcurrent element time-outs. Subtract the 51S1T assertion time from the 51S1 assertion time to check the operation time for this element. Use the factory defaults for the operating quantity, pickup level, curve, time dial, electromechanical reset, and torque control (*Table 10.4*).

The procedure in the following steps shows how to set the SER trigger lists to capture the selectable operating quantity time-overcurrent element 51S1 operating times. The procedure also shows how to set the torque control supervision for the 51S1 element.

Example 10.2 Testing the SEL-451 51S1 Element by Using the SER (Continued)

Table 10.4 Selectable Operating Quantity Time-Overcurrent Element (51S1) Test Settings

Setting	Description	5A
51S1O	51S1 Operating Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, IA*n*R, IB*n*R, IC*n*R, IMAX*n*R, I1L, 3I2L, 3I0*n*)[a]	3I0L
51S1P	51S1 Overcurrent Pickup (0.25–16 A, secondary)	0.75
51S1C	51S1 Inverse-Time Overcurrent Curve (U1–U5, C1–C5)	U3
51S1TD	51S1 Inverse-Time Overcurrent Time Dial (0.50–15.00)	1.00
51S1RS	51S1 Inverse-Time Overcurrent EM Reset (Y, N)	N
51S1TC	51S1 Torque Control (SELOGIC control equation)	1

[a] n = L, 1, and 2 for Line, Circuit Breaker 1, and Circuit Breaker 2, respectively. R suffix selects rms quantities. For more information on rms, refer to RMS in the Glossary.

The relay uses *Equation 10.1* and *Equation 10.2* to determine the operating time for the 51S1 element. For a current input 50 percent greater than the default pickup, the test value, I_{TEST}, is:

$$\begin{aligned} I_{TEST} &= M \bullet (51S1P) \\ &= 1.5 \bullet (0.75\ A) \\ &= 1.125\ A \end{aligned}$$

Equation 10.1

where M is the pickup multiple and 51S1P is the element pickup value (see *Table 10.4*).

The operating time (t_p) for a time dial (TD) equal to 1 for the U3 (Very Inverse) Curve is:

$$\begin{aligned} t_p &= TD \bullet \left(0.0963 + \frac{3.88}{M^2 - 1}\right) \\ &= 1 \bullet 0.0963 + \frac{3.88}{1.5^2 - 1} \\ &= 3.2 \text{ seconds} \end{aligned}$$

Equation 10.2

In this example, use SEL Grid Configurator or QuickSet to configure the relay. You must have a computer that is communicating with the SEL-451 and running SEL Grid Configurator or QuickSet (see *Section 2: PC Software*). You also need a variable current source for relay testing.

Step 1. Establish communication with the relay through either SEL Grid Configurator or QuickSet, then read settings.

Step 2. Set the selectable operating quantity time-overcurrent element for test operation.

a. From Protection Elements View in SEL Grid Configurator, select the first 51 element available or open the **Group 1 > Set 1> Relay Configuration > Time Overcurrent** branch of the Settings tree view.

b. Verify that enable setting E51S (Selectable Inverse-Time Overcurrent Element) is set to 1.

Example 10.2 Testing the SEL-451 51S1 Element by Using the SER (Continued)

c. Change setting **51S1O Operating Quantity** to **3I0L**.

d. Change the remaining element configurations to match *Table 10.4*.

Step 3. View the SER settings.

a. Navigate to Report in the Settings tree view structure.

b. Select the **SER Points and Aliases** branch.

Step 4. Enter SER element names and aliases.

a. Assign an available SER Points and Aliases setting (SITM1 for example) to **51S1T**.

b. Type **GROUND O/C 1 LINE 1** in the **Reporting Name** field.

c. Type **51S1 TIMEOUT** in the **Set State Name** field.

d. Type **51S1 DROPOUT** in the **Clear State Name** field.

e. Repeat *Step a–Step d* for a second SER Points and Aliases setting (SITM2 for example), with setting values **51S1, GROUND O/C 1 LINE 1, 51S1 PICKED UP, 51S1 RESET**.

You can enter as many as 250 relay elements in the **SER Points and Aliases** list (see *Sequential Events Recorder (SER) on page 9.28*).

Step 5. Upload the new settings to the SEL-451.

If you see no error message, the new settings are loaded in the relay.

Step 6. Connect a test source to the relay.

a. Set the current output of a test source to zero output level.

b. Connect a single-phase current output of the test source to the IAW analog input.

Step 7. Test the element.

a. Increase the current source to produce a current magnitude of 1.125 A secondary in the relay.

b. Keep the current source at this level past the expected element time-out (longer than 3.2 seconds).

c. Return the current source to zero after the element times out.

Step 8. Navigate to the SER report on the relay front panel and verify the `51S1 PICKED UP` and `51S1 TIMEOUT` entries are shown.

The time difference between SER entries **51S1 PICKED UP** and **51S1 TIMEOUT** is approximately 3.2 seconds.

IEC 61850 Testing

Commissioning and maintenance testing of a relay typically involves applying an alternative source of secondary voltages and currents as well as isolating relay output contacts used to trip circuit breakers. Traditionally, physical panel switches have facilitated these testing operations. More recently, the IEC 61850 standard has introduced mechanisms for emulating these switching and isolation functions within the communications protocol itself. This gives testing personnel additional flexibility in designing test procedures. This section discusses three testing mechanisms: IEC 61850 Mode/Behavior, IEC 61850 Simulation mode, and the SEL **TEST SV** command.

NOTE: The example in this section is meant to illustrate the use of IEC 61850 standard operating modes. Always follow the testing practices and philosophy of your company.

IEC 61850 describes different protection and automation functions according to standardized language (IEC 61850-7-4). It describes substation protection and automation functions in abstract models and organizes components in hierarchical structures. A CID file describes components of an IED that is composed of logical devices and logical nodes (protection and automation functions, such as the distance protection element PDIS). An IED can host multiple logical devices, and, in turn, logical devices may host a group of logical nodes. Additionally, logical nodes inside a logical device can serve as supervision signals to logical nodes of other logical devices.

IEC 61850 Mode/Behavior are tools to isolate specific IEDs and logical nodes for testing, analogous to how test switches are used to physically isolate specific devices in a testing procedure. IEC 61850 Simulation mode is used to inject test signals into the network that will be used by subscribing IEDs being tested.

When in IEC 61850 Simulation mode, and the normal messages and simulated messages are both present, the IED processes the simulated messages and ignores the normal ones. For example, if an SV subscriber in IEC 61850 Simulation mode sees an SV message and a similar SV message with the simulated flag set in the header, the subscriber processes the simulated SV messages and ignores the normal SV messages until the relay is no longer in Simulation mode. IEC 61850 Simulation mode has no effect on the Manufacturing Message Specification (MMS) communications service.

IEC 61850 Simulation mode is applied at the IED level. Additionally, messages produced by the IED in response to simulated data do not have their own simulation flag set. The simulation flag does not propagate automatically. For these reasons, IEC 61850 Simulation mode is insufficient to handle many testing scenarios, especially when device isolation in an energized substation is necessary.

IEC 61850 Mode/Behavior is a mechanism that enables isolation of one IED or a set of IEDs in a system. While the IED or a logical node is placed in different modes, the IED reports its status by setting or clearing the quality attribute validity and test. While other IEDs or logical nodes do not participate in the testing, they remain in the On mode and discard messages with test quality set. *Example 10.3* describes an example of applying IEC 61850 Mode/Behavior and Simulation mode.

See *IEC 61850 Simulation Mode on page 17.38* and *IEC 61850 Mode/Behavior on page 17.38* for operation details.

Example 10.3 Maintenance Testing SEL-487B Bus Differential Protection

Figure 10.1 describes a partial logical diagram for a breaker-and-a-half bus protection. In this application, SEL-401 #1 and SEL-401 #3 provide current measurements to the SEL-487B SV Subscriber for bus differential protection. If the SEL-487B detects an internal fault, it sends a trip signal to SEL-401 #1 and SEL-401 #3 to operate Circuit Breaker 1 and Circuit Breaker 3, respectively. The logical models for current and voltage measurement are logical nodes TCTR and TVTR. The logical model for circuit breakers is represented by logical node XCBR. The logical node PDIS represents distance protection. Logical node IHMI represents the human-machine interface. *Figure 10.1* describes the logical model of the application. *Table 10.5* describes the data GOOSE and SV messages transmit.

Example 10.3 Maintenance Testing SEL-487B Bus Differential Protection (Continued)

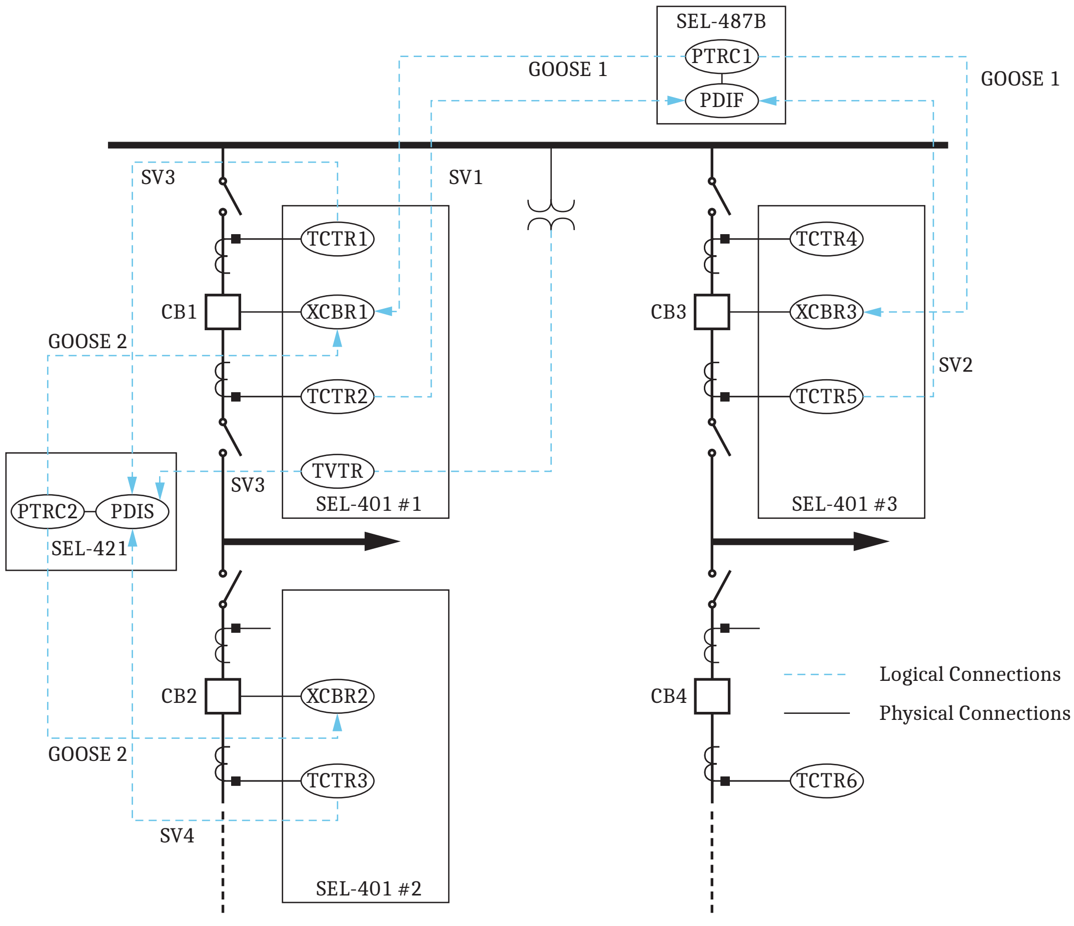


Figure 10.1 IEC 61850 Logical Modeling

Table 10.5 Data Transmitted in GOOSE and SV Messages

Messages	Information Transmitted
GOOSE 1	PTRC1.Op.general PTRC1.q
GOOSE 2	PTRC.Op.general PTRC2.q
SV1	TCTR2
SV2	TCTR5
SV3	TCTR1, TVTR
SV4	TCTR3

Example 10.3 Maintenance Testing SEL-487B Bus Differential Protection (Continued)

NOTE: The procedures specified in this section are for initial relay testing only. Follow your company policy for connecting the relay to the power system.

To test a device in an energized substation, perform the following general steps:

Step 1. Isolate the device(s) under test.

Step 2. Connect a test set to those device(s) under test.

Step 3. Apply test signals and execute test.

Step 4. Disconnect the test equipment and place the device(s) back in normal operation.

Figure 10.2 illustrates use of IEC 61850 Mode/Behavior and IEC 61850 Simulation mode in the process of testing PDIF of the SEL-487B in *Figure 10.1*.

Step 1. Isolate the SEL-487B by placing the device into Test/Blocked mode and then Simulation mode.

Change SEL-487B IEC 61850 Mode/Behavior and Simulation mode so that Mod.stVal = Test/Blocked and Sim.stVal = True. The IED is isolated, so SV messages from SEL-401 #1 and SEL-401 #3 are not processed. The outgoing GOOSE messages from the SEL-487B sent to control CB1 and CB3 are not processed because they are flagged with q.test = True and the SEL-401 #1 and SEL-401 #3 are in the On mode. The MMS communication between the PDIF and logical node IHMI is also flagged with q.test = True. The SEL-487B is logically isolated and its contact outputs are physically blocked as *Figure 10.2* shows. If the device is placed into Test mode (as opposed to Test/Blocked mode), the physical contact outputs operate if the device detects a bus fault based on received testing SV messages.

SEL-400 series relays support other communications protocols such as MIRRORED BITS and IEEE C37.118 Synchrophasor Protocols. If the device under test communicates with other IEDs over protocols that IEC 61850 does not define, it is necessary to consider the impact of IEC 61850 Simulation mode and Mode/Behavior. For example, consider the impact on block signals exchanged via MIRRORED BITS protocol when testing requires that there be no misoperation on IEDs that receive MB messages.

To support such situations, you may need to build logic to provide supervisory information that is transmitted via MB.

For example, if we want to block MB from transmitting a status change of PLT01 while the relay is in Blocked or Test/Blocked mode, we can supply the following custom logic example to the protection logic.

PSV01 := (I850MOD = 2) OR (I850MOD = 4)

Example 10.3 Maintenance Testing SEL-487B Bus Differential Protection (Continued)

PSV01 can thus supervise transmitted MIRRORED BITS.

For example, TMB1A := PLT01 AND NOT PSV01.

If using IEEE C37.238 Synchrophasor Protocol, engineers can use SELOGIC control equation PMTEST to associate IEC 61850 Mode/Behavior with Synchrophasor data quality. PMTEST is the SELOGIC control equation that indicates PMU is in a test mode.

PSV01 := (I850MOD = 2) OR (I850MOD = 4)

PMTEST := PSV01

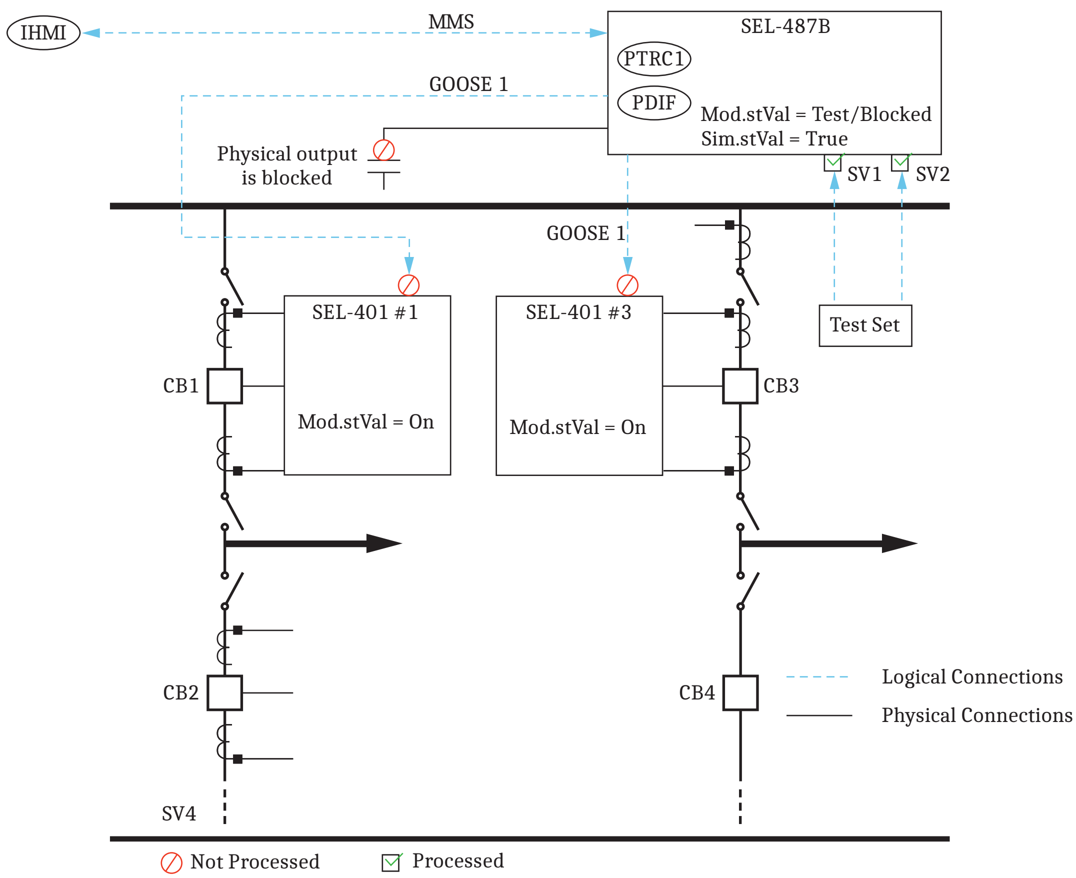


Figure 10.2 Isolate an IED Through Use of IEC 61850 Mode/Behavior and Simulation Mode

Step 2. Connect test equipment and start injecting testing signals. In this example, the test set transmits SV messages SV1_Test and SV2_Test with q.test = True and the simulation flag = True.

Step 3. Use the testing equipment to vary testing signals, and execute required test cases to verify the PDIF function. *Table 10.6* lists the quality test and simulation flag for the normal and simulated GOOSE and SV messages.

Example 10.3 Maintenance Testing SEL-487B Bus Differential Protection (Continued)

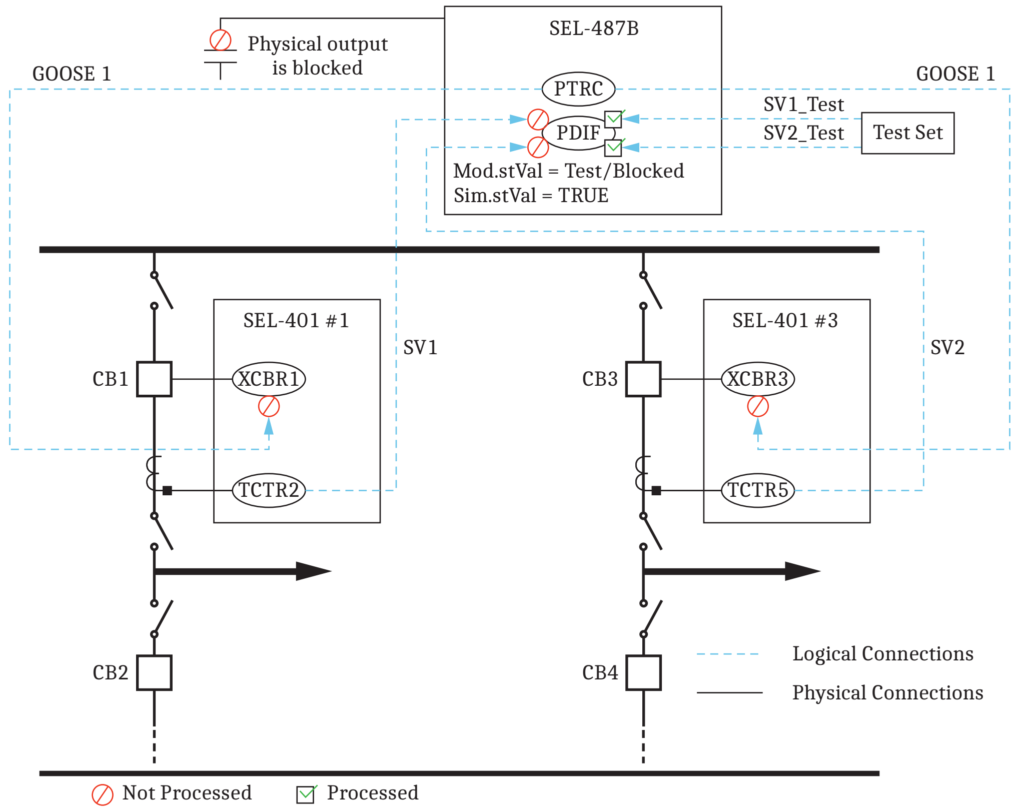


Figure 10.3 Inject Simulated Test Signals Through Use of Test Equipment

NOTE: The IEC 61850 Mode/Behavior and IEC 61850 Simulation mode are implemented at the physical device level on SEL-400 series relays.

Table 10.6 Message Quality Test and Simulation Flag

Message	q.test	Simulation Flag
SV1_Test	True	True
SV2_Test	True	True
GOOSE1	True	False
SV1	False	False
SV2	False	False

Step 4. Return the device to normal operation by first taking the device under test out of Simulation mode (Sim.stVal = False). The relay stops processing test signals from the test equipment to avoid any possible misoperation resulting from the presence of simulated messages. Then change the relay IEC 61850 mode to On mode (Mod.stVal = On) to cause the IED to resume normal operation.

Example 10.4 Checking Data Acquisition With the TEST SV Command

SV subscribers do not support copper connections to instrument transformers. Because of this, it is necessary to check the validity of the digital samples. To provide assistance with this validity check, the SEL subscriber supports the SEL TEST SV mode.

This example uses the **TEST SV** command and the **COM SV** command. Refer to *Section 9: ASCII Command Reference* in the product-specific instruction manual for descriptions of the **TEST SV** and **COM SV** commands.

SEL created the TEST SV mode as a commissioning tool to help users perform easy validation of the process bus communication and the SV samples. While in TEST SV mode, the SEL merging unit generates test signals on all configured SV streams. The test bit in the quality attribute asserts for all published SV messages. The published signals are scaled from secondary (*Table 10.7*) to primary, in accordance with the CT and PT ratio setting as follows:

- CTRW is used for both IW and IX scaling
- PTRY is used for both VY and VZ scaling

Table 10.7 Secondary Quantities for the SEL-401, SEL-421-7, and SEL-451-6 SV Publishers

IEC	SEL	Magnitude (RMS)		Angle (Degrees)	
		5 A[a]	1 A[a]	ABC Rotation	ACB Rotation
I1	IA	5	1	0	0
I2	IB	5	1	–120	120
I3	IC	5	1	120	–120
I4	IN	0[b]	0[b]	0[b]	0[b]
V1	VA	67	67	0	0
V2	VB	67	67	–120	120
V3	VC	67	67	120	–120
V4	VN	0[b]	0[b]	0[b]	0[b]

[a] 1 A or 5 A nominal current.
[b] The neutral channel is the sum of the waveforms for A-, B-, and C-Phase.

NOTE: The **TEST SV** command is not supported in the SEL-487E-5 SV Publisher.

The neutral channel is the sum of the waveforms for A-, B-, and C-Phase. The published SV message rate is determined by the NFREQ setting.

Whenever the **TEST SV** command is entered, the relay starts or restarts a 15-minute timer to run in TEST SV mode before terminating TEST SV mode.

See the following procedure for verifying SV process bus communications between configured merging units and SV relays.

NOTE: Users can also see TEST SV mode indications from the ASCII commands **COM SV**, **STA A**, and **CST**.

On a merging unit that is configured to publish the desired current and voltage channels, enter TEST SV mode by issuing the **TEST SV** command.

Step 1. Issue the **COM SV** command to view the publication status (shown in *Figure 10.4*).

Step 2. Issue the **TAR SVPTST** command to view the TEST SV mode indicator, as shown in *Figure 10.5*. If SVPTST asserts, the merging unit is operating in TEST SV mode.

Example 10.4 Checking Data Acquisition With the TEST SV Command (Continued)

```
=>>TEST SV
WARNING: Test mode is not a regular operation.
Actual values will be overridden by test values.

Are you sure (Y/N)?Y

Relay 1                                   Date: 03/17/2023  Time: 10:42:33:331
Station A                                 Serial Number: 1230769999

Test mode active. Use TEST SV OFF to exit test mode.
Test mode will automatically terminate after 15 minutes.

=>>COM SV

IEC 61850 Mode/Behavior: On

SEL TEST SV Mode: On

IEC 61850 Simulation Mode: Off

SV Publication Information

 MultiCastAddr   Ptag:Vlan AppID  smpSynch
________________________________________________________________________________

A0421_7P_006_ICD_1CFG/LLN0$MS$MSVCB01
 01-0C-CD-04-00-66  4:1    4000      1
 SV ID: 4000
 Data Set: A0421_7P_006_ICD_1CFG/LLN0$PhsMeas1
A0421_7P_006_ICD_1CFG/LLN0$MS$MSVCB02
 01-0C-CD-04-00-67  4:1    4000      1
 SV ID: 4000
 Data Set: A0421_7P_006_ICD_1CFG/LLN0$PhsMeas1

=>>
```

```
=>>TAR SVPTST

*       SVPTST  *       *       *       *       *       *
0       1       0       0       0       0       0       0

=>>
```

Figure 10.5 TEST SV Mode Indicator

On the SV subscriber, enter TEST SV mode by issuing the **TEST SV** command.

Step 1. Issue the **COM SV** command to view the subscription status, as shown in *Figure 10.6*. *Figure 10.6* also shows that before entering the TEST SV mode, the relay indicates **INVALID QUAL** for the incoming SV stream. After the relay enters the TEST SV mode, the relay recognizes the quality and indicates that the quality attribute test bit asserts by displaying the **QUALITY (TEST)** code.

Example 10.4 Checking Data Acquisition With the TEST SV Command (Continued)

```
=>>COM SV

IEC 61850 Mode/Behavior: On

SEL TEST SV Mode: Off

IEC 61850 Simulation Mode: Off

SV Subscription Status

 MulticastAddr   Ptag:Vlan AppID  smpSynch    Code          Network Delay(ms)
________________________________________________________________________________
A0421_7P_006_ICD_1CFG/LLN0$MS$MSVCB01
 01-0C-CD-04-00-66  4:1    4000      1      INVALID QUAL          NA
 SV ID: 4000
 Data Set: A0421_7P_006_ICD_1CFG/LLN0$PhsMeas1
A0421_7P_006_ICD_1CFG/LLN0$MS$MSVCB02
 01-0C-CD-04-00-67  4:1    4000      1      INVALID QUAL          NA
 SV ID: 4000
 Data Set: A0421_7P_006_ICD_1CFG/LLN0$PhsMeas1

=>>TEST SV

WARNING: Test mode is not a regular operation.
Actual values will be overridden by test values.

Are you sure (Y/N)?Y

Relay 1                                     Date: 03/17/2023  Time: 10:49:39:552
Station A                                   Serial Number: 1230769999

Test mode active. Use TEST SV OFF to exit test mode.
Test mode will automatically terminate after 15 minutes.

=>>COM SV

IEC 61850 Mode/Behavior: On

SEL TEST SV Mode: On

IEC 61850 Simulation Mode: Off

SV Subscription Status

 MulticastAddr   Ptag:Vlan AppID  smpSynch    Code          Network Delay(ms)
________________________________________________________________________________
A0421_7P_006_ICD_1CFG/LLN0$MS$MSVCB01
 01-0C-CD-04-00-66  4:1    4000      1      QUALITY (TEST)        0.63
 SV ID: 4000
 Data Set: A0421_7P_006_ICD_1CFG/LLN0$PhsMeas1
A0421_7P_006_ICD_1CFG/LLN0$MS$MSVCB02
 01-0C-CD-04-00-67  4:1    4000      1      QUALITY (TEST)        0.63
 SV ID: 4000
 Data Set: A0421_7P_006_ICD_1CFG/LLN0$PhsMeas1

=>>
```

Figure 10.6 Enter TEST SV Mode in the Relay

Step 2. Issue the **TAR SVTST** command to view the TEST SV mode indicator, as shown in *Figure 10.7*.

```
=>>TAR SVSTST

SVSALM  SVSTST  SVCC    *       *       *       *       *
0       1       1       0       0       0       0       0

=>>
```

Figure 10.7 TEST SV Mode Indicator

Step 3. Issue the **MET** command to verify that the relay current and voltage inputs are the proper magnitude and phase rotation (see *Examining Metering Quantities on page 3.34*). *Figure 10.8* shows the output of the **MET** command in this example.

Example 10.4 Checking Data Acquisition With the TEST SV Command (Continued)

```
=>>MET <Enter>

Relay 1                                    Date: 03/17/2023 Time: 02:08:46.920
Station A                                  Serial Number: 1230769999



Fundamental Meter: Terminal S

               Phase Currents                         Sequence Currents
           IA        IB        IC            I1        3I2       3I0
MAG(A,pri)  999.293   999.319   999.317      999.310    0.008      0.059
ANG(deg)     -0.00   -120.00    120.00        -0.00     1.46    -177.41

            Phase Voltages - PT -                Sequence Voltages
           VA        VB        VC            V1        3V2       3V0
MAG (kV)    133.903   133.903   133.903      133.903    0.00       0.00
ANG(deg)     -0.00   -120.00    120.00         0.00   137.62     173.77

Power Quantities
Active Power P (MW,pri)
     PA          PB          PC          3P
 133.81      133.81      133.81       401.43

Reactive Power Q (MVAr,pri)
     QA          QB          QC          3Q
   0.00        0.00       -0.00        0.00

Apparent Power  S (MVA,pri)
     SA          SB          SC          3S
 133.81      133.81      133.81       401.43

Power factor
 Phase A     Phase B     Phase C     3-Phase
 1.00        1.00        1.00        1.00

Line-to-Line Voltage
                   PT - V                              PT - Z
           VAB       VBC       VCA          VAB       VBC       VCA
MAG (kV)   231.925   231.930   231.923        0.005     0.007     0.005
ANG(deg)    30.00    -90.00    150.00      -166.32     61.99    -75.31

FREQ (Hz) 60.00           Frequency Tracking = Y
VDC (V)   115.82          V/Hz      -----%

=>>
```

Figure 10.8 MET Command Response

Commissioning tests help you verify that you have properly connected the relay to the power system and all auxiliary equipment. These tests confirm proper connection of control inputs and control outputs as well (see *Operating the Relay Inputs and Outputs on page 3.55*).

Relay Self-Tests

The relay continuously runs many self-tests to detect out-of-tolerance conditions. These tests run at the same time as relay protection and automation logic, but do not degrade relay performance.

The relay provides a number of alarms to indicate different conditions, as shown in *Table 10.8*.

Table 10.8 Alarm Relay Word Bits (Sheet 1 of 2)

Alarm Relay Word Bit	Description
HALARML	Latches for any relay failures.
HALARMP	Asserts for approximately five seconds when a warning condition occurs.

Table 10.8 Alarm Relay Word Bits (Sheet 2 of 2)

Alarm Relay Word Bit	Description
HALARMA	Starts pulsing for five seconds every minute whenever a new warning condition occurs and continues to pulse until the RST_HAL logic reset is asserted.
RST_HAL	Resets the HALARMA operation (similar to the other logic resets in the relay).
HALARM	Equivalent to HALARML OR HALARMP.
SETCHG	Pulses for at least one second whenever settings are changed.
GRPSW	Pulses for at least one second whenever groups are switched.
ACCESS	This bit is set when a user is logged in at Access Level B or higher.
BADPASS	Pulses for at least one second whenever a user enters three successive bad passwords.
SALARM	BADPASS OR SETCHG OR GRPSW OR Ethernet FW upgrade attempt.

The relay reports out-of-tolerance conditions as a status warning or status failure. For conditions that do not compromise relay protection, yet are beyond expected limits, the relay issues a status warning and continues to operate. A severe out-of-tolerance condition causes the relay to declare a status failure and enter a protection-disabled state. During a protection-disabled state, the relay suspends protection element processing and trip logic processing and de-energizes all control outputs. When disabled, the **ENABLED** front-panel LED is not illuminated.

The relay signals a status warning by pulsing the HALARMP, HALARMA, and HALARM Relay Word bits (hardware alarm) to logical 1 for five seconds. For a status failure, the relay latches the HALARML and HALARM Relay Word bits at logical 1. Some hardware failures prevent the relay from operating. In such cases, Relay Word bits HALARML and HALARM do not assert.

Once HALARMP pulses, Relay Word bit HALARMA continues to assert for approximately five seconds once per minute to indicate that a hardware warning has occurred. HALARMA continues to pulse until it is reset by pulsing SELOGIC control equation RST_HAL. Restarting the relay also resets HALARMA. HALARMP does not assert again for the same alarm condition, unless the condition is cleared and returns.

The relay will automatically restart as many as two times on certain diagnostic failures. In many instances, this will correct the failure. When this occurs, the relay will log a `Diagnostic Restart` in the SER.

To provide remote status indication, connect the b contact of OUT108 to your control system remote alarm input and program the output SELOGIC control equation to respond to NOT (SALARM OR HALARM).

If you repeatedly receive status warnings, check relay operating conditions as soon as possible. Take preventive action early during the development of potential problems to avoid system failures. For any status failure, contact your Technical Service Center or the SEL factory immediately (see *Technical Support on page 10.35*).

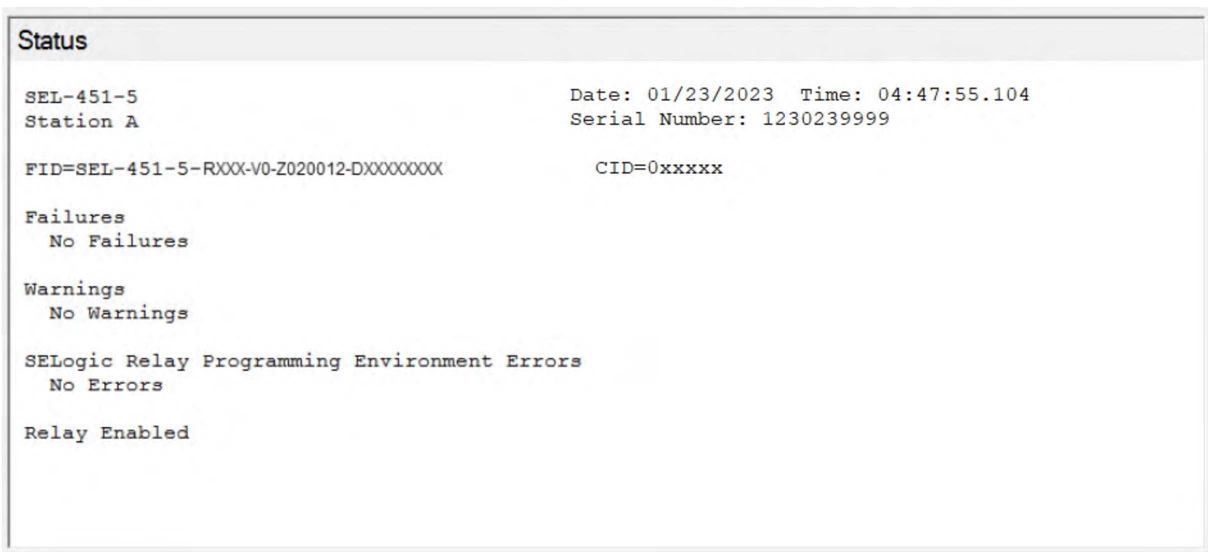
The relay generates an automatic status report at the serial ports for a self-test status failure if you set Port setting AUTO := Y. The relay issues a status message with a format identical to the **STATUS** command output, but includes the power supply information from the **STA A** response. The relay also displays status warning and status failure automatic messages on the front-panel LCD. Use the serial port **STATUS** and **CSTATUS** commands and the front-panel `RELAY STA-`

TUS menu to display status warnings and status failures. See *STATUS on page 14.60*, *Checking Relay Status on page 3.13*, and *Relay Status on page 4.30* for more information on automatic status notifications and on viewing relay status.

The relay includes self-diagnostics that monitor settings, hardware, and communication. The settings diagnostic checks if an internal error may have caused the calibration settings to be lost or corrupted, which would introduce errors in the magnitude and angles of the voltages and currents measured. The hardware diagnostics monitor any component change that does not match the part number, as well as hardware failures in the power supply, processors, and digital samplers. For relays that support DSS, the relay will monitor the connection to the DSS data or the communication board in the relay that receives the DSS data. Finally, the diagnostics monitor communications such as Ethernet, serial, and 87L connections. The **STATUS** command notifies the user if any of the diagnostics trigger a warning or a failure. In cases where the issue is a failure the relay will become disabled and protection will be inhibited.

Status

Figure 10.9 is a sample **STATUS** screen from the Status option of the QuickSet **HMI > Meter and Control** tree view (the terminal **STATUS** report is similar). *Figure 10.10* is a sample **STATUS A** report that shows all status information from an SEL-411L-2 with the five-port Ethernet card installed.



```
Status

SEL-451-5                                   Date: 01/23/2023  Time: 04:47:55.104
Station A                                   Serial Number: 1230239999

FID=SEL-451-5-RXXX-V0-Z020012-DXXXXXXXX       CID=0xxxxx

Failures
  No Failures

Warnings
  No Warnings

SELogic Relay Programming Environment Errors
  No Errors

Relay Enabled
```

Figure 10.9 Relay Status: QuickSet HMI

```
=>STA A <Enter>

Relay 1                                         Date: 03/17/2023  Time: 04:48:49.938
Station A                                       Serial Number: 1230769999

FID=SEL-411L-2-Rxxx-V0-Zxxxxxx-Dyyyymmdd            CID=0xxxxx

Failures
  No Failures

Warnings
  No Warnings

Channel Offsets (mV)   W=Warn    F=Fail
  MOF
    3
```

Figure 10.10 Relay Status From a STATUS A Command on a Terminal

```
Mainboard Power Supply Voltages (V)   W=Warn    F=Fail
  3.3V_PS  5V_PS  N5V_PS  15V_PS   N15V_PS
     3.30   5.01   -5.00   15.00    -14.99

Five-Port Ethernet Card Power Supply Voltages (V)
  0.85V_PS  1.20V_PS  1.35V_PS  1.80V_PS  3.30V_PS  15.00V_PS
      0.84      1.19      1.35      1.78      3.27      14.96

Temperature (C)
  Mainboard    5-Port Eth SoC
       37.3              55.5

Communication Interfaces

Active High Accuracy Time Synchronization Source: PTP
  IRIG-B Source ABSENT
  PTP Source PRESENT

SELogic Relay Programming Environment Errors
  No Errors

IEC 61850 Mode/Behavior
   On

IEC 61850 Simulation Mode
   Off

Relay Enabled

=>
```

Figure 10.10 Relay Status From a STATUS A Command on a Terminal (Continued)

CSTATUS

The relay also reports status information in the Compressed ASCII format when you issue the CST command. An example Compressed ASCII status message is shown in *Figure 10.11*.

```
"RID","SID","FID","yyyy",
"relay_name","station_name","SEL-451-x-Rxx-Vx-Zxxxxxx-Dxxxxxxxx","yyyy"
"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","yyyy"
(Month),(Day),(Year),(Hour),(Min),(Sec),(MSec),"yyyy"

"CPU_RAM","CPU_PROG","SELBOOT","CPU_SET","DSP_RAM","DSP","DSP_CSUM","DSP_T_OUT","CPUDSP_RAM","FRNT_PNL","CAL_BOARDA","CCRD_
   CHG","COMM_CARD","ANA_CONV","IO_1","IO_2","yyyy"
"(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)","(Ok or
   F)","(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)","yyyy"
"ATOD_OFFST","MSTR_OFFST","3.3V_PS","5V_PS","N5V_PS","15V_PS","N15V_PS","TEMP_STA","TEMP","PRT_O_LOAD","LCD_ERROR","FPGA","
   yyyy"

"(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)",(Temp value),"(Ok or
   F)","(Ok or F)","(Ok or F)","yyyy"
"MBA","MBB","ACTTIM_SRC","SELOG_MATH","FM_TEST","DB_TEST","DB2_TEST","RLY_STA","PRT_F_TP","PRT_1_TP","PRT_2_TP","PRT_3_TP",
   "PRT_5_TP", "87L_TEST", "SV_TEST", "I850_MOD", "SIM_MOD","yyyy"
(Inac or Ok or F),(Inac or Ok or F),(HIRIG or IRIG or HPTP or " "),(Enabled or Disabled), (Enabled or Disabled), (Enabled
   or Disabled), (Enabled or Disabled),(F,0-5), (F,0-5), (F,0-5), (F,0-5), (F,0-5),(Enabled or Disabled), (Enabled or
   Disabled), (Enabled or Disabled), (Enabled or Disabled)"yyyy"
```

Figure 10.11 Example Compressed ASCII Status Message

Definitions for the items and fields in the Compressed ASCII configuration are listed below:

- ➤ *yyyy* is the checksum
- ➤ *x* is text in the FID (Firmware ID) string
- ➤ (description) is text that the relay supplies
- ➤ (Ok or W or F) is normal, warning, or failure, respectively

Firmware Version Number

At the top of each status report the relay displays the present firmware version number that identifies the software program that controls relay functions. The firmware version is the four-place designator immediately following the relay model number (the first characters in the firmware identification or FID string). The first character in the four-place firmware version number is R (representing Release).

Figure 10.9 and *Figure 10.10* show the location of the FID sting, with a blank or generic response. To see the actual FID string for the firmware version described in this manual, see *Appendix A: Firmware, ICD File, and Manual Versions* in the product-specific instruction manual for firmware version information.

Relay Troubleshooting

Inspection Procedure

Complete the following inspection procedure before disturbing the system. After you finish the inspection, proceed to *Troubleshooting Procedures on page 10.23*.

Step 1. Confirm that the power is on. Do not turn the relay off.

Step 2. Measure and record the control power voltage at the relay **POWER** terminals marked **+** and **–** on the rear-panel terminal strip.

Step 3. Measure and record the voltages at all control inputs.

Step 4. Measure and record the state of all control outputs.

Step 5. Inspect the serial communications ports cabling to be sure that a communications device is connected to at least one communications port.

Troubleshooting Procedures

Troubleshooting procedures for common problems are listed in *Table 10.9* and *Table 10.10*. The table lists each symptom, possible causes, and corresponding diagnoses/solutions. Related ASCII commands are listed in bold capitals. See *Section 14: ASCII Command Reference* for details on SEL-400 series commands and *Section 12: Settings* for details on relay settings.

Table 10.9 Troubleshooting Procedures[a] (Sheet 1 of 3)

Symptom/Cause	Diagnosis/Solution
Dark Front Panel	
Power is off.	Verify that substation battery power is operational.
Input power is not present.	Verify that power is present at the rear-panel terminal strip.
Blown power supply fuse.	Replace the fuse (see *Power Supply Fuse Replacement on page 10.28*).
Poor HMI contrast.	Press and hold **ESC** for two seconds. Press **Up Arrow** and **Down Arrow** pushbuttons to adjust contrast.
Status Failure Notice on Front Panel	
Self-test failure.	See *Table 10.10* for guidance on the specific failure type. The OUT108 relay control output b contacts will be closed if you programmed NOT HALARM to OUT108.
Alarm Output Asserts	
Power is off.	Restore power.
Blown power supply fuse.	Replace the fuse (see *Power Supply Fuse Replacement on page 10.28*).
Power supply failure.	LCD displays `STATUS FAILURE` screen. See *Table 10.10*.

Table 10.9 Troubleshooting Procedures[a] (Sheet 2 of 3)

Symptom/Cause	Diagnosis/Solution
Main board or interface board failure.	LCD displays STATUS FAILURE screen. See *Table 10.10*.
Other self-test failure.	LCD displays STATUS FAILURE screen. See *Table 10.10*.
System Does Not Respond to Commands	
NOTE: If Port setting PROTO := PMU, that serial port will not respond to ASCII commands. Additionally, a PROTO := PMU port will not respond to any messages when Global setting EPMU := N.	
No communication.	Confirm cable connections and types. If correct, type **<Ctrl+X> <Enter>**. This resets the terminal program.
Communications device is not connected to the system.	Connect a communications device.
Incorrect data speed (baud rate) or other communications parameters.	Configure your terminal port parameters to the particular relay port settings. Use the front panel to check port settings (see *Set/Show on page 4.26*).
Incorrect communications cables.	Use SEL communications cables, or cables you build according to SEL specifications (see *Serial Communication on page 15.2*).
Communications cabling error.	Check cable connections.
Handshake line conflict; system is attempting to transmit information, but cannot do so.	Check communications cabling. Use SEL communications cables, or cables you build according to SEL specifications (see *Serial Communication on page 15.2*).
System is in the XOFF state, halting communications.	Type **<Ctrl+Q>** to put the system in the XON state.
Terminal Displays Meaningless Characters	
Data speed (baud rate) is set incorrectly.	Check the terminal parameters configuration (see *Serial Communication on page 15.2*).
Terminal emulation is not optimal.	Try other terminal types, including VT-100 and VT-52 terminal emulations.
System Does Not Respond to Faults	
Relay is set improperly.	Review the relay settings.
Improper test settings.	Restore operating settings.
PT or CT connection wiring error.	Confirm PT and CT wiring.
Input voltages and currents phasing, and rotation errors.	Use relay metering. Use the **TRI** event trigger command and examine the generated event report (see *Examining Metering Quantities on page 3.34*).
The analog input (flat multipin ribbon) cable between the input module board and the main board is loose or defective.	Reseat both ends of the analog input cable, observing proper ESD precautions (see *Installing Optional I/O Interface Boards on page 10.30*).
Check the relay self-test status.	Take preventive action as directed by relay Status Warning and Status Failure information (see *Checking Relay Status on page 3.13*).
Sequence of Events Recorder	
SER DATA LOSS Reported	This is caused by an internal buffer overrun, which can occur if SER points are being triggered faster than they can be processed. It will recover as soon as the SER processing can catch up. SER data loss can also be caused by excessive SER triggering (>6000 points per hour), causing the relay to temporarily suspend storing points. In this case, it will normally recover within an hour, but the SER DATA LOSS END message will not be reported until the first SER point is triggered after the suspension ends.
Tripping Output Relay Remains Closed Following a Fault	
Auxiliary contact control inputs are improperly wired.	Check circuit breaker auxiliary contacts wiring.
Control output relay contacts have burned closed.	Remove relay power. Remove the control output connection. Check continuity—Form A contacts should be open and Form B contacts should be closed. Contact the SEL factory or your Technical Service Center if continuity checks fail.
I/O interface board failure.	LCD displays STATUS FAILURE screen. Contact the SEL factory or your Technical Service Center.

Table 10.9 Troubleshooting Procedures[a] (Sheet 3 of 3)

Symptom/Cause	Diagnosis/Solution
Time/Date Errors	
External IRIG time source error.	Check IRIG-B time source or cables. Check **TIME Q** command or `HMI SET/SHOW | Date/Time` screen.
A low-priority time source error.	Check last update source (**TIME Q** command or `HMI SET/SHOW | Date/Time` screen) (see *Table 11.6 on page 11.8*).
Lithium clock battery failure.	Verify that the battery has failed before replacing the battery–it should last for 10 years if the relay is energized (see *Replacing the Lithium Battery on page 10.27*).
TiDL (T-Protocol)	
TiDL system will not successfully commission.	Check all fiber connections and verify link budget and received/transmit power of both the TiDL relay and SEL-TMU.
Loss of communications with an SEL-TMU.	Check the SEL-TMU front panel. If disabled (see SEL-TMU instruction manual), see *VECTOR on page 14.73*. If the SEL-TMU is enabled, check fiber connections and verify the link budget and received/transmit power of both the TiDL relay and the SEL-TMU.
TiDL (EtherCAT) Applications	
Relay will not successfully commission.	Check the configuration of axion CT/PT modules and verify that they match a supported topology (see *Section 2: Installation* in the product-specific instruction manual).
Relay disabled.	Check the CT/PT modules for failure. If a module is identified as failed, replace the CT/PT module and then press the commissioning button on the back of the relay (see *TiDL System Commissioning on page 10.2*).
Firmware Upgrade	
Model mismatch.	Firmware file does not match relay model (see *Resolving Model Mismatch on page B.24*).
SELBOOT flash mismatch.	SELBOOT checksum has failed. Try to reload the SELBOOT firmware with the **REC BOOT** command. If reload fails, return to SEL (see *E Upload New SELBOOT Firmware to the Relay on page B.13*).
CID File	
Out of memory error when sending a CID file to the relay	This can be caused by a large number of data attributes in the configured datasets and/or by a large number of supervised subscriptions (LGOS and/or LSV logical nodes). Reduce either the number of supervised subscriptions or the number of data attributes in the configured Datasets, or remove any default datasets not required in the application. By default, all GOOSE/SV subscriptions are supervised. Supervised GOOSE/SV subscriptions can be removed in Architect by right-clicking in the data field in GOOSE/SV Subscriptions and selecting **Disable supervision**.

[a] For SV applications, refer to Table 14.45.

Table 10.10 Troubleshooting for Relay Self-Test Warnings and Failures (Sheet 1 of 3)

Diagnostic Message	Diagnosis/Solution
Memory Failures	
RAM Error[b]	This indicates a processor memory device detected an error. Contact your Technical Service Center for analysis of the error.
Memory Failures	
RAM Failure[b]	This indicates a failure of a memory device. Contact the SEL factory or your Technical Service Center.
Flash Failure	
EEPROM Failure	
Settings Failed	
Default Settings Failure	
Default Cal Settings	This indicates that something has occurred that has caused the relay to lose its calibration. Contact the SEL factory or your Technical Service Center.

Table 10.10 Troubleshooting for Relay Self-Test Warnings and Failures (Sheet 2 of 3)

Diagnostic Message	Diagnosis/Solution
MAC Address Warning	
MAC Address Conflict	Not all MAC Addresses are unique. Contact the SEL factory or your Technical Service Center.
Missing MAC Address	Not all MAC Addresses are valid. Contact the SEL factory or your Technical Service Center.
Five-Port Ethernet Card	
Comm Card Error or Failure	Contact the SEL factory or your Technical Service Center.
Comm Card Firmware Mismatch	The five-port Ethernet card is installed, but either the relay firmware or SELBOOT is not compatible with the Ethernet card. To resolve the error, verify SELBOOT R302 or later is installed and load any relay firmware that supports the five-port Ethernet card (see *Appendix A: Firmware, ICD File, and Manual Versions* in the product-specific manuals). If supported firmware is already loaded, reload the firmware. If the error persists, contact SEL for assistance.
Port *n*[a] SFP Not Compliant	An SFP transceiver is connected to an enabled PORT n but could not be authenticated because it is not compatible. See *Table 15.7* or selinc.com/products/sfp for a list of compatible SFP transceivers.
Port *n*[a] SFP Speed Not Compliant	An SFP transceiver is connected to an enabled PORT n but has a speed that is not compatible with that port. Replace the transceiver with one with the correct speed.
SFP Speed Mismatch Port 5A, 5B Disabled	The SFP transceivers in PORT 5A and PORT 5B have mismatching speeds. Replace one of the transceivers so that they have matching speeds.
Port *n*[a] SFP Not Installed	PORT n is enabled but has no SFP transceiver installed. Install a compatible transceiver in that port.
Port *n*[a] SFP Error	An SFP transceiver is connected to an enabled PORT n but has a hardware failure. Replace the failed transceiver and report the error to the SEL factory or your Technical Service Center.
Port *n*[a] SFP TX Fault	The relay logs this warning when the transmit voltage of an SFP transceiver goes out of range on enabled PORT n. The relay attempts to resolve the condition by disabling and re-enabling the affected port. If the condition occurs three times in one week, the relay permanently disables the affected port until the SFP is replaced.
Line-Current Differential Warnings	
87L Watchdog Alarm	This alarm indicates that the relay has received more than three unwarranted 87L pickup operations associated with 87L communication channel impairments. This logic asserts Relay Word bit 87ALARM and does not inhibit 87L protection. This alarm can be reset at Access Level 2 by issuing a **COM 87L WD C** command.
87L Watchdog Error 1	This error indicates that the relay has received more than five unwarranted 87L pickup operations associated with 87L communication channel impairments. This logic asserts Relay Word bit 87ERR1 and inhibits 87L protection. This alarm can be reset at Access Level 2 by issuing a **COM 87L WD C** command.
87L Watchdog Error 2	This error indicates that the relay has received more than ten unwarranted 87L pickup operations associated with 87L communications channel impairments and non-channel related issues. This logic asserts Relay Word bit 87ERR2 and inhibits 87L protection. This alarm can be reset at Access Level 2 by issuing a **COM 87L WD C** command. **NOTE:** In firmware R105 and older, this alarm can only be reset at Access Level C.
87L Watchdog Reset	This warning occurs when the **COM 87L WD C** command is issued.
Hardware Changes	
Card or Board Change	This indicates that the installed hardware does not match the part number. If the hardware was intentionally changed, use the **STA** command from Access Level 2 to accept the new hardware configuration. If the hardware was not changed, make sure all connections are fully seated and then restart the relay. If the error persists, contact the SEL factory or your Technical Service Center.
Power Supply Voltage Status Warning	
Power supply voltage(s) are out-of-tolerance.	Log the Status Warning. If repeated warnings occur, take preventive action.
A/D converter failure.	LCD displays STATUS FAILURE screen. Contact the SEL factory or your Technical Service Center.

Table 10.10 Troubleshooting for Relay Self-Test Warnings and Failures (Sheet 3 of 3)

Diagnostic Message	Diagnosis/Solution
Power Supply Voltage Status Failure	
Power supply voltage(s) are out-of-tolerance.	LCD displays `STATUS FAILURE` screen. Contact the SEL factory or your Technical Service Center.
A/D OFFSET WARN Status Warning	
Loose ribbon cable between the input module board and the main board.	Reseat both ends of the analog input cable.
A/D converter drift.	Log the Status Warning. If repeated warnings occur, contact the SEL factory or your Technical Service Center.
Master offset drift.	LCD displays `STATUS FAILURE` screen. Contact the SEL factory or your Technical Service Center.
FPGA Error	
FPGA diagnostics identified an out-of-tolerance condition.[b]	In this rare event, the relay will automatically restart to clear the error and resume protection. If the failure occurs three times in seven days, the LCD displays the FPGA FAIL screen and the relay safely disables. Contact the SEL factory or your Technical Service Center. **NOTE:** In older firmware versions, the relay did not automatically restart. Contact the SEL factory or your Technical Service Center.
Serial Port Power Overload	
+5V EIA-232 Overload	The relay rear serial ports are capable of providing +5 V power to an external transceiver, but have a limited power output. This warning indicates that the power limit has been exceeded and the current has been limited. Check what is connected to the serial ports to ensure that there is no unintentional load on the +5 V outputs.
All Other Warnings and Failures	
	Contact the SEL factory or your Technical Service Center.

[a] Where n = 5A, 5B, 5C, 5D, or 5E
[b] The relay will automatically restart for some of these failures. Contact the factory if the failure reoccurs.

Maintenance

Instructions for Cleaning

Use care when cleaning the relay. Use a mild soap or detergent solution and a damp cloth to clean the chassis. Do not use abrasive materials, polishing compounds, or harsh chemical solvents (such as xylene or acetone) on any surface.

Replacing the Lithium Battery

You can replace the lithium battery in the relay. Perform the following steps to replace the lithium battery.

⚠CAUTION
There is danger of explosion if the battery is incorrectly replaced. Replace only with Rayovac no. BR2335 or equivalent recommended by manufacturer. See Owner's Manual for safety instructions. The battery used in this device may present a fire or chemical burn hazard if mistreated. Do not recharge, disassemble, heat above 100°C or incinerate. Dispose of used batteries according to the manufacturer's instructions. Keep battery out of reach of children.

Step 1. Remove the relay from service.

a. Follow your company standard procedure for removing a relay from service.

b. Disconnect power from the relay.

c. Remove the relay from the rack or panel.

d. Retain the **GND** connection, if possible, and ground the equipment to an ESD mat.

Step 2. Remove the front panel from the relay.

Step 3. Disconnect the front-panel cable from the front panel.

Step 4. Disconnect the power cable, interface board cable(s), and input board analog cable from the main board.

Step 5. Pull out the drawout tray containing the main board. In some SEL-400 series relays, the main board is not in a drawout tray. In these cases, you will need to remove the top cover to access the battery.

Step 6. Locate the lithium battery.

The lithium battery is at the front of the main board.

Step 7. Remove the spent battery from beneath the clip of the battery holder.

⚠CAUTION
Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.

Step 8. Replace the battery with an exact replacement.

Use a 3 V lithium coin cell, Rayovac No. BR2335 or equivalent. The positive side (+) of the battery faces up.

Step 9. Reinstall the relay main board drawout tray.

Step 10. Reattach the power cable, interface board cable(s), and input board analog cable.

Step 11. Reconnect the front-panel cable to the front panel.

Step 12. Reattach the front panel.

Step 13. Set the relay date and time via the communications ports or front panel (see *Making Simple Settings Changes on page 3.15*).

Step 14. Follow your company's standard procedure to return the relay to service.

Power Supply Fuse Replacement

⚠DANGER
Disconnect or de-energize all external connections before opening this device. Contact with hazardous voltages and currents inside this device can cause electrical shock resulting in injury or death.

⚠WARNING
Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.

You can replace a bad fuse in a relay power supply, or you can return the relay to SEL for fuse replacement. If you decide to replace the fuse, perform the following steps:

Step 1. Follow your company standard to remove the relay from service.

Step 2. Disconnect power from the relay.

Step 3. Remove the relay from the rack or panel.

Step 4. Retain the **GND** connection, if possible, and ground the equipment to an ESD mat.

Step 5. Remove the communications cable connected to the front-panel serial port, if applicable.

Step 6. Remove the rear-panel **EIA-232 PORT** mating connectors.

Unscrew the keeper screws and disconnect any serial cables connected to the **PORT 1**, **PORT 2**, and **PORT 3** rear-panel receptacles.

⚠CAUTION
Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.

Step 7. Loosen the four front-panel screws (they remain attached to the front panel), and remove the relay front panel.

Step 8. Remove the 34-pin ribbon cable from the front panel by pushing the extraction ears away from the connector.

Step 9. Disconnect the power, the interface board, and the analog input board cables from the main board.

Step 10. Remove the screw-terminal connectors.

a. Loosen the attachment screws at each end of the 100-addresses, 200-addresses, and 300-addresses screw-terminal connectors.

b. Pull straight back to remove.

Step 11. Remove the top chassis plate by unscrewing seven screws from the chassis.

Step 12. Pull out the drawout tray containing the main board.

Step 13. Pull out the drawout tray containing the I/O interface board(s).

Step 14. Locate the power supply. Fuse F1 is at the rear of the power supply circuit board (see *Figure 10.12*).

Step 15. Examine the power supply for blackened parts or other damage. If you can see obvious damage, reinstall all boards and contact SEL to arrange return of the relay for repair.

Step 16. Remove the spent fuse from the fuse clips.

Step 17. Replace the fuse with an exact replacement (see *Section 2: Installation* in the product-specific instruction manual for the proper fuse for your power supply).

Step 18. Reinstall the interface board.

Step 19. Reinstall the main board, and reconnect the power, the interface board, and the analog input board cables.

Step 20. Replace the chassis top on the relay and secure it with seven screws.

Step 21. Reconnect the cable removed in *Step 8* and reinstall the relay front-panel cover.

Step 22. Reattach the rear-panel connections.

Affix the screw-terminal connectors to the appropriate 100-addresses, 200-addresses, and 300-addresses locations on the rear panel.

Step 23. Reconnect any serial cables that you removed from the **EIA-232 PORTS** in the disassembly process.

Step 24. Follow your company standard procedure to return the relay to service.

NOTE: Some versions of this relay will have the PS50 power supply. The fuse is located in the same location as the PS30, but it is rotated 90 degrees.

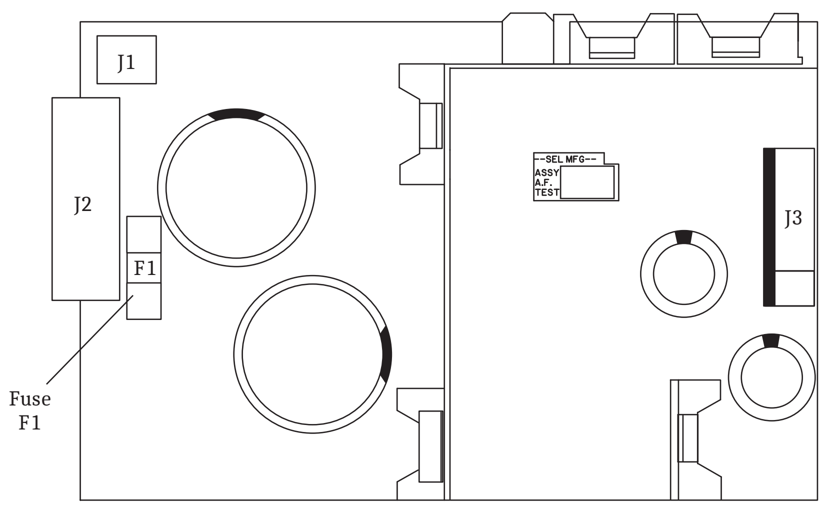


Figure 10.12 PS30 Power Supply Fuse Location

Installing Optional I/O Interface Boards

⚠CAUTION
Equipment components are sensitive to electrostatic discharge (ESD). Permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.

Perform the following steps to install SEL-400 series relay I/O interface boards.

Step 1. Follow your company standard to remove the relay from service. It will be necessary to remove power from the relay as part of this process.

Step 2. Disconnect power from the relay. Isolate any contact inputs or outputs that will be affected by the installation of the I/O interface board.

Step 3. Retain the **GND** connection, located to the right of the power supply terminals to the relay, and ground the equipment to an ESD mat, or other grounding point.

Step 4. Remove the communications cable connected to the front-panel serial port, if applicable.

Step 5. Remove the rear-terminal block connectors for the I/O board that is being installed. Two screws are used to retain each connector. Once these screws are loosened, pull the connector firmly to remove it from the rear of the relay. Note that these connectors are keyed to their mating connectors in the relay.

Figure 10.13 SEL-400 Series Relay Rear Panel

Step 6. Remove the front panel.

a. Unscrew the front cover of the relay.

b. Slowly pull the front cover off of the relay.

There will be a short ribbon cable between the front panel of the relay and the main board of the relay that will prevent the relay front panel from being pulled more than five inches from the relay. Do not let the relay front panel hang from this ribbon cable.

c. Remove the ribbon cable at the front panel by pushing the cable retention levers toward the back of the front panel, as shown in *Figure 10.14*.

If your front panel is equipped with auxiliary trip and close pushbuttons, remove the connectors to the pushbuttons connected at the front panel and the expansion I/O board.

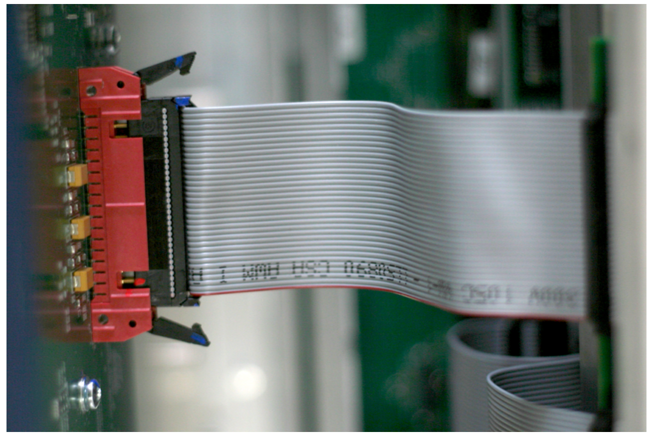


Figure 10.14 Front-Panel Ribbon Cable Connector With Clasps Open

Step 7. Remove the power supply, expansion I/O and calibration board ribbon cables from their connectors on the main board (see *Figure 10.15*).

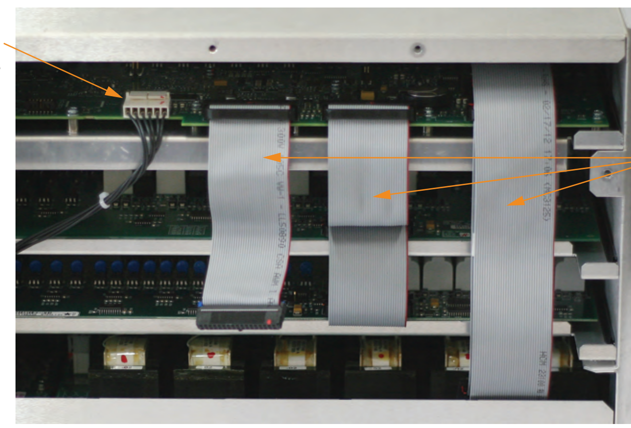


Figure 10.15 Main Board Cable Connections

Step 8. Remove the main board power cable (white connector) from the main board by lifting up the retaining tabs on top of the header and sliding the connector out.

Do not bend the retaining tabs any higher than is necessary to remove the connector as this could damage the tabs.

Step 9. Use the Jumper Configuration table shown in *Figure 10.16* to confirm that the jumper arrangement on the I/O board matches the correct jumper configuration for the interface board being installed. For example, the jumper configuration in *Figure 10.16(a)* is for an interface board being installed at the 300 level (i.e., the jumpers are set to ON, OFF, ON, OFF).

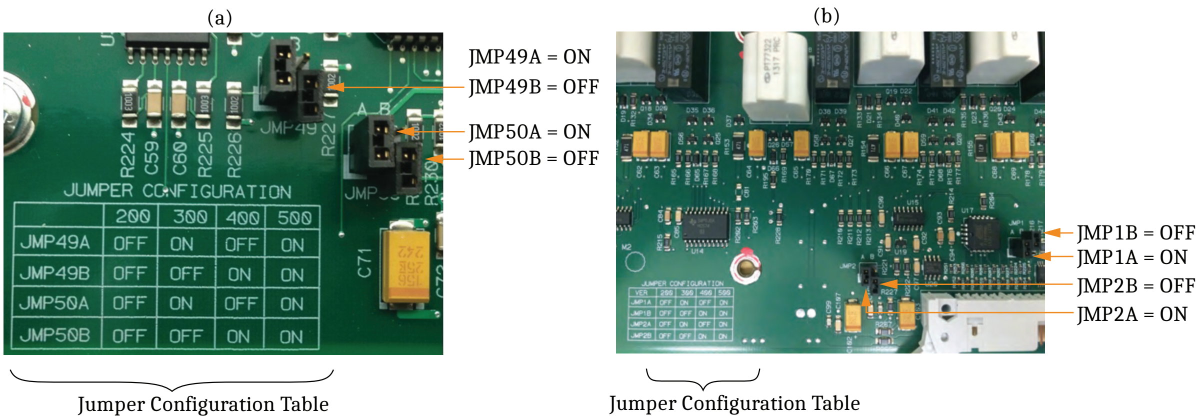


Figure 10.16 I/O Board Jumper Configuration

Step 10. Install the drawout tray with the I/O interface board.

a. Position the drawout tray edges into the left-side and right-side internally mounted slots.

b. Slide the I/O interface board into the relay by pushing the front edge of the board drawout tray.

c. Apply firm pressure to fully seat the I/O interface board.

If you encounter resistance, STOP and withdraw the board.

Inspect the drawout tray edge guide slots for damage.

If you see no damage, take all of the precautions outlined above and try again to insert the board.

Step 11. Confirm screw-terminal connector keying.

a. Inspect the screw-terminal connector receptacles on the rear of the I/O interface board.

Figure 10.17 shows the I/O board section without terminal blocks. The yellow dividers are the connector keying for each terminal block.

b. Refer to *Figure 10.18* for the corresponding key positions inside the receptacle.

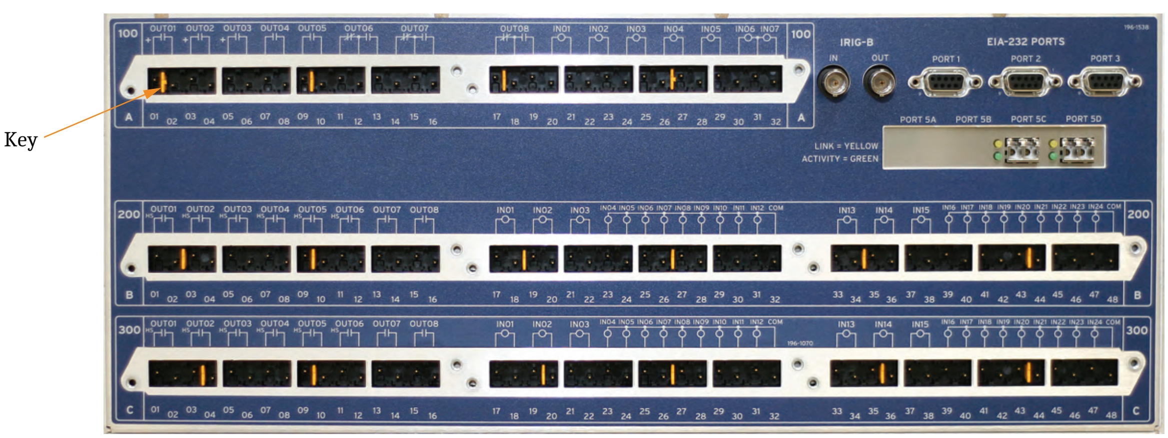


Figure 10.17 Screw-Terminal Connector Receptacles

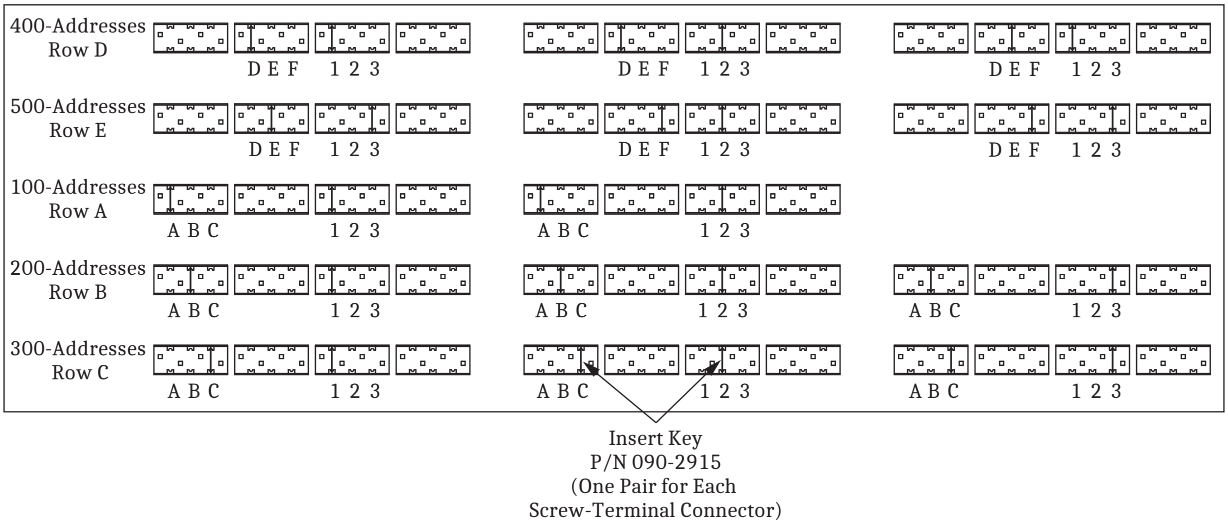


Figure 10.18 Screw-Terminal Connector Keying

c. If the keys inside the I/O interface board receptacles are not in the positions indicated in *Figure 10.18*, grasp the key edge with long-nosed pliers to remove the key and reinsert the key in the correct position.

d. Break the webs of the screw-terminal connectors in the position that matches the receptacle key, as shown in *Figure 10.19*.

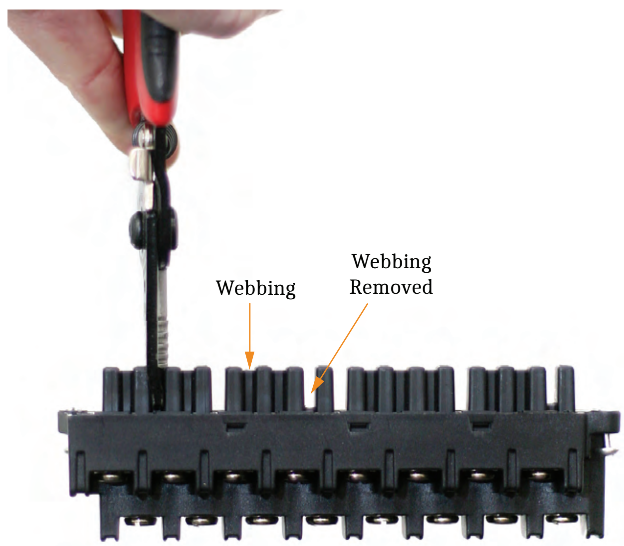


Figure 10.19 Screw-Terminal Connector With Webs

Step 12. Attach the screw-terminal connector.

a. Mount the screw-terminal connectors to the rear panel of the relay.

b. Tighten the screw-terminal connector mounting screws to between 7 in-lb and 12 in-lb (0.8 Nm to 1.4 Nm).

Step 13. Reconnect the power, the interface board, and the analog input board cables to the relay main board.

Step 14. Reconnect the cables removed in *Step 6–Step 8* and reinstall the relay front-panel cover.

Step 15. Apply power.

Step 16. Reconnect any serial cables that you removed from the communications ports in the disassembly process.

Step 17. Establish a terminal emulation session with the relay by using QuickSet or another terminal emulation program.

Step 18. Using the terminal emulation program, enter Access Level 2.

Step 19. From Access Level 2, issue the **STA** command, and answer **Y <Enter>** if prompted to accept the new hardware configuration. (Note: If the I/O board was replaced with exactly the same board, you will not be prompted to accept new hardware.)

Step 20. Inspect the relay targets to confirm that the relay reads the I/O interface board(s).

a. Verify the I/O interface board control inputs and outputs in the target listings by using a terminal or the QuickSet software.

b. Use a communications terminal to issue the following commands.

TAR IN*n*01 <Enter>

TAR OUT*n*01 <Enter>

n = 1–5 for boards in the 100–500 address slots

Step 21. Follow your company's standard procedure to return the relay to service.

Troubleshooting

Step 1. If the I/O board jumpers were not correctly configured in *Step 9* and *Step 10*, the front panel will display the error `RELAY DISABLED SETTINGS FAILED`. You will also receive a `SETTINGS FAILED` failure in the terminal emulation window following an **STA** command, as shown in *Figure 10.20*.

```
Level 2
=>>STA

Relay 1                                 Date: 01/10/2000   Time: 18:13:10.769
Station A                               Serial Number: 1130320464

FID=SEL-487B-1-R305-V0-Z007005-D20121221    CID=0XF3A0

Failures
  SETTINGS FAILED


Warnings
  No Warnings

SELogic Relay Programming Environment Errors
  No Errors

Relay Disabled
```

Figure 10.20 I/O Board Installation Error Message in the Terminal Window

Step 2. Disconnect power to the relay and return to *Step 8* to verify you have correctly configured the jumpers (*Step 9*). If the jumpers are not correct, repeat the I/O board installation instructions, beginning with *Step 9*.

Step 3. If the jumpers are correct, enter Access Level C (CAL).

a. Enter the **VEC D** command.

b. If you see the error `SETTINGS FAILURE in C n`

(*n* = 1–4), enter the **SET C *n*** command.

c. When prompted to do so, save the settings.
d. Return to Access Level 2, and enter the **STA** command to verify that the status is free of warnings.

If the problem persists, please contact your SEL representative.

Technical Support

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

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2350 NE Hopkins Court
Pullman, WA 99163-5603 U.S.A.
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SECTION 11

Time and Date Management

The SEL-400 series relays can determine the time from a variety of sources, including IRIG-B, Precision Time Protocol (PTP) (IEEE 1588), SNTP, DNP3, MIRRORED BITS, terminal **TIME** and **DATE** commands, and HMI settings. (Refer to the appropriate sections in the product-specific instruction manual to learn about using these various time sources.) Most of these sources provide only an approximate measure of time. For high-accuracy time synchronization, which is needed to support synchrophasors and to ease comparison of system-wide events, a high-accuracy time source must be provided, such as IRIG-B with C37.118 extensions or PTP with power system profile. This section focuses on issues related to high-accuracy timekeeping. The relay records power system events with very high accuracy when you provide high-accuracy clock input signals. Relays placed at key substations can give you information on power system operating conditions in real time.

NOTE: Not all SEL-400 series relays support synchrophasors.

Based on the high-accuracy time input, the relay calculates synchrophasors for currents and line voltages (for each phase and for positive-sequence), as specified in IEEE C37.118, Standard for Synchrophasor Measurements for Power Systems. You can then perform detailed analysis and calculate load flow from the synchrophasors. See *Section 18: Synchrophasors* for more information about phasor measurement functions in the relay.

This section presents details on these measurements as well as suggestions for further application areas. The topics of this section are the following:

IRIG-B Timekeeping

The relay is capable of high-accuracy timekeeping when supplied with an IRIG-B signal. When the supplied clock signal is sufficiently accurate, the relay can act as a phasor measurement unit (PMU) and transmit synchrophasor data representative of the power system at fixed time periods to an external data processor. The relay can also record COMTRADE event report data by using the high-accuracy time stamp.

The relay has two input connectors that accept IRIG-B demodulated time-code format: the IRIG-B pins of serial PORT 1, and the IRIG-B BNC connector. See *Section 2: Installation* in the product-specific instruction manual for more information on connecting these inputs.

NOTE: The SEL-2407 Satellite-Synchronized Clock meets both the relay accuracy and IEEE C37.118 requirements for a high-accuracy time source.

The IRIG-B inputs can be used for high-accuracy timekeeping purposes with as high as 1 µs accuracy with an appropriate time source. See *Table 11.1* for relay timekeeping mode details.

Table 11.1 Relay Timekeeping Modes

Item	Internal Clock	IRIG	HIRIG (or High-Accuracy IRIG)	PTP	HPTP
Best accuracy (condition)	Depends on last method of setting, or synchronization[a]	500 µs (when time-source jitter is less than 3 ms)	1 µs (when time-source jitter is less than 500 ns, and time-error is less than 1 µs)[b]	Determined by PTP master (Master clock sync and announce interval <= 4 s)	1 µs (Master clock sync and announce interval <= 4 s, and TQUAL <1 µs)
IRIG-B connection required	None	BNC connector (preferred), or serial PORT 1	BNC connector (preferred), or serial PORT 1	PTP time source connected	PTP time source connected
Relay Word bits	TIRIG = 0 TSOK = 0 BNC_TIM = 0 SER _TIM = 0 BNC_OK = 0 SER_OK = 0 TLOCAL = 0 TGLOBAL = 0	TIRIG = 1 TSOK = 0 BNC_TIM = 1 or SER_TIM = 1 BNC_OK = 1 or SER_OK = 1 TLOCAL = 1 TGLOBAL = 0	TIRIG = 1 TSOK = 1 BNC_TIM = 1 or SER_TIM = 1 BNC_OK = 1 or SER_OK = 1 TLOCAL = 0 TGLOBAL = 1	TPTP = 1 TSOK = 0 TLOCAL = 1 TGLOBAL = 0 PTP_OK = 1	TPTP = 1 TSOK = 1 TLOCAL = 0 TGLOBAL = 1 PTP_OK = 1

[a] The internal clock in the relay can be synchronized via SNTP, DNP3, SEL-2030 Communications Processor, or MIRRORED BITS communications.

[b] The time source must include the IEEE C37.118 IRIG-B control bit assignments and the Global setting IRIGC must be set to C37.118 to provide the time-error estimate for the clock. In products that support line-current differential protection, the jitter requirement for HIRIG is 50 ns.

NOTE: If the time-code signal connected to the BNC connector degrades in quality, the relay will not switchover to the IRIG-B pins of serial PORT 1. The relay will only switch to serial PORT 1 if the signal on the BNC connector completely fails or the accuracy is better on serial PORT 1 than on the BNC input (e.g., the cable is unplugged).

Only one IRIG-B time source can be used by the relay, and the signal connected to the IRIG-B BNC connector takes priority over the serial PORT 1 IRIG-B pins. If a signal is detected on the IRIG-B BNC input, the IRIG-B pins of serial PORT 1 will be ignored, unless the serial PORT 1 IRIG-B has better quality than the BNC input.

The relay determines the suitability of the IRIG-B signal connected to the BNC connector for high-accuracy timekeeping by applying two tests:

- ➤ Measuring whether the jitter between positive-transitions (rising edges) of the clock signal is less than 500 ns.
- ➤ Decoding the time-error information contained in the IRIG-B control field and determining that analog quantity TQUAL is less than 10^{-6} seconds (1 µs).

If a valid source is detected on the BNC or serial port IRIG inputs, BNC_TIM and BNC_OK or SER_TIM and SER_OK will be set, respectively.

PTP Timekeeping

NOTE: The SEL-487V does not support PTP.

In addition to IRIG-B, Precision Time Protocol (PTP), as specified in IEEE 1588-2008, can be used for high-accuracy timekeeping. The relay can only be synchronized by a grandmaster on the PTP timescale, not an arbitrary (ARB) timescale. With the ARB timescale, the epoch is set by an administrative procedure and can change at any time during normal operation. The PTP timescale uses the PTP epoch of January 1 1970 00:00:00 TAI (International Atomic Time), which corresponds to December 31 1969 23:59:51.999918 UTC (Coordinated Universal Time). Its unit of time is the SI second and accounts for leap seconds.

The offset between TAI and UTC time is included in the PTP announce message, along with a flag that indicates whether or not the offset is valid. The relay will use the offset sent by the Grand Master (GM) clock to determine UTC time regardless of validity. Because of this, all SEL devices (and other slave devices that share this behavior) synchronized with the GM will retain relational accuracy with each other even if, in certain cases, the GM may be incorrect in relation to UTC.

The announce message may also include the current TAI to Local offset value (required in the C37.238 profile). In accordance with IEEE 1588-2008 16.3.3.4, this value must include the TAI to UTC offset to reflect local time at the node, or slave device. If the relay receives a TAI to Local offset value that does not include the TAI to UTC offset, it may incorrectly calculate UTC and Local time. Also, if the announce message does not include the TAI to Local offset value, the relay will use its configured Time and Date settings (UTCOFF, BEG_DST, and END_DST) to calculate local time. This is one reason that the relay Time and Date settings must match the settings in the GM clock, or devices that are synchronized may have issues with time-alignment.

To use PTP, the relay part number must include the Ethernet card option that supports PTP and PTP must be enabled in **PORT 5** settings and properly configured. The relay must be connected to a network containing an appropriate PTP master, and all intervening switches must be IEEE 1588 aware. For SEL-400 series relays with a two- or four-port Ethernet card, PTP is only available on Ethernet **PORT 5A** and **PORT 5B**. For SEL-400 series relays with the five-port Ethernet card, PTP is available on either Ethernet **PORT 5A** and **PORT 5B** or **PORT 5C** and **PORT 5D**. PTPPORT is an analog quantity that can be used to identify the active port. PTPPORT = 1 if **PORT A** is the active port, PTPPORT = 2 if **PORT B** is the active port, PTPPORT = 3 if **PORT C** is the active port, PTPPORT = 4 if **PORT D** is the active port, and PTPPORT = 0 if PTP is not synchronized. See *Precision Time Protocol (PTP) on page 15.18* for more information on configuring the relay and the Ethernet network for PTP.

To achieve basic synchronization to PTP, the master clock sync and announce interval must not exceed four seconds. The Relay Word bit PTP_TIM indicates that this basic level of synchronization has been achieved. If the network is not introducing excessive jitter in the time-synchronized messages, PTP_OK will be set indicating the presence of time synchronization. The analog quantity PTPSTEN can be used to indicate the state of the PTP port as follows: 1 = Initializing, 2 = Faulty, 3 = Disabled, 4 = Listening, 8 = Uncalibrated, 9 = Slave.

PTP Over PRP Networks

SEL-400 series relays support PTP time synchronization over a PRP network. When the relay operates in this network mode, the default, C37.238, and 61850-9-3 PTP profiles are available. When using PTP time synchronization over a PRP network, you must use the LAYER2 option for the PTP transport mechanism setting PTPTR.

The SEL-400 series relays support PTP time synchronization over Parallel Redundancy Protocol (PRP) networks. In a PRP network, a dual attached node (DAN) receives a pair of duplicated packets.

PTP messages that transverse through two distinct networks suffer a different amount of delays. *Figure 11.1* shows that path delays via LAN A and LAN B are different. These delays include link delays and residence time. PTP-capable Ethernet switches in these LANs should update PTP messages with the actual residence time and request/reply to path delay messages. It should not alter PTP messages by appending RCTs. The dual attached slave clock receives two different sets of PTP messages, as shown in *Figure 11.1*. The two ports independently determine its port state.

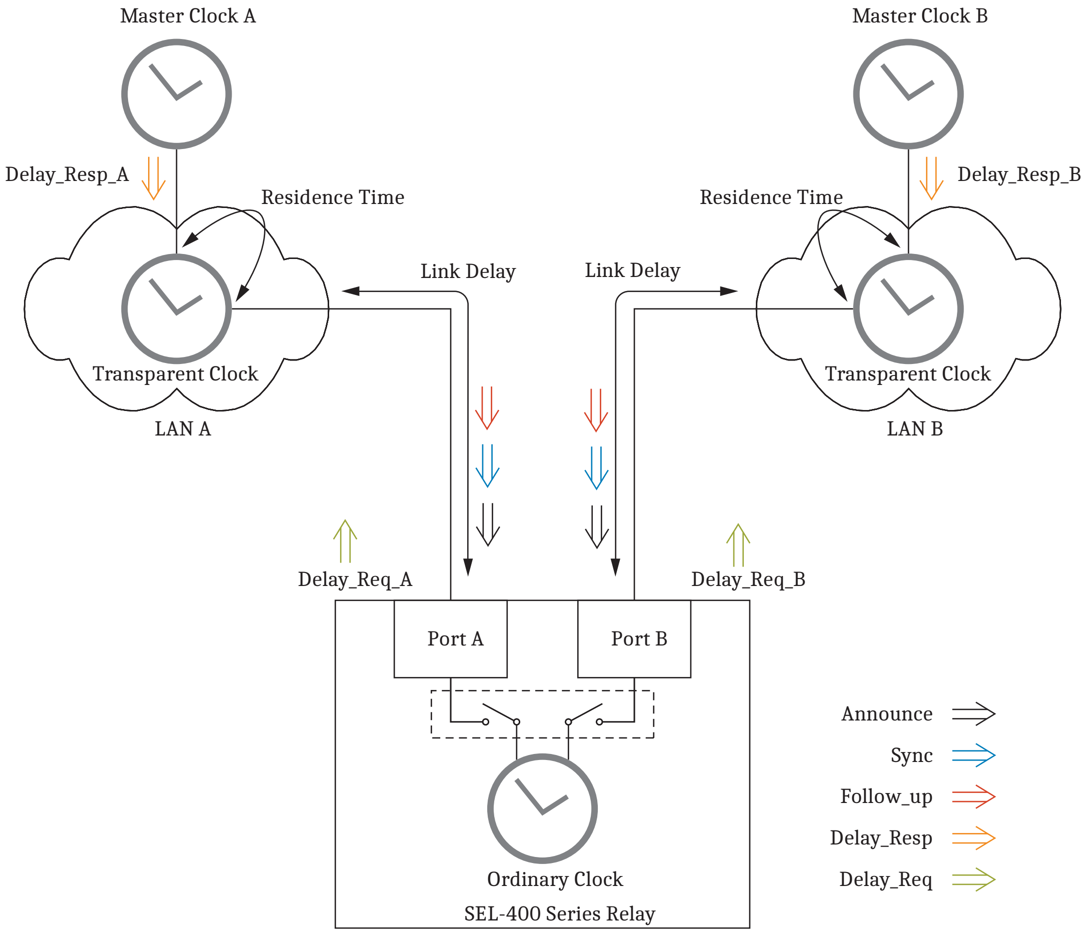

Figure 11.1 PTP Time Synchronization Over a PRP Network

NOTE: For the five-port Ethernet card, configure the PTHDLY setting to **P2P** to cause the relay to synchronize both the primary and standby ports. This allows the relay to seamlessly maintain PTP synchronization during a failover operation. This does not apply when PTHDLY is set to E2E or when using the two- or four-port Ethernet card.

As shown in *Figure 11.1*, the SEL-400 Series Relay Best Master Clock Algorithm (BMCA) synchronizes to one grandmaster clock on either LAN A or LAN B. The relay synchronizes to the best grandmaster based on the characteristics of the grandmaster and the locally derived offset from the relay to each grandmaster. For applications such as synchrophasors requiring high-accuracy time synchronization, the accuracy of both the grandmaster (TQUAL) and the locally derived offset (PTPOFST) must be better or equal to 1 µs. The SEL-400 series relays use the analog quantity PTPPORT to indicate the port to which the relay is synchronized to the best PTP master (see *Table 11.2*).

Table 11.2 PTPPORT Synchronized to the Best PTP Master

PTPPORT	Ethernet Port
1	5A
2	5B
3	5C
4	5D

The ASCII command **COM PTP 5*n*** displays PTP statistics for the specific interface on PORT 5. The ASCII command **COM PTP** also displays the port status in *COM PTP on page 14.15*. If a port is selected to synchronize the relay, the port status is ACTIVE; otherwise, it is PASSIVE.

Time Source Selection

IRIG-B via BNC connection, IRIG-B via serial **PORT 1** , and PTP can all be connected to the relay. Each of these can provide a high-quality time value. The relay selects between these sources by using the following priority scheme:

1. BNC IRIG if BNC_OK and BNC time quality ≤ 1 µs
2. Serial IRIG if SER_OK and serial time quality ≤ 1 µs
3. PTP if PTP_OK and PTP time quality ≤ 1 µs
4. BNC IRIG if BNC_OK
5. Serial IRIG if SER_OK
6. PTP if PTP_OK

The **TIME** command indicates what source is being used. This is also available in the analog quantity CUR_SRC as shown in *Table 11.3*.

Table 11.3 CUR_SRC Encoding

Source	CUR_SRC value
BNC IRIG-B	1
Serial Port IRIG-B	2
PTP	4
None of the above	8

If IRIG-B and PTP are not available, then the time can be set via any low-priority time source: SNTP, DNP3, **TIME** and **DATE** commands, front-panel set date/time, and extended MIRRORED BITS.

Time Quality Indications

Analog Quantities and Relay Word Bits

You can check the status of timekeeping by checking the relevant analog quantities or Relay Word bits. Once a time source is connected, wait at least 20 seconds to allow for a solid synchronization to take place.

If you are using a time source that provides time-quality information (IRIG-B with C37.118 or PTP), then the presently reported time quality is available via the TQUAL analog quantity and the TQUAL1, TQUAL2, TQUAL4, and TQUAL8 Relay Word bits. *Table 11.4* and *Table 11.5* show how these are encoded for IRIG and the three supported PTP Profiles.

Table 11.4 Time Quality Encoding (IRIG) (Sheet 1 of 2)

IRIG					
Master Clock Accuracy (ns)	TQUAL8	TQUAL4	TQUAL2	TQUAL1	TQUAL (seconds)
Clock failure, time not reliable	1	1	1	1	Unknown[a]
10 seconds	1	0	1	1	10
1 second	1	0	1	0	1
100 milliseconds	1	0	0	1	0.1
10 milliseconds	1	0	0	0	0.01

Table 11.4 Time Quality Encoding (IRIG) (Sheet 2 of 2)

IRIG					
1 millisecond	0	1	1	1	0.001
100 microseconds	0	1	1	0	0.0001
10 microseconds	0	1	0	1	0.00001
1 microsecond	0	1	0	0	0.000001
100 nanoseconds	0	0	1	1	0.0000001
10 nanoseconds	0	0	1	0	0.00000001
1 nanosecond	0	0	0	1	0.000000001

[a] The relay reports the 32-bit float limit (i.e., 3.40282347E+38).

Table 11.5 Time Quality Encoding (PTP)

PTP Profile (PTPPRO = DEFAULT, C37.238, 61850-9-3)					
Time_inaccuracy = Grandmaster timeinaccuracy + Network timeinaccuracy (ns)[a]	TQUAL8	TQUAL4	TQUAL2	TQUAL1	TQUAL (seconds)
Grandmaster timeinaccuracy ≥ 4294967295 or Network timeinaccuracy ≥ 4294967295[a]	1	1	1	1	Grandmaster timeinaccuracy + Network timeinaccuracy[a]
1,000,000,000 ≤ time_inaccuracy < 10,000,000,000	1	0	1	1	
100,000,000 ≤ time_inaccuracy < 1,000,000,000	1	0	1	0	
10,000,000 ≤ time_inaccuracy < 100,000,000	1	0	0	1	
1,000,000 ≤ time_inaccuracy < 10,000,000	1	0	0	0	
100,000 ≤ time_inaccuracy < 1,000,000	0	1	1	1	
10,000 ≤ time_inaccuracy < 100,000	0	1	1	0	
1,000 ≤ time_inaccuracy < 10,000	0	1	0	1	
100 ≤ time_inaccuracy < 1,000	0	1	0	0	
10 ≤ time_inaccuracy < 100	0	0	1	1	
1 ≤ time_inaccuracy < 10[a]	0	0	1	0	
time_inaccuracy = 0[a]	0	0	0	0	

[a] This only applies to C37.238.

PTP supports Default profile, C37.238 Power Profile, and IEC/IEEE 61850-9-3 Power Utility Automation Profile, which is set by the PORT 5 setting PTPPRO. PTP reports the time quality through TQUAL1, TQUAL2, TQUAL4, and TQUAL8 Relay Word bits, which are the same bits used if IRIG-B is the time source. If PTPPRO = DEFAULT or 61850-9-3, the time quality is reported based only on the accuracy of the master clock. If PTPPRO = C37.238, the time quality is reported based on the accuracy of the master clock (Grandmaster timeinaccuracy) plus the inaccuracy of the network (Network timeinaccuracy). For this profile, if either Grandmaster timeinaccuracy or Network time-inaccuracy is the maximum value, the relay will set all TQUAL bits to 1.

If the relay is synchronized to an IRIG-B or PTP time source, the TSYNC bit will be set. If the quality of this synchronization is 1 µs or better, then TSOK is set, indicating this bit has sufficient accuracy for synchrophasors. TGLOBAL will assert if a high-accuracy source is being used and the source indicates it is providing 1 µs or better accuracy, and the Global setting IRIGC = C37.118 for BNC IRIG applications. Refer to *Figure 11.3* for TLOCAL qualifying criteria.

As an example of checking IRIG status, use the command **TAR TIRIG** to view the relevant Relay Word bits, as shown in *Figure 11.2*. Only the state of the TIRIG and TSOK Relay Word bits are discussed in the troubleshooting steps below. The other Relay Word bits of interest to this discussion are TUPDH, which indicates that the relay internal clock is presently being updated by the HIRIG source, TSYNCA, which acts as an alarm bit that asserts when the relay is not synchronized to either an internal or an external source. TSYNCA will only assert briefly when the HIRIG time source is connected or disconnected.

```
=>TAR TIRIG <Enter>

*       *       TIRIG   TUPDH   TSYNCA  TSOK    PMDOK   FREQOK
0       0       1       1       0       1       1       0
=>
```

Figure 11.2 Confirming the High-Accuracy Timekeeping Relay Word Bits

The TIRIG and TSOK Relay Word bits should be asserted (logical 1), indicating that the relay is in the high-accuracy IRIG timekeeping mode (HIRIG).

If TSOK is not asserted, but TIRIG is asserted, the relay is in regular IRIG timekeeping mode. Following is a list of possible reasons for not entering HIRIG mode:

➤ The IRIG-B clock does not use the IEEE C37.118 control bit assignments, or the IRIG-B signal is not of sufficient accuracy.
➤ The termination resistor, required by some IRIG clocks, is not installed.
➤ The time-source clock is reporting that its time error is greater than 1 µs.

If neither TSOK nor TIRIG is asserted, the relay is not in an IRIG time-source mode. Following is a list of possible reasons for not entering IRIG mode:

➤ The IRIG-B clock signal is improperly configured.
➤ The termination resistor, required by some IRIG clocks, is not installed.

NOTE: At startup, TPTP can assert as fast as 1.5 seconds after PTP_TIM asserts.

TBNC asserts when BNC IRIG is used to update the relay master time. Likewise, TSER asserts when serial IRIG is selected and TPTP asserts when PTP is the active source updating the relay master time. At any given time, only one of these three bits can equal logical 1.

Global Time Source vs Local Time Source

An SEL-400 series relay indicates that it is synchronized with either a global or local time source according to the logic as shown in *Figure 11.3*. When CUR_SRC is IRIG or PTP and TSYNC is asserted, the relay determines the status of TGLOBAL or TLOCAL following the logic diagram in *Figure 11.3*.

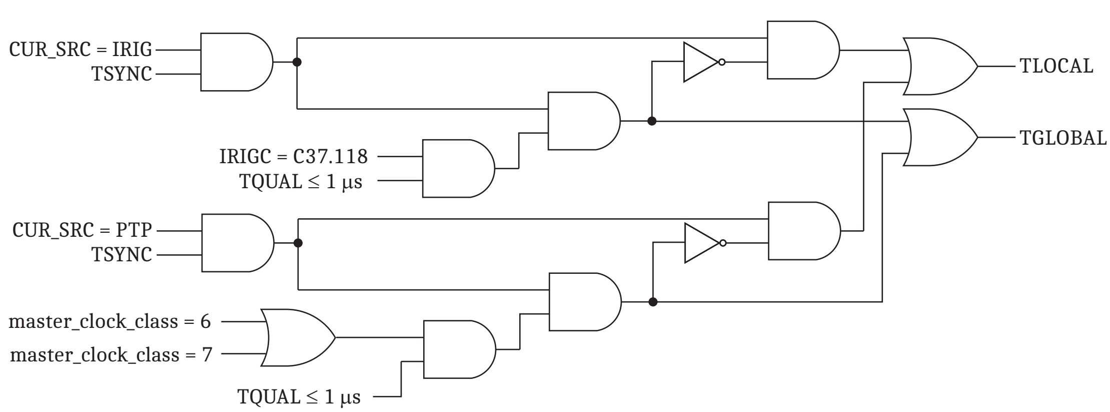

Figure 11.3 TLOCAL and TGLOBAL Logic

The relay can maintain a 1 µs time accuracy for at least 8 seconds after the loss of time synchronization.

TIME Q Command

The **TIM Q** command provides details about relay timekeeping (see *Table 11.4* and *Table 11.5*). The internal clock of the relay is initially calibrated at the SEL factory. An external IRIG or PTP source is required to eliminate clock drift. The `Time Source` field provides the present high-accuracy timing input source; entries for this line are HIRIG, IRIG, HPTP, PTP, or OTHER. The `Last Update Source` reports the source from which the relay referenced the last time value measurement. Entries for this line can be high-priority or low-priority sources. *Table 11.6* lists the possible `Last Update Source` values for the relay.

```
=>>TIM Q <Enter>

Relay 1                                    Date: 03/17/2023 Time: 15:08:41.468
Station A                                  Serial Number: 1230769999

Time Source: HPTP
Last Update Source: HPTP
Grandmaster Clock Quality
    Clock Class : Synchronized with PTP timescale (6)
    Time Traceable : TRUE
    Clock Accuracy : Within 25 ns
    Offset Log Variance : 0

Time Mark Period:  1000.000061 ms

Internal Clock Period:  19.999935 ns

=>>
```

Figure 11.4 Sample TIM Q Command Response

Table 11.6 Date/Time Last Update Sources

Time Input Source Mode	Priority	Time Source
HIRIG	High	Time/date from the high-accuracy IRIG-B input
SNTP	Low	Simple Network Time Protocol
IRIG	High	Time/date from the IRIG-B format time base signal
HPTP	High	Time/date from a high-accuracy PTP source
PTP	High	Time/date from a PTP source
DNP	Low	Time/date from the DNP3 communications port
MIRRORED BITS	Low	Time/date from the Mirrored Bit port
SNTP	Low	Time/date from SNTP server
ASCII TIME	Low	Time from the relay serial ports
ASCII DATE	Low	Date from the relay serial ports
NONV CLK	Low	Time/date from the nonvolatile memory clock
FRONT PANEL TIME	Low	Time from the front-panel TIME entry screen
FRONT PANEL DATE	Low	Time from the front-panel DATE entry screen

The `Time Mark Period` value indicates the instantaneous period in which the relay measures the time-source inputs. The relay displays the time mark periods showing the present time precision derived from the applied time-source signals.

The **TIME Q** command is also helpful for troubleshooting IRIG and PTP problems. If the `Time Mark Period` value changes significantly between successive **TIME Q** commands, there may be too much noise in the time signal for the relay timekeeping function.

Adaptive Internal Clock Period Adjustment

The Internal Clock Period, as shown in the **TIME Q** command response in *Figure 11.4*, is the internal relay timekeeping period. The relay adjusts this master internal clock when you apply HIRIG or HPTP mode timekeeping, adapting the internal relay clock for your installation temperature conditions. If you lose the timing lock, the relay internal clock operates at this precisely adapted clock period until HIRIG or HPTP mode is restored. Time tags for event reports during a loss of high-accuracy timekeeping remain very accurate. Lower-accuracy time sources do not adaptively adjust the internal relay clock period.

COM PTP Command

The **COM PTP** command provides a report of the PTP data sets maintained by the device as well as statistics for the measured time offsets with the parent (master) clock. The PTP data sets contain information about the state, identity, and configuration of the local, parent, and grandmaster clocks in addition to properties of the time being distributed by the grandmaster clock. See *COM PTP on page 14.15* for more information on this command.

Daylight-Saving Time (DST)

The status of DST time can be determined by one of three possible high-priority sources (BNC, SER, or PTP). The daylight-saving time pending Relay Word bit (DSTP) is valid only when IRIG is the active source. When PTP is selected, it sets the DSTP bit to zero at all times. If no high-priority source with daylight-saving time information is available, the DST bit is determined based on the BEG_DST and END_DST Global settings.

When using PTP as the Time Synchronization source, the PTP master may not provide valid DST information as the relay powers up. To ensure the relay powers up with the correct time when synced to a PTP source, you must ensure that the relay Time and Date Management settings and the PTP master configuration are in agreement.

Time-Synchronized Events

Time-Synchronized Triggers

You can program the relay to perform data captures at *specific* times. Relays that are time-locked by using HIRIG mode provide high-accuracy time-synchronized data captures. When you use this method on multiple relays, the actual trigger times can differ by as much as 5 ms, but the information in the binary COMTRADE file outputs from each relay is time-stamped at very high accuracy. Do not assume that the relay triggers are locked with high accuracy; rather, compare corresponding time-stamped data points from each COMTRADE file.

Time Triggering the Relay

NOTE: The **MET PM time** command can be used to capture synchrophasor data at a specific time if synchrophasors are enabled with Global setting EPMU := Y.

Perform the following steps to trigger an event data capture in the relay at a specific time. These settings cause the relay to initiate a data capture at 12:00:30 p.m. Use other SELOGIC control equations in a similar manner to trigger relay event recordings.

Step 1. Start SEL Grid Configurator and establish communications with the relay.

Step 2. Select **Read** to read the present configuration in the relay.

The relay sends all configuration and settings data to SEL Grid Configurator.

Step 3. Select the **Settings Grid > Protection > Protection Logic**. Leave the Protection Group dropdown menu set at 1.

Step 4. Enter time trigger settings:

a. Select in the first available line of protection logic.

b. In the Edit Pane for the line, enter or search for **PMV64**, then enter := to continue building the equation.

c. On the right side of the equation, search for and select **THR** (which is the Time in Hours analog quantity) or enter **THR** after the equation equal sign.

d. Double-click **THR** (Time in Hours).

e. Use the **#** character to add a comment to the line.

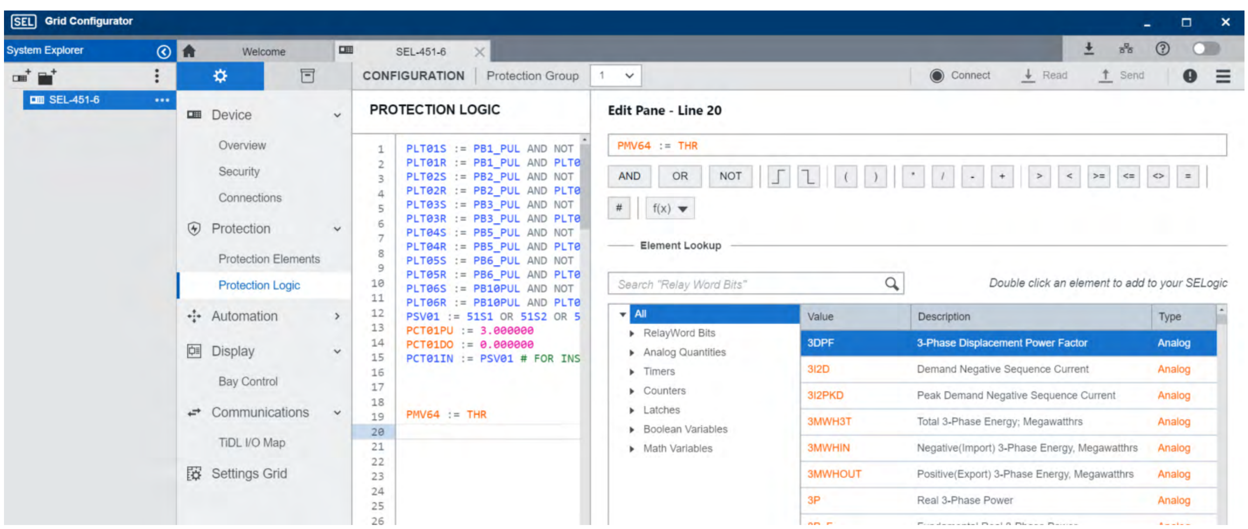

Figure 11.5 Setting PMV64 With the Expression Builder Dialog Box

NOTE: In this example, the event report trigger will occur between 12:30:00.002 and 12:30:00.005 because of the method of relay protection logic processing.

Step 5. In a similar manner, build a freeform SELOGIC control equation program in **Protection Logic** that causes protection freeform SELOGIC control equation variable PSV02 to assert to logical 1 at 12:00:30.005 p.m. Use the following expressions:

PMV64 := THR # Clock hours

PMV63 := TMIN # Clock minutes

PMV62 := TSEC # Clock seconds

PSV02 := (PMV64=12) AND (PMV63=00) AND (PMV62=30) # Set PSV02 at 12:00:30

NOTE: You should be careful to remove this event report trigger once you have completed your testing. Otherwise, the relay will continue to trigger new events every day at the programmed time.

Step 6. Navigate to the **ER** setting in your Settings Grid view under Group 1 settings.

Step 7. Select in the **ER Event Report Trigger Equation** (SELOGIC) text box and add **OR R_TRIG PSV02** to the end of elements already in this SELOGIC control equation.

COMTRADE File Information

Retrieve the COMTRADE files for the time-triggered data captures from each relay with the **FILE READ** command.

Parse the binary COMTRADE data for the power system currents and voltages you need to calculate system quantities.

Fault Analysis

Use the relay measurement and communications capabilities to obtain precise simultaneous measurements from the power system at different locations. Combining system measurements from a number of key substations gives you a snapshot picture of the phasor relationships in the power system at a particular time. You can perform extensive fault analysis by evaluating the simultaneous measurements gathered at a central computer or data server.

Install at least two relays in the power system to implement dynamic phasor determination. *Figure 11.6* shows an example of a 230 kV overhead transmission line with a relay at each terminal. Connect GPS clocks (such as the SEL-2407) at each substation to provide high-accuracy time-signal inputs for each relay.

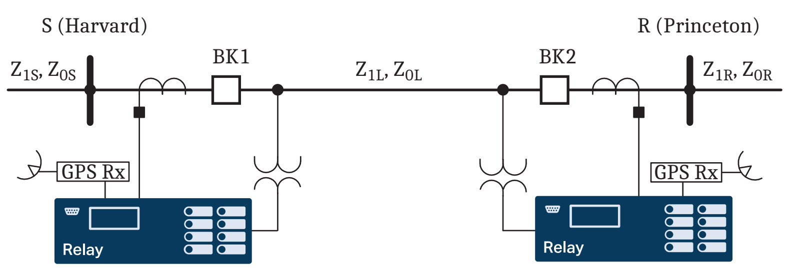

Figure 11.6 230 kV Transmission Line System

With synchronized and time-stamped binary COMTRADE data, you can develop automated computer algorithms for comparing these data from different locations in the power system.

In particular, you can use fault data extracted from two relays. Use third-party software to filter the binary COMTRADE data so that the signals are composed of fundamental quantities only (50 Hz or 60 Hz). You can also use third-party software to convert the binary COMTRADE data to ASCII COMTRADE files. Use the Phasor Diagram in the SEL-5601-2 SYNCHROWAVE Event Software to select the appropriate pre-fault and post-fault quantities.

Power Flow Analysis

Use SEL-400 series relays to develop instantaneous power flow data. Obtain the voltage and current phasors from different power system buses at the same instant and use these measurements to determine power flow at that instant. Use the synchronized phasor measurement capabilities of the relay and the **METER PM** command or a Synchrophasor Protocol to collect synchronized voltage and current data. Use this information to confirm your power flow models.

For example, consider four SEL-421 Relays installed in the power system as shown in *Figure 11.7*. Substations S and R provide generation for the load at Substation T.

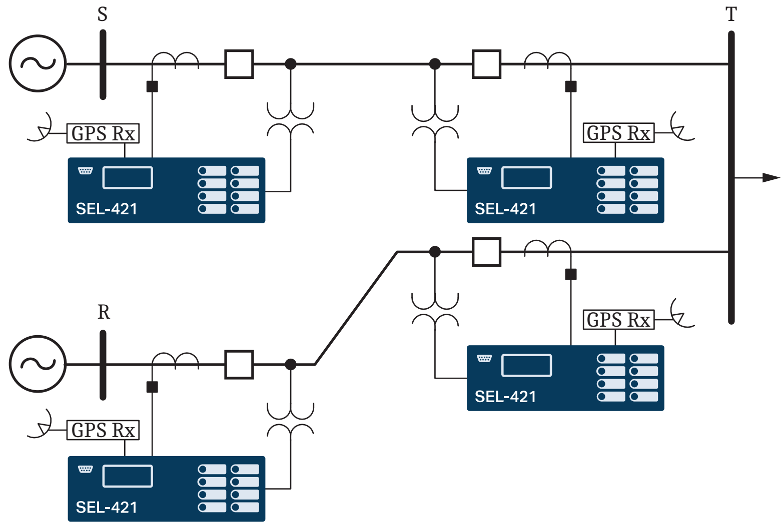

Figure 11.7 500 kV Three-Bus Power System

Table 11.7 lists the voltage and current measured by the four SEL-421 Relays at one particular time.

Table 11.7 SEL-421 Voltage and Current Measurement

Voltage		Current	
SEL-421 at Substation S			
V_{AS}	288.675 kV ∠0°	I_{AS}	238.995 A ∠41.9°
V_{BS}	288.675 kV ∠240°	I_{BS}	238.995 A ∠–78.1°
V_{CS}	288.675 kV ∠120°	I_{CS}	238.995 A ∠161.9°
SEL-421 at Substation R			
V_{AR}	303.109 kV ∠–0.2°	I_{AR}	234.036 A ∠–44.2°
V_{BR}	303.109 kV ∠239.8°	I_{BR}	234.036 A ∠195.8°
V_{CR}	303.109 kV ∠119.8°	I_{CR}	234.036 A ∠75.8°
SEL-421 at Substation T Looking Toward Substation S			
$V_{AT–S}$	295.603 kV ∠–1.6°	$I_{AT–S}$	238.995 A ∠–138.1°
$V_{BT–S}$	295.603 kV ∠238.4°	$I_{BT–S}$	238.995 A ∠101.9°
$V_{CT–S}$	295.603 kV ∠118.4°	$I_{CT–S}$	238.995 A ∠–18.1°
SEL-421 at Substation T Looking Toward Substation R			
$V_{AT–R}$	295.603 kV ∠–1.6°	$I_{AT–R}$	234.036 A ∠135.8°
$V_{BT–R}$	295.603 kV ∠238.4°	$I_{BT–R}$	234.036 A ∠15.8°
$V_{CT–R}$	295.603 kV ∠118.4°	$I_{CT–R}$	234.036 A ∠–104.2°

Use *Equation 11.1* to calculate the generation supplied from Substation S and Substation R, plus the load at Substation T.

$$
\begin{aligned}
S_{3\phi} &= P_{3\phi} + jQ_{3\phi} \\
&= \sqrt{3} \bullet V_{pp} \bullet I^*_L \\
&= 3 \bullet V_p \bullet I^*_L
\end{aligned}
$$

Equation 11.1

where:

$S_{3\phi}$ = Three-phase complex power (MVA)
$P_{3\phi}$ = Three-phase real power (MW)
$Q_{3\phi}$ = Three-phase imaginary power (MVAR)
V_{pp} = Phase-to-phase voltage
V_p = Phase-to-neutral voltage
I^*_L = Complex conjugate of the line current

The complex power generation supplied by Substation S is:

$$
\begin{aligned}
S_S &= (3 \bullet 288.675\ \text{kV}\angle 0°) \bullet (238.995\ \text{A}\angle{-41.9°}) \\
&= 154.1\ \text{MW} - j138.2\ \text{MVAR}
\end{aligned}
$$

The complex power generation supplied by Substation R is:

$$
\begin{aligned}
S_R &= (3 \bullet 303.109\ \text{kV}\angle{-0.2°}) \bullet (234.036\ \text{A}\angle 44.2°) \\
&= 152.6\ \text{MW} + j148.3\ \text{MVAR}
\end{aligned}
$$

The load at Substation T supplied by Substation S is:

$$
\begin{aligned}
S_{T-S} &= (3 \bullet 295.603\ \text{kV}\angle{-1.6°}) \bullet (238.995\ \text{A}\angle 138.1°) \\
&= -153.7\ \text{MW} + j145.9\ \text{MVAR}
\end{aligned}
$$

The load at Substation T supplied by Substation R is:

$$
\begin{aligned}
S_{T-R} &= (3 \bullet 295.603\ \text{kV}\angle{-1.6°}) \bullet (234.036\ \text{A}\angle{-135.8°}) \\
&= -152.8\ \text{MW} - j140.5\ \text{MVAR}
\end{aligned}
$$

The total load at Substation T is:

$$
\begin{aligned}
S_T &= S_{T-S} + S_{T-R} \\
&= -306.5\ \text{MW} + j5.4\ \text{MVAR}
\end{aligned}
$$

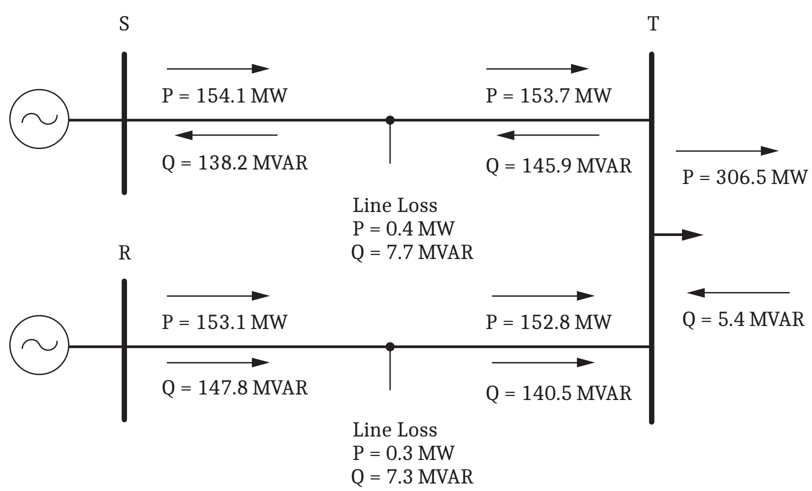

Figure 11.8 Power Flow Solution

Use the power flow solution to verify the instantaneous positive-sequence impedances of your system transmission lines.

State Estimation Verification

Electric utility control centers have used state estimation to monitor the state of the power system for the past 20 years. The state estimator calculates the state of the power system by using measurements such as complex power, voltage magnitudes, and current magnitudes received from different substations. State estimation uses an iterative, nonlinear estimation technique. The state of the power system is the set of all positive-sequence voltage phasors in the network. Typically, several seconds or minutes elapse from the time of the first measurement to the time of the first estimation. Therefore, state estimation is a steady-state representation of the power system.

Consider using precise simultaneous positive-sequence voltage measurements from the power system to verify your state estimation model. Take time-synchronized high-resolution positive-sequence voltage measurements at all substations. Send the relay synchrophasor messages to a central database to determine the power system state.

Power system contingency analysis models rely on state-estimation techniques, and may have inaccuracies caused by incorrect present-state information, or errors in system characteristics, such as incorrect line and source impedance estimates. The simultaneous event-report triggering technique described earlier in this section can be used to verify present models.

NOTE: Not all SEL-400 series relays support synchrophasors.

With SEL-400 series relays acting as phasor measurement units (PMUs) installed in several substations, synchrophasor measurements can be transmitted to a central processor in near-real time, providing very accurate snapshots of the power system. This type of data processing system provides system-state measurements that are a few seconds old, rather than state estimates that may be several minutes old. In addition, the synchrophasor results are real measurements, rather than estimates.

See *Section 18: Synchrophasors* for information on the PMU settings and the communications protocols available for synchrophasor data collection.

S E C T I O N 1 2

Settings

This section contains tables of relay settings that are common to most SEL-400 series relays. See the product-specific instruction manuals for details of all settings available in the relay.

The relay hides some settings based upon other settings. If you set an enable setting to OFF, for example, the relay hides all settings associated with that enable setting. This section does not explain rules for hiding settings; these rules are discussed in *Section 6: Protection Application Examples* in the product-specific instruction manuals, where appropriate.

⚠**WARNING**
Isolate the relay trip circuits while changing settings. When changing settings for multiple classes, it is possible to be in an intermediate state that will cause an unexpected trip.

The settings prompts in this section are similar to the ASCII terminal and SEL Grid Configurator software prompts. The prompts in this section are unabbreviated and show all possible setting options.

This section describes how settings are organized, explains the concept of settings groups, and then describes some common relay settings:

Settings Structure

The settings structure assigns each relay setting to a specific location based on the setting type. A top-down organization allocates relay settings into these layers:

➤ Class
➤ Instance
➤ Category
➤ Setting

Examine *Figure 12.1* to understand the settings structure in a typical SEL-400 series relay. The top layer of the settings structure contains classes and instances. Class is the primary sort level; all classes have at least one instance, and some classes have multiple instances. Typical settings classes and related instances are listed in *Table 12.1*.

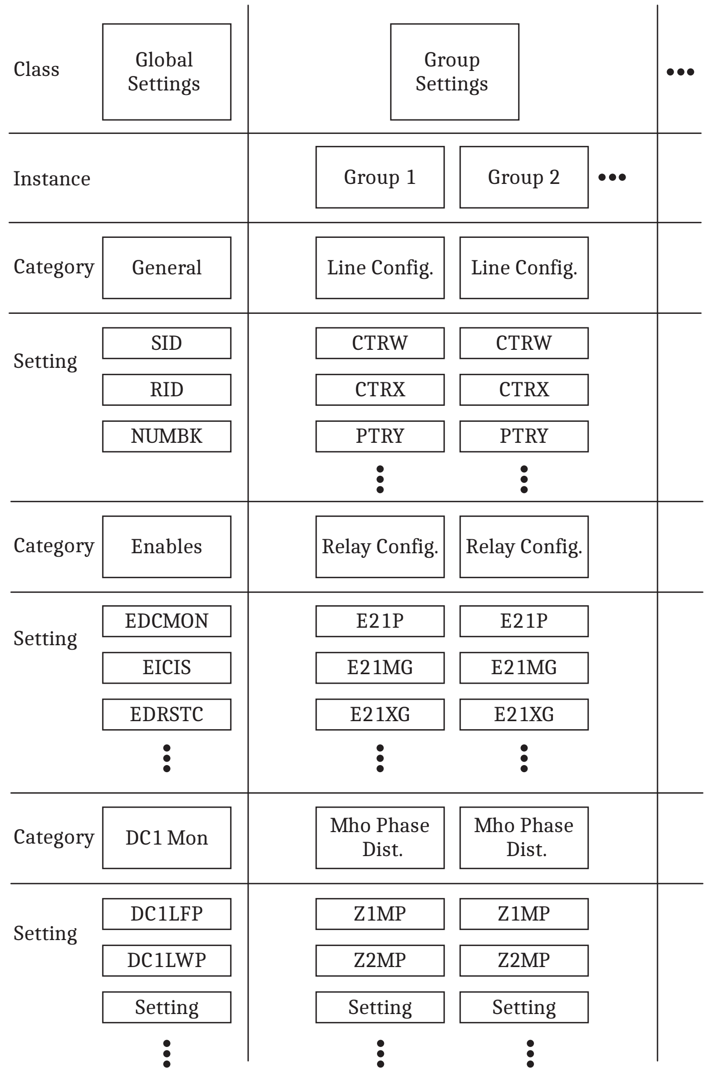

Figure 12.1 Typical Relay Settings Structure Overview

Table 12.1 Typical Settings Classes and Instances (Sheet 1 of 2)

Class	Description	Instance	Description	ASCII Command	Access Level
Global	Relay-wide applications settings	Global	Global settings	SET G	P, A, O, 2
Group	Individual scheme settings	Group 1 • • • Group 6	Group 1 settings • • • Group 6 settings	SET 1, SET S 1 • • • SET 6, SET S 6	P, 2
Breaker Monitor	Circuit breaker monitoring settings	Breaker Monitor		SET M	P, 2
Bay Control	Bay Control Settings	Bay Control		SET B 1	P, A, O, 2

Table 12.1 Typical Settings Classes and Instances (Sheet 2 of 2)

Class	Description	Instance	Description	ASCII Command	Access Level
Port	Communications port settings	PORT F PORT 1 • • • PORT 3 PORT 5 PORT 6 (TiDL [T-Protocol] relays only)	Front-panel port PORT 1 settings • • • PORT 3 settings Ethernet card settings TiDL topology settings (TiDL [T-Protocol] relays only)	SET P F SET P 1 • • • SET P 3 SET P 5 (Only available via SEL Grid Configurator)	P, A, O, 2
Report	Event report and SER settings	Report		SET R	P, A, O, 2
Front Panel	Front-panel HMI settings	Front Panel		SET F	P, A, O, 2
Protection	Protection-related SELOGIC control equations	Protection 1 • • • Protection 6	Group 1 protection SELOGIC control equations • • • Group 6 protection SELOGIC control equations	SET L 1 • • • SET L 6	P, 2
Automation	Automation-related SELOGIC control equations	Automation 1 • • • Automation 10	Block 1 automation SELOGIC control equations • • • Block 10 automation SELOGIC control equations	SET A 1 • • • SET A 10	A, 2
DNP	Distributed Network Protocol data remapping	DNP 1 • • • DNP 5		SET D 1 • • • SET D 5	P, A, O, 2
Output	Relay control output settings and MIRRORED BITS communications transmit equations	Output		SET O	O, 2
Alias	Alias settings	Alias		SET T	P, A, O, 2
Notes	Freeform programming to include notes	Notes	100 lines	SET N	P, A, O, 2

Note that some settings classes have only one instance and you do not specify the instance designator when accessing these classes. An example is the Global settings class. You can view or modify Global settings with a communications terminal by entering **SET G** as shown in the ASCII Command column of *Table 12.1*. The relay presents the Global settings categories at the **SET G** command; no instance numbers follow **SET G**. Conversely, the Port settings command has five instances (PORT F, PORT 1, PORT 2, PORT 3, and PORT 5). To access the PORT 1 settings, type **SET P 1 <Enter>**. If you do not specify which port to set, the relay defaults to the active port (the port you are presently using).

The Group settings can have the optional one-letter acronym S attached to the command; you can enter SET 1 or SET S 1 for Group 1 settings, SET 2 or SET S 2 for Group 2 settings, etc. If you do not specify which group to set, the relay defaults to the present active group. If Group 6 is the active group, and you type **SET <Enter>**, for example, you will see the settings prompts for the Group 6 settings.

Multiple Setting Groups

The SEL-400 series relays have six independent setting groups. Each setting group has complete relay settings and protection SELOGIC settings. The active setting group can be:

- ➤ Shown or selected with the SEL ASCII serial port **GROUP** command—see *GROUP on page 14.41*.
- ➤ Shown or selected from the front-panel LCD with the `MAIN` menu `Set/Show` menu item and the `Active Group` submenu item as described in *Figure 4.32*.
- ➤ Selected with SELOGIC control equation settings SS1 through SS6. Settings SS1 through SS6 have priority over all other selection methods. Use remote bits in these equations to select setting groups with Fast Operate commands as described in *SEL Fast Meter, Fast Operate, Fast SER Messages, and Fast Message Data Access on page 15.34*.
- ➤ Shown with DNP3 Objects 20 and 22 and selected with Objects 40 and 41.

Setting Groups: Application Ideas

Setting groups can be used for such applications as:

- ➤ Environmental conditions such as winter storms, periods of high summer heat, etc.
- ➤ Hot-line tag that disables closing and sensitizes protection
- ➤ Commissioning and operation

Active Setting Group Indication

Only one setting group can be active at a time. Relay Word bits SG1 through SG6 indicate the active setting group, as shown in *Table 12.2*.

Table 12.2 Definitions for Active Setting Group Indication Relay Word Bits SG1 Through SG6

Relay Word Bit	Definition
CHSG	Indication that a group switch timer is operating or a group switch change is underway
SG1	Indication that setting Group 1 is the active setting group
SG2	Indication that setting Group 2 is the active setting group
SG3	Indication that setting Group 3 is the active setting group
SG4	Indication that setting Group 4 is the active setting group
SG5	Indication that setting Group 5 is the active setting group
SG6	Indication that setting Group 6 is the active setting group

For example, if setting Group 4 is the active setting group, Relay Word bit SG4 asserts to logical 1, and the other Relay Word bits SG1, SG2, SG3, SG5, and SG6 are all deasserted to logical 0.

Active Setting Group Selection

NOTE: The settings group switching settings are checked once per cycle. When setting TGR := 0, in order for a transient assertion to be recognized, it should be conditioned to remain asserted for at least 1 cycle.

The Global settings class contains the SELOGIC control equation settings SS1 through SS6, as shown in *Table 12.3*.

Table 12.3 Definitions for Active Setting Group Switching SELOGIC Control Equation Settings SS1 Through SS6

Setting	Definition
SS1	Go to (or remain in) setting Group 1
SS2	Go to (or remain in) setting Group 2
SS3	Go to (or remain in) setting Group 3
SS4	Go to (or remain in) setting Group 4
SS5	Go to (or remain in) setting Group 5
SS6	Go to (or remain in) setting Group 6

The operation of these settings is explained with the following example.

Assume the active setting group starts out as setting Group 3. Corresponding Relay Word bit SG3 is asserted to logical 1 as an indication that setting Group 3 is the active setting group.

With setting Group 3 as the active setting group, setting SS3 has priority. If setting SS3 is asserted to logical 1, setting Group 3 remains the active setting group, regardless of the activity of settings SS1, SS2, SS4, SS5, and SS6. With settings SS1 through SS6 all deasserted to logical 0, setting Group 3 still remains the active setting group.

With setting Group 3 as the active setting group, if setting SS3 is deasserted to logical 0 and one of the other settings (e.g., setting SS5) asserts to logical 1, the relay switches from setting Group 3 as the active setting group to another setting group (e.g., setting Group 5) as the active setting group, after qualifying time setting TGR (Global settings):

TGR	Group Change Delay Setting	(settable from 0 to 54000 cycles)

NOTE: The CHSG Relay Word bit does not operate for settings changes initiated by the serial port or front panel methods.

In this example, TGR qualifies the assertion of setting SS5 before it can change the active setting group. Relay Word bit CHSG asserts when the TGR timer is picked up and timing, and also when a setting group change has been initiated.

Active Setting Group Changes

NOTE: The SEL-487E and SEL-487B support 96 remote bits and all 96 are retained.

NOTE: The SEL-487E supports 96 local bits and all 96 are retained.

The relay is disabled for less than one second while in the process of changing active setting groups. Relay elements, timers, and logic are reset, unless indicated otherwise in the specific logic description. For example, local bit (LB01 through LB64), remote bit (RB01 through RB64), and latch bit (PLT01 through PLT32) states are retained during an active setting group change. The output contacts do not change state until the relay enables in the new settings group and the SELOGIC control equations are processed to determine the output contact status for the new group.

After a group change, an automatic message will be sent to any serial port that has setting AUTO := Y (see *Table 12.7*).

Active Setting: Nonvolatile State

Power Loss

The active setting group is retained if power to the relay is lost and then restored. If a particular setting group is active (e.g., setting Group 5) when power is lost, the same setting group is active when power is restored.

Settings Change

If individual settings are changed for the active setting group or one of the other setting groups, the active setting group is retained, much like in the preceding explanation.

If individual settings are changed for a setting group other than the active setting group, there is no interruption of the active setting group, so the relay is not momentarily disabled.

If the individual settings change causes a change in one or more SELOGIC control equation settings SS1 through SS6, the active setting group can be changed, subject to the newly enabled SS1 through SS6 settings.

Port Settings

Table 12.4 Port Settings Categories (Sheet 1 of 2)

Settings	Reference
Serial Settings	
Protocol Section (Serial)	*Table 12.5*
Communications Settings	*Table 12.6*
SEL Protocol Settings	*Table 12.7*
Fast Message Read Data Access	*Table 12.8*
DNP Configuration (Serial)	*Table 12.9*
MIRRORED BITS Protocol Settings	*Table 12.10*
RTD Protocol Settings	*Table 12.11*
PMU Protocol Settings	*Table 12.12*
Ethernet Settings (Two- or Four-Port Ethernet Card)	
Protocol Selection (Ethernet)	*Table 12.13*
SEL Protocol Settings	*Table 12.7*
Fast Message Read Data Access	*Table 12.8*
IP Configuration	*Table 12.14*
FTP Configuration	*Table 12.15*
HTTP Server Configuration	*Table 12.16*
Telnet Configuration	*Table 12.17*
IEC 61850 Configuration	*Table 12.18*
IEC 61850 Mode/Behavior Configuration	*Table 12.19*

Table 12.4 Port Settings Categories (Sheet 2 of 2)

NOTE: SV configuration settings are only available in SV relays.

Settings	Reference
SV Transmit Configuration	*Table 12.20*
SV Receive Configuration	*Table 12.21*
IEC SV Channel Settings	*Table 12.22*
DNP Configuration (Ethernet)	*Table 12.23*
Phasor Measurement Configuration	*Table 12.24*
SNTP Selection	*Table 12.25*
PTP Settings	*Table 12.26*
Ethernet Settings (Five-Port Ethernet Card)	
Protocol Selection (Five-Port Ethernet Card)	*Table 12.27*
SEL Protocol Settings	*Table 12.7*
Fast Message Read Data Access	*Table 12.8*
IP/Network Configuration	*Table 12.28*
FTP Configuration (Five-Port Ethernet Card)	*Table 12.29*
HTTP Server Configuration (Five-Port Ethernet Card)	*Table 12.30*
Telnet Configuration (Five-Port Ethernet Card)	*Table 12.31*
IEC 61850 Configuration	*Table 12.18*
IEC 61850 Mode/Behavior Configuration	*Table 12.19*
SV Transmit Configuration	*Table 12.20*
SV Receive Configuration	*Table 12.21*
IEC SV Channel Settings	*Table 12.22*
DNP Configuration	*Table 12.23*
Phasor Measurement Configuration (Five-Port Ethernet Card)	*Table 12.32*
SNTP Selection	*Table 12.25*
PTP Settings (Five-Port Ethernet Card)	*Table 12.33*
TiDL Settings	
TiDL Channel Map (Port 6)	See *TiDL (T-Protocol) on page 19.1*

NOTE: TiDL Channel Map is only available in SEL Grid Configurator and only for TiDL (T-Protocol) relays.

Serial Settings

Table 12.5 Protocol Selection (Serial)

Setting	Prompt	Default
EPORT[a]	Enable Port (Y, N)	Y
EPAC	Enable Port Access Control (Y, N)	N
MAXACC	Maximum Access Level (1, B, P, A, O, 2, C)	C
PROTO	Protocol (SEL, DNP, MBA, MBB, MBGA, MBGB, RTD, PMU)	SEL

[a] Setting EPORT to N on PORT 1 has no effect on the operation of IRIG-B on PORT 1.

Table 12.6 settings are available for serial ports if the preceding setting PROTO ≠ RTD.

Table 12.6 Communications Settings

Setting	Prompt	Default
MBT[a]	Using Pulsar 9600 modem? (Y, N)	N
SPEED[b]	Data Speed (300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600, SYNC[c])	9600
DATABIT[d]	Data Bits (7, 8 bits)	8
PARITY[c]	Parity (Odd, Even, None)	N
STOPBIT[e]	Stop Bits (1, 2 bits)	1
RTSCTS[f]	Enable Hardware Handshaking (Y, N)	N

[a] Only applicable if PROTO := MBA, MBB, MBGA, or MBGB.
[b] For PROTO := MBA, MBB, MBGA, or MBGB, 57600 is not available.
[c] SYNC option only available for PROTO := MBA, MBB, MBGA, or MBGB on rear-panel serial ports.
[d] For PROTO := SEL only.
[e] For PROTO := SEL, DNP, MBA, MBB, MBGA, MBGB, or PMU only.
[f] For PROTO := SEL or PMU only.

Table 12.7 settings are available if Port setting PROTO := SEL, DNP, or PMU.

Table 12.7 SEL Protocol Settings

Setting	Prompt	Default
TIMEOUT[a]	Port Time-Out (OFF, 1–60 minutes)	5
AUTO[b]	Send Auto-Messages to Port (Y, N)	Y
FASTOP[c]	Enable Fast Operate Messages (Y, N)	N
TERTIM1[d]	Initial Delay-Disconnect Sequence (0–600 seconds)	1
TERSTRN[d]	Termination String-Disconnect Sequence (9 characters maximum)[e]	"\005"
TERTIM2[d]	Final Delay-Disconnect Sequence (0–600 seconds)	0

[a] Hidden for PROTO := PMU. For Ethernet ports, TIMEOUT := TIDLE.
[b] Hidden for PROTO := DNP or PMU.
[c] Hidden for PROTO := DNP.
[d] Hidden for PROTO := PMU.
[e] TERSTRN set at /005 is <Ctrl+E>.

NOTE: Not all of these settings are available in every SEL-400 series relay. Just those that apply to features in the relay are available.

Table 12.8 Fast Message Read Data Access

Setting	Prompt	Default
FMRENAB	Enable Fast Message Read Data Access (Y/N)	Y
FMRLCL	Enable Local Region for Fast Message Access (Y/N)	N
FMRMTR	Enable Meter Region for Fast Message Access (Y/N)	Y
FMRDMND	Enable Demand Region for Fast Message Access (Y/N)	Y
FMRTAR	Enable Target Region for Fast Message Access (Y/N)	Y
FMRHIS	Enable History Region for Fast Message Access (Y/N)	N
FMRBRKR	Enable Breaker Region for Fast Message Access (Y/N)	N
FMRSTAT	Enable Status Region for Fast Message Access (Y/N)	N
FMRANA	Enable Analog Region for Fast Message Access (Y/N)	Y

Table 12.9 settings are available if Port setting PROTO := DNP.

Table 12.9 DNP Configuration (Serial) (Sheet 1 of 2)

Setting	Prompt	Default
DNPADR	DNP Address (0–65519)	0
DNPID	DNP ID for Object 0, Var 246 (20 characters)	"Relay1-DNP"
DNPMAP	DNP Session Map (1–5)	1
ECLASSB	Class for Binary Event Data (OFF, 1–3)	1
ECLASSC	Class for Counter Event Data (OFF, 1–3)	OFF
ECLASSA	Class for Analog Event Data (OFF, 1–3)	2
ECLASSV	Class for Virtual Terminal Data (OFF, 1–3)	OFF
TIMERQ	Time-Set Request Interval (I, M, 1–32767 minutes)	I
DECPLA	Currents Scaling (0–3 decimal places)	1
DECPLV	Voltages Scaling (0–3 decimal places)	1
DECPLM	Misc Data Scaling (0–3 decimal places)	1
STIMEO	Select/Operate Time-Out (0.0–60.0 seconds)	1.0
DRETRY	Data Link Retries (OFF, 1–15)	OFF
DTIMEO	Data Link Time-Out (0.0–30.0 seconds)	1.0
MINDLY	Minimum Delay from DCD to TX (0.00–1.00 seconds)	0.05
MAXDLY	Maximum Delay from DCD to TX (0.00–1.00 seconds)	0.10
PREDLY	Settle Time -RTS On to TX (OFF, 0.00–30.00 seconds)	0.00
PSTDLY	Settle Time -TX to RTS Off (0.00–30.00 seconds)	0.00
DNPCL	Enable Control Operations (Y, N)	N
AIVAR	Default Variation for Analog Inputs (1–6)	2
ANADBA	Analog Reporting Deadband for Currents (0–32767)	100
ANADBV	Analog Reporting Deadband for Voltages (0–32767)	100
ANADBM	Analog Reporting Deadband (0–32767)	100
ETIMEO	Event Message Confirm Time-Out (1–50 seconds)	2
UNSOL	Enable Unsolicited Reporting (Y, N)	N
PUNSOL	Enable Unsolicited Reporting at Power-Up (Y, N)	N
REPADR	DNP Address to Report to (0–65519)	1
NUMEVE	Number of Events to Transmit On (1–200)	10
AGEEVE	Age of Oldest Event to Transmit On (0–99999)	2
URETRY	Unsolicited Message Max Retry Attempts (2–10)	3
UTIMEO	Unsolicited Message Offline Time-Out (OFF, 1–5000 sec)	60
EVEMOD	Event Mode (SINGLE, MULTI)	SINGLE
MODEM	Modem Connected to Port (Y, N)	N
MSTR	Modem Startup String (30 chars max)	"E0X0&D0S0=4"
PH_NUM1	Phone Number for Dial-Out (30 chars max)	""
PH_NUM2	Backup Phone Number for Dial-Out (30 chars max)	""
RETRY1	Retry Attempts for Phone 1 Dial-Out (1–20)	5
RETRY2	Retry Attempts for Phone 2 Dial-Out (1–20)	5

Table 12.9 DNP Configuration (Serial) (Sheet 2 of 2)

Setting	Prompt	Default
MDTIME	Time to Attempt Dial (5–300 seconds)	60
MDRET	Time Between Dial-Out Attempts (5–3600 seconds)	120

Table 12.10 settings are available if Port setting PROTO := MBA, MBB, MBGA, or MBGB.

Table 12.10 MIRRORED BITS Protocol Settings (Sheet 1 of 2)

Setting	Prompt	Default
TX_ID	MIRRORED BITS ID of This Device (1–4)	2
RX_ID	MIRRORED BITS ID of Device Receiving From (1–4)	1
RBADPU	Outage Duration to Set RBAD (0–10000 seconds)	10
CBADPU	Channel Unavailability to Set CBAD (1–100000 ppm)	20000
TXMODE	Transmission Mode (N-Normal, P-Paced)	N
MBNUM	Number of MIRRORED BITS Channels (0–8)	8
RMB1FL	RMB1 Channel Fail State (0, 1, P)	P
RMB1PU	RMB1 Pickup Time (1–8 messages)	1
RMB1DO	RMB1 Dropout Time (1–8 messages)	1
RMB2FL	RMB2 Channel Fail State (0, 1, P)	P
RMB2PU	RMB2 Pickup Time (1–8 messages)	1
RMB2DO	RMB2 Dropout Time (1–8 messages)	1
RMB3FL	RMB3 Channel Fail State (0, 1, P)	P
RMB3PU	RMB3 Pickup Time (1–8 messages)	1
RMB3DO	RMB3 Dropout Time (1–8 messages)	1
RMB4FL	RMB4 Channel Fail State (0, 1, P)	P
RMB4PU	RMB4 Pickup Time (1–8 messages)	1
RMB4DO	RMB4 Dropout Time (1–8 messages)	1
RMB5FL	RMB5 Channel Fail State (0, 1, P)	P
RMB5PU	RMB5 Pickup Time (1–8 messages)	1
RMB5DO	RMB5 Dropout Time (1–8 messages)	1
RMB6FL	RMB6 Channel Fail State (0, 1, P)	P
RMB6PU	RMB6 Pickup Time (1–8 messages)	1
RMB6DO	RMB6 Dropout Time (1–8 messages)	1
RMB7FL	RMB7 Channel Fail State (0, 1, P)	P
RMB7PU	RMB7 Pickup Time (1–8 messages)	1
RMB7DO	RMB7 Dropout Time (1–8 messages)	1
RMB8FL	RMB8 Channel Fail State (0, 1, P)	P
RMB8PU	RMB8 Pickup Time (1–8 messages)	1
RMB8DO	RMB8 Dropout Time (1–8 messages)	1
MBTIME	Accept Mirrored Bits Time Synchronization (Y, N)	N
MBNUMAN	Number of Analog Channels (0–7)	0
MBANA1	Selection for Analog Channel 1 (analog label)	[a]
MBANA2	Selection for Analog Channel 2 (analog label)	[a]

Table 12.10 MIRRORED BITS Protocol Settings (Sheet 2 of 2)

Setting	Prompt	Default
MBANA3	Selection for Analog Channel 3 (analog label)	[a]
MBANA4	Selection for Analog Channel 4 (analog label)	[a]
MBANA5	Selection for Analog Channel 5 (analog label)	[a]
MBANA6	Selection for Analog Channel 6 (analog label)	[a]
MBANA7	Selection for Analog Channel 7 (analog label)	[a]
MBNUMVT	Number of Virtual Terminal Channels (OFF, 0-7)	OFF

[a] The default of the MBANAn settings is relay-specific. See the product-specific instruction manual to find these defaults.

Table 12.11 settings are available if Port setting PROTO := RTD.

Table 12.11 RTD Protocol Settings

Setting	Prompt	Default
RTDNUM	RTD Number of Inputs (0–12)	12
RTD*n*TY[a]	RTD *n* Type (NA, PT100, NI100, NI120, CU10)[b]	PT100

[a] Where n is the number of RTD inputs enabled in the RTDNUM setting.
[b] NA designates an input that is not connected to an RTD device.

Table 12.12 settings are available if Port setting PROTO := PMU.

Table 12.12 PMU Protocol Settings

Setting	Prompt	Default
PMUMODE	PMU Mode (CLIENTA, CLIENTB, SERVER)	SERVER
RTCID[a]	Remote PMU Hardware ID (1–65534)	1
PMODC[b]	PMU Output Data Configuration (1–5)	1

[a] Setting hidden when PMUMODE := SERVER.
[b] Setting hidden when PMUMODE := CLIENTA or CLIENTB.

Ethernet Settings

Two- or Four-Port Ethernet Card

Table 12.13 Protocol Selection (Ethernet)

Setting	Prompt	Default
EPORT	Enable Port (Y, N)	Y
EPAC[a]	Enable Port Access Control (Y, N)	N
MAXACC[a]	Maximum Access Level (1, B, P, A, O, 2, C)	C
EETHFWU	Enable Ethernet Firmware Upgrade (Y, N)	N

[a] Does not apply to TiDL Channel Map (PORT 6).

See *Table 12.7* for SEL protocol settings.

See *Table 12.8* for Fast Message read data access settings.

Table 12.14 IP/Network Configuration

Setting	Prompt	Default
ETCPKA	Enable TCP Keep-Alive (Y, N)	Y
KAIDLE	TCP Keep-Alive Idle Range (1–20 seconds)	10
KAINTV	TCP Keep-Alive Interval Range (1–20 seconds)	1
KACNT	TCP Keep-Alive Count Range (1–20)	6
IPADDR	Device IP Address / CIDR Prefix (w.x.y.z/t)	192.168.1.2/24
DEFRTR	Default router (w.x.y.z)	192.168.1.1
BUSMODE[a]	Bus Operating Mode (INDEPEND, MERGED)	INDEPEND
NETMODE	Operating Mode (FIXED, FAILOVER, SWITCHED, PRP...)	FAILOVER
NETPORT	Primary Network Port (A, B, C, D)[b]	A
PRPTOUT	PRP Entry Time-Out (100–10000 milliseconds)	500
PRPINTV	PRP Supervision TX Interval (1–10 seconds)	2
PRPADDR	PRP Supervision Address LSB (0–255)[c]	0
FTIME	Failover Time-Out (0–65535 milliseconds)	1
NETASPD[d]	Port 5A Speed (Auto, 10, 100)	AUTO
NETBSPD[d]	Port 5B Speed (Auto, 10, 100)	AUTO
NETCSPD[d]	Port 5C Speed (Auto, 10, 100)	AUTO
NETDSPD[d]	Port 5D Speed (Auto, 10, 100)	AUTO

[a] Available on devices with IEC 61850 Sampled Values (SV) publication or subscription capability.
[b] The specific options available depend on the physical ports installed in the hardware.
[c] LSB stands for least significant bit.
[d] This setting applies only if the port is installed and it is a twisted-pair port (10/100BASE-T).

NOTE: SEL advises against enabling anonymous File Transfer Protocol (FTP) logins (FTPANMS = Y) except under test conditions. The Ethernet card does not require a password for the special FTP username "anonymous". If you enable anonymous FTP logins, you are allowing unrestricted access to the SEL-400 series relay and host files.

Table 12.15 FTP Configuration

Setting	Prompt	Default
FTPSERV	Enable FTP Server (Y, N)	N
FTPCBAN	FTP Connect Banner	FTP SERVER:
FTPIDLE	FTP Idle Time-Out (5-255 minutes)	5
FTPANMS	Enable Anonymous FTP Login (Y, N)	N
FTPAUSR	Anonymous User Access Level	0

NOTE: Ethernet setting changes result in a restart of the Ethernet card. This closes active network connections and briefly pauses network operation.

Table 12.16 HTTP Server Configuration

Setting	Prompt	Default
EHTTP	Enable HTTP Server (Y, N)	N
HTTPPOR	HTTP Server TCP/IP Port Number (1–65534)	80
HIDLE	HTTP Session Inactivity Timeout (1–30 minutes)	5

Table 12.17 Telnet Configuration

Setting	Prompt	Default
ETELNET	Enable Telnet (Y, N)	N
TCBAN	Telnet Connect Banner	TERMINAL SERVER:
TPORT	Telnet Port (23, 1025–65534)	23
TIDLE	Telnet Port Time-Out (1–30 minutes)	15

Table 12.18 IEC 61850 Configuration

Setting	Prompt	Default
E61850	Enable IEC 61850 Protocol (Y, N)	N
EGSE[a]	Enable IEC 61850 GSE (Y, N)	N
EMMSFS[a]	Enable MMS File Services (Y, N)	N

[a] Hidden if E61850 := N.

Table 12.19 IEC 61850 Mode/Behavior Configuration

Setting	Prompt	Default
E850MBC	Enable 61850 Mode/Behavior Control (Y, N)	N
EOFFMTX	Enable GOOSE and SV Tx in Off Mode (Y, N)	N

Table 12.20 settings are available in relays that support IEC 61850-9-2 SV publications.

NOTE: SV configuration settings are only available in SV relays.

NOTE: The destination MAC addresses of all published multicast messages (SV, GOOSE) must be unique. Otherwise, messages may be incorrectly routed. The relay issues a diagnostic warning if any SVT destination MAC address (SVTADRp) is the same as a GOOSE destination MAC address.

Table 12.20 SV Transmit Configuration

Setting[a]	Prompt	Default
SVTXEN	Enable SV Transmission (Number of streams 0–7)	0
SVTADR*p*[b]	SVT *p* Destination MAC Address[c]	01-0C-CD-04-00-0p
TAPPID*p*[b]	SV Stream *p* Tx APPID (0x4000–0x7FFF)[d]	0x4000
TSVID*p*[b]	SVID *p* (String of 63 characters a–z, A–Z, _, 0–9)[e]	"4000"
TVLAN*p*[b]	SV *p* Transmit VLAN ID (1–4094)	1
TPRIO*p*[b]	SV *p* Transmit VLAN Priority (0–7)	4
SVT*p*ICH[b]	SVTX*p* Channel Current Terminal (W, X)	W
SVT*p*VCH[b]	SVTX*p* Channel Voltage Terminal (Y, Z)	Y

[a] Available for SV publishers only. Hidden and disabled if E61850 := N.
[b] p represents the publication number. Only settings for publications enabled by SVTXEN will be visible.
[c] Layer 2 multicast address only. Broadcast address is not allowed.
[d] The 0x prefix is used to indicate that this setting is in hexadecimal.
[e] The 9-2LE guideline supports as many as 34 characters in SVID strings. Consider this limit when configuring interoperable SV systems.

Table 12.21 settings are available in relays that support IEC 61850-9-2 SV subscriptions.

NOTE: SV configuration settings are only available in SV relays.

Table 12.21 SV Receive Configuration (Sheet 1 of 2)

Setting[a]	Prompt	Default
SVRXEN	Enable SV Reception (Number of streams 0–7)[b]	0
SVRADR*s*[c]	SV Stream *s* Subscribed MAC Address[d]	01-0C-CD-04-00-0s
RAPPID*s*[c]	SV Stream *s* Rx APPID (0x4000–0x7FFF)[e]	0x4000

Table 12.21 SV Receive Configuration (Sheet 2 of 2)

Setting[a]	Prompt	Default
SVRsICH[c, f]	SVRX*s* Channel Current Terminal (OFF, W, X)	W
SVRsVCH[c, g]	SVRX*s* Channel Voltage Terminal (OFF, Y, Z)	Y

[a] Available for SV subscribers only. Hidden and disabled if E61850 := N.
[b] The SEL-411L, SEL-421, and SEL-451 support 0–4 streams.
[c] s represents the subscription number. Only settings for subscriptions enabled by SVRXEN will be visible.
[d] Layer 2 multicast address only. Broadcast address is not allowed.
[e] The 0x prefix is used to indicate that this setting is in hexadecimal.
[f] The SEL-487E supports current Terminals S, T, U, W, X, and Y with Terminal S serving as default. The SEL-487B supports current Terminals I01–I19 with Terminal I01 serving as default. Each terminal option listed refers to three terminals grouped together. For example, I01 refers to I01–I03, I04 refers to I04–I06, etc.
[g] The SEL-487E supports voltage Terminals V and Z with Terminal V serving as default. The SEL-487B only supports the voltage Terminal V01, which serves as default. The setting V01 includes voltage terminals V01, V02, and V03.

NOTE: SV channel delay settings are only available in SV relays.

Table 12.22 IEC SV Channel Settings

Setting	Prompt	Default
CH_DLY	Sampled Value Channel Delay (1.00–3.00 milliseconds)	1.50

Table 12.23 settings are available if Port setting PROTO := DNP.

Table 12.23 DNP Configuration (Ethernet) (Sheet 1 of 2)

Setting	Prompt	Default
EDNP	Enable DNP Sessions (0–6)	0
DNPADR[a]	DNP Address (0–65519)	0
DNPPNUM[a]	DNP TCP and UDP Port (1025–65534)	20000
DNPID[a]	DNP ID for Object 0, Var 246 (20 characters)	"RELAY1-DNP"
Ethernet DNP3 Master n Configuration, n = 1 to value of EDNP, max 6[a]		
DNPIP*n*	IP Address (w.x.y.z)	192.168.1.[100+*n*]
DNPTR*n*	Transport Protocol (UDP, TCP)	TCP
DNPUDP*n*[b]	UDP Response Port (REQ, 1025–65534)	20000
DNPMAP*n*	DNP Session Map (1–5)	1
CLASSB*n*	Class for Binary Event Data (OFF, 1–3)	1
CLASSC*n*	Class for Counter Event Data (OFF, 1–3)	OFF
CLASSA*n*	Class for Analog Event Data (OFF, 1–3)	2
TIMERQ*n*	Time-Set Request Interval (I, M, 1–32767 minutes)	I
DECPLA*n*	Currents Scaling (0–3 decimal places)	1
DECPLV*n*	Voltages Scaling (0–3 decimal places)	1
DECPLM*n*	Misc Data Scaling (0–3 decimal places)	1
STIMEO*n*	Select/Operate Time-Out (0.0–60.0 seconds)	1.0
DNPINA*n*[c]	Seconds to Send Data Link Heartbeat (0–7200)	120
DNPCL*n*	Enable Control Operations (Y, N)	N
AIVAR*n*	Default Variation for Analog Inputs (1–6)	2
ANADBA*n*[d]	Analog Reporting Deadband for Currents (0–32767)	100
ANADBV*n*[d]	Analog Reporting Deadband for Voltages (0–32767)	100
ANADBM*n*[d]	Analog Reporting Deadband (0–32767)	100

Table 12.23 DNP Configuration (Ethernet) (Sheet 2 of 2)

Setting	Prompt	Default
ETIMEO*n*	Event Message Confirm Time-Out (1–50 seconds)	2
UNSOL*n*[e]	Enable Unsolicited Reporting (Y, N)	N
PUNSOL*n*[f]	Enable Unsolicited Reporting at Power-Up (Y, N)	N
REPADR*n*[f]	DNP Address to Report to (0–65519)	1
NUMEVE*n*[f]	Number of Events to Transmit On (1–200)	10
AGEEVE*n*[f]	Age of Oldest Event to Transmit On (0–99999)	2
URETRY*n*[f]	Unsolicited Message Max Retry Attempts (2–10)	3
UTIMEO*n*[f]	Unsolicited Message Offline Time-Out (1–5000 seconds)	60
EVEMOD*n*	Event Mode (SINGLE, MULTI)	SINGLE

[a] Hidden if EDNP := 0.
[b] Hidden if DNPTRn := TCP.
[c] Hidden if DNPTRn := UDP.
[d] Hidden if CLASSAn := OFF.
[e] Hidden if CLASSAn := CLASSBn := CLASSCn := OFF.
[f] Hidden if UNSOLn := N.

Table 12.24 Phasor Measurement Configuration

Setting	Prompt	Default
EPMIP[a]	Enable C37.118 Communications (Y, N)	N
PMOTS1	PMU Output 1 Scheme (OFF, TCP, UDP_S, UDP_T, UDP_U)	OFF
PMODC1	PMU Output 1 Data Configuration (1–5)	1
PMOIPA1[b]	PMU Output 1 Client IP Address (w.x.y.z)	192.168.1.3
PMOTCP1[b, c]	PMU Output 1TCP/IP Port Number (1–65534)[d]	4712
PMOUDP1[b, e]	PMU Output 1 UDP/IP Data Port Number (1–65534)	4713
PMOTS2	PMU Output 2 Scheme (OFF, TCP, UDP_S, UDP_T, UDP_U)	OFF
PMODC2	PMU Output 2 Data Configuration (1–5)	1
PMOIPA2[f]	PMU Output 2 Client IP Address (w.x.y.z)	192.168.1.4
PMOTCP2[f, g]	PMU Output 2 TCP/IP Port Number (1–65534)[d]	4722
PMOUDP2[f, h]	PMU Output 2 UDP/IP Data Port Number (1–65534)	4714

[a] Set EPMIP := Y to access remaining settings.
[b] Setting hidden when PMOTS1 := OFF.
[c] Setting hidden when PMOTSI := UDP_S.
[d] Port number must be unique compared to TPORT and DNPPNUM.
[e] Setting hidden when PMOTS1 := TCP.
[f] Setting hidden when PMOTS2 := OFF.
[g] Setting hidden when PMOTS2 := UDP_S.
[h] Setting hidden when PMOTS2 := TCP.

Table 12.25 SNTP Selection (Sheet 1 of 2)

Setting	Prompt	Default
ESNTP	SNTP Enable (OFF, UNICAST, MANYCAST, BROADCAST)	OFF
SNTPRAT	SNTP Request Update Rate (15–3600 seconds)	60
SNTPTO[a]	SNTP Timeout (5–20 seconds)	5
SNTPPIP	SNTP Primary Server IP Address (w.x.y.z)[b]	192.168.1.110

Table 12.25 SNTP Selection (Sheet 2 of 2)

Setting	Prompt	Default
SNTPBIP[c]	SNTP Backup Server IP Address (w.x.y.z)[b]	192.168.1.111
SNTPPOR	SNTP IP Local Port Number (1–65534)	123

[a] Setting hidden and forced to 5 if ESNTP := BROADCAST.
[b] Where w: 0–126, 128–239, x: 0–255, y: 0–255, z: 0–255 if ESNTP := MANYCAST or where w: 0–126, 128-223, x: 0–255, y: 0–255, z: 0–255 if ESNTP := UNICAST or BROADCAST.
[c] This setting is hidden if ESNTP ≠ UNICAST.

NOTE: PTP is only supported on Ethernet **PORT 5A** and **PORT 5B**. Most SEL-400 series relays only support two ports at a time and must have **PORT 5A** and **PORT 5B** selected by the MOT option in these relays. Relays that support four ports will have PTP on **PORT 5A** and **PORT 5B** but will not require selection of a different MOT option to have PTP available.

Table 12.26 PTP Settings

Setting	Prompt	Default
EPTP[a]	Enable PTP (Y, N)	N
PTPPRO	PTP Profile (DEFAULT, C37.238, 61850-9-3)	DEFAULT
PTPTR[b]	PTP Transport Mechanism (UDP, LAYER2)	UDP
DOMNUM	PTP Domain Number (0–255)	0
PTHDLY	PTP Path Delay Mechanism (P2P, E2E, OFF)[c]	E2E
PDINT[d]	Peer Delay Request Interval (1, 2, 4, ...64 seconds)	1
AMNUM	PTP Number of Acceptable Masters (OFF, 1–5)	OFF
AMIP*n*[e]	PTP Acceptable Master *n* IP (w.x.y.z)	192.168.1.12n
AMMAC*n*[f]	PTP Acceptable Master *n* MAC (xx:xx:xx:xx:xx:xx)	00.30.A7:00:00:0[p]
ALTPRI*n*[g]	PTP Alternate Priority1 for Master *n* (0–255)	0
PVLAN[h]	PTP VLAN Identifier (1–4094)	1
PVLANPR[h]	PTP VLAN Priority (0–7)	4

[a] This setting is not available if the hardware does not support PORT 5A and PORT 5B or if the ports are used in SWITCHED mode.
[b] Hidden and forced to LAYER2 if PTPPRO := C37.238 or 61850-9-3. Hidden and forced to LAYER2 if NETMODE := PRP and NETPORT := A or B. Also hidden and forced to LAYER2 if NETPORT := C or D.
[c] If PTPPRO := C37.238 or 61850-9-3, E2E is removed from the setting range.
[d] Hidden if PTHDLY := E2E or OFF.
[e] Hidden if AMNUM := OFF or if PTPTR := LAYER2.
[f] Hidden if AMNUM := OFF or if PTPTR := UDP.
[g] Hidden if AMNUM := OFF.
[h] Hidden if PTPPRO := DEFAULT or 61850-9-3.

Five-Port Ethernet Card

Table 12.27 Protocol Selection (Five-Port Ethernet Card) (Sheet 1 of 2)

Setting	Prompt	Default
EPORT	Enable Port (Y, N)	Y
BUSMODE	Bus Operating Mode (INDEPEND, MERGED)	INDEPEND
EINTF	Enable Interface (combo of AB, CD, E)	AB, CD, E
EPAC[a]	Enable Port Access Control (Y, N)	N
MAXACC[a, b]	Max Acc Level for Stn Bus (1, B, P, A, O, 2, C)	C

Table 12.27 Protocol Selection (Five-Port Ethernet Card) (Sheet 2 of 2)

Setting	Prompt	Default
MAXACCE[a, c]	Max Acc Level for Eng Acc (1, B, P, A, O, 2, C)	C
EETHFWU	Enable Ethernet Firmware Upgrade (Y, N)	N

[a] Does not apply to TiDL Channel Map (PORT 6).

[b] Hidden if EINTF does not contain CD and BUSMODE := INDEPEND. If BUSMODE := MERGED, the prompt is "Max ACC Level for Prc Bus (1, B, P, A, O, 2, C)."

[c] Hidden if EINTF does not contain E.

See *Table 12.7* for SEL protocol settings. See *Table 12.8* for Fast Message read data access settings. *Table 12.28* settings are available on the five-port Ethernet card (**PORT 5**).

Table 12.28 IP/Network Configuration

Setting	Prompt	Default
ETCPKA	Enable TCP Keep-Alive (Y, N)	Y
KAIDLE	TCP Keep-Alive Idle Range (1–20 seconds)	10
KAINTV	TCP Keep-Alive Interval Range (1–20 seconds)	1
KACNT	TCP Keep-Alive Count Range (1–20)	6
NETMODP	Operating Mode for 5A, 5B (FIXED, FAILOVER, PRP, HSR)	FAILOVER
NETPORP	Primary Network Port for 5A, 5B (A, B)	A
PRPINTP	PRP Supervision TX Interval for 5A, 5B (1–10 seconds)	2
PRPADDP	PRP Supervision Address LSB for 5A, 5B (0–255)[a]	0
HSRADDP	HSR Supervision Address LSB for 5A, 5B, (0–255)[a]	0
IPADDR	Device IP Address / CIDR Prefix (w.x.y.z/t)	192.168.1.2/24
DEFRTR	Default Router (w.x.y.z)	192.168.1.1
NETMODE	Operating Mode for 5C, 5D (FIXED, FAILOVER, PRP, HSR)	FAILOVER
NETPORT	Primary Network Port for 5C, 5D (C, D)	C
PRPINTV	PRP Supervision TX Interval for 5C, 5D (1–10 seconds)	2
PRPADDR	PRP Supervision Address LSB for 5C, 5D (0–255)[a]	0
FTIME[b]	Failover Time-Out for 5C, 5D (0–65535 milliseconds)	1
PRPTOUT	PRP Entry Time-Out (100–10000 milliseconds)	500
HSRADDR	HSR Supervision Address LSB for 5C, 5D, (0–255)[a]	0
IPADDRE	Device IP Address / CIDR Prefix for 5E (w.x.y.z/t)	192.168.2.2/24
DEFRTRE	Default Router for 5E (w.x.y.z)	192.168.2.1

[a] LSB stands for least significant bit.

[b] If BUSMODE := MERGED, the prompt is "Failover Time-Out for 5A, 5B (0-65535 milliseconds)."

NOTE: SEL advises against enabling anonymous File Transfer Protocol (FTP) logins (FTPANMS = Y) except under test conditions. The Ethernet card does not require a password for the special FTP username "anonymous". If you enable anonymous FTP logins, you are allowing unrestricted access to the SEL-400 series relay and host files.

Table 12.29 FTP Configuration (Five-Port Ethernet Card) (Sheet 1 of 2)

Setting	Prompt	Default
FTPSERV[a]	Enable FTP Server (OFF or combo of CD, E)	OFF
FTPCBAN	FTP Connect Banner	FTP SERVER:
FTPIDLE	FTP Idle Time-Out (5-255 minutes)	5

Table 12.29 FTP Configuration (Five-Port Ethernet Card) (Sheet 2 of 2)

Setting	Prompt	Default
FTPANMS	Enable Anonymous FTP Login (Y, N)	N
FTPAUSR	Anonymous User Access Level	0

[a] If BUSMODE := MERGED, the range is (OFF or combo of AB, E).

NOTE: Ethernet setting changes result in a restart of the Ethernet card. This closes active network connections and briefly pauses network operation.

Table 12.30 HTTP Server Configuration (Five-Port Ethernet Card)

Setting	Prompt	Default
EHTTP[a]	Enable HTTP Server (OFF or combo of CD, E)	OFF
HTTPPOR	HTTP Server TCP/IP Port Number (1-65534)	80
HIDLE	HTTP Session Inactivity Timeout (1-30 minutes)	5

[a] If BUSMODE := MERGED, the range is (OFF or combo of AB, E).

Table 12.31 Telnet Configuration (Five-Port Ethernet Card)

Setting	Prompt	Default
ETELNET[a]	Enable Telnet Server (OFF or combo of CD, E)	OFF
TCBAN	Telnet Connect Banner	TERMINAL SERVER:
TPORT	Telnet Port (23, 1025–65534)	23
TIDLE	Telnet Port Time-Out (1–30 minutes)	15

[a] If BUSMODE := MERGED, the range is (OFF or combo of AB, E).

NOTE: If BUSMODE := INDEPEND and EINTF contains CD and E, enabling SEL protocol, MMS, or DNP allows the protocol to be processed on both the station bus and engineering access interfaces. Similarly, if BUSMODE := MERGED and EINTF contains E, enabling these protocols allows them to be processed on both the process bus and engineering access interfaces.

See *Table 12.18* for IEC 61850 configuration settings.

See *Table 12.19* for IEC 61850 mode/behavior configuration settings.

See *Table 12.20* for SV transmit configuration settings.

See *Table 12.21* for SV receive configuration settings.

See *Table 12.22* for IEC SV channel settings.

See *Table 12.23* for DNP configuration settings.

Table 12.32 Phasor Measurement Configuration (Five-Port Ethernet Card) (Sheet 1 of 2)

Setting	Prompt	Default
EPMIP[a]	Enable C37.118 Comms (N, CD, E)	N
PMOTS1	PMU Output 1 Scheme (OFF, TCP, UDP_S, UDP_T, UDP_U)	OFF
PMODC1	PMU Output 1 Data Configuration (1–5)	1
PMOIPA1[b]	PMU Output 1 Client IP Address (w.x.y.z)	192.168.1.3
PMOTCP1[b, c]	PMU Output 1TCP/IP Port Number (1–65534)[d]	4712
PMOUDP1[b, e]	PMU Output 1 UDP/IP Data Port Number (1–65534)	4713
PMOTS2	PMU Output 2 Scheme (OFF, TCP, UDP_S, UDP_T, UDP_U)	OFF
PMODC2	PMU Output 2 Data Configuration (1–5)	1
PMOIPA2[f]	PMU Output 2 Client IP Address (w.x.y.z)	192.168.1.4

Table 12.32 Phasor Measurement Configuration (Five-Port Ethernet Card) (Sheet 2 of 2)

Setting	Prompt	Default
PMOTCP2[f, g]	PMU Output 2 TCP/IP Port Number (1–65534)[d]	4722
PMOUDP2[f, h]	PMU Output 2 UDP/IP Data Port Number (1–65534)	4714

[a] If BUSMODE := MERGED, the range is (N, AB, E). Set EPMIP := AB, CD, or E to access remaining settings.
[b] Setting hidden when PMOTS1 := OFF.
[c] Setting hidden when PMOTSI := UDP_S.
[d] Port number must be unique compared to TPORT and DNPPNUM.
[e] Setting hidden when PMOTS1 := TCP.
[f] Setting hidden when PMOTS2 := OFF.
[g] Setting hidden when PMOTS2 := UDP_S.
[h] Setting hidden when PMOTS2 := TCP.

See *Table 12.25* for SNTP selection settings.

Table 12.33 PTP Settings (Five-Port Ethernet Card)

Setting	Prompt	Default
EPTP	Enable PTP (N, AB, CD)	N
PTPPRO	PTP Profile (DEFAULT, C37.238, 61850-9-3)	DEFAULT
PTPTR[a]	PTP Transport Mechanism (UDP, LAYER2)	UDP
DOMNUM	PTP Domain Number (0–255)	0
PTHDLY	PTP Path Delay Mechanism (P2P, E2E, OFF)[b]	E2E
PDINT[c]	Peer Delay Request Interval (1, 2, 4, ...64 seconds)	1
AMNUM	PTP Number of Acceptable Masters (OFF, 1–5)	OFF
AMIP*n*[d]	PTP Acceptable Master *n* IP (w.x.y.z)	192.168.1.12*n*
AMMAC*n*[e]	PTP Acceptable Master *n* MAC (xx:xx:xx:xx:xx:xx)	00.30.A7:00:00:0[p]
ALTPRI*n*[f]	PTP Alternate Priority1 for Master *n* (0–255)	0
PVLAN[g]	PTP VLAN Identifier (1–4094)	1
PVLANPR[g]	PTP VLAN Priority (0–7)	4

[a] Hidden and forced to LAYER2 if PTPPRO := C37.238 or 61850-9-3. Hidden and forced to LAYER2 if EPTP := AB and BUSMODE := INDEPEND. Hidden and forced to LAYER2 if EPTP := AB and BUSMODE := MERGED and NETMODP := PRP. Also hidden and forced to LAYER2 if EPTP := CD and NETMODE := PRP.
[b] If PTPPRO := C37.238 or 61850-9-3, E2E is removed from the setting range.
[c] Hidden if PTHDLY := E2E or OFF.
[d] Hidden if AMNUM := OFF or if PTPTR := LAYER2.
[e] Hidden if AMNUM := OFF or if PTPTR := UDP.
[f] Hidden if AMNUM := OFF.
[g] Hidden if PTPPRO := DEFAULT or 61850-9-3.

DNP3 Settings—Custom Maps

Table 12.34 DNP3 Settings Categories (Sheet 1 of 2)

Settings	Reference
DNP3 Fault Location Min and Max	*Table 12.35*
Binary Input Map	*Table 12.36*
Binary Output Map	*Table 12.36*

Table 12.34 DNP3 Settings Categories (Sheet 2 of 2)

Settings	Reference
Counter Map	*Table 12.36*
Analog Input Map	*Table 12.36*
Analog Output Map	*Table 12.36*

The fault location minimum and maximum settings determine what fault data are sent to a DNP3 master. This affects all DNP3 sessions that use the current DNP3 map.

NOTE: MINDIST and MAXDIST only apply to relays that provide a fault location.

Table 12.35 Minimum and Maximum Fault Location

Setting	Prompt	Default
MINDIST	Min Fault Location to Capture (OFF, –1000.0 to 1000.0)	OFF
MAXDIST	Max Fault Location to Capture (OFF, –1000.0 to 1000.0)	OFF

The remainder of this settings class consists of a set of freeform categories for configuring the map for the various DNP3 data types. The category headers indicate the syntax of the entries. *Table 12.36* shows these headers. All entries require a data label. The deadband and scale-factor parameters are optional. The defaults are relay-specific, so refer to the product-specific instruction manual to see the defaults for these settings.

Table 12.36 DNP3 Map Category Headers

Binary Input Map (Binary Input Label)
Binary Output Map (Binary Output Label)
Counter Map (Counter Label, Deadband)
Analog Input Map (Analog Input Label, Scale Factor, Deadband)
Analog Output Map (Analog Output Label)

Front-Panel Settings

Table 12.37 Front-Panel Settings Categories

Settings	Reference
Front-Panel Settings	*Table 12.38*
Selectable Screens for the Front Panel	*Table 12.39*
Selectable Operator Pushbuttons	*Table 12.40*
Front-Panel Event Display	*Table 12.41*
Display Points	
Local Control	
Local Bit SELOGIC	*Table 12.42*
SER Parameters	*Table 12.43*

The defaults for the pushbuttons and targets in the Front-Panel Settings category are relay-specific. See the product-specific instruction manual to find these defaults.

Table 12.38 Front-Panel Settings (Sheet 1 of 3)

Setting	Prompt
FP_TO	Front Panel Display Time-Out (OFF,1–60 min)
EN_LEDC	Enable LED Asserted Color (R,G)
TR_LEDC	Trip LED Asserted Color (R,G)
PB1_LED	Pushbutton LED 1 (SELOGIC Equation)
PB1_COL	PB1_LED Assert and Deassert Color (Enter 2: R,G,A,O)
PB2_LED	Pushbutton LED 2 (SELOGIC Equation)
PB2_COL	PB2_LED Assert and Deassert Color (Enter 2: R,G,A,O)
PB3_LED	Pushbutton LED 3 (SELOGIC Equation)
PB3_COL	PB3_LED Assert and Deassert Color (Enter 2: R,G,A,O)
PB4_LED	Pushbutton LED 4 (SELOGIC Equation)
PB4_COL	PB4_LED Assert and Deassert Color (Enter 2: R,G,A,O)
PB5_LED	Pushbutton LED 5 (SELOGIC Equation)
PB5_COL	PB5_LED Assert and Deassert Color (Enter 2: R,G,A,O)
PB6_LED	Pushbutton LED 6 (SELOGIC Equation)
PB6_COL	PB6_LED Assert and Deassert Color (Enter 2: R,G,A,O)
PB7_LED	Pushbutton LED 7 (SELOGIC Equation)
PB7_COL	PB7_LED Assert and Deassert Color (Enter 2: R,G,A,O)
PB8_LED	Pushbutton LED 8 (SELOGIC Equation)
PB8_COL	PB8_LED Assert and Deassert Color (Enter 2: R,G,A,O)
PB9_LED[a]	Pushbutton LED 9 (SELOGIC Equation)
PB9_COL[a]	PB9_LED Assert and Deassert Color (Enter 2: R,G,A,O)
PB10LED[a]	Pushbutton LED 10 (SELOGIC Equation)
PB10COL[a]	PB10LED Assert and Deassert Color (Enter 2: R,G,A,O)
PB11LED[a]	Pushbutton LED 11 (SELOGIC Equation)
PB11COL[a]	PB11LED Assert and Deassert Color (Enter 2: R,G,A,O)
PB12LED[a]	Pushbutton LED 12 (SELOGIC Equation)
PB12COL[a]	PB12LED Assert and Deassert Color (Enter 2: R,G,A,O)
T1_LED	Target LED 1 (SELOGIC Equation)
T1LEDL	Target LED 1 Latch (Y, N)
T1LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T2_LED	Target LED 2 (SELOGIC Equation)
T2LEDL	Target LED 2 Latch (Y, N)
T2LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T3_LED	Target LED 3 (SELOGIC Equation)
T3LEDL	Target LED 3 Latch (Y, N)
T3LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T4_LED	Target LED 4 (SELOGIC Equation)
T4LEDL	Target LED 4 Latch (Y, N)
T4LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T5_LED	Target LED 5 (SELOGIC Equation)
T5LEDL	Target LED 5 Latch (Y, N)

Table 12.38 Front-Panel Settings (Sheet 2 of 3)

Setting	Prompt
T5LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T6_LED	Target LED 6 (SELOGIC Equation)
T6LEDL	Target LED 6 Latch (Y, N)
T6LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T7_LED	Target LED 7 (SELOGIC Equation)
T7LEDL	Target LED 7 Latch (Y, N)
T7LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T8_LED	Target LED 8 (SELOGIC Equation)
T8LEDL	Target LED 8 Latch (Y, N)
T8LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T9_LED	Target LED 9 (SELOGIC Equation)
T9LEDL	Target LED 9 Latch (Y, N)
T9LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T10_LED	Target LED 10 (SELOGIC Equation)
T10LEDL	Target LED 10 Latch (Y, N)
T10LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T11_LED	Target LED 11 (SELOGIC Equation)
T11LEDL	Target LED 11 Latch (Y, N)
T11LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T12_LED	Target LED 12 (SELOGIC Equation)
T12LEDL	Target LED 12 Latch (Y, N)
T12LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T13_LED	Target LED 13 (SELOGIC Equation)
T13LEDL	Target LED 13 Latch (Y, N)
T13LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T14_LED	Target LED 14 (SELOGIC Equation)
T14LEDL	Target LED 14 Latch (Y, N)
T14LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T15_LED	Target LED 15 (SELOGIC Equation)
T15LEDL	Target LED 15 Latch (Y, N)
T15LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T16_LED	Target LED 16 (SELOGIC Equation)
T16LEDL	Target LED 16 Latch (Y, N)
T16LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T17_LED[b]	Target LED 17 (SELOGIC Equation)
T17LEDL[b]	Target LED 17 Latch (Y, N)
T17LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T18_LED[b]	Target LED 18 (SELOGIC Equation)
T18LEDL[b]	Target LED 18 Latch (Y, N)
T18LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T19_LED[b]	Target LED 19 (SELOGIC Equation)

Table 12.38 Front-Panel Settings (Sheet 3 of 3)

Setting	Prompt
T19LEDL[b]	Target LED 19 Latch (Y, N)
T19LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T20_LED[b]	Target LED 20 (SELOGIC Equation)
T20LEDL[b]	Target LED 20 Latch (Y, N)
T20LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T21_LED[b]	Target LED 21 (SELOGIC Equation)
T21LEDL[b]	Target LED 21 Latch (Y, N)
T21LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T22_LED[b]	Target LED 22 (SELOGIC Equation)
T22LEDL[b]	Target LED 22 Latch (Y, N)
T22LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T23_LED[b]	Target LED 23 (SELOGIC Equation)
T23LEDL[b]	Target LED 23 Latch (Y, N)
T23LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T24_LED[b]	Target LED 24 (SELOGIC Equation)
T24LEDL[b]	Target LED 24 Latch (Y, N)
T24LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)

[a] PB9–PB12 settings are only available on 12 pushbutton models.
[b] T17–T24 settings are only available on 12 pushbutton models.

NOTE: The specific settings available in this category for a relay depends on the features of that relay.

NOTE: In some relays, rather than picking from a list of screens, as shown here, there is a freeform settings block in which you can list the screens you want in the order you want them displayed.

Table 12.39 Selectable Screens for the Front Panel

Setting	Prompt	Default
SCROLD	Front-Panel Display Update Rate (OFF, 1–15 sec)	5
ONELINE	One-Line Bay Control Diagram (Y,N)	Y
RMS_V	RMS Line Voltage Screen (Y,N)	N
RMS_I	RMS Line Current Screen (Y,N)	Y
RMS_VPP	RMS Line Voltage Phase to Phase Screen (Y,N)	N
RMS_W	RMS Active Power Screen (Y,N)	N
FUNDVAR	Fundamental Reactive Power Screen (Y,N)	N
RMS_VA	RMS Apparent Power Screen (Y,N)	N
RMS_PF	RMS Power Factor Screen (Y,N)	N
RMS_BK1	RMS Breaker 1 Currents Screen (Y,N)	N
RMS_BK2	RMS Breaker 2 Currents Screen (Y,N)	N
STA_BAT	Station Battery Screen (Y,N)	N
FUND_VI	Fundamental Voltage and Current Screen (Y,N)	Y
FUNDSEQ	Fundamental Sequence Quantities Screen (Y,N)	N
FUND_BK	Fundamental Breaker Currents Screen (Y,N)	N
DIFF_L	Differential Metering Local Currents Screen (Y,N)	Y
DIFF_T	Differential Metering Total Currents Screen (Y,N)	Y
DIFF	Differential Metering (Y,N)	Y
ZONECFG	Terminals Associated with Zones (Y,N)	Y

Table 12.40 Selectable Operator Pushbuttons

Setting	Prompt	Default
PB1_HMI	Pushbutton 1 HMI Screen (OFF,AP,DP,EVE,SER)[a, b]	OFF
PB2_HMI	Pushbutton 2 HMI Screen (OFF,AP,DP,EVE,SER)[a, b]	OFF
PB3_HMI	Pushbutton 3 HMI Screen (OFF,AP,DP,EVE,SER)[a, b]	OFF
PB4_HMI	Pushbutton 4 HMI Screen (OFF,AP,DP,EVE,SER)[a, b]	OFF
PB5_HMI	Pushbutton 5 HMI Screen (OFF,AP,DP,EVE,SER)[a, b]	OFF
PB6_HMI	Pushbutton 6 HMI Screen (OFF,AP,DP,EVE,SER)[a, b]	OFF
PB7_HMI	Pushbutton 7 HMI Screen (OFF,AP,DP,EVE,SER)[a, b]	OFF
PB8_HMI	Pushbutton 8 HMI Screen (OFF,AP,DP,EVE,SER)[a, b]	OFF
PB9_HMI[c]	Pushbutton 9 HMI Screen (OFF,AP,DP,EVE,SER)[a, b]	OFF
PB10HMI[c]	Pushbutton 10 HMI Screen (OFF,AP,DP,EVE,SER)[a, b]	OFF
PB11HMI[c]	Pushbutton 11 HMI Screen (OFF,AP,DP,EVE,SER)[a, b]	OFF
PB12HMI[c]	Pushbutton 12 HMI Screen (OFF,AP,DP,EVE,SER)[a, b]	OFF

[a] PBn_HMI can only be set to DP if a valid display point has been set.
[b] Each instance (AP, DP, EVE, SER) can only be set to a single operator pushbutton.
OFF = No HMI Pushbutton Operation
AP = Alarm Points
DP = Display Points
EVE = Event Summaries
SER = SER HMI Display
[c] PB9–PB12 settings are only available on 12-pushbutton models.

Table 12.41 Front-Panel Event Display

Setting	Prompt	Default
DISP_ER	Enable HMI Auto Display of Events Summaries (Y,N)	Y
TYPE_ER	Types of Events for HMI Auto Display (ALL,TRIP)[a]	ALL
NUM_ER	Operator Pushbutton Events to Display (1–100)[b]	10[c]

[a] Setting is only available if DISP_ER := Y.
[b] Setting is only available if an operator pushbutton has been set to EVE.
[c] Some relays default NUM_ER to 3.

Boolean display points are selected by using freeform settings fields. Two types of display points can be entered: Boolean and analog. For Boolean display points, the entry syntax is:

Bit name, "Label", "Set String", "Clear String", Text Size"

For an analog display point, the syntax is:

Analog name, "User Text and Formatting", "Text Size"

See the Front-Panel Operations section for more information on configuring display points.

Local control bits are configured by using the Local Control category. This is a freeform category. Each entry has the following syntax:

Local bit name, "Label", "Set State", "Clear State", Pulse enable

See *Local Control on page 4.20* for more information on configuring local control bits.

Table 12.42 Local Bit SELOGIC[a]

Setting	Prompt	Default
LB_SPmm	Local Bit Supervision (SELOGIC Equation, NA)	1
LB_DPmm	Local Bit Status Display (SELOGIC Equation, NA)	LBmm

[a] Settings in Table Table 12.42 appear if the associated local bit is defined. If no local bits are defined, the whole category is hidden.

Table 12.43 SER Parameters

Setting	Prompt	Default
SER_PP	Five Events per SER Events page? (Y for 5, N for 3)	N

Alias Settings

Although SEL-400 series relays provide extensive programming facilities and opportunity for comments, troubleshooting customized programs is sometimes difficult. Aliases provide an opportunity to assign more meaningful names to the generic variable names to improve the readability of the program. These aliases can be used in settings and SELOGIC equations and are used in most relay reports. Assign a valid seven-character alias name to any Relay Word bit or any Analog Quantity. (Some SEL-400 series relays support aliasing additional types of data.)

Invalid alias names include the following keywords used by settings and SELOGIC control equations:

- ➤ END
- ➤ INSERT
- ➤ DELETE
- ➤ LIST
- ➤ NA
- ➤ OFF

SELOGIC control equation operators (e.g., NOT, AND, OR, COS) cannot be used as alias names. A quantity may only be assigned one alias. An alias cannot match an existing Relay Word or analog quantity name.

Alias names are valid when the following are true:

- ➤ They consist of a maximum of seven characters.
- ➤ They are constructed using characters 0–9, uppercase A–Z, or the underscore (_).

For example, the default name for contact output OUT101 is OUT101. You could change the default name to an alias, BK1_TR, for example.

Alias settings consists of a single freeform settings category. As many as 200 aliases may be assigned. The default alias configuration is relay-specific. See the relay instruction manual for the default aliases. *Figure 12.2* shows an example that uses the **SET T** command to set two aliases.

```
=>>SET T <Enter>
Alias
Relay Aliases
(RW Bit or Analog Qty. 7 Character Alias [0-9 A-Z _])

1: EN,"RLY_EN"
? <Enter>
2:
?  OUT101, BK1_TR
3:
? END <Enter>

Alias
Relay Aliases
(RW Bit or Analog Qty. 7 Character Alias [0-9 A-Z _])
1: EN,"RLY_EN"
2: OUT101,"BK1_TR"
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 12.2 Changing a Default Name to an Alias

Protection Freeform SELOGIC Control Equations

Protection freeform SELOGIC control equations are in Classes 1 through 6 corresponding to settings Groups 1 through Group 6 (see *Multiple Setting Groups on page 12.4*).

As many as 250 lines of freeform equations may be entered in each of six settings groups, although the actual maximum capacity may be less. See *SELOGIC Control Equation Capacity on page 13.5* for more information. The default configuration of the protection SELOGIC control equations is relay-specific. See the product-specific instruction manual to see the defaults.

Automation Freeform SELOGIC Control Equations

Automation freeform SELOGIC control equations are in Blocks 1 through 10.

NOTE: Some versions of some SEL-400 series relays have only one automation setting block with a capacity of 100 lines of automation freeform SELOGIC control equations.

The SEL-400 series relays do not contain any automation freeform SELOGIC settings in the factory-default settings.

The relay has a capacity of 100 lines of automation freeform SELOGIC control equations in each of 10 automation setting blocks. See *SELOGIC Control Equation Capacity on page 13.5* for more information.

Output Settings

Table 12.44 Output Settings Categories (Sheet 1 of 2)

Settings	Reference
Main Board	
Interface Board #1	
Interface Board #2	

Table 12.44 Output Settings Categories (Sheet 2 of 2)

Settings	Reference
Interface Board #3	
Interface Board #4	
Remote Analog Outputs	*Table 12.45*
MIRRORED BITS Transmit Equations	*Table 12.46*
87L Communications Bits[a]	*Table 12.47*

[a] Only available in products that support 87L communication.

The Main Board output settings consists of SELOGIC control equations OUT101–OUT108. The defaults are relay-specific; see the relay-specific instruction manual to see the defaults. Some SEL-400 series relays do not have any main board outputs, in which case this category is not available.

NOTE: In TiDL (EtherCAT) relays, Interface Boards 2–4 are always considered to be available. Depending on the Axion modules connected, these outputs may or may not be physically present. In TiDL (T-Protocol) relays, Interface Boards 1–4 are always considered to be available. Depending on the SEL-TMU modules connected, Outputs 2–4 may or may not be physically present.

The Interface Board output settings consists of SELOGIC control equations OUT*x*01–OUT*x*16 where *x* = 2–5, corresponding to Interface Boards 1 to 4. The category for any interface board is only available if the interface board is installed. The defaults are relay-specific; see the relay-specific instruction manual to see the defaults.

Table 12.45 settings are available if an Ethernet card is present and IEC 61850 is ordered.

Table 12.45 Remote Analog Outputs

Setting	Prompt	Default
RAO01 • • • RAO64	Remote Analog Output 01 (SELOGIC) • • • Remote Analog Output 64 (SELOGIC)	NA • • • NA

Table 12.46 MIRRORED BITS Transmit Equations

Setting	Prompt	Default
TMB1A • • • TMB8A	Mirrored Bit 1 Channel A Equation (SELOGIC) • • • Mirrored Bit 8 Channel A Equation (SELOGIC)	NA • • • NA
TMB1B • • • TMB8B	Mirrored Bit 1 Channel B Equation (SELOGIC) • • • Mirrored Bit 8 Channel B Equation (SELOGIC)	NA • • • NA

NOTE: This category is only available in relays that support 87L communications.

Table 12.47 87L Communications Bits

Setting[a, b]	Prompt	Default
87T*x*P1	Serial Comm. Transmit Bit *x* Port 1 (SELOGIC)	NA
87T*x*P2	Serial Comm. Transmit Bit *x* Port 2 (SELOGIC)	NA
87T*nn*E	Ethernet Comm. Transmit Bit *nn* (SELOGIC)	NA

[a] x = 1–8. These settings are hidden when E87CH = N or 2E or 3E or 4E. Also hidden if there is no serial communications card installed.
[b] nn = 01–32. These settings are visible when E87CH = 2E, 3E, or 4E, and are hidden in all other cases.

Report Settings

Table 12.48 Report Settings Categories

Settings	Reference
SER Chatter Criteria	*Table 12.49*
SER Points	
Signal Profile	*Table 12.50*
Event Reporting	*Table 12.51*
Event Reporting Analog Quantities	
Event Reporting Digital Elements	

Table 12.49 SER Chatter Criteria

Setting	Prompt	Default
ESERDEL	Automatic Removal of Chattering SER Points (Y, N)	Y
SRDLCNT[a]	Number of Counts Before Auto-Removal (2–20)	10
SRDLTIM[a]	Time for Auto-Removal (0.1–30 seconds)	0.5

[a] Setting is only available if ESERDEL := Y.

The SER Points category is a freeform category for listing points to record in the SER. Each point can be given a reporting name, a set state name, and a clear state name. You can also indicate whether or not to make this point visible as an alarm point on the front-panel LCD. The syntax for entry is:

> Relay Word Bit Label, "Reporting Name", "Set State Name", "Clear State Name", HMI Alarm Indication

Each of the names may consist of any printable ASCII character. The HMI alarm condition is a Y/N choice. By default, there are no SER points configured.

The signal profile settings category consists of a freeform block for selecting analog quantities to include in the signal profile followed by the settings described in *Table 12.50*. Any of the analog quantities listed in *Section 12:Analog Quantities* in the product-specific instruction manual may be selected. As many as 20 analog quantities can be included in the signal profile.

Table 12.50 Signal Profile

Setting	Prompt	Default
SPAR	Signal Profile Acq. Rate (1,5,15,30,60 min)	5
SPEN	Signal Profile Enable (SELOGIC Eqn.)	0

Table 12.51 Event Reporting (Sheet 1 of 2)

Setting	Prompt	Default
ERDIG	Store Selected (S) or All (A) Relay Word Bits for COMTRADE events	A
SRATE	Sample Rate of Event Report (1, 2, 4, 8 kHz)	2
LER[a]	Length of Event Report (0.25–3.00 seconds); SRATE := 8	0.50
PRE[b]	Length of Pre-Fault (0.05–0.25 seconds); SRATE := 8	0.10
LER[a]	Length of Event Report (0.25–6.00 seconds); SRATE := 4	0.50
PRE[b]	Length of Pre-Fault (0.05–0.25 seconds); SRATE := 4	0.10

Table 12.51 Event Reporting (Sheet 2 of 2)

Setting	Prompt	Default
LER[a]	Length of Event Report (0.25–12.00[c] seconds); SRATE := 2	0.50
PRE[b]	Length of Pre-Fault (0.05–0.25 seconds); SRATE := 2	0.10
LER[a]	Length of Event Report (0.25–24.00[d] seconds); SRATE := 1	0.50
PRE[b]	Length of Pre-Fault (0.05–0.25 seconds); SRATE := 1	0.10

[a] The upper end of the range is reduced by a factor of 4 if ERDIG is set to A.
[b] The upper limit for PRE is the set LER minus 0.05 s.
[c] In the SEL-411L, the upper bound is 9.00 s.
[d] In the SEL-411L, the upper bound is 12.00 s.

The Event Report Analog Quantities category is a freeform category in which you can select as many as 20 analog quantities to report in the filtered relay event reports. By default, no analog quantities are configured.

The Event Reporting Digital Elements category is a freeform settings area in which as many as 800 Relay Words from as many as 100 Relay Word bit rows may be selected. See the product-specific instruction manual for the default configuration. The 100 row limit includes the base set of Relay Word bits always included in oscillography and event reports as described in *Section 7: Metering, Monitoring, and Reporting* in the product-specific instruction manual.

Notes Settings

Avoid losing important information about the relay. Use the Notes settings like a text pad to leave notes about the relay in the Notes area of the relay. Notes entries are in a single block of 100 lines. By default, there is no text stored in the Notes settings.

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S E C T I O N 1 3

SELOGIC Control Equation Programming

This section describes use of SELOGIC control equations and programming to customize relay operation and automate substations. This section covers the following topics:

Separation of Protection and Automation Areas

SEL-400 series relays act as protective relays and as smart nodes in distributed substation automation. The relay collects data, coordinates inputs from many interfaces, and automatically controls substation equipment. The relay performs protection and automation functions but keeps programming of these functions separate. For example, someone modifying or testing a capacitor bank control system or station restoration system created in automation programming should not be able to corrupt programming for protection tasks. Similarly, extended protection algorithms must operate at protection speeds unaffected by the volume of automation programming.

SEL-400 series relays contain several separate programming areas discussed in SELOGIC Control Equation Setting Structure. Separate access levels and passwords control access to each programming area and help eliminate accidental programming changes. For example, use Access Level P to modify protection configuration and protection freeform SELOGIC control equation programming and Access Level A to access automation programming. If you want unlimited access to both automation and protection configuration and programming, use Access Level 2.

NOTE: If you want unlimited access to both automation and protection configuration and programming, log in to Access Level 2.

Protection and automation areas must interact and exchange information. Protection and automation interact and exchange information through separate storage areas (variables) for results of automation and protection programming. The relay combines the results in the output settings that drive relay outputs to control substation equipment. Separation of protection and automation storage areas is illustrated in *Figure 13.1*.

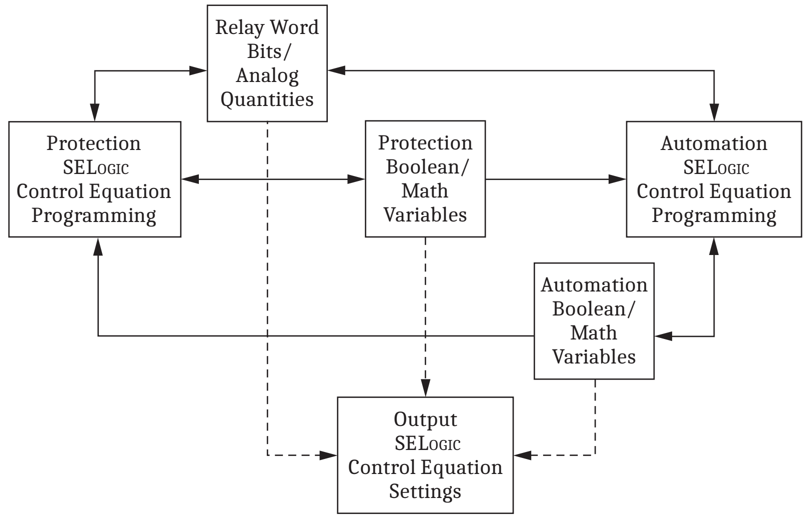

Figure 13.1 Protection and Automation Separation

Figure 13.1 illustrates how the SEL-400 series relays keep protection and automation programming separate while still exchanging information. The arrows indicate data flow between components. The Relay Word Bits and Analog Quantities are visible to protection, automation, and output programming. Protection programming uses the Relay Word Bits, Analog Quantities, Protection Variables, and Automation Variables as inputs, but only writes and stores information to the Protection Variables. Similarly, automation programming uses data from all parts of the relay, but only stores data in the Automation Variables.

The Output SELOGIC control equation settings use the Relay Word Bits, Analog Quantities, Protection Variables, and Automation Variables to control outputs and other information leaving the relay. Use the output settings to create a custom combination of the results of protection and automation operations. For example, an OR operation will activate an output when protection or automation programming results necessitate activating the output. You can use more complicated logic to supervise control of the output with other external and internal information. For example, use a command from the SCADA master to supervise automated control of a motor-operated disconnect in the substation.

SELOGIC Control Equation Setting Structure

SEL-400 series relays use SELOGIC control equations in three major areas. First, you can customize protection operations with SELOGIC control equation settings and freeform programming. Second, there is a freeform programming area for more sophisticated automation SELOGIC control equation programming. Third, there is a fixed area for relay output programming. The SELOGIC control equation programming areas are shown in *Figure 13.2*. There are also a small number of fixed SELOGIC control equations in other settings areas including front-panel settings that allow you to customize relay features not directly related to protection or automation.

NOTE: Some versions of some SEL-400 series relays only support one block of automation SELOGIC control equations.

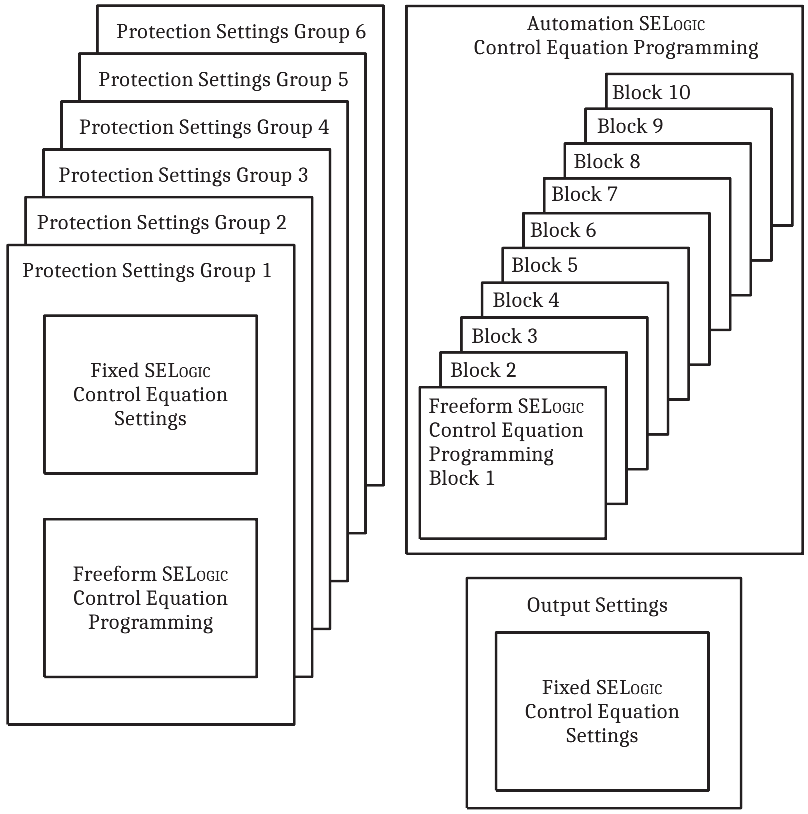

Figure 13.2 SELOGIC Control Equation Programming Areas

Protection

Protection SELOGIC control equation programming includes a fixed area and a freeform area. You can configure many protection settings within the relay (for example TR) with fixed SELOGIC control equation programming. Use these settings to control protection operation and customize relay operation. The programming and operation of fixed SELOGIC control equations in this area is very similar to programming in SEL-300 series relays.

There is a freeform SELOGIC control equation programming area associated with protection. Because this area operates at the protection processing interval along with protection algorithms and outputs, use this area to extend and customize protection operation. Protection freeform SELOGIC control equation programming includes a complete set of timers, counters, and variables.

For all protection settings, including protection SELOGIC control equation programming, there are six groups of settings that you activate with the protection settings group selection. Only one group is active at a time. When you switch groups, for example, you can activate completely different programming that corresponds to the conditions indicated by the active group. See *Multiple Setting Groups on page 12.4* for more information.

If you want the programming to operate identically in all groups, develop the settings in one group and copy these to all groups. You can copy settings by using the **COPY** command documented in *COPY on page 14.26*. You can also perform cut-and-paste operations in the ACSELERATOR QuickSet SEL-5030 software.

NOTE: Perform operations that are not time critical in automation SELOGIC control equation programming. You can use this automation to reduce the demand and complexity of protection SELOGIC control equation programming.

All of the SELOGIC control equation programming in the protection area executes at the same deterministic interval as the protection algorithms. Because of this type of programming execution, you can use protection freeform and fixed programming to extend and customize protection operation.

Automation

Automation SELOGIC control equation programming is a large freeform programming area that provides as many as ten blocks. The relay executes each block sequentially from the first block to the last. You do not need to fill a block completely or enter any equations in a block before starting to write SELOGIC control equations in the following blocks.

SEL-400 series relays dedicate a minimum processing time when executing automation SELOGIC control equations. If the processing load is light, the relay uses more processing time for executing automation programming. This means that the overall execution time fluctuates. You can display the average and peak execution time with the **STATUS S** ASCII command. Use the **STATUS SC** command to reset the peak execution time.

NOTE: Organize automation SELOGIC control equation programming into blocks based on function. It is easier to edit and troubleshoot small partially filled blocks that contain related programming.

Use automation SELOGIC control equation programming to automate tasks that do not require time-critical, deterministic execution. For example, if you are coordinating control inputs from a substation HMI and SCADA master, use automation freeform SELOGIC control equations and set the output contact setting to the automation SELOGIC control equation variable that contains the result.

Perform time-critical tasks with protection freeform SELOGIC control equations. For example, if you require a SELOGIC control equation for TR (trip) that contains more than 15 elements, you must perform that calculation in several steps. Because detection of a TR condition is a time-critical activity, perform the calculation with protection freeform SELOGIC control equations and set TR to the protection SELOGIC control equation variable that contains the result.

Because automation runs at a slower rate than protection, you must be careful when using protection bits within automation equations. Protection bits can assert and deassert again too fast for automation equations to consistently see them. Therefore, you may need to hold protection bits asserted for a second, by using conditioning timers, before using them in SELOGIC equations.

Outputs

To provide protection and automation area separation, the output settings are in a fixed SELOGIC control equation area separate from protection and automation programming. You can take advantage of this separation to combine protection and automation in a manner that best fits your application. Outputs include the relay control outputs, outgoing MIRRORED BITS points, and remote analog outputs. The relay executes output logic and processes outputs at the protection processing interval.

SELOGIC Control Equation Capacity

SELOGIC control equation capacity is a measure of how much remaining space you have available for programming. In both protection and automation, SELOGIC control equation capacity includes execution capacity and settings storage capacity.

The relay will reject any setting that exceeds the available settings storage capacity and execution capacity. You can then accept the previous settings you have entered and examine your settings.

Protection

SEL-400 series relays typically provide storage space for as many as 250 lines of protection freeform programming. See the product-specific instruction manual for the number of lines limit for any specific product. Because the relay executes protection fixed and freeform logic at a deterministic interval, there is a limit to the amount of SELOGIC control equation programming that the relay can execute. The relay calculates total capacity in terms of settings capacity and execution capacity.

NOTE: The SEL-487B supports 100 lines of protection freeform programming.

Rather than limit parameters to guarantee that your application not exceed the maximum processing requirements, the relay measures and calculates the available capacity when you enter SELOGIC control equations. The relay will not allow you to enter programming that will cause the relay to be unable to complete all protection SELOGIC control equations each protection processing interval.

There are six protection settings groups. Only one protection settings group can be active. When a protection settings group is active, the relay executes SELOGIC control equations in the Global Settings, Protection Group Settings, Protection Freeform Settings, Output Settings, and several other settings areas. The relay calculates protection capacities based on the total amount of SELOGIC control equation programming executed when the protection settings group is active. Use the **STATUS S** command to display the remaining settings capacity and execution capacity for protection fixed and freeform logic.

Automation

SEL-400 series relays provide storage space for as many as 10 blocks of as many as 100 lines of automation freeform programming each. Use the **STATUS S** command to display the remaining settings capacity and execution capacity for automation freeform logic.

There is a maximum execution capacity and settings storage capacity. If you enter a setting that exceeds maximum capacity, the relay will reject the setting. You will have the opportunity to reenter the setting or save any other settings you entered during that session.

SELOGIC Control Equation Programming

There are two major areas where SEL-400 series relays use SELOGIC control equations. First, fixed SELOGIC control equations define the operation of fixed protection elements or outputs. As with SEL-300 series relay programming, protection programming and outputs use fixed SELOGIC control equations. Second, you can use freeform SELOGIC control equations for freeform programming that includes mathematical operations, custom logic execution order, extended relay customization, and automated operation.

Fixed SELOGIC Control Equations

Fixed result SELOGIC control equations are equations in which the left side (result storage location), or LVALUE, is fixed. Programming in SEL-300 series relays consists of all fixed SELOGIC control equations. Fixed equations include protection and output settings that you set with SELOGIC control equations.

Fixed SELOGIC control equations are Boolean equations. Fixed result control equations can be as simple as a single element reference (for example PSV01) or can include a complex equation. An example of fixed programming is shown in *Example 13.1*.

Example 13.1 Fixed SELOGIC Control Equations

The following equations are examples of fixed SELOGIC control equations for relay Output OUT101. The text after the # character is a comment included in the equation and stored in the relay for future reference and documentation.

OUT101 := **1** # Turn on OUT101

OUT101 := **NA** # Do not evaluate an equation for OUT101

OUT101 := **OUT102 AND RB02** # Turn on OUT101 if OUT102 and RB02 are on

Fixed SELOGIC control equations include expressions that evaluate to a Boolean value, True or False, represented by a logical 1 or logical 0.

OUT101 := **PSV04** # Turn on OUT101 if protection PSV04 is on

More complex programming in the freeform area controls OUT101. The result of the freeform programming is available as an element in a fixed equation.

OUT101 := **AMV003 > 5** # Turn on OUT101 if AMV003 is greater than 5

While you cannot perform mathematical operations in fixed programming, you can perform comparisons on the results of mathematical operations performed elsewhere.

Freeform SELOGIC Control Equations

Freeform SELOGIC control equations provide advanced relay customization and automation programming. There are freeform SELOGIC control equation programming areas used for protection and automation. You can use freeform SELOGIC control equation programming to enter program steps sequentially so that the relay will perform steps in the order that you specify. You can refer to storage locations multiple times and build up intermediate results in successive equations. You can also enter entire line comments to help document programming. Mathematical operations are available only in freeform SELOGIC control equation programming areas. An example of freeform SELOGIC control equation programming is shown in *Example 13.2*.

Example 13.2 Freeform SELOGIC Control Equations

The following equations are examples of freeform SELOGIC control equations. The text after the # character is a comment included in the equation and stored in the relay for future reference and documentation.

Freeform equation example programming

#

Is 80% of A-Phase fundamental voltage greater than 12kV?

PMV01 := **VAFM * 0.8** # 80% of A-Phase fundamental voltage

PSV04 := **PMV01 >= 12000** # True if A-Phase fundamental voltage is greater than or equal to 12000

Use comments to Group settings in the freeform SELOGIC control equations by task and to document individual equations. In this example, an intermediate calculation generates the value we want to test to determine if PSV04 will be turned on.

Assignment Statements

Both fixed and freeform SELOGIC control equations are a basic type of computer programming statement called an assignment statement. Assignment statements have a basic structure similar to that shown below:

LVALUE := Expression

Starting at the left, the LVALUE is the location where the result of an evaluation of the expression on the right will be stored. The := symbol marks the statement as an assignment statement and provides a delimiter or separator between the LVALUE and the expression. Type the := symbol as a colon and equal sign. The assignment symbol is different than a single equal sign (=) to avoid confusion with a logical comparison between two values. The type of LVALUE must match the result of evaluating the expression on the right.

There are two basic types of assignment statements that form SELOGIC control equations. In the first type, Boolean SELOGIC control equations, the relay evaluates the expression on the right to a result that is a logical 1 or a logical 0. The LVALUE must be some type of Boolean storage location or setting that requires a Boolean value. For example, the setting for the Protection Conditioning Timer 7 Input, PCT07IN, requires a value of 0 or 1, which you set with a Boolean SELOGIC control equation.

The second type is a math SELOGIC control equation. Use the math SELOGIC control equation to perform numerical calculations on data in the relay. For example, in protection freeform programming in an SEL-451, enter AMV034 := 5 * BK1IAFM to store the product of 5 and the Circuit Breaker 1 A-Phase current in automation math variable 34. *Example 13.3* lists several examples of Boolean and math SELOGIC control equations.

Example 13.3 Boolean and Math SELOGIC Control Equations

The equations below are examples of Boolean SELOGIC control equations.

Example Boolean SELOGIC control equations

PSV01 := **IN101** # Store the value of IN101 in PSV01

PSV02 := **IN101 AND RB03** # Store result of logical AND in PSV02

PST01IN := **IN104** # Use IN104 as the input value for PST01

PSV03 := **PMV33 >= 7** # Set PSV03 when PMV33 greater than or equal to 7

The lines below are examples of math SELOGIC control equations.

Example math SELOGIC control equations

PMV01 := **5** # Store the constant 5 in PMV01

PMV02 := **0.5 * VAFM** # Store the product of A-Phase voltage and 0.5 in PMV02

Comments

Include comment statements in SELOGIC control equations to help document SELOGIC control equation programming. The relay provides the following two type of comments:

- in-line comments: (*comment*)
- end-of-line comments: #xxx

Example of in-line comment:

PCT01IN := (*this is an in-line comment*) PMV04 (*this is an in-line comment *)

Example of end-of-line comment:

PCT01IN := **10** # this is an end-of-line comment

If you begin a SELOGIC control equation with an end-of-line comment character, then the entire line is a comment.

NOTE: During troubleshooting or testing, reenter a line and insert the comment character to disable it. Enter the line without the comment character to enable the line later when you want it to be executed.

Comments are a powerful documentation tool for helping both you and others understand the intent of programming and configuration of the settings. You can use comments liberally; comments do not reduce SELOGIC control equation execution capacity.

SELOGIC Control Equation Elements

SELOGIC control equation elements are a collection of storage locations, timers, and counters that you can use to customize the operation of your relay and to automate substation operation. The elements that you can use in SELOGIC control equations are summarized in *Table 13.1*. The specific number of the various types of elements varies between SEL-400 series relays. See the product-specific instruction manual to determine the number of each type of element in that relay.

Table 13.1 Summary of SELOGIC Control Equation Elements

Element	Description
Relay Word bits	Boolean value data
Analog quantities	Received, measured, and calculated values
Special condition bits	Bits that indicate special SELOGIC control equation execution conditions
SELOGIC control equation variables	Storage locations for the results of Boolean SELOGIC control equations
SELOGIC control equation math variables	Storage locations for the results of math SELOGIC control equations
Latch bits	Nonvolatile storage for the results of Boolean SELOGIC control equations
Conditioning timers	Pickup and dropout style timers similar to those used in SEL-300 series relays
Sequencing timers	On-delay timers similar to those used in programmable logic controllers
Counters	Counters that count rising edges of Boolean value inputs

Relay Word Bits and Analog Quantities

Data within the relay are available for use in SELOGIC control equations. Relay Word bits are binary data that include protection elements, input status, and output status. See *Section 11: Relay Word Bits* in each product-specific instruction manual to view a list of Relay Word bits available within that relay. Analog quantities are analog values within the relay including measured and calculated values. *Section 12: Analog Quantities* in each product-specific instruction manual contains a list of analog quantities available within the relay.

Special Condition Bits

Several Relay Word bits are available for special conditions related to SELOGIC control equation programming in the relay. You can use these bits in SELOGIC control equation programming to react to these conditions. You can also send these bits to other devices through relay interfaces including MIRRORED BITS communications and DNP3. The special condition bits are shown in *Table 13.2*.

The relay sets the first execution bits AFRTEXA, AFRTEXP, and PFRTEX momentarily to allow you to detect changes in the relay operation. The relay sets these bits and clears them as described in *Table 13.2*, *Table 13.3*, and *Table 13.4*. You can use these bits to force logic and calculations to reset or take a known state on power-up or settings change operations.

Table 13.2 First Execution Bit Operation on Startup

Name	Description
AFRTEXA	Relay sets on startup and clears after each automation programming block has been executed once.
AFRTEXP	Relay sets on startup. Relay clears after it enables protection and all automation programming blocks have been executed once.
PFRTEX	Relay sets on startup. Relay clears after protection runs for 1 cycle.

Table 13.3 First Execution Bit Operation on Automation Settings Change

Name	Description
AFRTEXA	Relay sets on settings change and clears after each automation programming block has been executed once.
AFRTEXP	Relay sets on settings change. Relay clears after it enables protection and all automation programming blocks have been executed once.
PFRTEX	Relay sets on settings change. Relay clears after protection runs for 1 cycle.

Table 13.4 First Execution Bit Operation on Protection Settings Change, Group Switch, and Source Selection

Name	Description
AFRTEXA	Relay does not set.
AFRTEXP	Relay sets when listed event occurs. Relay clears after it enables protection and all automation programming blocks have been executed once.
PFRTEX	Relay sets when listed event occurs. Relay clears after protection runs for 1 cycle.

SELOGIC Control Equation Variables

There are two types of SELOGIC control equation variables: Boolean and math.

SELOGIC Control Equation Boolean Variables

SELOGIC control equation Boolean variables are binary storage locations. Each variable equals either logical 1 or logical 0. This manual refers to these variables and the relay displays these as 1 and 0, respectively. Think also of the states 1 and 0 as True and False, respectively, when you evaluate Boolean logic statements. The quantities of SELOGIC control equation Boolean variables available in the different programming areas are listed in *Table 13.5*.

NOTE: The SEL-487E supports 96 protection SELOGIC variables.

Table 13.5 SELOGIC Control Equation Boolean Variable Quantities

Type	Typical Quantity	Name Range
Protection SELOGIC control equation Boolean variables	64	PSV01–PSV64
Automation SELOGIC control equation Boolean variables	256	ASV001–ASV256

Use the SELOGIC control equation Boolean variables in freeform logic statements in any order you want. Use a SELOGIC control equation Boolean variable more than once in freeform logic programming, and use SELOGIC control equation Boolean variables as arguments in SELOGIC control equations. *Example 13.4* illustrates SELOGIC control equation variable usage. You can view the status of individual control equation Boolean bits in the Relay Word using the **TARGET** command. Use the **TAR PSV*nn*** command or the **TAR ASV*nnn*** command to view the Relay Word row containing the protection or automation Boolean bit specified by the number *nn*. You can also view the status of Boolean bits through the relay LCD front-panel display by selecting `RELAY ELEMENTS` from the Main Menu and scrolling through the rows of Relay Word bits.

Example 13.4 SELOGIC Control Equation Boolean Variables

The equations below show freeform SELOGIC control equation programming examples that use SELOGIC control equation Boolean variables. Each line has a comment after the # that provides additional detail.

PSV01 := **1** # Set PSV01 to 1 always

PSV09 := **PSV54 AND ASV005** # Set to result of Boolean AND

PSV02 := **PMV05 > 5** # Set if PMV05 is greater than 5

You can use SELOGIC control equation variables more than once in freeform programming. The SELOGIC control equations below use ASV100 and ASV101 to calculate intermediate results.

Remote control 1

ASV100 := **RB14 AND ALT01** # Supervise remote control with ALT01

ASV101 := **RB15 AND PLT07** # Supervise remote control with PLT07

ASV201 := **ASV100 OR ASV101** # Store desired control in ASV201

Remote control 2

ASV100 := **RB18 AND ALT09** # Supervise remote control with ALT09

ASV101 := **RB19 AND PLT13** # Supervise remote control with PLT13

ASV202 := **ASV100 OR ASV101** # Store desired control in ASV202

SELOGIC Control Equation Math Variables

SELOGIC control equation math variables are math calculation storage results. As with protection and automation SELOGIC control equation Boolean variables, there are separate storage areas for protection and automation math calculations. The quantities of SELOGIC control equation math variables available in the SEL-400 series relays are shown in *Table 13.6*.

Table 13.6 SELOGIC Control Equation Math Variable Quantities

Type	Typical Quantity	Name Range
Protection SELOGIC control equation math variables	64	PMV01–PMV64
Automation SELOGIC control equation math variables	256	AMV001–AMV256

Use math variables in freeform programming to store the results of math calculations as arguments in math calculations and comparisons. *Example 13.5* illustrates SELOGIC control equation math variable usage. You can view the results of protection and automation math variables by using the **METER** command. Use the **MET PMV** command to see all protection math variable results (PMV01–PMV64). Similarly, use the **MET AMV** command to see all automation math variable results (AMV001–AMV256).

Example 13.5 SELOGIC Control Equation Math Variables

The equations below show freeform SELOGIC control equation programming examples that use SELOGIC control equation math variables by using analog quantities available in the SEL-421. Each line has a comment after the # that provides additional description.

PMV01 := **378.62** # Store 387.62 in PMV01

PMV09 := **5 + VAFM** # Store sum of 5 and A-Phase voltage in kV in PMV09

You can use SELOGIC control equation math variables more than once in freeform programming. Use AMV010 in the following SELOGIC control equations to calculate intermediate results.

Determine if any phase voltage is greater than 13 kV

A-Phase

AMV010 := **VAFIM/1000** # VA in kV

ASV010 := **AMV010 > 13** # Set if greater than 13 kV

B-Phase

AMV010 := **VBFIM/1000** # VB in kV

ASV011 := **AMV010 > 13** # Set if greater than 13 kV

C-Phase

AMV010 := **VCFIM/1000** # VC in kV

ASV012 := **AMV010 > 13** # Set if greater than 13 kV

Combine phase results

ASV013 := **ASV010 OR ASV011 OR ASV012**

Latch Bits

Latch bits are nonvolatile storage locations for Boolean information. Latch bits are in several settings areas of the relay, as shown in *Table 13.7*. Latch bits have two input parameters, Reset and Set, and one Latched Value, as shown in *Table 13.8*.

Table 13.7 Latch Bit Quantities

Type	Typical Quantity	Name Range
Protection freeform latch bits	32	PLT01–PLT32
Automation latch bits	32	ALT01–ALT32

Table 13.8 Latch Bit Parameters

Type	Item	Description	Setting	Name Examples
Input	Reset	Reset latch when on	Boolean SELOGIC control equation	PLT01R ALT01R
Input	Set	Set latch when on	Boolean SELOGIC control equation	PLT01S ALT01S
Output	Latched Value	Latched Value of 0 or 1	Value for use in Boolean SELOGIC control equations	PLT01 ALT24

Latch bits provide nonvolatile storage of binary information. A latch can have the value of logical 0 or logical 1. Latch bits also retain their state through changes in the active protection settings group. Because storage of latch bits is in nonvolatile memory, the state of latch bits remains unchanged indefinitely, even when power is lost to the relay.

As with logic latches used in digital electronics, each latch bit has a Set input and a Reset input. The relay evaluates the latch bit value at the end of each logic processing interval by using the values for Set and Reset calculated during the processing interval. Latch bits are reset dominant. If the Set and Reset inputs are both asserted, the relay will reset the latch.

NOTE: The SEL-487E supports 80 automation latch bits.

Latch bits are available in two different programming areas of the relay. First, there are 32 latch bits, PLT01–PLT32, that are associated with protection settings. Second, there are 32 latch bits, ALT01–ALT32, available in automation freeform programming. You can view the status of individual latch bits in the Relay Word using the **TARGET** command. Use the **TAR PLT*nn*** command or the **TAR ALT*nn*** command to view the Relay Word row containing the protection or automation latch bit specified by the two-digit number, *nn*. You can also view the status of latch bits through the relay LCD front-panel display by selecting `RELAY ELEMENTS` from the Main Menu and scrolling through the rows of Relay Word bits.

Protection Latch Bits

Program the 32 latch bits, PLT01–PLT32, in the protection freeform SELOGIC control equation programming area. There is a separate protection freeform SELOGIC control equation programming area associated with each protection settings group. The latches in protection can have separate programming for Set and Reset in each protection settings group. While each protection latch value remains unchanged for a change in the active protection settings group, you can enter different Set and Reset programming for each protection settings group.

There are Set and Reset settings for each latch bit available in each group. For example, PLT01R and PLT01S are available in all six freeform settings groups and all control the same Latch Bit, PLT01. This structure allows you to either program each latch to operate in the same way for each group or behave differently based on the active protection settings group. For example, you could program the protection latch to set on IN107 when Protection Settings Group 1 is active and program the latch to set on IN106 when Protection Settings Group 2 is active. If you do not enter a setting for the Reset and Set in a protection settings group, the latch bit will remain unchanged when that protection settings group is active. *Example 13.6* illustrates protection latch bit usage.

Example 13.6 Protection Latch Bits

This example studies the factory settings for the HOT LINE TAG operator control logic in the SEL-451. Protection Latch Bit 4 (PLT04) is used as a close enable signal, which is deasserted during Hot Line Tag conditions. When the HOT LINE TAG operator control is pressed, Relay Word bit PB5_PUL pulses for one processing interval, and one of two actions will occur, depending on the previous state of PLT04:

- ➤ If PLT04 was previously asserted, the PB5_PUL is ANDed with PLT04 in the PLT04R SELOGIC equation, causing PLT04 to deassert. In this state, closing is blocked.
- ➤ If PLT04 was previously deasserted, the PB5_PUL is ANDed with NOT PLT04 in the PLT04S SELOGIC equation, causing PLT04 to assert. In this state, closing is permitted.

The settings below are duplicated in the Protection SELOGIC control equation freeform programming areas corresponding to each of six setting groups:

Store HOT LINE TAG state in PLT04, controlled by front-panel pushbutton

#

PLT04S := PB5_PUL AND NOT PLT04

PLT04R := PB5_PUL AND PLT04 # HOT LINE TAG (WHEN PLT04 DEASSERTED)

#

PLT04 defeats the RECLOSE ENABLED operator control function

PLT02R := PB2_PUL AND PLT02 OR **NOT PLT04** # HOT LINE TAG DISABLES RECLOSE

In the factory settings for PLT04S and PLT04R, rising-edge operators are not required because Relay Word bit PB5_PUL only asserts for one processing interval. If the application required control input IN103 to set or clear the Hot Line Tag function in addition to the operator control pushbutton, the settings would look like this:

PLT04S := (PB5_PUL OR R_TRIG IN103) AND NOT PLT04

PLT04R := (PB5_PUL OR R_TRIG IN103) AND PLT04 # HOT LINE TAG (WHEN PLT04 DEASSERTED)

If the R_TRIG operators were not present, Protection Latch Bit 4 (PLT04) would oscillate whenever IN103 was asserted, and the final state after IN103 deasserts would be indeterminate. To prevent contact bounce sensed by Control Input IN103 from triggering multiple rising edges, make appropriate debounce time settings.

Protection Latch Bit 4 (PLT04) appears in the factory settings for several SELOGIC control equations in the SEL-451:

- ➤ In the Protection SELOGIC control equation freeform programming area, PLT04 defeats the RECLOSE ENABLED operator control function

  PLT02R := PB2_PUL AND PLT02 OR **NOT PLT04** # HOT LINE TAG DISABLES RECLOSE

- ➤ In the front-panel settings, PB5_LED follows the inverted state of PLT04:

  PB5_LED := **NOT PLT04** #HOT LINE TAG

Example 13.6 Protection Latch Bits (Continued)

- In Group settings, PLT04 supervises close and reclose conditions:
  - Autoreclose enable

    E3PR1 := PLT02 **AND PLT04**
  - Autoreclose drive-to-lockout

    79DTL := NOT (PLT02 **AND PLT04**) AND (3PT OR NOT 52AA1)
  - Manual close

    BK1MCL := (CC1 OR PB7_PUL) **AND PLT04**

The above settings allow the HOT LINE TAG operator control pushbutton to enable or disable close operations in the SEL-451. Any changes to these factory settings should be carefully designed and tested to ensure proper operation.

Evaluation of the latch bit value occurs at the end of the protection SELOGIC control equation execution cycle. The values evaluated for Reset (PLT*nn*R) and Set (PLT*nn*S) during SELOGIC control equation execution remain unchanged until after the evaluation of all SELOGIC control equations, when the relay evaluates the latch bit value (PLT*nn*). For example, if you have multiple SELOGIC control equations for set, the last equation in the protection freeform area dominates, and the relay uses this equation to evaluate the latch.

Automation Latch Bits

NOTE: The SEL-487E supports 80 automation latch bits.

The automation latch bits, ALT01–ALT32, are available in automation freeform settings. Write freeform SELOGIC control equations to set and reset these bits. As with protection latch bits, the relay stores automation latch bits in nonvolatile memory and preserves these through a relay power cycle and group change operations. With protection latch bits, you can implement Set and Reset programming for each protection settings group. Automation SELOGIC control equation programming, however, has only one programming area active for all protection settings groups.

The relay evaluates the latch bit value at the end of the automation freeform SELOGIC control equation execution cycle. The values for Reset (ALT*nn*R) and Set (ALT*nn*S) remain unchanged until evaluation of all SELOGIC control equations, when the relay evaluates the latch (ALT*nn*). For example, if you have multiple SELOGIC control equations for set, the last equation in the automation freeform area dominates, and the relay uses this equation to evaluate the latch.

Conditioning Timers

Use conditioning timers to condition Boolean values. Conditioning timers either stretch incoming pulses or allow you to require that an input take a state for a certain period before reacting to the new state. Conditioning timers are available in the protection freeform area and automation freeform area, as shown in *Table 13.9*. Conditioning timers have the three input parameters and one output shown in *Table 13.10*.

NOTE: Times for protection timers must not exceed 2,000,000 cycles for proper operation.

NOTE: The SEL-487B supports 16 protection conditioning timers.

IMPORTANT: The SEL-400G uses seconds for conditioning timer settings.

NOTE: The SEL-487E supports 48 automation conditioning timers.

Table 13.9 Conditioning Timer Quantities

Type	Quantity	Name Range
Automation freeform conditioning timers	32	ACT01–ACT32
Protection freeform conditioning timers	32	PCT01–PCT32

Table 13.10 Conditioning Timer Parameters

Type	Item	Description	Setting	Name Examples
Input	Pickup Time	Time that the input must be on before the output turns on	Time value. Protection uses the relay protection logic processing interval[a], and automation uses seconds.	PCT01PU ACT01PU
Input	Dropout Time	Time that the output stays on after the input turns off	Time value. Protection uses the relay protection logic processing interval[a], and automation uses seconds.	PCT01DO ACT01DO
Input	Input	Value that the relay times	Boolean SELOGIC control equation setting	PCT01IN ACT01IN
Output	Output	Timer output	Value for Boolean SELOGIC control equations	PCT01Q ACT01Q

[a] The SEL-400G uses seconds for both protection and automation conditioning timers.

A conditioning timer output turns on and becomes logical 1, after the input turns on and the Pickup Time expires. An example timing diagram for a conditioning timer, PCT01, with a Pickup Time setting greater than zero and a Dropout Time setting of zero is shown in *Figure 13.3*. In the example timing diagram, the Input, PCT01IN, turns on and the timer Output, PCT01Q, turns on after the Pickup Time, PCT01PU, expires. Because the Dropout Time setting is zero, the Output turns off when the Input turns off.

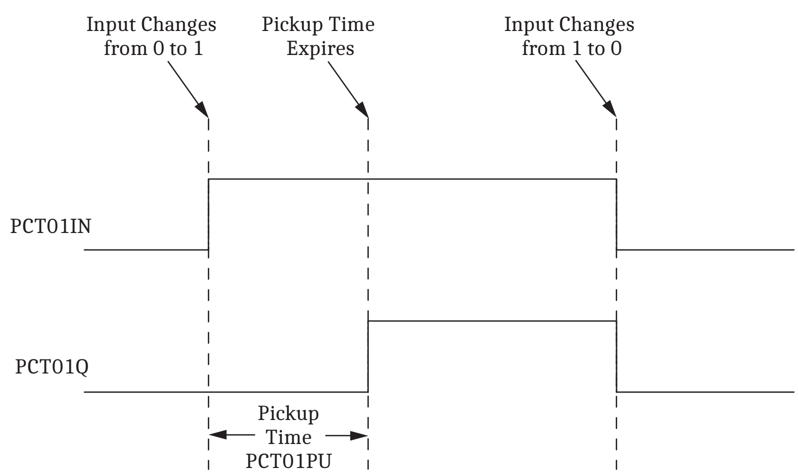

Figure 13.3 Conditioning Timer With Pickup and No Dropout Timing Diagram

If the Pickup Time is not satisfied, the timer Output never turns on, as illustrated in *Figure 13.4*. If the input reasserts again, one or more processing intervals later, the conditioning timer pickup timer begins timing again from zero.

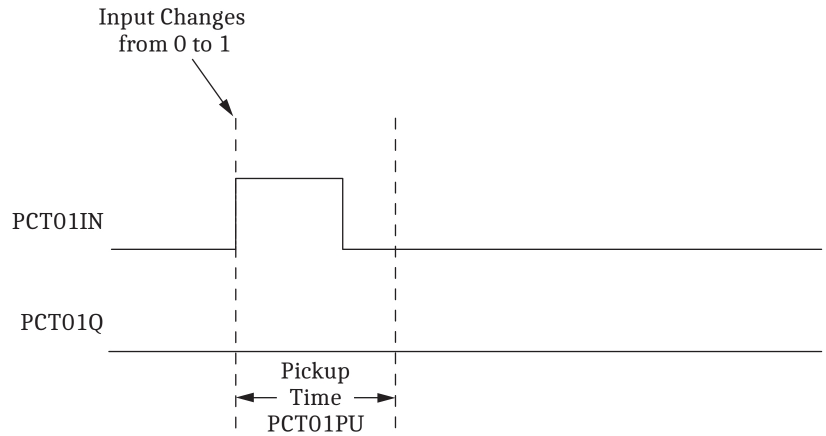

Figure 13.4 Conditioning Timer With Pickup Not Satisfied Timing Diagram

A conditioning timer output turns off when the input turns off and the Dropout Time expires. An example timing diagram for a conditioning timer, PCT02, with a Pickup Time setting of zero and a Dropout Time setting greater than zero is shown in *Figure 13.5*. Because the Pickup Time, PCT02PU, setting is zero, the Output, PCT02Q, turns on when the Input, PCT02IN, turns on. The Output turns off after the Input turns off and the Dropout Time, PCT02DO, expires. If the input reasserts before the dropout time expires, the dropout timer resets so it begins timing again from zero when the input drops out again.

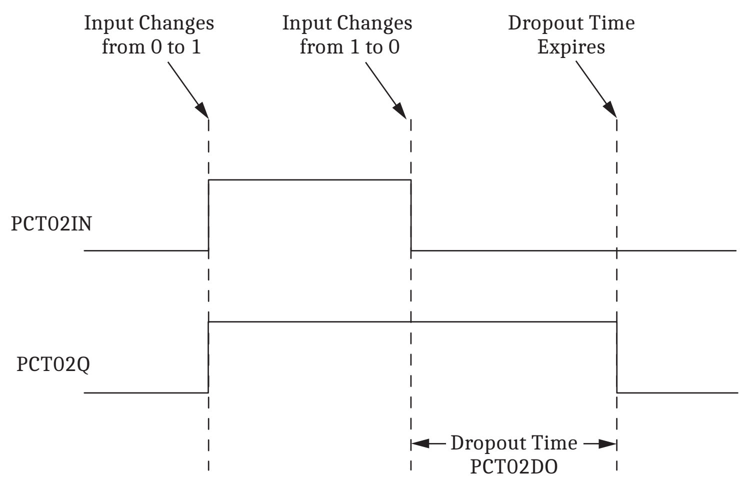

Figure 13.5 Conditioning Timer With Dropout and No Pickup Timing Diagram

Combining the features shown above, *Figure 13.6* illustrates conditioning timer operation for use of both the pickup and dropout characteristics. The Output, PCT03Q, turns on after the Input, PCT03IN, turns on and the Pickup Time, PCT03PU, expires. The Output turns off after the Input turns off and the Dropout Time, PCT03DO, expires.

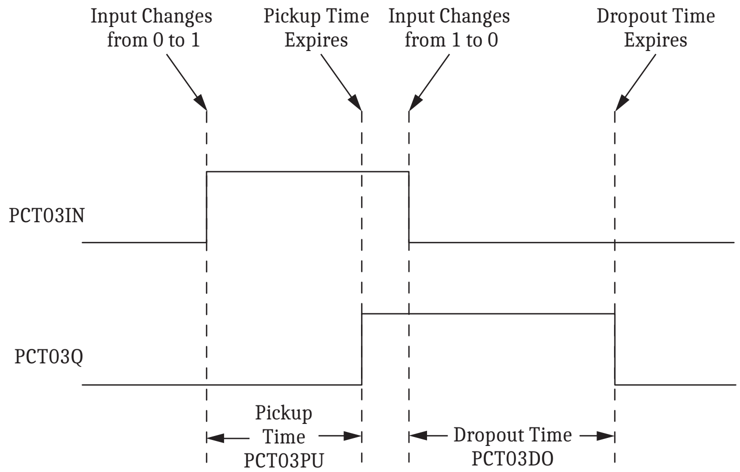

Figure 13.6 Conditioning Timer With Pickup and Dropout Timing Diagram

For protection conditioning timers, set the Pickup Time and Dropout Time in cycles and fractions of a cycle (represented in decimal form). In the SEL-400G, the pickup and dropout timers are set in seconds. The relay processes protection conditioning timers once for each protection processing interval. The relay asserts the timer output on the first processing interval when the elapsed time exceeds the setting. In most SEL-400 series relays, the protection processing interval is 1/8 cycle (or 0.125 cycles). See the product-specific instruction manual to determine the specific processing interval. Actual settings, programming, and operation are illustrated in *Example 13.7*.

For automation conditioning timers, set the Pickup Time and Dropout Time in seconds. The relay processes automation conditioning timers once for each automation processing interval. The execution interval depends on the amount of automation programming. Determine the average automation execution interval with the **STATUS S** command.

IMPORTANT: This example shows timer pickup and dropout settings in cycles. The SEL-400G uses seconds for these settings.

Example 13.7 Conditioning Timer Programming and Operation

This example uses protection freeform conditioning timer seven, PCT07. The freeform settings are as shown here:

PCT07PU := **5.3** # Pickup set to 5.3 cycles

PCT07D0 := **6.0** # Dropout set to 6.0 cycles

PCT07IN := **IN101** # Operate on the first input on the main board

PSV29 := **PCT07Q** # Protection SELOGIC control equation variable follows the timer output

The operation of the timer when IN101 turns on for 7 cycles is shown in the timing diagram in *Figure 13.7*. Because the pickup setting is an uneven number of protection processing intervals (1/8 cycle), the pickup occurs on the first 1/8th cycle after the Pickup Time of 5.3 cycles expires.

Example 13.7 Conditioning Timer Programming and Operation (Continued)

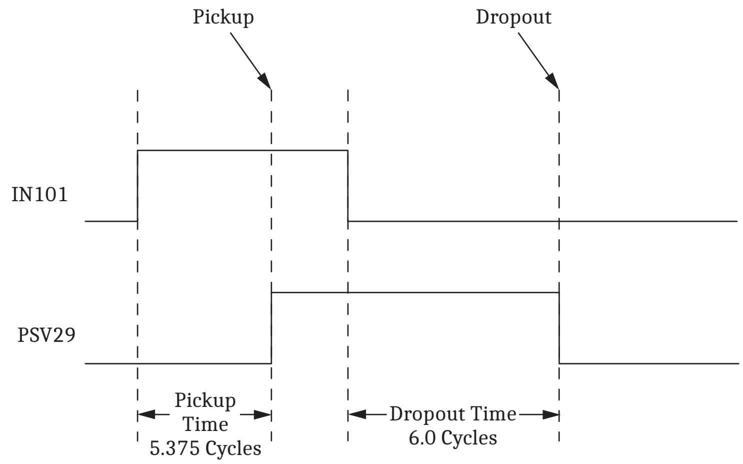

Figure 13.7 Conditioning Timer Timing Diagram for Example 13.7

In freeform programming, the relay evaluates the timer at execution of the timer Input SELOGIC control equation (PCT*nn*IN or ACT*nn*IN). The relay loads the Pickup Time (PCT*nn*PU or ACT*nn*PU) and Dropout Time (PCT*nn*DO or ACT*n-n*DO) into the timer when the relay observes the appropriate edge in the input. If you enter a math expression for Pickup Time or Dropout Time, the relay uses the value calculated before the Input SELOGIC control equation. If your Pickup Time or Dropout Time equation is below the Input equation (has a higher expression line number), the relay will use the value calculated on the previous SELOGIC control equation execution interval. Because the relay calculates the last value for pickup or dropout in this manner, we recommend for most applications that you enter the Pickup Time, Dropout Time, and Input statements together in the order shown in *Example 13.7*. You can view the status of the conditioning timer output Relay Word bits by using the **TAR PCT*nn*Q** or **TAR ACT*nn*Q** command, where *nn* is the number of the conditioning timer. You can also view the status of these timer elements through the relay front-panel LCD by selecting `RELAY ELEMENTS` from the Main Menu and scrolling through the rows of Relay Word bits.

Sequencing Timers

NOTE: Times for protection timers with timer settings based on power system cycles must not exceed 2,000,000 cycles for proper operation.

IMPORTANT: The SEL-400G uses seconds for sequencing timer settings.

NOTE: The SEL-487E supports 48 automation conditioning timers.

Sequencing timers are useful for sequencing operation. There are two main differences between sequencing timers and conditioning timers. First, sequencing timers integrate pulses of the input to count up a total time. Second, the elapsed time a sequencing timer counts is visible; you can use this time in other SELOGIC control equation programming or make this time visible through one of the relay communications protocol interfaces. Sequencing timers are available in the protection freeform area and automation freeform area as shown in *Table 13.11*. Sequencing timers have three input parameters and two outputs listed in *Table 13.12*.

Table 13.11 Sequencing Timer Quantities

Type	Typical Quantity	Name Range
Protection freeform sequencing timers	32	PST01–PST32
Automation freeform sequencing timers	32	AST01–AST32

Table 13.12 Sequencing Timer Parameters

Type	Item	Description	Setting	Name Examples
Input	Preset Time	Time the input must be on before the output turns on	Time value. Protection uses the relay protection logic processing interval[a], while automation uses seconds.	PST01PT AST07PT
Input	Reset	Timer reset	Boolean SELOGIC control equation setting	PST01R AST07R
Output	Elapsed Time	Time accumulated since the last reset	Value for math SELOGIC control equations. Protection uses the relay protection logic processing interval[a], while automation uses seconds.	PST01ET AST07ET
Input	Input	Value that the relay times	Boolean SELOGIC control equation setting	PST01IN AST07IN
Output	Output	Timer output	Value for Boolean SELOGIC control equations	PST01Q AST07Q

[a] The SEL-400G uses seconds for both protection and automation conditioning timers.

A sequencing timer counts time by incrementing the Elapsed Time when SELOGIC control equation execution reaches the Input equation if the Reset is off and the Input is on. The Output turns on when the Elapsed Time reaches or exceeds the Preset Time. Whenever the Reset is on, the relay sets the Output to zero, then clears the Elapsed Time, and stops accumulating time (even if Input is on).

Figure 13.8 is a timing diagram for typical sequencing timer operation.

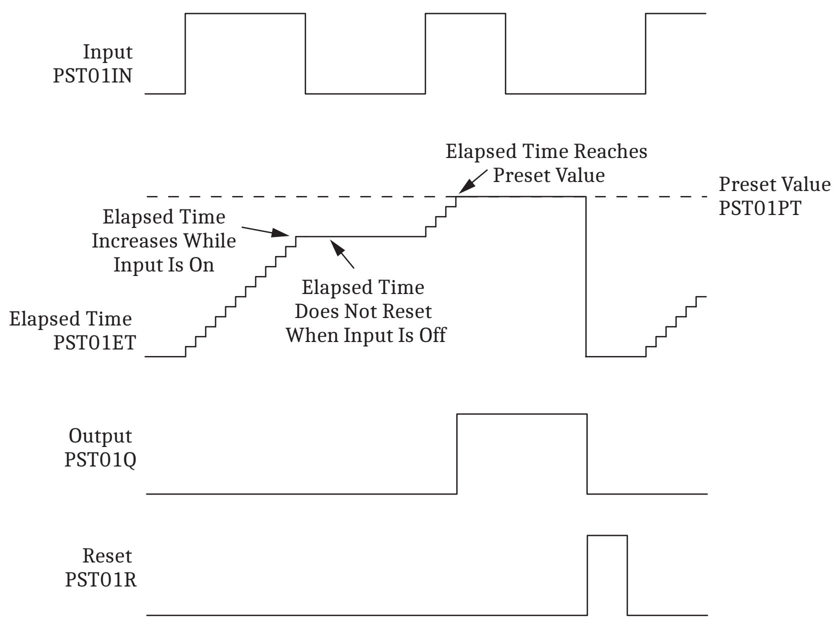

Figure 13.8 Sequencing Timer Timing Diagram

Timers in protection programming operate in the relay protection logic processing interval, while timers in automation programming operate in seconds. In the SEL-400G, the pickup and dropout timers are set in seconds. As with protection conditioning timers, operation depends on the logic processing interval. For example, in most SEL-451 series relays the logic processing interval is 1/8 cycle, so the relay effectively rounds up all operation to the nearest 0.125 cycles. With automation programming, the execution interval depends on the amount of automation programming. Determine the average automation execution interval with the **STATUS S** command.

The automation timers operate using a real-time clock. Each time the relay evaluates the Input (AST*nn*IN) the relay adds the elapsed time since the last execution to the Elapsed Time (AST*nn*ET). The accuracy of the timer in stopping and starting when the input of the timer turns on averages half an automation execution cycle. If you change automation freeform programming, you must also check the new automation average execution cycle to verify that you will obtain satisfactory accuracy for your application. *Example 13.8* describes typical timer programming and describes the resulting operation.

IMPORTANT: This example shows the timer pickup and dropout settings in cycles. The SEL-400G uses seconds for these settings.

Example 13.8 Automation Sequencing Timer Programming

The equations below are an example of programming for an automation sequencing timer, AST01. Each timer input is programmed as a separate statement in automation SELOGIC control equation programming.

Example programming of sequencing timer to time Input IN101 and IN102

AST01PT := **7.5** # Timer Preset Time of 7.5 seconds

AST01R := **RB03** # Reset timer when RB03 turns on

AST01IN := **IN101 AND IN102** # Timing time when IN101 and IN102 are on

ASV001 := **AST01Q** # ASV001 tracks output of timer

AMV256 := **AST01ET** # AMV256 tracks timing progress

In this example, timer AST01 times the quantity IN101 AND IN102 and turns on when the total time reaches 7.5 seconds. If the Input, AST01IN, is on for approximately 1 second every minute, the Output, AST01Q, will turn on during the eighth minute, when the accumulated elapsed time exceeds 7.5 seconds.

In freeform programming, the relay evaluates the timer at the timer Input SELOGIC control equation (PST*nn*IN or AST*nn*IN). If you enter an expression for the timer Reset (PST*nn*R or AST*nn*R) or Preset Time (PST*nn*PT or AST*nn*PT), the values for Reset and Preset Time that the relay uses are the last values that the relay calculates before the input SELOGIC control equation calculation. Because the relay uses the last values for Reset and Preset Time value in this manner, we recommend for most applications that you enter the Preset Time, Reset, and Input statements together in the order shown in *Example 13.8*. You can view the current state of the timer by assigning the elapsed time output of the sequencing timer to a math variable. *Example 13.8* shows how you would assign the elapsed time output for automation sequence timer AST01 to automation math variable AMV256. To see the elapsed time value, issue the **MET AMV** command to display the values of the automation math variables. Likewise, you can assign the elapsed time output of a protection sequence timer to a protection math variable.

The elapsed time output is stored in volatile memory. Elapsed time resets to zero for both protection and automation sequential timers when relay power cycles, you change settings or settings groups, or you perform any function that restarts the relay.

Counters

NOTE: Preset values for counters must not exceed 8,000,000 for proper operation.

Use counters to count changes or edges in Boolean values. Each time the value changes from logical 0 to logical 1 (a rising edge), the counter Current Value increments. Counters are available in the protection freeform area and automation freeform area, as shown in *Table 13.13*. Counters have three input parameters, Input, Preset Value, and Reset; and two outputs, Current Value and Output, as listed in *Table 13.14*.

Table 13.13 Counter Quantities

Type	Typical Quantity	Name Range
Protection counters	32	PCN01–PCN32
Automation counters	32	ACN01–ACN32

Table 13.14 Counter Parameters

Type	Item	Description	Setting	Name Examples
Input	Preset Value	Number of counts before the output turns on	Constant or expression for the number of counts	PCN01PV ACN09PV
Input	Reset	Counter reset	Boolean SELOGIC control equation setting	PCN01R ACN09R
Output	Current Value	Current accumulated count	Value for math SELOGIC control equations	PCN01CV ACN09CV
Input	Input	Value that the relay counts	Boolean SELOGIC control equation setting	PCN01IN ACN09IN
Output	Output	Counter output	Value for Boolean SELOGIC control equations	PCN01Q ACN09Q

In freeform programming, the relay evaluates the counter at execution of the counter Input SELOGIC control equation (PCN*nn*IN or ACN*nn*IN). If you enter an expression for the counter Reset (PCN*nn*R) or the counter Preset (PCN*nn*PV), the values for Reset and Preset that the relay uses are the last values the relay calculates before the input SELOGIC control equation calculation. Because the relay uses the last values for Reset and Preset in this manner, we recommend for most applications that you enter the Preset, Reset, and Input statements together in the order shown in *Example 13.9*. You can view the current value of the counter by assigning the protection counter current value, PCN*nn*CV, to a protection math variable or by assigning the automation counter current value, ACN*nn*CV, to an automation math variable. View the math variable values by issuing the appropriate **MET PMV** or **MET AMV** commands.

The current value count is stored in volatile memory. The count resets to zero for both protection and automation sequential timers when relay power cycles, you change settings or settings groups, or you perform any function that restarts the relay.

Example 13.9 Counter Programming

The freeform programming equations that follow demonstrate how to enter settings to control a protection counter in protection freeform SELOGIC control equation programming. Programming for an automation counter is similar.

Example 13.9 Counter Programming (Continued)

Protection Counter 1 counts close operations of the circuit breaker associated with the 52AA1 element. Initially, the current value, PCN01CV, is zero. The relay increments the current value each time the circuit breaker closes. The relay increases the count value, PCN01CV, each time the circuit breaker closes and the element 52AA1 value changes from 0 to 1 (a rising edge). When the count reaches 1000, the timer automatically resets and begins counting again.

Example protection counter programming

#

This example counts how many times a circuit breaker closes

The counter automatically resets every 1,000 operations

PCN01PV := **1000**

PCN01R := **PCN01Q**

PCN01IN := **52AA1**

The SELOGIC control equations below provide multiple-change detection counting both close and open operations of the circuit breaker. The intermediate value PSV01 turns on for one processing interval each time the circuit breaker closes. The intermediate value PSV02 turns on for one processing interval each time the circuit breaker opens. The OR combination of PSV01 and PSV02 contains a rising edge for each circuit breaker operation, open or closed, that Protection Counter 1 counts.

Example protection counter programming

#

This example counts how many times a circuit breaker operates either open or closed

#

Detect OPEN and CLOSE and combine

PSV01 := **R_TRIG 52AA1** # Pulse for each close

PSV02 := **F_TRIG 52AA1** # Pulse for each open

PSV03 := **PSV01 OR PSV02** # Pulse for each open or close

#

The counter automatically resets every 1,000 operations

PCN01PV := **1000**

PCN01R := **PCN01Q**

PCN01IN := **PSV03** # Count open and close operations

PSV04 := **PCN01CV >900** # PSV04 signals impending reset

SELOGIC Control Equation Operators

There are two types of SELOGIC control equations. Boolean SELOGIC control equations comprise the first type. These equations are expressions that evaluate to a Boolean value of 0 or 1. Math SELOGIC control equations constitute the second type. The relay evaluates these equations to yield a result having a numerical value (for example, 6.25 or 1055).

Left value, LVALUE, determines the type of SELOGIC control equation you need for a setting or for writing freeform programming. If the LVALUE is a Boolean type (ER, ASV001, etc.) then the type of expression you need is a Boolean SELOGIC control equation. If the LVALUE is a numerical (non-Boolean) value (PMV12, PCT01PV, etc.), the type of expression you need is a math SELOGIC control equation.

Writing SELOGIC control equations requires that you use the appropriate operators and correct SELOGIC control equation syntax to combine relay elements including analog values, Relay Word bits, incoming control points, and SELOGIC control equation elements within the relay. The operators are grouped into two types, according to the type of SELOGIC control equation in which you can apply these operators.

Operator Precedence

When you combine several operators and operations within a single expression, the relay evaluates the operations from left to right, starting with the highest precedence operators working down to the lowest precedence. This means that if you write an equation with three AND operators, for example PSV01 AND PSV02 AND PSV03, each AND will be evaluated from the left to the right. If you substitute NOT PSV04 for PSV03 to make PSV01 AND PSV02 AND NOT PSV04, the relay evaluates the NOT operation of PSV04 first and uses the result in subsequent evaluation of the expression. While you cannot use all operators in any single equation, the overall operator precedence follows that shown in *Table 13.15*.

Table 13.15 Operator Precedence From Highest to Lowest (Sheet 1 of 2)

Operator	Description
(Expression)	Parenthesis
Identifier (argument list)	Function evaluation
–	Negation
NOT	Complement
R_TRIG	
F_TRIG	Edge Trigger
SQRT, LN, EXP, LOG, COS, SIN, ACOS, ASIN, ABS, CEIL, FLOOR	Math Functions
*	Multiply
/	Divide
+	Add
–	Subtract
<, >, <=, >=	Comparison
=	Equality
<>	Inequality

Table 13.15 Operator Precedence From Highest to Lowest (Sheet 2 of 2)

Operator	Description
AND	Boolean AND
OR	Boolean OR

Boolean Operators

Use Boolean operators to combine values with a resulting Boolean value. The arguments of the operator may be either numbers or Boolean values, but the result of the operation must be a Boolean value. Combine the operators to form statements that evaluate complex Boolean logic. *Table 13.16* contains a summary of Boolean operators available in SEL-400 series relays.

Table 13.16 Boolean Operator Summary

Operator	Description
( )	Parentheses
NOT	Logical inverse
AND	Logical AND
OR	Logical OR
R_TRIG	Rising-edge trigger
F_TRIG	Falling-edge trigger
>, <, =, <=, >=, <>	Comparison of values

Parentheses

Use paired parentheses to control the execution order of operations in a SELOGIC control equation. Use as many as 14 nested sets of parentheses in each SELOGIC control equation. The relay calculates the result of the operation on the innermost pair of parentheses first and then uses this result with the remaining operations. *Table 13.17* is a truth table for an example operation that illustrates how parentheses can affect equation evaluation.

Table 13.17 Parentheses Operation in Boolean Equation

A	B	C	A AND B OR C	A AND (B OR C)
0	0	0	0	0
0	0	1	1	0
0	1	0	0	0
0	1	1	1	0
1	0	0	0	0
1	0	1	1	1
1	1	0	1	1
1	1	1	1	1

NOT

Use NOT to calculate the inverse of a Boolean value according to the truth table shown in *Table 13.18*.

Table 13.18 NOT Operator Truth Table

Value A	NOT A
0	1
1	0

AND

Use AND to combine two Boolean values according to the truth table shown in *Table 13.19*.

Table 13.19 AND Operator Truth Table

Value A	Value B	A AND B
0	0	0
0	1	0
1	0	0
1	1	1

OR

Use OR to combine two Boolean values according to the truth table shown in *Table 13.20*.

Table 13.20 OR Operator Truth Table

Value A	Value B	A OR B
0	0	0
0	1	1
1	0	1
1	1	1

R_TRIG

R_TRIG is a time-based function that creates a pulse when another value changes, as shown in *Figure 13.9*. Use R_TRIG to sense when a value changes from logical 0 to logical 1 and take action only once when the value changes. The R_TRIG output is a pulse of one protection processing interval duration (typically 1/8th cycle). This rising-edge pulse output asserts one processing interval after the monitored element asserts.

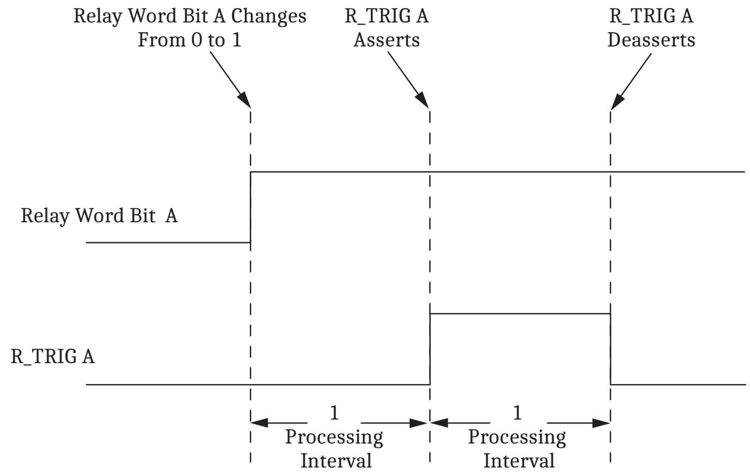

Figure 13.9 R_TRIG Timing Diagram

The argument of an R_TRIG statement must be a single bit within the relay. An example of the relay detecting a rising edge of a calculated quantity is shown in *Example 13.10*.

Example 13.10 R_TRIG Operation

The SELOGIC control equation below is invalid.

PSV15 := **R_TRIG (PSV01 AND PSV23)** # Invalid statement, do not use

Use a SELOGIC control equation variable to calculate the quantity and then use the R_TRIG operation on the result, as shown below.

PSV14 := **PSV01 AND PSV23** # Calculate quantity in an intermediate result variable

PSV15 := **R_TRIG PSV14** # Perform an R_TRIG on the quantity

F_TRIG

F_TRIG is a time-based function that creates a pulse when another value changes, as shown in *Example 13.10*. Use F_TRIG to sense when a value changes from logical 1 to logical 0 and take action only after the value changes state. The F_TRIG output is a pulse of one protection processing interval duration (typically 1/8th cycle). This pulse output asserts one processing interval after the monitored element deasserts.

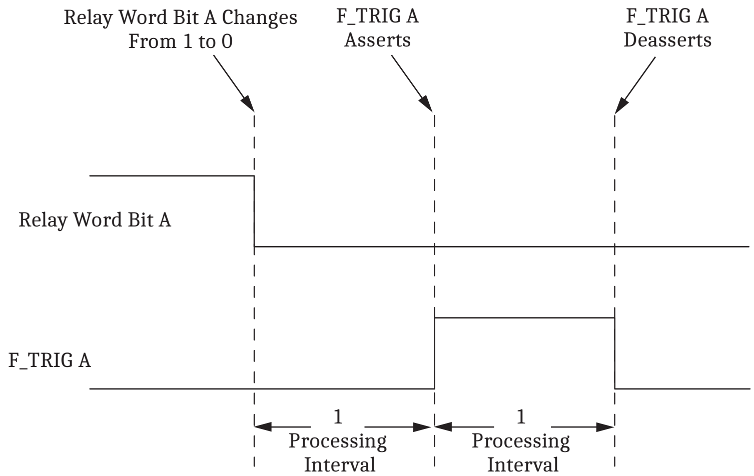

Figure 13.10 F_TRIG Timing Diagram

The argument of an F_TRIG statement must be a single bit within the relay. An example of the relay detecting a falling edge of a calculated quantity is shown in *Example 13.11*.

Example 13.11 F_TRIG Operation

The SELOGIC control equation below shows an invalid use of the F_TRIG operation.

ASV015 := **F_TRIG (ASV001 AND ALT11)** # Invalid statement, do not use

Use a SELOGIC control equation variable to calculate the quantity and then use the F_TRIG operation on the result, as shown below.

ASV014 := **ASV001 AND ALT11** # Calculate quantity in an intermediate result variable

ASV015 := **F_TRIG ASV14** # Perform an F_TRIG on the quantity

Comparison

Comparison is a mathematical operation that compares two numerical values with a result of logical 0 or logical 1. AND and OR operators compare Boolean values; comparison functions compare floating-point values such as currents and other quantities. Comparisons and truth tables for operation of comparison functions are shown in *Table 13.21*.

NOTE: Be careful how you use the equal (=) and the inequality (<>) operators. Because the relay uses a floating-point format to calculate analog values, only integer numbers will match exactly. Allow a small hysteresis of the following form: PSV01 := I01FM < 10.002 AND I01FM > 9.988.

Table 13.21 Comparison Operations

A	B	A > B	A ≥ B	A = B	A <> B	A ≤ B	A < B
6.35	7.00	0	0	0	1	1	1
5.10	5.10	0	1	1	0	1	0
4.25	4.00	1	1	0	1	0	0

Math Operators

Use math operators when writing math SELOGIC control equations. Math SELOGIC control equations manipulate numerical values and provide a numerical base 10 result. *Table 13.22* summarizes the operators available for math SELOGIC control equations.

Table 13.22 Math Operator Summary

Operator	Description
( )	Parentheses
+, –, *, /	Arithmetic
SQRT	Square root
LN, EXP, LOG	Natural logarithm, exponentiation of e, base 10 logarithm
COS, SIN, ACOS, ASIN	Cosine, sine, arc cosine, arc sine
ABS	Absolute value
CEIL	Rounds to the nearest integer toward infinity
FLOOR	Rounds to the nearest integer toward minus infinity
–	Negation

Parentheses

Use parentheses to control the order in which the relay evaluates math operations within a math SELOGIC control equation. Also use parentheses to group expressions that you use as arguments to function operators such as SIN and COS. Include as many as 14 levels of nested parentheses in your math SELOGIC control equation. *Example 13.12* shows how parentheses affect the operation and evaluation of math operations.

Example 13.12 Using Parentheses in Math Equations

The freeform math SELOGIC control equations below show examples of parentheses usage.

Examples of parenthesis usage

AMV001 := **AMV005 * (AMV004 + AMV003)** # Calculate sum first, then product

AMV002 := **AMV010 * (AMV009 + (AMV016 / AMV015))** # Nest parentheses

AMV003 := **SIN (AMV037 + PMV42)** # Group terms for a function

Math Error Detection

If a math operation results in an error, the relay turns on the math error bit, MATHERR, in the Relay Word. A settings change or the **STATUS SC** command resets this bit. For example, if you attempt to take the square root of a negative number (SQRT –5), the math error bit will be asserted until you clear the bit with a **STATUS SC** command or change settings.

Table 13.23 Math Error Examples

Example	Value in PMV01	Type	MATHERR
PMV01 := PMV02 / 0	0[a]	Divide by zero	Yes
PMV01 := LN (0)	0[a]	LN of 0	Yes
PMV01 := LN (-1)	0[a]	LN of negative number	Yes
PMV01 := SQRT (-1)	0[a]	Square root of a negative number	Yes

[a] Evaluation of expression results in an error and prevents storage of new result. In the example, PMV01 remains 0. If the argument were a variable, PMV01 would contain the result of the last evaluation when the argument is valid.

Arithmetic

Use arithmetic operators to perform basic mathematical operations on numerical values. Arguments of an arithmetic operation can be either Boolean or numerical values. In a numerical operation, the relay converts logical 0 or logical 1 to the numerical value of 0 or 1. For example, multiply numerical values by Boolean values to perform a selection operation. Use parentheses to group terms in math SELOGIC control equations and control the evaluation order and sequence of arithmetic operations.

NOTE: IEEE 32-bit floating-point numbers have a precision of approximately seven significant digits. This means that numbers bigger than 10,000,000 will lose precision in the least significant digit. Do not implement counters expecting them to get bigger than 10,000,000. Do not expect precise accuracy in analog quantities when they get bigger than 10,000,000.

The relay uses IEEE 32-bit floating-point numbers to perform SELOGIC control equation mathematical operations. If an operation results in a quantity that is not a numerical value, the SELOGIC control equation status bit that signals a math error, MATHERR, asserts. The value that the relay stored previously in the specified result location is not replaced. The relay clears the corresponding math error bits if you change SELOGIC control equation settings (protection or automation), or if you issue a **STATUS SC** command. *Example 13.13* contains examples of arithmetic operations in use.

Example 13.13 Using Arithmetic Operations

The freeform math SELOGIC control equations below show examples of arithmetic operator usage.

Arithmetic examples

AMV001 := **AMV005 + AMV034** # Calculate sum

AMV002 := **AMV005 – AMV034** # Calculate difference

AMV003 := **AMV005 * AMV034** # Calculate product

AMV004 := **AMV005 / AMV034** # Calculate quotient

The lines below demonstrate the use of Boolean values with the multiplication operation.

Use of multiplication to select numerical values based on active settings group

Use 7 if protection settings group 1 active

Use 5 if protection settings group 2 active

AMV005 := **7 * SG1 + 5 * SG2**

Example 13.13 Using Arithmetic Operations (Continued)

The lines below demonstrate math calculation error detection.

The line below results in a math error if AMV029 becomes 0

AMV006 := **732 / AMV029**

In the second line, if AMV029 is 6 on the first pass through the automation programming, the relay stores the result 122 in AMV006. If on the next pass AMV029 is 0, the MATHERR bit asserts and the value in AMV006 does not update.

SQRT

Use the SQRT operation to calculate the square root of the argument. Use parentheses to delimit the argument of a SQRT operation. A negative argument for the SQRT operation results in a math error and assertion of the corresponding math error bit described in Arithmetic. *Example 13.14* shows examples of the SQRT operator in use.

Example 13.14 Using the SQRT Operator

The freeform math SELOGIC control equations below show examples of SQRT operator usage.

SQRT examples

AMV001 := **SQRT (AMV005)** # Single argument version of SQRT

AMV002 := **SQRT (AMV005 + AMV034)** # Calculates the square root of the sum

AMV003 := **SQRT (AMV007)** # Produces a math error if AMV007 is negative

LN, EXP, and LOG

LN and EXP are complementary functions for operating with natural logarithms or logarithms calculated to the natural base e. LN calculates the natural logarithm of the argument. LOG calculates the base 10 logarithm of the argument. A negative or zero argument for the LN and LOG operation results in a math error and assertion of the corresponding math error bit described in Arithmetic. EXP calculates the value of e raised to the power of the argument. *Example 13.15* shows examples of expressions that use the LN, EXP, and LOG operators. Use parentheses to delimit the argument of a LN, EXP, or LOG operation.

Example 13.15 Using the LN, EXP, and LOG Operators

The freeform math SELOGIC control equations below are examples of LN, EXP, and LOG operator usage.

LN examples

AMV001 := **LN (AMV009)** # Natural logarithm of AMV009

AMV002 := **LN (AMV009 + AMV034)** # Natural logarithm of the sum

AMV003 := **LN (AMV010)** # Produces error if AMV010 is 0 or negative

Example 13.15 Using the LN, EXP, and LOG Operators (Continued)

EXP examples

AMV004 := **EXP (2)** # Calculates e squared

AMV005 := **EXP (AMV003)** # Calculates e to the power AMV003

AMV006 := **EXP (AMV046 + AMV047)** # e raised to the power of the sum

LOG examples

AMV007 := **LOG (AMV012)** # Base 10 logarithm of AMV012

AMV008 := **LOG (AMV012 + AMV022)** # Base 10 logarithm of the sum

AMV009 := **LOG (AMV100)** # Produces an error if AMV100 is 0 or negative

SIN and COS

Use the SIN or COS operators to calculate the sine or cosine of the argument. SIN and COS operate in degrees, the unit of angular measure the SEL-451 uses to express metering quantities. *Example 13.16* shows examples of SIN and COS. Use parentheses to delimit the argument of a SIN or COS operation.

Example 13.16 Using the SIN and COS Operators

The freeform math SELOGIC control equations below are examples of SIN and COS.

SIN examples

AMV001 := **SIN (AMV005)** # Sine of AMV005

AMV002 := **SIN (AMV005 + AMV034)** # Sine of the sum

COS examples

AMV003 := **COS (AMV005)** # Cosine of AMV005

AMV004 := **COS (AMV005 + AMV006)** # Cosine of the sum

ASIN and ACOS

Use the ASIN or ACOS operators to calculate the angle resulting from the trigonometric function equivalent to a given number (the argument), where the function is sine or cosine. ASIN and ACOS operate in degrees. An argument less than –1 or larger than 1 results in a math error and assertion of the corresponding math bit described in *Arithmetic on page 13.30*. *Example 13.17* shows examples of ASIN and ACOS. Use parentheses to delimit the argument of an ASIN or ACOS operation.

Example 13.17 Using the ASIN and ACOS Operators

The freeform math SELOGIC control equations below are examples of ASIN and ACOS.

ASIN examples

AMV001 := **ASIN (AMV010)** # Arc sine of AMV010

AMV002 := **ASIN (AMV010 + AMV011)** # Arc sine of the sum

AMV003 := **ASIN (AMV012)** # Produces an error if |AMV012| > 1

ACOS examples

AMV004 := **ACOS (AMV010)** # Arc cosine of AMV010

AMV005 := **ACOS (AMV010 + AMV011)** # Arc cosine of the sum

AMV006 := **ACOS (AMV012)** # Produces an error if |AMV012| > 1

ABS

Use the ABS operation to calculate absolute value of the argument. Use parentheses to group a math expression as the argument of an ABS operation. If the argument of the ABS operation is negative, the result is the value multiplied by –1. If the argument of the ABS operation is positive, the result is the same quantity as the argument. *Example 13.18* contains examples of the ABS operator in use.

Example 13.18 Using the ABS Operator

The freeform math SELOGIC control equations below show examples of the ABS operator usage.

ABS examples

AMV001 := **ABS (-6)** # Stores 6 in AMV001

AMV002 := **ABS (6)** # Stores 6 in AMV002

AMV003 := **ABS (AMV009)** # Absolute value of AM009

AMV004 := **ABS (AMV005 + AMV034)** # Absolute value of the sum

CEIL

Use the CEIL operator to round the argument to the nearest integer toward positive infinity. Use parentheses to group a math expression as the argument of a CEIL operation. *Example 13.19* contains examples of the CEIL operator.

Example 13.19 Using the CEIL Operator

The freeform math SELOGIC control equations below show examples of the CEIL operator usage.

CEIL examples

AMV001 := **CEIL (5.99)** # Stores 6 in AMV001

AMV002 := **CEIL (–4.01)** # Stores –4 in AMV002

FLOOR

Use the FLOOR operator to round the argument to the nearest integer toward minus infinity. Use parentheses to group a math expression as the argument of a FLOOR operation. *Example 13.20* contains examples of the FLOOR operator.

Example 13.20 Using the FLOOR Operator

The freeform math SELOGIC control equations below show examples of the FLOOR operator usage.

FLOOR examples

AMV001 := **FLOOR (5.99)** # Stores 5 in AMV001

AMV002 := **FLOOR (–4.01)** # Stores –5 in AMV002

Negation

Use the negation (–) operation to change the sign of the argument. The argument of the negation operation is multiplied by –1. Negation of a positive value results in a negative value, while negation of a negative value results in a positive value. *Example 13.21* contains examples of expressions that use the negation operator.

Example 13.21 Using the Negation Operator

The freeform math SELOGIC control equations below show examples of negation operator usage.

Negation examples

AMV001 := **-AMV009** # If AMV009 is 5, stores –5 in AMV001

AMV002 := **-AMV009** # If AMV009 is –5, stores 5 in AMV002

Effective Programming

This section contains several ideas useful for creating, maintaining, and troubleshooting programming in SEL-451 series relays protection and automation SELOGIC control equation programming environments.

Planning and Documentation

When you begin to configure the relay to perform a new automation task or customize protection operation, take time to design, document, and implement your project. Scale the planning effort to match the overall size of the project, but spend sufficient time planning to do the following:

- Document the inputs and outputs of your programming. This may include protection elements, physical inputs and outputs, metering quantities, user inputs, and other information within the relay.
- Document the processing or outcome of the programming. List the major tasks you want the relay to perform and provide detail about the algorithm you will use for each task. For example, if you need a timer or a counter, make a note of the requirements and how you will use these elements.

➤ Work in a top-down method, specifying and moving to more detailed levels, until you have sufficient information to create the settings. For simple tasks, one level may be sufficient. For complex tasks, such as automated station restoration, you may need several levels to move from idea to implementation.

Comments

SELOGIC control equation comments are very powerful tools for dividing, documenting, and clarifying your programming. Even if you completely understand your programming during installation and commissioning, comments will be very helpful if you need to modify operation a year later.

Create these comments in the fixed and freeform SELOGIC control equations, and store these comments in the relay. Obtain comments to assist you in using the ASCII interface or SEL configuration software, regardless of whether you have the original files downloaded to the relay.

Comments add structure to freeform programming environments such as Visual Basic, C, and freeform SELOGIC control equations. *Example 13.22* shows how to use comments to divide and structure freeform SELOGIC control equation programming.

Example 13.22 Comments in Freeform SELOGIC Control Equation Programming

Use comments to divide and direct your eye through freeform programming.

#

This is a header comment that divides sections of freeform programming

#

AMV003 := **15 * AMV003** # Explain this line here

#

This comment is a header for the next section.

Inputs: provide more detail for more complex tasks

Outputs: describe how the programming affects the relay operation

Processing: discuss how the programming itself operates

#

ASV004 := **ACN01Q AND RB03** # First line of next section

Many texts on programming in various computer programming languages suggest that you cannot include too many comments. The main reason to include comments is that something you find obvious may not be obvious to your coworker who will have to work with your programming in the future. Adding comments also gives you the opportunity to think about whether the program performs the function you intended.

Aliases

SEL-400 series relays provide the ability to alias Relay Word bit and analog quantity names. To make SELOGIC programming more understandable, alias the names of variables being used to something meaningful. For example, you could assign PMV01 an alias of THETA and PMV02 an alias of TAN and then write a SELOGIC equation of:

TAN := SIN(THETA)/COS(THETA)

See *Alias Settings on page 12.25* for more information on creating aliases.

Testing

After documentation and comments, the next essential element of an effective approach to programming is testing. Two types of testing are critical for determining if programming for complex tasks operates properly. First, test and observe whether the program performs the function you want under the conditions you anticipated. Second, look for opportunities to create conditions that are abnormal and determine how your program reacts to unusual conditions.

For example, test your system in unanticipated, but possible conditions such as loss of power, loss of critical field inputs, unexpected operator inputs, and conditions that result from likely failure scenarios of the equipment in your system. It is unlikely that you will find every possible weakness, but careful consideration and testing for abnormal conditions will help you avoid a failure and may reveal deficiencies in the normal operation of your system. Alternatively, you can substitute a remote bit or local bit that you can manually control to help exercise your logic.

Modify your SELOGIC control equations to simulate the process. While you may be unable to change the state of a discrete input easily, such as IN101, you can substitute a logical 1 or logical 0 in your logic to simulate the operation of IN101 and observe the results. Alternatively, you can substitute a remote bit or local bit that you can manually control to help exercise your logic.

Use the SER capabilities of the relay to monitor and record inputs, internal calculations, and outputs. For operations that occur very quickly, use the SER during testing to reconstruct the operation of your logic.

Use the **MET PMV** and **MET AMV** commands to display the contents of the protection or automation math variables.

SEL-311 and SEL-351 Series Users

You can convert logic that you have used in SEL-311 and SEL-351 series relays to logic for an SEL-400 series relay. In the SEL-351 series relays, SELOGIC control equation programming is restricted to equations where the left-side value, LVALUE, is fixed. SEL-400 series relays use a combination of fixed and freeform programming. *Table 13.24* shows comparable features between the fixed logic settings of the SEL-351-5, -6, -7 series relays and the corresponding logic elements that can be programmed in an SEL-400 series relay by using freeform logic programming.

Table 13.24 SEL-351 Series Relays and SEL-400 Series SELOGIC Control Equation Programming Equivalent Functions

Feature	SEL-351 Series	SEL-400 Series Protection Freeform Style
SELOGIC control equation variables	SV1–SV16	PSV01–PSV64
Timer Input	SV1–SV16	PCT01–PCT32
Timer Pickup settings	SV1PU–SV16PU	PCT01PU–PCT32PU
Timer Dropout settings	SV1DO–SV16DO	PCT01DO–PCT32DO
Timer Outputs	SV1T–SV16T	PCT01Q–PCT32Q
Latch Bit Set Control	SET1–SET16	PLT01S–PLT16S
Latch Bit Reset Control	RST1–RST16	PLT01R–PLT16R
Latch Bit	LT1–LT16	PLT01–PLT16

Table 13.25 is a summary that compares SELOGIC control equation programming in SEL-351 series relays and SEL-311 series relays with typical SEL-400 series relays.

Table 13.25 SEL-400 Series SELOGIC Control Equation Programming Summary

Element	SEL-351 Series/ SEL-311 Series	Typical SEL-400 Series	
		Protection Free Form	Automation Free Form
SELOGIC control equation variables	16	64[a]	256
SELOGIC math variables	0	64	256
Conditioning timers[b]	16	32[c]	32[d]
Sequencing timers	0	32	32[e]
Counters	0	32	32
Latch bits	16	32	32[f]

[a] The SEL-487E supports 96 protection SELOGIC variables.
[b] Similar to SEL-300 series relay SELOGIC control equation programming.
[c] The SEL-487B supports 16 protection conditioning timers.
[d] The SEL-487E supports 48 automation conditioning timers.
[e] The SEL-487E supports 48 automation sequencing timers.
[f] The SEL-487E supports 80 automation latch bits.

Table 13.26 shows the SEL-400 series Boolean operators compared to the operators used in the SEL-351 series relays.

Table 13.26 SEL-351 Series Relays and SEL-400 Series SELOGIC Control Equation Boolean Operators

Feature	SEL-351 Series	SEL-400 Series
Logical AND operator	*	AND
Logical OR operator	+	OR
Logical NOT operator	!	NOT
Parentheses	( )	( )
Rising, falling-edge operators	/, \	R_TRIG, F_TRIG

In the SEL-351 series relays, SELOGIC control equation variables and timers are connected. Each SELOGIC control equation variable is the input to a timer. In SEL-400 series relays, timers and SELOGIC control equation variables are independent.

The SELOGIC control equation Boolean operators in SEL-400 series relays are different from those used in SEL-300 series relays. For example, if you wish to convert programming from an SEL-311 or SEL-351 series relay to an SEL-400 series relay, you must convert the operators. *Example 13.23* and *Example 13.24* demonstrate conversion of several settings to the SEL-451 setting.

Example 13.23 Converting SEL-351 Series Relay SELOGIC Control Equation Variables

If you have the following SELOGIC control equation in an SEL-351 series relay, convert it as shown below.

```
SV1 = IN101 + RB3 * LT4
```

In an SEL-400 series relay, use the line shown below.

PSV01 := **IN101 OR RB03 AND PLT04** # Freeform example

In the example above, first convert the + and * operators in the expression to the OR and AND operators. In the freeform example, use a protection SELOGIC control equation variable for the result. In the protection Group settings example, use the input of a timer, as shown in *Table 13.21*.

NOTE: Not all SEL-400 series relay SELOGIC timers are set in cycles. See the product-specific instruction manual for the applicable timer settings.

Example 13.24 Converting SEL-351 Series Relay SELOGIC Control Equation Timers

If you have the following SELOGIC control equation timer in an SEL-351 series relay, convert it as shown below.

```
SV1 = IN101
SV1PU = 5.25
SV1DO = 3.50
OUT101 = SV1T
```

In an SEL-400 series relay, use the format shown below.

#

Freeform programming conversion of timer

#

PCT01PU := **5.25** # Pickup of 5.25 cycles

PCT01DO := **3.5** # Dropout of 3.5 cycles

PCT01IN := **IN101** # Use the timer to monitor IN101

In the output settings, set OUT101 as shown below:

OUT101 := **PCT01Q**

Example 13.25 Converting SEL-351 Series Relay Latch Bits

If you have the following SELOGIC control equation latch programming in an SEL-351 series relay, convert it as shown below.

```
SET1 = RB4
RST1 = RB5
OUT101 = LT1
```

Example 13.25 Converting SEL-351 Series Relay Latch Bits (Continued)

In an SEL-400 series relay, use the format shown below.

Protection freeform style settings:

#

Freeform programming conversion of latch bit

#

PLT01S := **RB04** # Set if RB04

PLT01R := **RB05** # Reset if RB05

In the output settings, set OUT101 as shown below:

OUT101 := **PLT01**

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SECTION 14

ASCII Command Reference

You can use a communications terminal or terminal emulation program to set and operate the relay. This section explains common SEL-400 series relay commands that you send to the relay by using SEL ASCII communications protocol. The relay responds to commands such as settings, metering, and control operations.

Not every command listed in this section is supported by every SEL-400 series relay. Additionally, some SEL-400 series relays support additional commands. See the product-specific instruction manual to see what specific commands are supported in that relay.

This section lists ASCII commands alphabetically. Commands, command options, and command variables that you enter are shown in bold. Lowercase italic letters and words in a command represent command variables that you determine based on the application (for example, circuit breaker number *n* = 1 or 2, remote bit number *nn* = 01–32, and level).

Command options appear with brief explanations about the command function. Refer to the references listed with the commands for more information on the relay function corresponding to the command or examples of the relay response to the command.

You can simplify the task of entering commands by shortening any ASCII command to the first three characters; for example, **ACCESS** becomes **ACC**. Always send a carriage return <CR> character, or a carriage return character followed by a line feed character <CR><LF> to command the relay to process the ASCII command. Usually, most terminals and terminal programs interpret the **<Enter>** key as a <CR>. For example, to send the **ACCESS** command, type **ACC <Enter>**. For more information on SEL ASCII protocol, including handshaking, see *Section 15: Communications Interfaces*.

Tables in this section show the access level(s) where the command or command option is active. Access levels in the relay are Access Level 0, Access Level 1, Access Level B (breaker), Access Level P (protection), Access Level A (automation), Access Level O (output), and Access Level 2. For information on access levels see *Changing the Default Passwords in the Terminal on page 3.11*.

Command Description

2ACCESS

Use the **2AC** command to gain access to Access Level 2 (full relay control). See *Access Levels and Passwords on page 3.7* for more information.

Table 14.1 2AC Command

Command	Description	Access Level
2AC	Go to Access Level 2 (full relay control).	1, B, P, A, O, 2

89CLOSE n

Use the **89CLOSE *n*** command to close disconnect switches. (The number of disconnects supported, *n*, depends on the relay.) The main board circuit breaker jumper (on jumper **BREAKER**) must be in place.

NOTE: The SEL-487B does not support disconnect control operations.

If the disconnect switch is open and Relay Word bit LOCAL is deasserted, the **89CLOSE *n*** command asserts Relay Word bit 89CLS*n* for the 89CSIT*n* time. See *Disconnect Switch Close and Open Control Logic on page 5.2*. If the Relay Word bit 89OIP*n* asserts, indicating that the disconnect has started to close, the relay displays `Operation in Progress...` With Relay Word bit 89OIP*n* asserted and Relay Word bit 89ALP*n* deasserted, a dot (.) is appended to the above message every half second to show progress. While the operation is in progress, communications are unavailable on the port where the **89CLOSE** command was executed. Assertion of Relay Word bit 89OIP*n* starts the 89ALP*n* alarm timer. The relay waits for the 89ALP*n* timer to expire and then checks the status of the 89AM*n* and 89BM*n* disconnect inputs. If the 89ALP*n* timer does not expire within 30 seconds, the relay exits the **89CLOSE** command and reads the status of the disconnect inputs. The state of Relay Word bits 89AM*n* and 89BM*n* determine which disconnect status message the relay displays (`Disconnect OPEN`, `Disconnect CLOSED`, or `Status Undetermined - check wiring`). Use the 89CLS*n* Relay Word bit as part of a SELOGIC Output control equation to close the appropriate disconnect switch.

Table 14.2 89CLOSE n Command

Command	Description	Access Level
8**9CLOSE *n***	Set Relay Word bit 89CLS*n*	B, P, A, O, 2

If the relay is disabled and you attempt an **89CLOSE *n*** command, the relay responds with `Command aborted because the relay is disabled`. If the circuit breaker control enable jumper **J18C** (BREAKER) is not in place, the relay aborts the command and responds, `Aborted: the breaker jumper is not installed`.

When the **89CLOSE *n*** command is issued and the circuit breaker control enable jumper is in place, the relay responds, `CLOSE DISNAMn (Y/N)?`. If you answer **Y <Enter>**, the relay responds with `Are you sure (Y/N)?`. If you answer **Y <Enter>**, the command is executed. If the response to either prompt is not y or Y, the relay responds with `Command Aborted`.

89OPEN n

Use the **89OPEN *n*** command to open disconnect switches. (The number of disconnects supported, *n*, depends on the relay.) The main board circuit breaker jumper (on jumper BREAKER) must be in place.

NOTE: The SEL-487B does not support disconnect control operations.

If the disconnect switch is closed and Relay Word bit LOCAL is deasserted, the **89OPEN n** command asserts Relay Word bit 89OPEN*n* for the 89OSIT*n* time. See *Disconnect Switch Close and Open Control Logic on page 5.2*. If the Relay Word bit 89OIP*n* asserts, indicating that the disconnect has started to open, the relay displays `Operation in Progress...` With Relay Word bit 89OIP*n* asserted and Relay Word bit 89ALP*n* deasserted, a dot (.) is appended to the above message every half second to show progress. While the operation is in progress, communications are unavailable on the port where the **89OPEN** command was executed. Assertion of Relay Word bit 89OIP*n* starts the 89ALP*n* alarm timer. The relay waits for the 89ALP*n* timer to expire and then checks the status of the 89AM*n* and 89BM*n* disconnect inputs. If the 89ALP*n* timer does not expire within 30 seconds, the relay exits the **89OPEN** command and reads the status of the disconnect inputs. The state of Relay Word bits 89AM*n* and 89BM*n* determine which disconnect status message the relay displays (`Disconnect OPEN`, `Disconnect CLOSED`, or `Status Undetermined - check wiring`). Use Relay Word bit 89OPEN*n* as part of a SELOGIC Output control equation to open the appropriate disconnect switch.

Table 14.3 89OPEN n Command

Command	Description	Access Level
89OPEN *n*	Set Relay Word bit 89OPEN*n*	B, P, A, O, 2

If the relay is disabled and you attempt an **89OPEN *n*** command, the relay responds with `Command Aborted` because the relay is disabled. If the circuit breaker control enable jumper **J18C** (BREAKER) is not in place, the relay aborts the command and responds `Aborted: the breaker jumper is not installed`.

When the **89OPEN *n*** command is issued and the circuit breaker control enable jumper is in place, the relay responds with `Open DISNAMn (Y/N)?`. If you answer **Y <Enter>**, the relay responds `Are you sure (Y/N)?`. If you answer **Y <Enter>**, the command is executed. If the response to either prompt is not y or Y, the relay responds with `Command Aborted`.

AACCESS

Use the **AAC** command to gain access to Access Level A (automation). See *Access Levels and Passwords on page 3.7* for more information.

Table 14.4 AAC Command

Command	Description	Access Level
AAC	Go to Access Level A (automation).	1, B, P, A, O, 2

ACCESS

Use the **ACC** command to gain access to Access Level 1 (monitor). See *Access Levels and Passwords on page 3.7* for more information.

Table 14.5 ACC Command

Command	Description	Access Level
ACC	Go to Access Level 1 (monitoring).	0, 1, B, P, A, O, 2

BACCESS

Use the **BAC** command to gain access to Access Level B (breaker). See *Access Levels and Passwords on page 3.7* for more information.

Table 14.6 BAC Command

Command	Description	Access Level
BAC	Go to Access Level B (breaker).	1, B, P, A, O, 2

BNAME

The **BNA** command produces ASCII names of all relay Fast Meter status bits in a Compressed ASCII format. See *SEL Protocol on page 15.29* for more information on Fast Meter and the Compressed ASCII command set.

Table 14.7 BNA Command

Command	Description	Access Level
BNA	Display ASCII names of all relay status bits.	0, 1, B, P, A, O, 2

BREAKER

NOTE: Not all SEL-400 series relays support breaker monitoring.

Use the **BREAKER** command to display circuit breaker reports and the circuit breaker history reports. You can also preload accumulated breaker monitor data. The **BRE** command also resets the circuit breaker monitor data. To use the **BRE** command, you must enable the circuit breaker monitors for the circuit breakers of interest. See *Circuit Breaker Monitor on page 8.1* for more information.

BRE n

The **BRE *n*** command displays the comprehensive circuit breaker report that includes interrupted currents, number of operations, and mechanical and electrical operating times, among many parameters. The relay displays a listing of breaker monitor alarms with the breaker report.

Table 14.8 BRE n Command

Command	Description	Access Level
BRE *n*[a]	Display the breaker report for the most recent Circuit Breaker n operation.	1, B, P, A, O, 2

[a] Parameter n = breaker identification character.

BRE n C and BRE n R

The **BRE *n* C** and **BRE *n* R** commands clear/reset the circuit breaker monitor data. Options **C** and **R** are identical.

Table 14.9 BRE n C and BRE n R Commands

Command	Description	Access Level
BRE *n*[a] **C**	Clear Circuit Breaker *n* data to zero.	B, P, A, O, 2
BRE *n* R	Clear Circuit Breaker *n* data to zero.	B, P, A, O, 2

[a] Parameter n = breaker identification character.

BRE C A and BRE R A

The **BRE C A** and **BRE R A** commands clear all circuit breaker monitor data for all circuit breakers from memory. Options **C A** and **R A** are identical.

Table 14.10 BRE C A and BRE R A Commands

Command	Description	Access Level
BRE C A	Clear all circuit breaker data.	B, P, A, O, 2
BRE R A	Clear all circuit breaker data.	B, P, A, O, 2

BRE n H

Display the circuit breaker monitor history report with the **BRE *n* H** command. The breaker history report is a summary of recent circuit breaker operations.

Table 14.11 BRE n H Command

Command	Description	Access Level
BRE *n*[a] H	Display history data for the last 128 Circuit Breaker *n* operations.	1, B, P, A, O, 2

[a] Parameter n = breaker identification character.

BRE n P

Use the **BRE *n* P** command to preload existing circuit breaker contact wear, operation counts, and accumulated currents to the circuit breaker monitor.

Table 14.12 BRE n P Command

Command	Description	Access Level
BRE *n*[a] P	Preload previously accumulated Breaker *n* data.	B, P, A, O, 2

[a] Parameter n = breaker identification character.

CAL

Use the **CAL** command to gain access to Access Level C. See *Access Levels and Passwords on page 3.7* for more information. Only go to Level C to modify the default password or under the direction of an SEL employee. The additional commands available at Level C are not intended for normal operational purposes.

Table 14.13 CAL Command

Command	Description	Access Level
CAL	Go to Access Level C.	2, C

CASCII

The **CAS** command produces the Compressed ASCII configuration message. This configuration instructs an external computer on the method for extracting data from other Compressed ASCII commands. See *SEL Compressed ASCII Commands on page 15.30* for an example of the **CAS** command configuration message and for further information on the Compressed ASCII command set.

Table 14.14 CAS Command

Command	Description	Access Level
CAS	Return the Compressed ASCII configuration message.	0, 1, B, P, A, O, 2

CBREAKER

NOTE: Not all SEL-400 series relays support breaker monitoring

The **CBREAKER** command provides a Compressed ASCII response circuit breaker report that is similar to the **BREAKER** command. You must enable the Breaker Monitor function for at least one breaker to generate the Compressed ASCII report. You can specify a specific circuit breaker to retrieve a report for one circuit breaker only. See *SEL Compressed ASCII Commands on page 15.30* for information on the Compressed ASCII command set.

CBR

Use the **CBR** command to gather the comprehensive circuit breaker report in Compressed ASCII format.

Table 14.15 CBR Command

Command	Description	Access Level
CBR	Return the most recent circuit breaker reports for all circuit breakers in Compressed ASCII format.	1, B, P, A, O, 2
CBR *n*[a]	Return the most recent circuit breaker report for Circuit Breaker *n* in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter n = breaker identification character.

CBR TERSE

The **CBR TERSE** command omits the breaker report labels.

Table 14.16 CBR TERSE Command

Command	Description	Access Level
CBR TERSE	Return the most recent circuit breaker report for all circuit breakers in Compressed ASCII format; suppress the labels; transmit only the data lines.	1, B, P, A, O, 2
CBR *n*[a] **TERSE**	Return the most recent circuit breaker report for Circuit Breaker *n* in Compressed ASCII format; suppress the labels; transmit only the data lines.	1, B, P, A, O, 2

[a] Parameter n = breaker identification character.

CEVENT

NOTE: The SEL-400G relay does not support Compressed ASCII events.

The **CEVENT** command provides a Compressed ASCII response similar to the **EVENT** command. See *SEL Compressed ASCII Commands on page 15.30* for information on the Compressed ASCII command set.

CEV

Use the **CEV** command to gather relay event reports. When parameter *n* is 1–9999, *n* indicates the order of the event report. The most recent event report is 1, the next most recent report is 2, and so on. When parameter n is 10000–42767, *n* indicates the absolute serial number of the event report.

Table 14.17 CEV Command

Command	Description	Access Level
CEV	Return the most recent event report (including settings and summary) at full length with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV *n*[a]	Return particular *n* event report (including settings and summary) at full length with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number.

CEV ACK

Use **CEV ACK** to acknowledge viewing the oldest unacknowledged event on the present communications port. View this event with the **CEV NEXT** or **EVE NEXT** commands.

Table 14.18 CEV ACK Command

Command	Description	Access Level
CEV ACK	Acknowledge the oldest unacknowledged event at the present communications port.	1, B, P, A, O, 2

CEV C

Use **CEV C** to return a 15-cycle length event report with analog and digital information in Compressed ASCII format. The L*yyy* option overrides the **C** option (see **CEV L*yyy***).

Table 14.19 CEV C Command

Command	Description	Access Level
CEV C	Return the most recent event report at a 15-cycle length with 8-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV C *n*	Return particular n event report at a 15-cycle length with 8-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2

CEV L

NOTE: Not all SEL-400 series relays support the CEV L option.

Use **CEV L** to return a large resolution event report in Compressed ASCII format. The **S*x*** option overrides the **L** option (see **CEV S*x***).

Table 14.20 CEV L Command

Command[a]	Description	Access Level
CEV L	Return the most recent event report at full length with large resolution data in Compressed ASCII format.	1, B, P, A, O, 2
CEV *n* L	Return particular n event report at full length with large resolution data in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number; see CEV on page 14.7.

CEV Lyyy

Command **CEV L*yyy*** returns a specified length event report in Compressed ASCII format, where **L*yyy*** indicates a length of *yyy* cycles. You can specify *yyy* from 1 cycle to a value including and beyond the event report total cycle length. If *yyy* is longer than the total length, the relay returns the full event report. The **L*yyy*** option overrides the **C** option.

Table 14.21 CEV Lyyy Command

Command	Description	Access Level
CEV L*yyy*	Return *yyy* cycles of the most recent event report (including settings) with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV *n*[a] L*yyy*	Return *yyy* cycles of a particular n event report with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number; see CEV on page 14.7.

CEV NEXT

CEV NEXT returns the oldest unacknowledged event report on the present communications port in Compressed ASCII format.

Table 14.22 CEV N Command

Command	Description	Access Level
CEV N	Return the oldest unacknowledged event report with 4-samples/cycle sampling in Compressed ASCII format.	1, B, P, A, O, 2

CEV NSET

The **CEV NSET** command returns the Compressed ASCII event report with no relay settings.

Table 14.23 CEV NSET Command

Command	Description	Access Level
CEV NSET	Return the most recent event report without settings at full length with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV *n*[a] NSET	Return a particular n event report without settings at full length with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number.

CEV NSUM

The **CEV NSUM** returns the Compressed ASCII event report with no event summary.

Table 14.24 CEV NSUM Command

Command	Description	Access Level
CEV NSUM	Return the most recent event report without the event summary at full length with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV *n*[a] **NSUM**	Return a particular n event report without the event summary at full length with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number; see CEV on page 14.7.

CEV Sx

Use the **CEV S*x*** command to specify the sample data resolution of the Compressed ASCII event report. The sample data resolution *x* can be 4, 8, or 12, depending on the relay; the default value is 4-samples/cycle if you do not specify **S*x***. The **S*x*** option overrides the **L** option.

Table 14.25 CEV Sx Command

Command	Description	Access Level
CEV S*x*	Return the most recent event report at full length with *x*-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV *n*[a] S*x*	Return a particular n event report at full length with *x*-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number; see CEV on page 14.7.

CEV TERSE

The **CEV TERSE** command returns a Compressed ASCII event report without the event report labels.

Table 14.26 CEV TERSE Command

Command	Description	Access Level
CEV TERSE	Return the most recent event report at full length without the report labels with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV *n*[a] TERSE	Return a particular n event report at full length without the report labels with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number.

Use the **TERSE** option with any of the **CEV** commands except **CEV ACK**.

CEV Command Option Combinations

You can combine options **C**, **L**, **L*yyy***, ***n***, **NSET**, **NSUM**, **S*x***, and **TERSE** in one command. Enter the options according to the following guidelines:

- ➤ The **L*yyy*** option overrides the **C** option
- ➤ The **S*x*** option overrides the **L** option
- ➤ Enter the options in any order

Table 14.27 lists the choices you can make in the **CEV** command. Combine options on each row, selecting one option from each column, to create a **CEV** command.

Table 14.27 CEV Command Option Groups

Acknowledge	Event Number	Data Resolution	Report Type	Report Length	Omit
ACK	*n*, **NEXT**	**S***x*, **L**	**C**	**L***yyy*, **C**	**NSET, NSUM, TERSE**

The following examples illustrate some possible option combinations.

Example	Description
CEV L10 S8	Return 10 cycles of an 8-samples/cycle Compressed ASCII event report for the most recent event.
CEV L10 L	Return 10 cycles of an large resolution Compressed ASCII event report for the most recent event (same as above).
CEV 2 C NSUM TERSE	For the second most recent event, return 15 cycles of the event in Compressed ASCII format with no event summary and no report label lines with large resolution data.

CFG

In TiDL and IEC Sampled Values (SV) subscribers, certain aspects of the relay must be configured before the relay can be set. This command is used to perform this configuration.

CFG CTNOM

NOTE: The SEL-487E-5 includes additional user inputs. See the SEL-487E-5 instruction manual for the additional user inputs.

NOTE: See the firmware entries in product-specific Appendix A tables for the following entry:

Modified **CFG CTNOM** command to only default global and group settings on a nominal secondary current configuration change.

The firmware versions prior to this change default all settings.

In TiDL and IEC SV subscribers, use the **CFG CTNOM** command to inform the relay which CT inputs are 1 A nominal and which are 5 A nominal. (By default, the relay assumes all CT inputs are 5 A nominal.) This is necessary so the relay scales the information correctly. See *Section 2: Installation* of the product-specific instruction manual for more information on using this command as part of configuring the relay. On a secondary current configuration change, the relay defaults the global and protection Group settings and then performs a restart, so make this command before sending Global or Group settings.

Table 14.28 CFG CTNOM Command

Command	Description	Access Level
CFG CTNOM *n*[a]	Change nominal CT configuration to selected value	2

[a] The parameter n (or parameters) is relay-specific.

CFG NFREQ

In TiDL (EtherCAT) relays that support SEL-2240 Axion nodes only, use the **CFG NFREQ** command to set the nominal frequency of the relay (which is 60 Hz by default). In relays that do not support TiDL (EtherCAT), the nominal frequency is controlled by the NFREQ Global setting. This should be configured after the nominal currents are configured (through the use of the **CFG CTNOM** command) and before settings are loaded into the relay. This will restart the relay.

Table 14.29 CFG NFREQ Command

Command	Description	Access Level
CFG NFREQ *f*	Change nominal frequency to *f* (50 or 60)	2

CHISTORY

The **CHISTORY** command provides a **HISTORY** report in the Compressed ASCII format.

CHI

Use the **CHI** command to gather one-line descriptions of event reports.

Table 14.30 CHI Command

Command	Description	Access Level
CHI	Return the data as contained in the History report (short form descriptions) for the most recent 100 event reports in Compressed ASCII format (for SEL-2030 compatibility).	1, B, P, A, O, 2
CHI A	Return one-line descriptions of the most recent 100 event reports in Compressed ASCII format.	1, B, P, A, O, 2
CHI *k*	Return one-line descriptions of the most recent *k* number of event reports in Compressed ASCII format.	1, B, P, A, O, 2

CHI TERSE

The **CHI TERSE** command returns a Compressed ASCII event report without the event report label lines.

Table 14.31 CHI TERSE Command

Command	Description	Access Level
CHI TERSE	Return one-line descriptions for the most recent 100 event reports without the label lines in Compressed ASCII format.	1, B, P, A, O, 2
CHI *k* TERSE	Return one-line descriptions for the most recent k number of event reports without the label lines in Compressed ASCII format.	1, B, P, A, O, 2

CLOSE n

Use the **CLOSE *n*** command to close a circuit breaker. The main board circuit breaker jumper (on jumper BREAKER) must be in place. Further, you must enable breaker control for any breakers you want to control.

NOTE: The SEL-487B does not support the **CLOSE** command.

The **CLOSE *n*** command asserts Relay Word bit CC*n*. The CC*n* bit must be included in the close SELOGIC equation for breaker *n* (BK*n*MCL) for this command to effect a close operation. The relay uses these equations and additional relay logic to assert a control output (for example, OUT103 := BK1CL) to close a circuit breaker.

NOTE: CCn Relay Word bits are pulsed for two processing intervals in the SEL-487E.

Table 14.32 CLOSE n Command

Command	Description	Access Level
CLOSE *n*	Command the relay to close Circuit Breaker *n*.	B, P, A, O, 2

If the circuit breaker control enable jumper BREAKER is in place, the relay responds with `Close breaker (Y/N)?`. When you answer **Y <Enter>** (for yes), the relay prompts, `Are you sure (Y/N)?`. If you again answer **Y <Enter>**, the relay asserts the Relay Word bit for one processing interval.

If you have assigned a circuit breaker auxiliary contact (52A) to a relay control input (based on the 52AA*n*, 52AB*n*, 52AC*n* settings), the relay waits 0.5 second, checks the state of the circuit breaker, and issues either a `Breaker OPEN` or `Breaker CLOSED` message.

If circuit breaker control enable jumper BREAKER is not in place, the relay aborts the command and responds, `Aborted: the breaker jumper is not installed`. If the relay is disabled, the relay responds with `Command aborted because relay is disabled`. If Breaker *n* is not enabled and you issue the **CLOSE *n*** command, the relay responds with `Breaker n is not available`.

COMMUNICATIONS

The **COMMUNICATIONS** command displays communications statistics for the MIRRORED BITS communications channels and for synchrophasor client channels. Some relays support additional options to the **COM** command besides those described here.

COM c

Use the **COM *c*** command to view records of the MIRRORED BITS communications buffers for specific relay communications channels.

Table 14.33 COM c Command[a]

Command	Description	Access Level
COM A	Return a summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel A.	1, B, P, A, O, 2
COM B	Return a summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel B.	1, B, P, A, O, 2
COM M	Return a summary report of the last 255 records in the communications buffer for either MIRRORED BITS communications Channel A or Channel B when only one channel is enabled.	1, B, P, A, O, 2

[a] Parameter c is A, B, or M for Channel A, Channel B, and MIRRORED BITS communications channels, respectively.

The *c* option in the **COM** command is **A** for MIRRORED BITS communications Channel A, B for MIRRORED BITS communications Channel B, and Channel M for the MIRRORED BITS communications channels in general. If both MIRRORED BITS communications channels are in use, then the **M** option does not function and you must specify **A** or **B**.

COM c C and COM c R

The **COM *c* C** and **COM *c* R** commands clear/reset the communications buffer data for the specified Channel *c*. Options **C** and **R** are identical.

Table 14.34 COM c C and COM c R Command

Command	Description	Access Level
COM A C	Clear/reset communications buffer data for MIRRORED BITS communications Channel A.	P, A, O, 2
COM B R	Clear/reset communications buffer data for MIRRORED BITS communications Channel B.	P, A, O, 2
COM M C	Clear/reset communications buffer data for either MIRRORED BITS communications Channel A or Channel B when only one channel is enabled.	P, A, O, 2

COM c L m n and COM c L date1 date2

Use **COM *c* L** to list the records in the communications buffer in a specified manner. The relay returns the list of records in rows. You can specify a range of buffer records in forward or reverse chronological order or in forward or reverse date order. Date parameter entries depend on the setting DATE_F format you chose in the relay Global settings.

The relay organizes the records in rows in a 256-entry buffer in newest to oldest time order. The relay puts the newest record in the buffer and discards the oldest record if the buffer is full.

Table 14.35 is a representative list of options for listing records in the communications buffer.

Table 14.35 COM c L Command

Command	Description	Access Level
COM A L	Display all available records from MIRRORED BITS communications Channel A; the most recent record is Row 1 (at the top of the report) and the oldest record is at the bottom of the report.	1, B, P, A, O, 2
COM B L *k*[a]	Display the first *k* records for MIRRORED BITS communications Channel B; the most recent record is Row 1 (at the top of the report) and the oldest record is at the bottom of the report.	1, B, P, A, O, 2
COM M L *m n*[b]	Display the records for either MIRRORED BITS communications Channel A or Channel B when only one channel is enabled; show the records with Record *m* at the top of the report through Record *n* at the bottom of the report.	1, B, P, A, O, 2
COM A L *date1*[c]	Display the records from MIRRORED BITS communications Channel A on the date *date1*.	1, B, P, A, O, 2
COM B L *date1 date2*[c]	Display the records from MIRRORED BITS communications Channel B between the dates *date1* and *date2*. The date listed first, *date1*, is at the top of the report; the date listed second, *date2*, is at the bottom of the report.	1, B, P, A, O, 2

[a] Parameter k indicates a specific number of communications buffer records.
[b] Parameters m and n are communications buffer row numbers.
[c] Enter date1 and date2 in the same format as Global setting DATE_F.

COM HSR

NOTE: The **COM HSR** command is only relevant when the relay is receiving HSR traffic while connected in a ring topology with other HSR compatible devices. The HSR supervision bits are time-delayed. SEL recommends using them for monitoring purposes only.

The **COM HSR** command is only available when using the five-port Ethernet card. The command displays the health of your HSR ring. The logic used to generate the status information is processed once per second and is designed to detect persistent errors in the ring. The logic is not intended to detect intermittent packet loss. If a device receives HSR messages on one port and receives a matching message on the other port pair, the relay asserts the applicable HSR supervision Relay Word bits HSRAOK, HSRBOK, HSRCOK, and HSRDOK and reports OK in the **COM HSR** response. If a port does not receive HSR messages within 12 seconds of receiving them on the other port, or if the relay does not receive the HSR supervision frame it initiated, the relay deasserts the applicable HSR supervision bits and reports `WARNING` in the **COM HSR** response. If the link is down on any of the ports, the relay reports `FAIL` for that port. If the station bus or process bus is not configured for HSR, the command reports `HSR DISABLED` for that bus.

Additionally, the command provides statistics for the process and station bus ports including the number of GOOSE and SV messages received on one port but not the other, the number of link-down incidents, and the accumulated link downtime since the last reset.

Table 14.36 COM HSR Command

Command	Description	Access Level
COM HSR	Display HSR information and statistics for the five-port Ethernet card.	1, B, P, A, O, 2
COM HSR C	Clear HSR statistics.	1, B, P, A, O, 2

Figure 14.1 shows an example response to the **COM HSR** command for an SV subscriber.

```
=>>COM HSR <Enter>

Relay 1                                      Date: 10/01/2024  Time: 15:35:00.450
Station A                                    Serial Number: 1242759999

PROCESS BUS
HSR Port 5A Status: OK
HSR Port 5B Status: OK
HSR Ring Latest Roundtrip Time: 12 us
HSR Ring MAX Roundtrip Time:    19 us

STATION BUS
HSR Port 5C Status: OK
HSR Port 5D Status: OK
HSR Ring Latest Roundtrip Time: 12 us
HSR Ring MAX Roundtrip Time:    $$$$$ us

HSR Statistics
                                        PORT 5A    PORT 5B    PORT 5C    PORT 5D
--------------------------------------------------------------------------------
Duplicate SV HSR Pkts Not RCVD               0          0          0          0
Other Duplicate Packets Not RCVD             0          0          0          5
Link Down Counter                            0          0          0          1
Link Downtime (s)                            0          0          0          4

Date and Time from the last reset: 10/01/2024 - 13:58:00
```

Figure 14.1 Sample COM HSR Command Response

COM PRP

NOTE: The **COM PRP** command is only relevant when the relay is receiving PRP traffic from the network. The PRP supervision bits are time-delayed. SEL recommends using them for monitoring purposes only.

The **COM PRP** command is only available when using the five-port Ethernet card. The command displays the health of your PRP network for GOOSE and SV. The logic used to generate the status information is processed once per second and is designed to detect persistent network errors. The logic is not intended to detect intermittent packet loss. If a port receives PRP messages on LAN A that match those received on LAN B, the relay asserts the applicable PRP supervision Relay Word bits PRPAGOK, PRPBGOK, PRPCGOK, PRPDGOK, PRPASOK, and PRPBSOK and reports `OK` in the **COM PRP** response. If a port does not receive PRP messages on one LAN within 6 seconds of receiving them on the other LAN, the relay deasserts the applicable PRP supervision bits and reports `WARNING` in the **COM PRP** response. If a port does not receive any expected PRP duplicates on one of the LANs, the relay reports `FAIL` for that port. If the station bus or process bus is not configured for PRP, the command reports `PRP DISABLED` for that bus. Note that a loss of link deasserts associated PRP supervision bits immediately. Also, these bits only supervise the PRP network and not the quality status of the SV and GOOSE protocols themselves.

Additionally, the command provides statistics for the process and station bus ports including the number of GOOSE and SV messages received on one LAN but not the other, the number of link-down incidents, and the accumulated link downtime since the last reset.

Table 14.37 COM PRP Command

Command	Description	Access Level
COM PRP	Display PRP information and statistics for the five-port Ethernet card.	1, B, P, A, O, 2
COM PRP C	Clear PRP statistics.	1, B, P, A, O, 2

Figure 14.2 shows an example response to the **COM PRP** command for an SV Subscriber.

```
=>>COM PRP <Enter>

Relay 1                                    Date: 03/17/2023  Time: 14:43:22.620
Station A                                  Serial Number: 1230769999

PROCESS BUS
PRP PORT 5A GOOSE Status: OK
PRP PORT 5A SV Status:    OK
PRP PORT 5B GOOSE Status: WARNING
PRP PORT 5B SV Status:    FAIL

STATION BUS
PRP PORT 5C GOOSE Status: OK
PRP PORT 5D GOOSE Status: FAIL

PRP Statistics Information
                                     PORT 5A    PORT 5B    PORT 5C    PORT 5D
------------------------------------------------------------------------------
Duplicate SV PRP Pkts Not RCVD            0      99999          0         20
Duplicate GOOSE PRP Pkts Not RCVD         0          0          0         20
Link Down Counter                         0          1          0          1
Link Downtime (s)                         0          2          0         60

Date and Time from the last reset: 01/23/2023 - 13:11:09

=>>
```

Figure 14.2 Sample COM PRP Command Response

COM PTP

The **COM PTP** command provides a report of the Precision Time Protocol (PTP) data sets maintained by the device as well as statistics for the measured time offsets with the parent (master) clock. The PTP data sets contain information about the state, identity, and configuration of the local, parent, and grandmaster clocks in addition to properties of the time being distributed by the grandmaster clock.

Table 14.38 COM PTP Command

Command	Description	Access Level
COM PTP	Display PTP data sets and offset statistics	2
COM PTP 5*n*	Display PTP data sets and offset statistics for PORT 5n (*n* = A, B, C, D)	2
COM PTP C	Clears PTP offset statistics	2

If PTP is disabled or the relay hardware does not support PTP, then the **COM PTP** command will respond with `PTP Not Enabled`. If a settings change is in progress or if the hardware is not yet initialized, then the **COM PTP** command will respond with `Data unavailable, please try again later`.

```
=>>COM PTP <Enter>

Relay 1                                     Date: 03/17/2023  Time: 15:08:43.516
Station A                                   Serial Number: 1230769999

PTP offset statistics previously cleared on 02/24/2016 14:08:36.303 (UTC)

Settings Data Set
  PTP Profile : Default
  Transport Mechanism : Layer2
  Path Delay : P2P

Default Data Set
  Two Step : true
  Clock Identity : 00 30 A7 FF FE 44 55 66
  Number of Ports : 1
  Clock Quality
    Clock Class : 255
    Clock Accuracy : 254
    Offset Log Variance : 0
  Priority1 : 255
  Priority2 : 255
  Domain Number : 1
  Slave Only : true

Current Data Set
  Steps Removed : 1
  Offset from Master : -5 ns
  Mean Path Delay : 0 ns

Parent Data Set
  Parent Port Identity
    Clock Identity : 00 30 A7 FF FE 04 7C 22
    Port Number : 1
  Grandmaster Clock Identity : 00 30 A7 FF FE 04 7C 22
  Grandmaster Clock Quality
    Clock Class : Synchronized with PTP timescale (6)
    Clock Accuracy : Within 25 ns
    Offset Log Variance : 0
  Grandmaster Priority1 : 0
  Grandmaster Priority2 : 0

Time Properties Data Set
  Current UTC Offset : 0
  Current UTC Offset Valid : true
  Leap59 : false
  Leap61 : false
  Time Traceable : true
  Frequency Traceable : true
  PTP Timescale : true
  Time Source : PTP
  Local Time Offset
    Offset Valid : true
    Name : PST
    Current Offset : 3600
    Jump Seconds : 3600
    Time of Next Jump : 1456797635
```

Figure 14.3 Sample COM PTP Command Response

```
Port Data Set
  Port Identity
    Clock Identity : 00 30 A7 FF FE 44 55 66
    Port Number: 1
  Port State : SLAVE
  Log Pdelay Request Interval : 0
  Peer Mean Path Delay : 0 ns
  Announce Receipt Timeout : 2 intervals
  Path Delay Mechanism : Peer-to-Peer
  Failed to Receive Response : true
  Received Multiple Pdelay Responses : false
  Reason for Non-synchronization :
  Port status : A, ACTIVE

Time Offset Statistics
  Mean : -0.013393 ns
  Standard Deviation : 5.291062 ns
  Latest Time Offsets with respect to Reference Time (in ns)
    #1 :                       -5
    #2 :                       -1
    #3 :                        0
    #4 :                        1
    #5 :                       -1
    #6 :                        2
    #7 :                        8
    #8 :                        3
    #9 :                        1

    #10 :                       -9
    #11 :                        2
    #12 :                        0
    #13 :                        3
    #14 :                       -4
    #15 :                       -9
    #16 :                        5
    #17 :                       -1
    #18 :                       -4
    #19 :                       -4
    #20 :                        1
    #21 :                        5
    #22 :                        7
    #23 :                       -7
    #24 :                       -1
    #25 :                        6
    #26 :                       -2
    #27 :                       -2
    #28 :                        8
    #29 :                       -5
    #30 :                        2
    #31 :                        0
    #32 :                       -2

=>>
```

Figure 14.3 Sample COM PTP Command Response (Continued)

COM RTC

Use the **COM RTC** to get a report on the status of the configured synchrophasor client channels.

NOTE: Not all SEL-400 series relays support synchrophasors.

Table 14.39 COM RTC Command

Command[a]	Description	Access Level
COM RTC	Return a report describing the communications on all enabled synchrophasor client channels.	1, B, P, A, O, 2
COM RTC A	Return a report describing the communications on synchrophasor client Channel A.	1, B, P, A, O, 2
COM RTC B	Return a report describing the communications on synchrophasor client Channel B.	1, B, P, A, O, 2

[a] Parameter c is A, B, or absent for Channel A, Channel B, or all enabled channels, respectively.

COM RTC c C and COM RTC c R

The **COM RTC C** and **COM RTC R** commands clear/reset the maximum packet delay. The **C** and **R** options are identical.

Table 14.40 COM RTC c C and COM RTC c R Command

Command	Description	Access Level
COM RTC C	Clear/reset the maximum packet delay on all enabled synchrophasor client channels.	P, A, O, 2
COM RTC A R	Clear/reset the maximum packet delay on synchrophasor client Channel A.	P, A, O, 2
COM RTC B C	Clear/reset the maximum packet delay on synchrophasor client Channel B.	P, A, O, 2

COM SV

COM SV (SEL SV Publishers)

NOTE: Not all SEL-400 series relays support the **COM SV** command

The **COM SV** command displays information and statistics for the SV publications that can be used for troubleshooting purposes.

Table 14.41 COM SV Command (SEL SV Publishers)

Command	Description	Access Level
COM SV	Displays information for the SV publications	1, B, P, A, O, 2
COM SV *k*	Displays information for the SV publications successively for *k* times	1, B, P, A, O, 2

The information displayed for each SV publication is described in *Table 14.42*.

Table 14.42 Accessible Information for Each SV Publication (Sheet 1 of 2)

Data Field	Description
SEL TEST SV Mode	When SEL TEST SV Mode = Off, the SEL SV publisher is publishing normal SV messages. When SEL TEST SV Mode = On, the SEL SV publisher is publishing TEST SV messages. When SEL TEST SV Mode = On, Relay Word bit SVPTST is asserted; SVPTST is deasserted otherwise. See *TEST SV on page 14.69* in this section for more information.
SV Control Reference	This field represents the control reference for the SV publication. When the SEL SV publisher is configured via Configured IED Description (CID) file, this field includes the iedName (IED name), ldInst (Logical Device Instance), LN0 lnClass (Logical Node Class) and the SampledValueControl name (SV Control Block Name). e.g., SEL_421CFG/LLN0MSMSVCB01 When the SEL SV publisher is configured via the **PORT 5** SV settings, this field is blank.
Multicast Address (MultiCastAddr)	This field is the multicast destination address for the SV publication and is expressed as six sets of hexadecimal values.
Priority Tag (Ptag)	This decimal field is the priority tag value. Spaces are used if the priority tag is unavailable or unknown.
VLAN (Vlan)	This decimal field is the virtual LAN of the SV publication. Spaces are used if the VLAN is unavailable or unknown.
AppID	This hexadecimal field is the value of the Application Identifier for the SV publication.

Table 14.42 Accessible Information for Each SV Publication (Sheet 2 of 2)

Data Field	Description
Sampled Value Identifier (SV ID)	This field is the identifier string value for the SV publication (as many as 63 characters).
Synchronization State (smpSynch)	This field represents the time-synchronization source of the SEL SV publisher at the time of the most recent SV published message. 0: Not synchronized. 1: Synchronized by an unspecified local area clock signal (low-accuracy). 2: Synchronized by a global area clock signal (high-accuracy). 3, 4: Reserved. 5–254: Synchronized by a grandmaster clock identified with this ID (PTP power profile only).
Data Set Reference	This field contains the DataSetReference (Data Set Reference) for the SV publication. When the SEL SV publisher is configured via CID file, this field includes the iedName (IED name), ldInst (Logical Device Instance), LN0 lnClass (Logical Node Class) and SampledValueControl datSet (Data Set Name), e.g., SEL_421CFG/LLN0$PhsMeas1. When the SEL SV publisher is configured via the PORT 5 SV settings, this field is blank.

Figure 14.4 shows an example response to the **COM SV** command with the SEL SV publisher configured via CID file.

```
=>>COM SV <Enter>

IEC 61850 Mode /Behavior: On
SEL TEST SV Mode: Off
IEC 61850 Simulation Mode: Off

SV Publication Information

 MultiCastAddr   Ptag:Vlan AppID  smpSynch
--------------------------------------------------------------------------------

SEL_421CFG/LLN0$MS$MSVCB01
 01-0C-CD-04-00-01  4:1    4001      2
 SV ID: 4001
 Data Set: SEL_421CFG/LLN0$PhsMeas1

SEL_421CFG/LLN0$MS$MSVCB02
 01-0C-CD-04-00-02  4:1    4002      2
 SV ID: 4002
 Data Set: SEL_421CFG/LLN0$PhsMeas2

SEL_421CFG/LLN0$MS$MSVCB03
 01-0C-CD-04-00-03  4:1    4003      2
 SV ID: 4003
 Data Set: SEL_421CFG/LLN0$PhsMeas3
```

Figure 14.4 COM SV Command Response When CID Configuration Is Used by the SEL SV Publisher

Figure 14.5 shows an example response to the **COM SV** command with the SEL SV publisher configured via PORT 5 Settings.

```
=>>COM SV <Enter>

IEC 61850 Mode /Behavior: On
SEL TEST SV Mode: Off
IEC 61850 Simulation Mode: Off

SV Publication Information

 MultiCastAddr   Ptag:Vlan AppID  smpSynch
-------------------------------------------------------------------------------

 01-0C-CD-04-00-01  4:1    4101      2
 SV ID: 4101
 Data Set:

 01-0C-CD-04-00-02  4:1    4102      2
 SV ID: 4102
 Data Set:

 01-0C-CD-04-00-03  4:1    4103      2
 SV ID: 4103
 Data Set:
```

Figure 14.5 COM SV Command Response When PORT 5 Settings Are Used by the SEL SV Publisher

If the **COM SV** command is issued during CID file processing or right after SV settings change in **PORT 5**, the relay responds with `IEC 61850 configuration is in progress. No SV statistics available.`

If the **PORT 5** settings for SV are not in use (SVTXEN = 0), and the CID file is not present or is invalid when the **COM SV** command is issued, the relay responds with `Error detected in parsing the CID file. All SV processing disabled.`

If the **PORT 5** SV settings are not in use and no SV publications or subscriptions are configured in the CID file when the **COM SV** command is issued, the relay responds with `No SV publications configured.`

COM SV (SV Subscribers)

The **COM SV** command displays information and statistics for the SV subscriptions that can be used for troubleshooting purposes.

Table 14.43 COM SV Command (SEL SV Subscribers)

Command	Description	Access Level
COM SV	Displays information for the SV subscriptions.	1, B, P, A, O, 2
COM SV *k*	Displays information for the SV subscriptions successively for *k* times.	1, B, P, A, O, 2
COM SV S	Displays a list with the SubsID, AppID, and ControlBlockReference identifier for each of the SV subscriptions configured.	1, B, P, A, O, 2
COM SV S [id|ALL]	Displays statistics information and downtime timers for all [ALL] or a specific SV subscription [id] based on the parameters entered.	1, B, P, A, O, 2
COM SV S [id|ALL] [L]	Displays an extended report containing statistics information, downtime timers and occurred failures for all [ALL] or a specific SV subscription [id] based on the parameters entered.	1, B, P, A, O, 2
COM SV S [id|ALL] C	Clears the statistics for a particular SV subscription if the identifier [id] is entered. Otherwise clears the statistics for all the configured SV subscriptions whether or not the [ALL] parameter is entered.	1, B, P, A, O, 2

Table 14.44 describes the available information for each SV subscription when commands in *Table 14.43* are entered.

Table 14.44 Accessible Information for Each IEC 61850 SV Subscription (Sheet 1 of 2)

Data Field	Description
SEL TEST SV Mode	This field indicates whether or not the SEL SV subscriber is in SEL TEST SV Mode. If On, then the SEL SV subscriber accepts SV publications that have the TEST bit of the quality attribute set. While in Test mode, the SEL SV subscriber continues to accept SV publications that do not have the TEST bit of the quality attribute set. When SEL TEST SV Mode = On, Relay Word bit SVSTST is asserted; SVSTST is deasserted otherwise. See *TEST SV on page 14.69* for more information.
SIMULATED Mode	This field indicates whether or not the SEL SV subscriber is currently accepting simulated SV publications. If On, then the SEL SV subscriber accepts all the SV publications that have the LPHDSIM mode set. See the *Section 17: IEC 61850 Communication* for more information about the Simulated Mode.
SV Control Reference	This field represents the control reference for the SV subscriptions. When the SEL SV subscriber is configured via CID file, this field includes the iedName (IED name), ldInst (Logical Device Instance), LN0 lnClass (Logical Node Class) and the SampledValueControl name (SV Control Block Name). e.g., SEL_421CFG/LLN0MSMSVCB01 When the SEL SV subscriber is configured via the **PORT 5** SV settings, this field is blank.
AppID	This hexadecimal field represents the value of the Application Identifier for the SV subscription.
Accumulated downtime duration (since last reset)	Displays the accumulated downtime duration attributed to errors since the last time the statistics were cleared.
Maximum downtime duration	Displays the maximum duration of continuous downtime attributed to errors, accumulated over the previous 30-second maximum rolling window to the issue of the **COM SV** command.
Code (SV Subscriptions Failure Report)	Displays one of the values under *Table 14.45* either for warning or error code. This code indicates a warning or error code for each SV subscription in effect at the time the command was executed. If multiple warnings or errors are present for an SV subscription, only the code with the highest priority is displayed. If the **COM SV S [id|ALL] L** is executed, a listed report containing the last eight most recent failures with the highest priority error code will be displayed for one or all the SV subscriptions based in the parameters entered.
Multicast Address (MultiCastAddr)	This field is the multicast destination address for the received SV message expressed as six sets of hexadecimal values.
Priority Tag (Ptag)	This decimal field is the priority tag value. Spaces are used if the priority tag is unavailable or unknown.
VLAN (Vlan)	This decimal field is the virtual LAN of the received SV message. Spaces are used if the VLAN is unavailable or unknown.
Sampled Value Identifier (SV ID)	This field is the identifier string value for the received SV message (as many as 63 characters).
Synchronization State (smpSynch)	This field represents the time-synchronization source for the most recent received SV message. 0: Not synchronized. 1: Synchronized by an unspecified local area clock signal (low-accuracy). 2: Synchronized by a global area clock signal (high-accuracy). 3, 4: Reserved. 5–254: Synchronized by a grandmaster clock identified with this ID (PTP power profile only).

Table 14.44 Accessible Information for Each IEC 61850 SV Subscription (Sheet 2 of 2)

Data Field	Description
Data Set Reference	This field contains the DataSetReference (Data Set Reference) for the received SV message. When the SEL SV subscriber is configured via CID file, this field includes the iedName (IED name), ldInst (Logical Device Instance), LN0 lnClass (Logical Node Class) and SampledValueControl datSet (Data Set Name), e.g., SEL_421CFG/LLN0$PhsMeas1. When the SEL SV subscriber is configured via the **PORT 5** SV settings, this field is blank.
Network Delay	This field contains the calculated real-time network delay SVND*mm*[a] for an SV subscription. When the SEL SV subscriber is in coupled clock mode (SVCC = 1) and subscribed to an SV publication (SVS*mm*OK = 1), this field contains the value of the network delay (SVND*mm*) for this particular SV subscription. If SVND*mm* > 9.99 ms, this field is $$$. When the SEL SV subscriber is not in coupled clock mode (SVCC = 0) or not subscribed to an SV publication (SVS*mm*OK = 0), this field is NA.

[a] Parameter mm = 1–7, representing the SV identifier for that SV subscription.

Table 14.45 Warning and Error Codes for SV Subscriptions (Sheet 1 of 2)

Code	Enumeration[a]	Definition	Error/Warning
–	0	No errors present.	–
–	1	The subscribing device is disabled or becomes unresponsive.	Error
MSG CORRUPTED	2	Displayed when a received SV message does not meet the proper format or is corrupted.	Error
ASDU ERROR	3	Displayed when the noASDU (Number of Application Service Data Units [ASDUs]) is greater than one. The SEL SV subscriber only supports a maximum of one ASDU per stream.	Error
SVID RANGE ERR	4	Displayed when the SVID of the received SV message is less than 1 character or greater than 63 characters long.	Error
SMPCNT RANGE ERR	5	Displayed when the out-of-range (OOR) error occurs. This error is present when the smpCnt exceeds the expected range (0–3999 for 4 kHz or 0–4799 for 4.8 kHz).	Error
CONF REV MISMA	6	Displayed when the value of the configuration revision number in the received SV message does not match with the value of the configuration revision number present in the CID file.	Error
SMPSYNC MISMA	7	Displayed when the SmpSynch of the received SV message does not match with the SmpSynch value of the first configured SV subscription. This message is also displayed if a received SV message is rejected because its SmpSynch value is zero.	Error
PDU LENGTH ERR	8	Displayed when the length of received SV message does not match with the length reported in the header of the SV message structure.	Error
INVALID QUAL	9	Displayed when any of the quality bits in *Table 14.46* are non-zero for any of the subscribed current or voltage channels (excluding the neutral channels) in a received SV message and the SEL SV subscriber is not in TEST Mode (SVSTST = 0). After three consecutive invalid SV messages are interpolated, subsequent received packets are discarded.	Error
SV STREAM LOST	10	Displayed after the SEL SV subscriber has not received four or more consecutive SV messages.	Error
CH DLY EXCEEDED	11	Displayed when the measured network delay (SVND*mm*[b]) of any subscribed SV messages exceeds the configured CH_DLY setting when in coupled clock mode (SVCC = 1).	Warning
INTERPOLATED	12	Displayed after the loss of 1–3 consecutive SV messages when the SEL SV subscriber starts to interpolate the lost SV message.	Warning

Table 14.45 Warning and Error Codes for SV Subscriptions (Sheet 2 of 2)

Code	Enumeration[a]	Definition	Error/Warning
OUT OF SEQUENC	13	Displayed when the out-of-sequence (OOS) error occurs. This error is present when the smpCnt value between the received SV messages is not sequential.	Warning
QUALITY (TEST)	14	Displayed when the TEST bit of the quality attribute in a received SV message is set and the SEL SV subscriber is in TEST mode (SVSTST = 1).	Warning
SIMULATED	–[c]	Displayed when the LPHDSIM mode in the received SV message is set.	Warning

[a] Enumerations are used to communicate SV error codes in the LSVS logical node.
[b] Parameter mm = 1–7, representing the SV identifier for that SV subscription.
[c] Simulation mode is indicated in the LSVS logical node by SimSt.stVal and is not part of the ErrSt.stVal enumeration list.

Table 14.46 details the quality bits defined by the IEC 61850-7-3:2010 standard (Section 6.2.1, Table 2) as well as the derived extension from the IEC 61850 9-2LE_R2-1 standard. If any of the quality bits (shown in italics) in *Table 14.46* is non-zero for any of the subscribed current or voltage channels excluding the neutral channels and unmapped channels in a received SV message, the corresponding incoming SV message is discarded.

Table 14.46 Quality Bits in an IEC SV Message

Attribute	Default Value
validity	Good
detailQual	
Overflow	FALSE
outOfRange	FALSE
badReference	FALSE
oscillatory	FALSE
Failure	FALSE
oldData	FALSE
inconsistent	FALSE
inaccurate	FALSE
Source	process
Test	FALSE
operatorBlocked	FALSE
Derived[a]	FALSE

[a] All values of the derived quality attribute are accepted.

Figure 14.6 gives an example response to the **COM SV** command with the SEL SV subscriber configured via CID file.

```
=>>COM SV <Enter>

IEC 61850 Mode /Behavior: On
SEL TEST SV Mode: Off
IEC 61850 Simulation Mode: Off

SV Subscription Status
```

Figure 14.6 COM SV Command Response When CID Configuration Is Used by the SEL SV Subscriber

```
 MultiCastAddr   Ptag:Vlan AppID  smpSynch    Code          Network Delay(ms)
-------------------------------------------------------------------------------
SEL_4217_MU01CFG/LLN0$MS$MU01_MSVCB01
 01-0C-CD-04-00-A1  4:5    41A1      2                          0.83
 SV ID: 41A1
 Data Set: SEL_4217_MU01CFG/LLN0$PhsMeas1

SEL_4217_MU02CFG/LLN0$MS$MU02_MSVCB01
 01-0C-CD-04-00-A2  4:5    41A2      1        SIMULATED          0.83
 SV ID: 41A2
 Data Set: SEL_4217_MU02CFG/LLN0$PhsMeas1

SEL_4217_MU03CFG/LLN0$MS$MU03_MSVCB01
 01-0C-CD-04-00-A3  4:5    41A3      2                          NA
 SV ID: 41A3
 Data Set: SEL_4217_MU03CFG/LLN0$PhsMeas1

SEL_4217_MU04CFG/LLN0$MS$MU04_MSVCB01
 01-0C-CD-04-00-A4  4:5    41A4      1        INTERPOLATED       1.83
 SV ID: 41A4
 Data Set: SEL_4217_MU04CFG/LLN0$PhsMeas1
```

Figure 14.6 COM SV Command Response When CID Configuration Is Used by the SEL SV Subscriber (Continued)

Figure 14.7 gives an example response to the **COM SV** command with the SEL SV subscriber configured via **PORT 5** settings.

```
=>>COM SV <Enter>

IEC 61850 Mode /Behavior: On
SEL TEST SV Mode: Off
IEC 61850 Simulation Mode: Off

SV Subscription Status

 MultiCastAddr   Ptag:Vlan AppID  smpSynch    Code          Network Delay(ms)
-------------------------------------------------------------------------------

 01-0C-CD-04-00-A1   :     41A1      2       QUALITY (TEST)       0.63
 SV ID:
 Data Set:

 01-0C-CD-04-00-A2   :     41A2      2                            0.63
 SV ID:
 Data Set:

01-0C-CD-04-00-A3   :      41A3      2                            0.63
 SV ID:
 Data Set:

01-0C-CD-04-00-A4   :      41A4      2       INTERPOLATED         0.63
 SV ID:
 Data Set:
```

Figure 14.7 COM SV Command Response When PORT 5 Settings Are Used by the SEL SV Subscriber

Figure 14.8 gives an example response to the **COM SV S ALL L** command with the SEL SV subscriber configured via CID file.

```
=>>COM SV S ALL L <Enter>

TEST SV Mode: Off

IEC 61850 Simulation Mode: Off

SV Subscription Status

 SV SubsID 1
-------------------------------------------------------------------------------
 Ctrl Ref: SEL_4217_MU01CFG/LLN0$MS$MU01_MSVCB01
 AppID   : 41A1
 Last Update : 05/12/2017 17:42:00

 Accumulated downtime duration (since last reset)   : 0000:00:00.002
 Maximum downtime duration                          : 00.000

 #    Date          Time        Failure
 1    05/13/2017    00:30:19    SV STREAM LOST
 2    05/13/2017    00:29:05    SMPSYNC MISMA

*Note - Only the highest priority error code for each stream is displayed
```

Figure 14.8 COM SV S ALL L Command Response When CID Configuration Is Used by the SEL SV Subscriber

```
 SV SubsID 2
--------------------------------------------------------------------------------
 Ctrl Ref: SEL_4217_MU02CFG/LLN0$MS$MU02_MSVCB01
 AppID   : 41A2
 Last Update : 05/12/2017 17:42:00

 Accumulated downtime duration (since last reset)   : 0000:00:00.000
 Maximum downtime duration                          : 00.000

 #    Date          Time        Failure

*Note - Only the highest priority error code for each stream is displayed

 SV SubsID 3
--------------------------------------------------------------------------------
 Ctrl Ref: SEL_4217_MU03CFG/LLN0$MS$MU03_MSVCB01
 AppID   : 41A3
 Last Update : 05/12/2017 17:42:00

 Accumulated downtime duration (since last reset)   : 0000:01:00.000
 Maximum downtime duration                          : 50.000

 #    Date          Time        Failure
 1    05/13/2017    23:10:19    SVID RANGE ERR

*Note - Only the highest priority error code for each stream is displayed

 SV SubsID 4
--------------------------------------------------------------------------------
 Ctrl Ref: SEL_4217_MU04CFG/LLN0$MS$MU04_MSVCB01
 AppID   : 41A4
 Last Update : 05/12/2017 17:42:01

 Accumulated downtime duration (since last reset)   : 0000:00:10.006
 Maximum downtime duration                          : 00.000

 #    Date          Time        Failure

*Note - Only the highest priority error code for each stream is displayed
```

Figure 14.8 COM SV S ALL L Command Response When CID Configuration Is Used by the SEL SV Subscriber (Continued)

If the **COM SV** command is issued during CID file processing or right after an SV settings change in **PORT 5**, the relay responds with `IEC 61850 configuration is in progress. No SV statistics available.`

If the **PORT 5** settings for SV are not in use (SVTXEN = 0), and the CID file is not present or is invalid when the **COM SV** command is issued, the relay responds with `Error detected in parsing the CID file. All SV processing disabled.`

If the **PORT 5** SV settings are not in use and no SV subscriptions are configured in the CID file when the **COM SV** command is issued, the relay responds with `No SV Subscriptions configured.`

CONTROL nn

Use the **CONTROL *nn*** command to set, clear, or pulse internal Relay Word bits. Remote bits in SELOGIC control equations are similar to hardwired control inputs, in that you use these bits to affect relay operation from outside sources. For control inputs, external input to the relay comes through the rear panel; in the case of the **CON *nn*** command, external control signals come through the communications ports. See *Remote Bits on page 5.12* for information on remote bits.

Table 14.47 CON nn Command

Command	Description	Access Level
CON *nn*[a] C	Clear Remote Bit *nn*.	P, A, O, 2
CON *nn* P	Pulse Remote Bit *nn* for one processing cycle.	P, A, O, 2
CON *nn* S	Set Remote Bit *nn*.	P, A, O, 2

[a] Parameter nn is the remote bit reference for RBnn.

If you enter **CON *nn*** with no set, clear, or pulse option specified, the relay responds, `Control RBnn:`. You must then provide the control action (set, clear, or pulse) that you want to perform. (The relay checks only the first character; you can type **Set** and **Clear**.) When you issue a valid **CON** command, the relay performs the control action immediately and displays `Remote Bit Operated`.

COPY

The **COPY** command copies the settings from one class instance to another instance in the same class. For example, you can copy Group settings from one group to another. You cannot copy Group settings to Port settings.

This command is limited to the same access level as the **SET** command for the class of settings you are copying.

Table 14.48 COPY Command

Command	Description	Access Level
COPY *m n*[a]	Copy settings from instance m of the Group settings to instance n of the Group settings.	P, A, O, 2
COPY *class m n*[b]	Copy settings from instance *m* of Class *class* to instance *n* of Class *class*.	P, A, O, 2

[a] Parameters m and n are 1 to 6 for the Group class and 1, 2, 3, and F for the Port class.

[b] Parameter class is S, P, and L for Group settings, port settings, and protection SELOGIC control equations, respectively.

The parameters *m* and *n* must be valid and distinct (not the same) instance numbers. You can typically choose from classes of group (S), port (P), and protection SELOGIC control equations (L). Some SEL-400 series relays support copying additional classes. The **COPY** command is not available within the Automation class and is not available for the Breaker Monitor settings.

In addition, port settings instances must be compatible; you cannot copy from/to **PORT 5** and the other communications ports settings. You cannot copy to a port that is presently in transparent communication. If you attempt such a copy, the relay responds with `Cannot copy to a port involved in transparent communication`. In addition, you cannot copy to the present port (the port you are using to communicate with the relay). If you attempt such a copy, the relay responds with `Cannot copy port settings to present port`.

When you enter the **COPY** command with valid parameters, the relay responds with `Are you sure (Y/N)?`. Answer **Y <Enter>** (for yes) to complete copying.

If the destination instance is the active group, the relay changes to the new settings and pulses the SALARM Relay Word bit.

CPR

Use the **CPR** command to access the Signal Profile data for as many as 20 user-selectable analog values in Compressed ASCII format. Notice that the CPR records are in reverse chronological progression as compared to the PRO reports.

Table 14.49 CPR Command

Command	Description	Access Level
CPR	Displays the first 20 rows of the profile report, with the oldest row at the bottom and the latest row at the top.	1, B, P, A, O, 2
CPR *m*	Displays the first *m* rows of the profile report, with the oldest row at the bottom and the latest row at the top.	1, B, P, A, O, 2
CPR *m n* (*m* > *n*)	Displays the row between *m* and *n*, (including *m* and *n*).	1, B, P, A, O, 2
CPR *date1*	Displays all the rows that were recorded on that date, with the latest row at the bottom and the oldest row at the top.	1, B, P, A, O, 2
CPR *date1 date2*	Displays all the rows that were recorded on and between (including) *date1* and *date2* (*date1* chronologically precedes *date2*), with the latest row at the bottom and the oldest row at the top.	1, B, P, A, O, 2
CPR *date2 date1*	Displays all the rows that were recorded on and between (including) *date1* and *date2* (*date2* chronologically precedes *date1*), with the latest row at the bottom and the oldest row at the top.	1, B, P, A, O, 2
CPR TERSE	The **CPR TERSE** command omits the report labels.	1, B, P, A, O, 2

CSER

The **CSER** command provides an **SER** report in Compressed ASCII format. The default order of the **CSER** command (chronologically newest to oldest from list top to list bottom) is the reverse of the **SER** command (oldest to newest from list top to list bottom).

CSE

Use the **CSE** command to gather Sequential Events Recorder (SER) records. You can sort these records in numerical or date order.

Table 14.50 CSE Command (Sheet 1 of 2)

Command	Description	Access Level
CSE	Return all records from the SER in Compressed ASCII format, with the most recent (lowest number) at the beginning of the list and the oldest (highest number) at the end of the list.	1, B, P, A, O, 2
CSE *k*[a]	Return the *k* most recent records from the SER in Compressed ASCII format, with the most recent (lowest number) at the beginning of the list and the oldest (highest number) at the end of the list.	1, B, P, A, O, 2

Table 14.50 CSE Command (Sheet 2 of 2)

Command	Description	Access Level
CSE *m n*[b]	Return the SER records in Compressed ASCII format from *m* to *n*. If *m* is greater than *n*, then records appear with the oldest (highest number) at the beginning of the list and the most recent (lowest number) at the end of the list. If *m* is less than *n*, then records appear with the most recent (lowest number) at the beginning of the list and the oldest (highest number) at the end of the list.	1, B, P, A, O, 2
CSE *date1*[c]	Return the SER records in Compressed ASCII format on date *date1*.	1, B, P, A, O, 2
CSE *date1 date2*[c]	Return the SER records in Compressed ASCII format from date *date1* to date *date2*.	1, B, P, A, O, 2

[a] Parameter k indicates a specific number of SER records.
[b] Parameters m and n indicate an SER record number.
[c] Enter date1 and date2 in the same format as Global setting DATE_F.

CSE TERSE

The **CSE TERSE** command returns a SER report in Compressed ASCII format without labels; the relay sends only the data (including header data). You can apply the **TERSE** option with any of the **CSE** commands.

Table 14.51 CSE TERSE Command

Command	Description	Access Level
CSE TERSE	Return all SER records without the label lines in Compressed ASCII format.	1, B, P, A, O, 2
CSE *k* TERSE[a]	Return the *k* most recent SER records without the label lines in Compressed ASCII format.	1, B, P, A, O, 2
CSE *m n* TERSE[b]	Return the SER records in Compressed ASCII format from *m* to *n* without the label lines in Compressed ASCII format. If *m* is greater than *n*, then records appear with the oldest (highest number) at the beginning of the list and the most recent (lowest number) at the end of the list. If *m* is less than *n*, then records appear with the most recent (lowest number) at the beginning of the list and the oldest (highest number) at the end of the list.	1, B, P, A, O, 2
CSE *date1* TERSE[c]	Return the SER records in Compressed ASCII format on date date1 without the label lines in Compressed ASCII format.	1, B, P, A, O, 2
CSE *date1 date2* TERSE[c]	Return the SER records in Compressed ASCII format from date *date1* to date *date2* without the label lines in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter k indicates a specific number of SER records.
[b] Parameters m and n indicate an SER record number.
[c] Enter date1 and date2 in the same format as Global setting DATE_F.

CSTATUS

The **CSTATUS** command provides a **STATUS** report in the Compressed ASCII format. The **TERSE** option eliminates the report label lines.

Table 14.52 CST Command

Command	Description	Access Level
CST	Return the relay status in Compressed ASCII.	1, B, P, A, O, 2
CST TERSE	Return the relay status in Compressed ASCII; suppress the label lines and transmit only the data lines.	1, B, P, A, O, 2

CSUMMARY

The **CSUMMARY** provides the same information as the **SUMMARY** command but in Compressed ASCII format. You can combine the *n*, **ACK**, **MB**, and **TERSE** options.

CSU

Use the **CSU** command to gather event report summaries.

Table 14.53 CSU Command

Command	Description	Access Level
CSU	Return the most recent event summary (with label lines) in Compressed ASCII format.	1, B, P, A, O, 2
CSU *n*[a]	Return a particular *n* event summary (with label lines) in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number.

When parameter *n* is 1–9999, *n* indicates the order of the event report. The most recent event report is 1, the next most recent report is 2, and so on. When parameter *n* is 10000–42767, *n* indicates the absolute serial number of the event report.

CSU ACK

Use the **CSU ACK** command to acknowledge an event summary that you recently retrieved with the **CSU NEXT** command on the present communications port.

Table 14.54 CEV ACK Command

Command	Description	Access Level
CSU ACK	Acknowledge the oldest unacknowledged event summary at the present communications port for Compressed ASCII format.	1, B, P, A, O, 2

CSU MB

The **CSU MB** command causes the relay to output the labels for the MIRRORED BITS communications channel data in Compressed ASCII format.

Table 14.55 CSU MB Command

Command	Description	Access Level
CSU MB	Return the MIRRORED BITS communications channel labels.	1, B, P, A, O, 2

CSU NEXT

Use the **CSU NEXT** command to view the oldest unacknowledged event summary in Compressed ASCII format.

Table 14.56 CSU N Command

Command	Description	Access Level
CSU N	View the oldest unacknowledged event summary.	1, B, P, A, O, 2

CSU TERSE

The **TERSE** command option returns an event summary report in Compressed ASCII format without labels; the relay sends only the data (including header data).

Table 14.57 CSU TERSE Command

Command	Description	Access Level
CSU TERSE	Return the event summary report without the label lines in Compressed ASCII format.	1, B, P, A, O, 2
CSU *n*[a] TERSE	Return a particular *n* event summary report without the label lines in Compressed ASCII format.	1, B, P, A, O, 2
CSU N TERSE	View the oldest unacknowledged event summary without the label lines in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter n indicates event number or serial order.

You can apply the **TERSE** option with any of the **CSU** commands except **CSU ACK** and **CSU MB**.

DATE

Use the **DATE** command to view and set the relay date. The relay can overwrite the date that you enter by using other time sources, such as IRIG and DNP3. Enter the **DATE** command with a date to set the internal clock date. You can separate the month, day, and year parameters with spaces, commas, slashes, colons, and semicolons.

Set the year in two-digit form (for dates 2000–2099) or four-digit form. If you enter the year as **12**, the relay date is 2012. You must enter the data in the format specified in the Global setting DATE_F.

If an IRIG-B time synchronization signal is connected to the relay, the DAT command cannot alter the month or day portion of the date. If the IRIG-B time SNTP time source is connected, the **DAT** command cannot alter any time setting.

Table 14.58 DATE Command

Command	Description	Access Level
DATE	Display the internal clock date.	1, B, P, A, O, 2
DATE *date*[a]	Set the internal clock date.	1, B, P, A, O, 2

[a] Enter date parameters in the same order as Global setting DATE_F.

DNAME X

The **DNA X** command produces the ASCII names of all relay digital I/O (input/output) quantities reported in a Fast Meter message in Compressed ASCII format.

Table 14.59 DNA Command

Command	Description	Access Level
DNA X	Display ASCII names of all relay digital I/O.	0, 1, B, P, A, O, 2

DNP

The **DNP** command accesses the serial port DNP3 settings and is similar to the **SHOW D** command. Use the **DNP** or **DNP VIEW** command to show the relay serial port DNP3 settings beginning at the first setting label just like **SHOW D**. Issue the **DNP** command with any parameter *param* to set the serial port DNP3 settings; the relay begins at the first DNP3 setting just like **SET D**.

Table 14.60 DNP Command

Command	Description	Access Level
DNP	Show the serial port DNP3 settings (same as **SHOW D**).	1, B, P, A, P, O, 2
DNP VIEW	Show the serial port DNP3 settings (same as **SHOW D**).	1, B, P, A, P, O, 2
DNP *param*	Set the serial port DNP3 settings (same as **SET D**); begin at the first DNP3 setting.	P, A, O, 2

ETHERNET

The **ETH** command displays the current Ethernet port (PORT 5) configuration and status. Communications statistics, such as the number of packets, bytes, and errors received and sent, are displayed for the ports that carry standard Ethernet, DNP3 or optional IEC 61850 communications. Other commands are available to display similar statistics for ports that exclusively carry other types of traffic, for example, **COM 87L** for 87L traffic.

ETH

Use the **ETH** command when troubleshooting Ethernet connections.

Table 14.61 ETH Command

Command	Description	Access Level
ETH	Displays information about Ethernet port(s)	1, B, P, A, O, 2

Figure 14.9 shows a sample **ETH** command response for a relay with four copper Ethernet ports and **PORT 5** setting NETMODE = FAILOVER. Different Ethernet configurations and different NETMODE settings result in slightly different information being displayed.

```
==>>ETH <Enter>

Relay 1                                    Date: 03/17/2023  Time: 16:07:59.368
Station A                                  Serial Number: 1230769999

MAC 1: 00-30-A7-06-21-EE
MAC 2: 00-30-A7-06-21-EF
IP ADDRESS: 192.168.1.89/20
DEFAULT GATEWAY: 192.168.1.1

NETMODE: FAILOVER

PRIMARY PORT:      5C
ACTIVE PORT:       5D

             LINK   SPEED  DUPLEX  MEDIA
PORT 5C      Down   ---    ---     FX
PORT 5D      Up     100M   Full    TX

        PACKETS                BYTES               ERRORS
       SENT     RCVD         SENT       RCVD       SENT    RCVD
     318292   326702     40080159   22834008         0       4
```

Figure 14.9 Sample ETH Command Response for the Two-Port Ethernet Card

Figure 14.10 shows a sample **ETH** command response for a relay with the five-port Ethernet card, BUSMODE set to INDEPEND, NETMODE and NETMODP set to PRP, and all interfaces enabled.

```
=>>ETH <Enter>

Relay 1                                    Date: 03/17/2023  Time: 14:41:24.123
Station A                                  Serial Number: 1230769999

BUSMODE: INDEPENDENT

PROCESS BUS
MODE: PRP
PORTS 5A/5B MAC: 00-30-A7-00-00-03

STATION BUS
MODE: PRP
PORTS 5C/5D MAC: 00-30-A7-00-00-04
IP ADDRESS: 192.168.1.31/24
DEFAULT GATEWAY: 192.168.1.1

ENGINEERING ACCESS
PORT 5E MAC: 00-30-A7-00-00-05
IP ADDRESS: 192.168.2.31/24
DEFAULT GATEWAY: 192.168.2.1

ETHERNET PORT STATUS
             LINK  SPEED  DUPLEX  MEDIA
--------------------------------------------------------------------
PORT 5A      Up    1000M  Full    SX
PORT 5B      Up    1000M  Full    SX
PORT 5C      Up    100M   Full    FX
PORT 5D      Up    100M   Full    FX
PORT 5E      Up    100M   Full    FX

PACKET COUNT
             SENT     RCVD     DISC     ERROR
--------------------------------------------------------------------
PORT 5A    284003  4238102        0        0
PORT 5B    283878  4238078        0        0
PORT 5C    137629   418243   355859        0
PORT 5D    137609   961288   960074        0
PORT 5E     12020    14880      640        0

SFP TRANSCEIVER INFO
             RX Power(dBm)  TX Power(dBm)  Temp(C)
--------------------------------------------------------------------
PORT 5A        -15.90        -17.06          41.1
PORT 5B        -33.98        -17.14          41.0
PORT 5C        -18.73        -17.06          40.2
PORT 5D        -18.01        -17.14          39.6
PORT 5E        -18.12        -17.08          49.2

=>>
```

Figure 14.10 Sample ETH Command Response for the Five-Port Ethernet Card

ETH C and ETH R

The **ETH C** and **ETH R** commands clear the Ethernet connection statistics. Option **C** and **R** are identical.

Table 14.62 ETH C and ETH R Command

Command	Description	Access Level
ETH C	Clears the statistics on PORT 5 Ethernet connection	1, B, P, A, O, 2
ETH R	Clears the statistics on PORT 5 Ethernet connection	1, B, P, A, O, 2

When you issue the **ETH C** and **ETH R** command, the relay sends the following prompt: `Are you sure (Y/N)?`. If you answer **Y <Enter>**, the relay clears the Ethernet statistics and response: `Ethernet Statistics Cleared`.

EVENT

NOTE: The SEL-400G relay does not support 4-sample/cycle events. Filtered and unfiltered events are presented in the COMTRADE format.

Use the **EVENT** command to view the relay filtered event reports (see *Event Report on page 9.14* for information on event reports).

EVE

The **EVE** command displays the full-length event reports stored in relay memory. When parameter *n* is 1–9999, *n* indicates the order of the event report. The most recent event report is 1, the next most recent report is 2, and so on. When parameter *n* is 10000–42767, *n* indicates the absolute serial number of the event report.

Table 14.63 EVE Command

Command	Description	Access Level
EVE	Return the most recent event report (including settings and summary) at full length with 4-samples/cycle data.	1, B, P, A, O, 2
EVE *n*[a]	Return a particular n event report (including settings and summary) at full length with 4-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number.

EVE A

The **EVE A** command returns only the analog information in the event report.

Table 14.64 EVE A Command

Command	Description	Access Level
EVE A	Return only the analog information for the most recent event report with 4-samples/cycle data.	1, B, P, A, O, 2
EVE A *n*[a]	Return only the analog information for a particular n event report with 4-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number; see EVE on page 14.33.

EVE ACK

Use **EVE ACK** to acknowledge the oldest unacknowledged event that you recently viewed with the **EVE NEXT** or the **CEV NEXT** commands on the present communications port.

Table 14.65 EVE ACK Command

Command	Description	Access Level
EVE ACK	Acknowledge the oldest unacknowledged event at the present communications port.	1, B, P, A, O, 2

If you attempt to acknowledge an event summary that you have not viewed on the present port with the **EVE NEXT** command, the relay responds with `Event summary number n has not been viewed with the NEXT option`.

EVE C

Use **EVE C** to return a 15-cycle length event report with both analog and digital data. You cannot mix the A and D options with the **EVE C** command. The L*yyy* option overrides the C option (see *EVE Lyyy on page 14.35*).

Table 14.66 EVE C Command

Command	Description	Access Level
EVE C	Return the most recent event report at a 15-cycle length with large resolution data.	1, B, P, A, O, 2
EVE C *n*[a]	Return a particular *n* event report at a 15-cycle length with large resolution data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number; see EVE on page 14.33.

EVE D

Use **EVE D** to return only the digital information in the event report.

Table 14.67 EVE D Command

Command	Description	Access Level
EVE D	Return only the digital information for the most recent event report with 4-samples/cycle data.	1, B, P, A, O, 2
EVE D *n*[a]	Return only the digital information for a particular n event report with 4-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number; see EVE on page 14.33.

EVE L

Use **EVE L** to return a large resolution event report. The **S*x*** option overrides the **L** option (see *EVE Sx on page 14.36*).

Table 14.68 EVE L Command

Command	Description	Access Level
EVE L	Return the most recent event report at full length with large resolution data.	1, B, P, A, O, 2
EVE *n*[a] L	Return a particular *n* event report at full length with large resolution data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number.

EVE Lyyy

Command **EVE L*yyy*** returns a specified length event report, where **L*yyy*** indicates a length of *yyy* cycles. You can specify *yyy* from 1 cycle up to a value including and exceeding the event report total cycle length. If *yyy* is longer than the total length, the relay returns the full duration event report. The **L*yyy*** option overrides the **C** option.

Table 14.69 EVE Lyyy Command

Command[a]	Description	Access Level
EVE L*yyy*	Return *yyy* cycles of the most recent event report (including settings) with 4-samples/cycle data.	1, B, P, A, O, 2
EVE *n* L*yyy*	Return *yyy* cycles of a particular n event report with 4-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number; see EVE on page 14.33.

EVE NEXT

EVE NEXT returns the oldest unacknowledged event report on the present communications port.

Table 14.70 EVE N Command

Command	Description	Access Level
EVE N	Return the oldest unacknowledged event report with 4-samples/cycle data.	1, B, P, A, O, 2

EVE NSET

The **EVE NSET** command returns the event report with no relay settings.

Table 14.71 EVE NSET Command

Command	Description	Access Level
EVE NSET	Return the most recent event report without settings at full length with 4-samples/cycle data.	1, B, P, A, O, 2
EVE *n*[a] NSET	Return a particular n event report without settings at full length with 4-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number; see EVE on page 14.33.

EVE NSUM

The **EVE NSUM** returns the event report with no event summary.

Table 14.72 EVE NSUM Command

Command	Description	Access Level
EVE NSUM	Return the most recent event report without the event summary at full length with 4-samples/cycle data.	1, B, P, A, O, 2
EVE *n*[a] NSUM	Return a particular n event report without the event summary at full length with 4-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number.

EVE Sx

Use the **EVE S*x*** command to specify the sample data resolution of the event report. The sample data resolution x is either 4-samples/cycle or large resolution; the default value is 4-samples/cycle if you do not specify **S*x***. The **S*x*** option overrides the **L** option.

Table 14.73 EVE Sx Command

Command	Description	Access Level
EVE S*x*	Return the most recent event report at full length with *x*-samples/cycle data.	1, B, P, A, O, 2
EVE *n*[a] S*x*	Return a particular n event report at full length with *x*-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number; x is 4, 8, or 12 to represent data at 4 samples/cycle, 8 samples/cycle, or 12 samples/cycle respectively. See the product-specific instruction manual to see whether 8 or 12 samples/cycle are supported for larger resolution reports.

EVE Command Option Combinations

You can combine options **C**, **L**, **L*yyy***, ***n***, **NSET**, **NSUM**, and **S*x***, in one command. Enter the options according to the following guidelines:

- The **L*yyy*** option overrides the **C** option.
- The **S*x*** option overrides the **L** option.
- When choosing option **A** or option **D** as a report type, you cannot use option **C** to specify the report length at 15 cycles. Use option **L*yyy*** at L015 to specify a 15-cycle report.
- Enter the options in any order.

Table 14.74 lists the choices you can make in the **EVE** command. Combine options on each row, selecting one option from each column, to create an **EVE** command.

Table 14.74 EVE Command Option Groups

Acknowledge	Event Number	Data Resolution	Report Type	Report Length	Omit
ACK	***n*, NEXT**	**S*x*, L**	**C, A, D**	**L*yyy*, C**	**NSET, NSUM**

The following examples illustrate some possible option combinations.

Table 14.75 EVE Command Examples

Example	Description
EVE L010 S8	Return 10 cycles of an 8-samples/cycle event report for the most recent event.
EVE L10 A	Return 10 cycles of the analog portion only of the most recent event report at 4-samples/cycle resolution.
EVE 2 C NSUM	For the second most recent event, return the event with 8-samples/cycle data, and omit the event summary.

EXIT

Use the **EXIT** command to terminate a Telnet session and revert to Access Level 0 (exit relay control).

Table 14.76 EXIT Command

Command	Description	Access Level
EXIT	Terminate the Ethernet port Telnet sessions and go to Access Level 0 (exit relay control)	0, 1, B, P, A, O, 2

FILE

The **FILE** command provides a safe and efficient means of transferring files between IEDs and external support software (ESS) by providing Ymodem file transfer. The **FILE** commands are especially useful for retrieving high-resolution sampled data in binary COMTRADE format from the relay.

Table 14.77 FILE Command

Command	Description	Access Level
FILE DIR *directory*	Returns a list of filenames in specified directory *(directory)*. If not specified, then the list of files and directories in the root directory is returned.	1, B, P, A, O, 2
FILE READ *directory filename*	Initiates a file transfer of the file *filename* (in the folder *directory*) from the relay to ESS. The *filename* parameter is required.	1, B, P, A, O, 2
FILE WRITE SETTINGS *filename*	Initiates a file transfer of the file *filename* from ESS to the relay. If the *filename* parameter is not specified, the file name must be given in the Ymodem header.	P, A, O, 2

All text enclosed in [brackets] indicates optional command line parameters. The specific directories available in the relay depends on the relay model, but typically includes EVENTS, REPORTS, SETTINGS, and SYNCHROPHASOR directories. For **FILE READ** operations, specify the directory parameters as needed. The **FILE WRITE** command is available only for the SETTINGS directory.

GOOSE

Use the **GOOSE** command to display transmit and receive GOOSE messaging information, which can be used for troubleshooting.

Table 14.78 GOOSE Command

Command	Description	Access Level
GOOSE	Displays GOOSE information	1, B, P, A, O, 2
GOOSE *k*	Displays GOOSE information successively for *k* times	1, B, P, A, O, 2

The information displayed for each GOOSE IED is described in *Table 14.79*.

Table 14.79 Accessible GOOSE IED Information

IED	Description
Transmit GOOSE Control Reference	This field represents the GOOSE control reference information that includes the IED name, ldInst (Logical Device Instance), LN0 lnClass (Logical Node Class), and GSEControl name (GSE Control Block Name) (e.g., SEL_411L_OtterCFG/LLN0$DSet13).
Receive GOOSE Control Reference	This field shall contain the goCbRef (GOOSE Control Block Reference) information that includes the iedName (IED name), ldInst (Logical Device Instance), LN0 lnClass (Logical Node Class) and cbName (GSE Control Block Name) (e.g., SEL_411L_1CFG/LLN0$DSet13).
Multicast Address (MultiCastAddr)	This hexadecimal field represents the GOOSE multicast address.
Priority Tag (Ptag)	This three-bit decimal field represents the priority tag value, where spaces are used if the priority tag is unknown.
VLAN (Vlan)	This 12-bit decimal field represents the virtual LAN setting, where spaces are used if the virtual LAN is unknown.
State Number (StNum)	This hexadecimal field represents the state number that increments with each state change.
Sequence Number (SqNum)	This hexadecimal field represents the sequence number that increments with each GOOSE message sent.
Time to Live (TTL)	This field contains the time (in ms) before the next message is expected.
Transmit Data Set Reference	This field represents the datSetRef (Data Set Reference) that includes the IED name, LN0 lnClass (Logical Node Class), and GSEControl datSet (Data Set Name) (e.g., SEL_411L_1CFG/LLN0$DSet13).
Receive Data Set Reference	This field represents the datSetRef (Data Set Reference) that includes the iedName (IED name), ldInst (Logical Device Instance), LN0 lnClass (Logical Node Class) and datSet (Data Set Name) (e.g., SEL_411L_1CFG/LLN0$DSet13).

Table 14.80 Warning and Error Codes for GOOSE Subscriptions (Sheet 1 of 2)

Code	Enumeration[a]	Definition	Error/Warning
–	0	No errors present.	–
HOST DISABLED	1	Optional code for when the subscribing device is disabled or becomes unresponsive after the **GOOSE** command has been issued.	Error
CONF REV MISMA	2	Configuration revision mismatch. Displayed when the value of the configuration revision number in the received GOOSE message does not match with the value of the configuration revision number present in the CID file.	Error
NEED COMMISSIO	3	Needs commissioning. Displayed when the received GOOSE message has NdsCom = true.	Error
MSG CORRUPTED	4	Message corrupted. Displayed when a received GOOSE message does not meet the proper format or is corrupted.	Error
TTL EXPIRED	5	Time-to-live expired.	Error

Table 14.80 Warning and Error Codes for GOOSE Subscriptions (Sheet 2 of 2)

Code	Enumeration[a]	Definition	Error/Warning
OUT OF SEQUENC	6	Out-of-sequence (OOS) error. This error is present when the StNum or SqNum value between received GOOSE messages is not sequential.	Warning
INVALID QUAL	7	Invalid data quality received	Warning

[a] Enumerations are used to communicate GOOSE error codes in the LGOS logical node.

An example response to the **GOOSE** command is shown in *Figure 14.11*.

```
=>>GOOSE <Enter>

GOOSE Transmit Status

   MultiCastAddr   Ptag:Vlan  StNum      SqNum      TTL    Code
----------------------------------------------------------------------------

SEL_411L_OtterCFG/LLN0$GO$GooseDSet13
   01-0C-CD-01-00-10  4:1     1          166        457
   Data Set: SEL_411L_OtterCFG/LLN0$DSet13

GOOSE Receive Status

   MultiCastAddr   Ptag:Vlan  StNum      SqNum      TTL    Code
----------------------------------------------------------------------------

SEL_411L_1CFG/LLN0$GO$GooseDSet13
   01-0C-CD-01-00-04   :      0          0          0      TTL EXPIRED
   Data Set: SEL_487B_1CFG/LLN0$DSet13


SEL_2440_1CFG/LLN0$GO$GooseDSet13
   01-0C-CD-01-00-0A   :      0          0          0      TTL EXPIRED
   Data Set: SEL_2440_1CFG/LLN0$DSet13


SEL_487E_1CFG/LLN0$GO$GooseDSet13
   01-0C-CD-01-00-10   :      0          0          0      TTL EXPIRED
   Data Set: SEL_487E_1CFG/LLN0$DSet13

SEL_710_1CFG/LLN0$GO$GooseDSet13
   01-0C-CD-01-00-08   :      0          0          0      TTL EXPIRED
   Data Set: SEL_710_1CFG/LLN0$DSet13

IEC 61850 Mode/Behavior: Blocked
IEC 61850 Simulation Mode: On
```

Figure 14.11 GOOSE Command Response for the Two- or Four-Port Ethernet Card

If the **GOOSE** command is issued during CID file processing, the relay responds with `CID file is currently being processed. No GOOSE statistics available`. When **GOOSE** is disabled by settings (EGSE = N), the relay sends `Command is not available` in responding to a **GOOSE** command. If an error is detected during the processing of the IEC 61850 file, the relay responds with `Error detected in parsing the CID file. All GOOSE processing disabled` to a **GOOSE** command.

GOO S

The **GOO S** command provides statistics for GOOSE subscriptions.

Table 14.81 GOO S Command (Sheet 1 of 2)

Command	Description	Access Level
GOO S	Display a list of GOOSE subscriptions with their ID.	1,B,P,A,O,2
GOO S *n*	Display GOOSE statistics for subscription ID *n*.	1,B,P,A,O,2
GOO S ALL	Display GOOSE statistics for all subscriptions.	1,B,P,A,O,2
GOO S *n* L	Display GOOSE statistics for subscription ID *n* including error history.	1,B,P,A,O,2

Table 14.81 GOO S Command (Sheet 2 of 2)

Command	Description	Access Level
GOO S ALL L	Display GOOSE statistics for all subscriptions including error history.	1,B,P,A,O,2
GOO S *n* C	Clear GOOSE statistics for subscription ID *n*.	1,B,P,A,O,2
GOO S ALL C	Clear GOOSE statistics for all subscriptions.	1,B,P,A,O,2

When reporting a list of subscriptions with the **GOO S** command, the response includes the subscription ID, the application identifier, and the GOOSE control block reference. The other variants of **GOO S** provide statistics on the selected subscriptions. *Figure 14.12* and *Figure 14.13* illustrates this.

```
==>GOO S 2 <Enter>

 SubsID 2
-----------------------------------------------------------------------------
 Ctrl Ref: GOOSE_SIM_CFG/LLN0$GO$GooseDSet02
 AppID   : 4114
 From    : 06/30/2014 10:59:29.760  To: 06/30/2014 11:10:32.817

 Accumulated downtime duration                      : 0000:10:59.325
 Maximum downtime duration                          : 0000:10:59.325
 Date & time maximum downtime began                 : 06/30/2014 10:59:33.492
 Number of messages received out-of-sequence(OOS)   : 0
 Number of time-to-live(TTL) violations detected    : 1
 Number of messages received with invalid quality   : 1
 Number of messages incorrectly encoded or corrupted: 654
 Number of messages lost due to receive overflow    : 0
 Calculated max. sequential messages lost due to OOS: 0
 Calculated number of messages lost due to OOS      : 0
```

Figure 14.12 Example GOO S Command Response

```
=>>GOO S ALL L <Enter>

 SubsID 1
-----------------------------------------------------------------------------
 Ctrl Ref: GOOSE_SIM_CFG/LLN0$GO$GooseDSet01
 AppID   : 4113
 From    : 07/01/2014 11:23:13.851  To: 07/01/2014 11:37:54.790

 Accumulated downtime duration                      : 0000:00:34.002
 Maximum downtime duration                          : 0000:00:13.000
 Date & time maximum downtime began                 : 07/01/2014 11:35:36.048
 Number of messages received out-of-sequence(OOS)   : 4
 Number of time-to-live(TTL) violations detected    : 0
 Number of messages received with invalid quality   : 1
 Number of messages incorrectly encoded or corrupted: 0
 Number of messages lost due to receive overflow    : 0
 Calculated max. sequential messages lost due to OOS: 12
 Calculated number of messages lost due to OOS      : 30

 #    Date        Time          Duration        Failure
 1    07/01/2014  11:37:02.051  0000:00:01.000  OUT OF SEQUENCE
 2    07/01/2014  11:36:59.051  0000:00:03.000  CONF. REV. MISMATCH
 3    07/01/2014  11:36:38.050  0000:00:00.999  OUT OF SEQUENCE
 4    07/01/2014  11:36:29.049  0000:00:09.000  NEEDS COMMISSIONING
 5    07/01/2014  11:36:09.049  0000:00:00.999  OUT OF SEQUENCE
 6    07/01/2014  11:36:03.049  0000:00:06.000  CONF. REV. MISMATCH
 7    07/01/2014  11:35:48.048  0000:00:00.999  OUT OF SEQUENCE

 SubsID 2
-----------------------------------------------------------------------------
 Ctrl Ref: GOOSE_SIM_CFG/LLN0$GO$GooseDSet02
 AppID   : 4114
 From    : 07/01/2014 11:37:45.158  To: 07/01/2014 11:37:54.796
```

Figure 14.13 Example GOO S ALL L Command Response

```
Accumulated downtime duration                    : 0000:00:09.638
Maximum downtime duration                        : 0000:00:09.638
Date & time maximum downtime began               : 07/01/2014 11:37:45.158
Number of messages received out-of-sequence(OOS)   : 0
Number of time-to-live(TTL) violations detected    : 0
Number of messages received with invalid quality   : 1
Number of messages incorrectly encoded or corrupted: 0
Number of messages lost due to receive overflow    : 0
Calculated max. sequential messages lost due to OOS: 0
Calculated number of messages lost due to OOS      : 0

#    Date        Time          Duration        Failure
```

Figure 14.13 Example GOO S ALL L Command Response (Continued)

GROUP

Use the **GROUP** command to view the present group number or to change the active group.

Table 14.82 GROUP Command

Command	Description	Access Level
GROUP	Display the presently active group.	1, B, P, A, O, 2
GROUP *n*[a]	Change the active group to Group n.	B, P, A, O, 2

[a] Parameter n indicates group numbers 1–6.

When you change the active group, the relay responds with a confirmation prompt: `Are you sure (Y/N)?`. Answer **Y <Enter>** to change the active group. The relay asserts the Relay Word bit SALARM for at least one second when you change the active group.

If any of the SELOGIC control equations SS1–SS6 are set when you issue the **GROUP *n*** command, the group change will fail. The relay responds with `No group change: SELogic equations SS1-SS6 have priority over GROUP command.`

HELP

The **HELP** command gives a list of commands available at the present access level. You can also get a description of any particular command; type **HELP** followed by the name of the command for help on each command.

Table 14.83 HELP Command

Command	Description	Access Level
HELP	Display a list of each command available at the present access level with a one-line description.	1, B, P, A, O, 2
HELP *command*	Display information on the command *command*.	1, B, P, A, O, 2

HISTORY

The **HISTORY** command displays a quick synopsis of the last 100 events that the relay has captured. The rows in the **HISTORY** report typically contains the event serial number, date, time, location, maximum current, active group, and targets. (The specific content depends on the relay.) See *Section 9: Reporting* and *Section 7: Metering, Monitoring, and Reporting* in the product-specific instruction manual for more information on history reports.

HIS

Use the **HIS** command to list one-line descriptions of relay events. You can list event histories by number or by date.

Table 14.84 HIS Command

Command	Description	Access Level
HIS	Return event histories with the oldest at the bottom of the list and the most recent at the top of the list.	1, B, P, A, O, 2
HIS *k*[a]	Return the *k* most recent event histories with the oldest at the bottom of the list and the most recent at the top of the list.	1, B, P, A, O, 2
HIS *date1*[b]	Return the event histories on date *date1*.	1, B, P, A, O, 2
HIS *date1 date2*[b]	Return the event histories from *date1* to *date2*, with *date1* at the bottom of the list and *date2* at the top of the list.	1, B, P, A, O, 2

[a] Parameter k indicates an event number.
[b] Enter date1 and date2 in the order selected by the Global setting DATE_F.

HIS C and HIS R

The **HIS C** and **HIS R** commands clear/reset the history data and corresponding high-resolution/event report data on the present port. Options **C** and **R** are identical.

Table 14.85 HIS C and HIS R Commands

Command	Description	Access Level
HIS C	Clear/reset event data on the present port only.	1, B, P, A, O, 2
HIS R	Clear/reset event data on the present port only.	1, B, P, A, O, 2

The relay prompts you with `Are you sure (Y/N)?` when you issue the **HIS C** and **HIS R** commands. If you answer **Y <Enter>**, the relay clears the present port history data.

HIS CA and HIS RA

The **HIS CA** and **HIS RA** commands clear all history data and event reports from memory. Use these commands to completely delete high-resolution/event report data captures.

Table 14.86 HIS CA and HIS RA Commands

Command	Description	Access Level
HIS CA	Clear all event data for all ports.	P, A, O, 2
HIS RA	Clear all event data for all ports.	P, A, O, 2

If you issue the **HIS CA** and **HIS RA** commands, the relay prompts you with `Are you sure (Y/N)?`. If you answer **Y <Enter>**, the relay clears all history data and event reports. The relay resets the event report number to 10000.

ID

Use the **ID** command to extract relay identification codes.

Table 14.87 ID Command

Command	Description	Access Level
ID	Return a list of relay identification codes.	0, 1, B, P, A, O, 2

Each line of the **ID** command report contains an identification code and a line checksum. The relay presents these codes in the following order:

FID: the Firmware Identification string

BFID: the Boot Firmware Identification string

CID: the checksum of the firmware

DEVID: the RID string as stored in the relay settings of the IED

DEVCODE: a unique Device Code (for Modbus identification purposes)

PARTNO: the Part Number

SERIALNO: the serial number of the relay

CONFIG: abcdef

The designator positions indicate a specific relay configuration:

"a" represents the nominal frequency, where 0 = N/A, 1 = 60 Hz, and 2 = 50 Hz.

"b" represents the phase rotation, where 0 = N/A, 1 = ABC, and 2 = ACB.

"c" represents the phase input current scaling, where 0 = N/A, 1 = 5 A, and 2 = 1 A.

"d" represents the neutral input current scaling, where 0 = N/A, 1 = 5 A, 2 = 1 A.

"e" represents the voltage input connection, where 0 = N/A, 1 = Delta, and 2 = Wye.

"f" represents the current input connection, where 0 = N/A, 1 = Delta, and 2 = Wye.

SPECIAL: the Special Configuration Designators—a mechanism for anticipating future product enhancements

If the device supports IEC 61850 and the IEC 61850 protocol is enabled, the **ID** command will display the following additional information.

- iedName: the IED name (e.g., SEL-411L_OtterTail)
- type: the IED type (e.g., SEL-411L)
- configVersion: the CID file configuration version (e.g., ICD-411L-R100-V0-Z001001-20060512)
- LIB61850ID: an eight-character code indicating the IEC 61850 library version within the product

A sample **ID** command response from the relay (with IEC 61850 enabled) is shown in *Figure 14.14*.

```
=ID <ENTER>
"FID=SEL-451-5-R319-V0-Z024013-D20170608","0916"
"BFID=SLBT-4XX-R209-V0-Z001002-D20150130","097C"
"CID=85F4","0264"
"DEVID=Relay 1","0467"
"DEVCODE=40","030B"
"PARTNO=04515415XC4X4H60X0XXX","07B3"
"SERIALNO=1230769999","0517"
"CONFIG=11102200","03EA"
"SPECIAL=000000","03CE"
"iedName=SEL_451_1","05CD"
"type=SEL_451","044C"
"configVersion=ICD-451-R301-V0-Z316006-D20170130","0D1C"
"LIB61850ID=9048BE8A","04EA"

=
```

Figure 14.14 Sample ID Command Response From Ethernet Card

IRIG

The **IRIG** command directs the relay to use the next available demodulated IRIG-B time code to update the relay internal clock. For information on the IRIG time mode, see *IRIG-B Timekeeping on page 11.1*.

Table 14.88 IRIG Command

Command	Description	Access Level
IRIG	Lock the relay internal clock to the IRIG-B time-code input.	1, B, P, A, O, 2

NOTE: Not all SEL-400 series relays support the **IRIG** command.

The **IRIG** command was originally provided in the relay as a testing aid. The **IRIG** command was used to update the relay internal clock with the IRIG-B time value without waiting for the 30-second confirmation time delay.

There is no longer a 30-second confirmation time delay—the relay uses the IRIG time source as soon as it determines that the signal is valid, a process that may take several seconds. Once the IRIG signal is verified, the relay clock is updated once per second. The **IRIG** command is still available, but is no longer necessary. To check IRIG status, use the **TIME Q** command instead—see *TIME Q Command on page 11.8*.

If the relay has no valid IRIG-B time code at the rear panel, or if the **TIME Q** command reports a relay time source other than IRIG or HIRIG, the relay responds to the **IRIG** command with the following error message, `IRIG-B DATA ERROR`. See the **TIME** command for more information.

LOOPBACK

Use the **LOOPBACK** command to instruct the relay to receive the transmitted MIRRORED BITS communications data on the same serial port. See *SEL MIRRORED BITS Communication on page 15.36* for more information on MIRRORED BITS communications.

LOOP

The **LOOP** command puts the relay serial port in loopback if you have previously configured the port for MIRRORED BITS communications. If you have enabled both of the MIRRORED BITS communications channels (A and B), then you must specify the channel parameter. If you have only one of the channels enabled, then the relay assumes that channel if you do not specify that channel in the command. If you do not specify a time-out period, the relay provides a 5-minute time-out.

Table 14.89 LOOP Command

Command	Description	Access Level
LOOP	Begin loopback of a single enabled MIRRORED BITS communications channel (either Channel A or Channel B) for 5 minutes; ignore input data and force receive bits (RMB) to defaults.	P, A, O, 2
LOOP *c*[a]	Begin loopback of MIRRORED BITS communications Channel *c* for 5 minutes; ignore input data and force receive bits (RMB) to defaults.	P, A, O, 2
LOOP *t*	Begin loopback of a single MIRRORED BITS communications channel (either Channel A or Channel B) and end the loopback after time-out *t* minutes; ignore input data and force receive bits (RMB) to defaults; *t* range is 1–5000 minutes.	P, A, O, 2
LOOP *t c*	Begin loopback of a single MIRRORED BITS communications channel (either Channel A or Channel B) and end the loopback after time-out t minutes; ignore input data and force receive bits (RMB) to defaults; *t* range is 1–5000 minutes.	P, A, O, 2

[a] Parameter c is A or B, representing Channel A or Channel B.

You can enter the options in any order. If you operate the relay by using both MIRRORED BITS communications channels (A and B), then you must specify the channel parameter by using the **LOOP A** command and the **LOOP B** command.

When you issue the **LOOP** command, the relay responds with statements about the loopback time, status of the RMB (Receive MIRRORED BITS), and `Are you sure (Y/N)?`. If you answer **Y <Enter>**, the relay responds with `Loopback Mode Started`.

In the loopback mode, ROK drops out and the relay uses LBOK to indicate whether the data transmissions are satisfactory. The relay collects COM data as usual. Time synchronization and virtual terminal modes are not available during loopback. The relay continues passing analog quantities.

LOOP DATA

The **LOOP DATA** command tells the relay to pass input MIRRORED BITS communications data through to the receive (RMB) bits, as in the nonloopback mode.

Table 14.90 LOOP DATA Command

Command	Description	Access Level
LOOP DATA	Begin loopback of a single MIRRORED BITS communications channel (either Channel A or Channel B) for 5 minutes: pass input data to receive data as in nonloopback mode.	P, A, O, 2
LOOP *c* DATA	Begin loopback of MIRRORED BITS communications Channel *c* only for 5 minutes: pass input data to receive data as in nonloopback mode.	P, A, O, 2
LOOP *c* DATA *t*	Begin loopback of MIRRORED BITS communications Channel *c* only for *t* minutes: pass input data to receive data as in nonloopback mode.	P, A, O, 2

The relay ignores received values if you do not specify the **DATA** option. You can enter the options in any order.

LOOP R

The **LOOP R** command terminates the loopback condition on MIRRORED BITS communications channels in loopback. If you do not specify a Channel *c*, then the relay disables loopback on both channels. If you specify a channel, you can enter the options in any order.

Table 14.91 LOOP R Command

Command	Description	Access Level
LOOP R	Cease loopback on all MIRRORED BITS communications channels. (Reset the channels to normal use.)	P, A, O, 2
LOOP *c* R	Cease loopback on MIRRORED BITS communications Channel *c*. (Reset Channel *c* to normal use.)	P, A, O, 2

MAC

The **MAC** command returns the Media Access Control (MAC) addresses of the Ethernet ports.

Table 14.92 MAC Command

Command	Description	Access Level
MAC	Display all Ethernet ports MAC addresses	1, B, P, A, O, 2

A sample **MAC** command response for a relay with the four-port Ethernet card is shown in *Figure 14.15*.

```
=>>MAC <Enter>
Port 5-1 MAC Address:  01-30-A7-00-00-01
Port 5-2 MAC Address:  01-30-A7-00-00-02
```

Figure 14.15 Sample MAC Command Response for the Two- or Four-Port Ethernet Card

A sample **MAC** command response for a relay with the five-port Ethernet card is shown in *Figure 14.16*. The first MAC address is associated with the station bus, the second with the process bus, and the third with the engineering access network.

```
=>MAC <Enter>
Port 5-1 MAC Address:  00-30-A7-00-00-03
Port 5-2 MAC Address:  00-30-A7-00-00-04
Port 5-3 MAC Address:  00-30-A7-00-00-05
=>
```

Figure 14.16 Sample MAC Command Response for the Five-Port Ethernet Card

MAP

Use the **MAP** command to view the organization of the relay database. The **MAP** command in the relay is very similar to the **MAP** command in the SEL-2020 and SEL-2030 Communications Processors.

MAP 1

The **MAP 1** command lists the relay database regions. Typical database region names are LOCAL, METER, DEMAND, TARGET, HISTORY, BREAKER, STATUS, and ANALOGS.

Table 14.93 MAP 1 Command

Command	Description	Access Level
MAP 1	List the database regions in the relay.	1, B, P, A, O, 2

MAP 1 region and MAP 1 region BL

Use the **MAP 1** command with the region option to view the layout of a specific region.

Table 14.94 MAP 1 region Command

Command	Description	Access Level
MAP 1 *region*	List the data labels, database address, and data type.	1, B, P, A, O, 2
MAP 1 *region* BL	List the data labels, database address, and data type; list the bit labels, if assigned.	1, B, P, A, O, 2

The *region* option is the database region name shown in the simple **MAP 1** command response. The region map consists of columns for data item labels, database address, and data type.

If you specify the **BL** option and the region contains items with bit labels, the relay lists these bit labels in MSB (most significant bit) to LSB (least significant bit) order. The TARGET region is usually the only region containing bit labels.

METER

The **METER** command displays reports about quantities the relay measures in the power system (voltages, currents, frequency, remote analogs, and so on) and internal relay operating quantities (math variables and synchronism-check values).

All SEL-400 series relays support a **METER** command, but the options and responses are device specific. See the product-specific instruction manual for details of the **METER** command. Included below are the variants of the **METER** command that are common.

MET AMV

The **MET AMV** command lists automation math variables.

Table 14.95 MET AMV Command

Command	Description	Access Level
MET AMV	Display all automation math variables.	1, B, P, A, O, 2
MET AMV *k*	Display all automation math variables successively for *k* times.	1, B, P, A, O, 2

The relay displays three places after the decimal point for these numerals. The relay shows variables with absolute value greater than 99999.999 or less than 0.100 as scientific notation (for example, –1.002E+22).

MET ANA

Use the **MET ANA** command to view the analog quantities from the MIRRORED BITS communications channels.

Table 14.96 MET ANA Command

Command	Description	Access Level
MET ANA	Display the MIRRORED BITS communications analog quantities.	1, B, P, A, O, 2
MET ANA *k*	Display the MIRRORED BITS communications analog quantities successively for *k* times.	1, B, P, A, O, 2

If you have not enabled the MIRRORED BITS communications channels and the remote analog data, the relay response to this command will not include any values. If MIRRORED BITS communications is enabled but not communicating, the relay will display `ERROR` under the `RMBA` or `RMBB` entries, depending on settings.

MET BAT

Use the **MET BAT** command to view the station dc monitor quantities for the battery voltages.

NOTE: Some relays provide one battery monitor channel and some support two.

Table 14.97 MET BAT Command

Command	Description	Access Level
MET BAT	Display station battery measurements.	1, B, P, A, O, 2
MET BAT *k*	Display station battery measurements successively for *k* times.	1, B, P, A, O, 2
MET RBM	Reset station battery measurements.	P, A, O, 2

If you have not enabled the Station DC Battery Monitor, the relay responds with `DC Monitor Is Not Enabled`. (Enable the dc monitor with the Global setting EDCMON.)

The reset command, **MET RBM**, resets the dc monitor maximum/minimum metering quantities. When you issue the **MET RBM** command, the relay responds with `Reset Max/Min Battery Metering (Y/N)?`. If you answer **Y <Enter>**, the relay responds, `Max/Min Battery Reset`.

MET D

Use the **MET D** command to view the demand and peak demand quantities.

NOTE: Not all SEL-400 series relays support demand metering.

Table 14.98 MET D Command

Command	Description	Access Level
MET D	Display demand metering data.	1, B, P, A, O, 2
MET D *k*	Display demand metering data successively for *k* times	1, B, P, A, O, 2
MET RD	Reset demand metering data.	P, A, O, 2
MET RP	Reset peak demand metering data.	P, A, O, 2

The reset command (**MET RD**) resets the demand metering quantities. When you issue the **MET RD** command, the relay responds, `Reset Demands (Y/N)?`. If you answer **Y <Enter>**, the relay responds, `Demands Reset`.

The reset command, **MET RP**, resets the peak demand metering quantities. When you issue the **MET RP** command, the relay responds, `Reset Peak Demands (Y/N)?`. If you answer **Y <Enter>**, the relay responds, `Peak Demands Reset`.

MET M

Use the **MET M** command to view power system maximum and minimum quantities.

NOTE: Not all SEL-400 series relays support maximum/minimum metering.

Table 14.99 MET M Command

Command	Description	Access Level
MET M	Display maximum/minimum metering data.	1, B, P, A, O, 2
MET M *k*	Display maximum/minimum metering data successively for *k* times.	1, B, P, A, O, 2
MET BK*n*[a] M	Display Breaker *n* maximum/minimum metering data.	1, B, P, A, O, 2
MET BK*n* M *k*	Display Breaker *n* maximum/minimum metering data successively for *k* times.	1, B, P, A, O, 2
MET RM	Reset maximum/minimum metering data.	P, A, O, 2

[a] Parameter n is the breaker indication.

The reset command, **MET RM**, resets the maximum/minimum metering quantities. When you issue the **MET RM** command, the relay responds, `Reset Max/Min Metering (Y/N)?` If you answer **Y <Enter>**, the relay responds, `Max/Min Reset`.

MET PM

Use the **MET PM** command to view the time-synchronized quantities. The relay must be in the high-accuracy timekeeping HIRIG or HPTP mode. For more information on high-accuracy timekeeping, see *Section 11: Time and Date Management*.

NOTE: Not all SEL-400 series relays support synchrophasors.

Table 14.100 MET PM Command

Command	Description	Access Level
MET PM	Display time-synchronized values.	1, B, P, A, O, 2
MET PM *k*	Display time-synchronized values successively for *k* times.	1, B, P, A, O, 2
MET PM *time*	Display time-synchronized values captured at trigger *time*.	1, B, P, A, O, 2
MET PM HIS	Display time-synchronized values captured for the previous **MET PM** command.	1, B, P, A, O, 2

If the relay is not in the high-accuracy IRIG (HIRIG) timekeeping mode, it will respond to the **MET PM** command with the following message:

```
Aborted: A High Accuracy Time Source is Required
```

If Global enable setting EPMU := N, the relay will respond to the **MET PM** command with:

```
Synchronized phasor measurement is not enabled
```

To request a report of the synchrophasor data at a specific time, enter the optional *time* parameter as a time of day. For example, the relay will respond to the **MET PM 16:40:10** command with:

```
Synchronized Phasor Measurement Data Will Be Displayed at
16:40:10.000
```

In this example, when the internal clock reaches 16:40:10.000, the relay will display the synchrophasor data from that exact time. If the relay is not in HIRIG mode at that time, it will display the following message:

```
Aborted: A High Accuracy Time Source is Required
```

After the **MET PM *time*** command is issued, other **MET PM** commands may be entered without affecting the timed request, even if the stated time has not arrived. However, issuing a second **MET PM *time*** command while the first command is still pending will cancel the first command request in favor of the newer request.

If you are not connected to the relay when the **MET PM *time*** command issues its timed response, you can use the **MET PM HIS** command to view this response. This permits you to issue **MET PM *time*** to multiple relays by using a common time and then go back later to see the results from all the relays at this common instant in time.

See *Section 18: Synchrophasors* for more information on phasor measurement functions, and *View Synchrophasors by Using the MET PM Command on page 18.21* for sample **MET PM** responses.

MET PMV

Use the **MET PMV** command to view the protection math variables.

Table 14.101 MET PMV Command

Command	Description	Access Level
MET PMV	Display all protection math variables.	1, B, P, A, O, 2
MET PMV *k*	Display all protection math variables.	1, B, P, A, O, 2

The relay displays three places after the decimal point for these numerals. The relay shows variables with absolute value greater than 99999.999 or less than 0.100 as scientific notation (for example, –1.002E+22).

MET RTC

Use the **MET RTC** command to view the data received on all active synchrophasor client channels.

Table 14.102 MET RTC Command

Command	Description	Access Level
MET RTC	Display received synchrophasor client data	1, B, P, A, O, 2
MET RTC *k*	Display received synchrophasor client data *k* times	1, B, P, A, O, 2

MET T

Use the **MET T** command to view the temperature data from the SEL-2600A RTD Module. This command requires setting PROTO = RTD for the serial port connected to the SEL-2600A RTD Module.

NOTE: Some SEL-400 series relays use the option MET RTD to get this same information.

Table 14.103 MET T Command

Command	Description	Access Level
MET T	Display as many as 12 temperature analog values from the SEL-2600A RTD Module.	1, B, P, A, O, 2
MET T *k*	Display as many as 12 temperature analog values from the SEL-2600A RTD Module successively for *k* times.	1, B, P, A, O, 2

NOTE: The SEL-487B does not support RTD inputs.

The relay displays the number of resistance temperature detector (RTD) channels specified by the RTDNUM Port Setting. If the RTD protocol is not enabled on any of the relay ports, the relay displays the following:

```
No data available
```

If there is a communications failure between the relay and the SEL-2600A, as indicated by the RTDCOMF Relay Word bit, the relay displays the following:

```
Communication Failure
```

If the RTDFL Relay Word bit is set to indicate a SEL-2600A failure, the relay displays the following:

```
SEL-2600 Failure
```

If any of the RTD*x*TY Port Settings are set to NA, the relay displays the following for that channel:

```
Channel Not Used
```

If the RTD*xx*ST Relay Word bit is set for any of the RTDNUM channels being reported, the relay displays the following:

```
Channel Failure
```

OACCESS

Use the **OACCESS** command to gain access to Access Level O (output). See *Access Levels and Passwords on page 3.7* for more information.

Table 14.104 OAC Command

Command	Description	Access Level
OAC	Go to Access Level O (output).	1, B, P, A, O, 2

OPEN n

Use the **OPEN *n*** command to open a circuit breaker(s). The **OPEN *n*** command pulses Relay Word bit OC*n*. Usually, you configure these Relay Word bits as part of the SELOGIC control equations that trip the appropriate circuit breaker. See *Trip Logic* in *Section 5: Protection Functions* of the product-specific instruction manual for information on trip SELOGIC control equations.

Table 14.105 OPEN n Command

Command	Description	Access Level
OPEN *n*	Pulse Relay Word bit OC*n*.	B, P, A, O, 2

If you have disabled the relay and attempt an **OPEN *n*** command, the relay responds, `Command aborted because the relay is disabled`. If the circuit breaker control enable jumper BREAKER is not in place, the relay aborts the command and responds, `Aborted: the breaker jumper is not installed`.

When you issue the **OPEN *n*** command, and the circuit breaker control enable jumper is in place, the relay responds, `Open breaker (Y/N)?`. If you answer **Y <Enter>**, the relay responds, `Are you sure (Y/N)?`. If you answer **Y <Enter>**, the relay asserts OC*n* for one processing interval.

If you have assigned auxiliary contact 52A inputs for this circuit breaker, the relay waits 0.5 seconds, checks the state of the breaker auxiliary contacts, and responds `Breaker OPEN` or `Breaker CLOSED`, as appropriate.

If Breaker *n* is not enabled, the relay responds, `Breaker n is not available`.

PACCESS

Use the **PACCESS** command to gain access to Access Level P (protection). See *Access Levels and Passwords on page 3.7* for more information.

Table 14.106 PAC Command

Command	Description	Access Level
PAC	Go to Access Level P (protection).	1, B, P, A, O, 2

PASSWORD

Use the **PASSWORD** command to control password protection for relay access levels.

PAS n

The relay changes the existing password for the specified access level that you specify when you issue the **PAS *n*** command. To change a password at any level, you must be Access Level 2.

⚠WARNING
This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private pass word may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.

Table 14.107 PAS level New_Password Command

Command	Description	Access Levels
PAS *n*[a]	Set a new password for Access Level *n*.	2

[a] Parameter n represents the relay Access Levels 1, B, P, A, O, or 2.

Relay access levels that have passwords are 1, B, P, A, O, 2, and C. Valid passwords are character sequences of as many as 12 characters. Valid characters are any printable ASCII character.

All passwords are case-sensitive. When you successfully enter a new password, the relay pulses the Relay Word bit SALARM for at least one second, and responds, `Set`.

Passwords for each access level can be disabled by setting the new password to DISABLE. When the password for a certain access level is set to DISABLE, no password is required for entering that access level in the **ACC** command, and the relay does not prompt for an old password when changing the password. The relay issues a `Password Disabled` message instead of `Password Changed` after disabling the password.

Entering **PAS *n*** and entering a new password re-enables the password requirement for that access level. SEL does not recommend disabling passwords.

PING

NOTE: The relay uses one router to route **PING** commands outside the local network. If default routers associated with station bus (DEFRTR) and engineering access (DEFRTRE) are configured, the relay sends ping requests to the router specified by the DEFRTR setting.

Use the **PING** command to determine whether the network is connected properly and other network devices are reachable.

Table 14.108 PING Command

Command	Description	Access Level
PING *addr*[a]	Send ICMP echo request messages to remote device at *addr*.	1, B, P, A, O, 2

[a] IP address of device to ping in the format of four decimal numbers (0–255) separated by periods.

When the IP address parameter is not of a valid format, the relay responds with `Invalid IP address`. After a valid **PING** command is issued, the relay sends out an Internet Control Message Protocol (ICMP) echo request messages at one second intervals until receiving a carriage return **<CR>** or five minutes elapses. A sample **PING** command response is shown in *Figure 14.17*.

```
=>>PING 192.9.201.1 <Enter>

Pinging 192.9.201.1
Press <Enter> to Terminate Ping Test.

Ping Echo Message Received.
Ping Echo Message Received.
Ping Echo Message Received.
Ping Echo Message Received.


Ping Results:

   Number of Ping Messages:
      Transmitted:   4
      Received:      4

   Elapsed Time:    11 seconds

=>>
```

Figure 14.17 Sample PING Command Response

PORT

The **PORT** command can be used to connect to a remote relay.

PORT p

The **PORT *p*** command connects a relay serial port to another device through a virtual terminal session.

NOTE: The BAY1 and BAY2 options only apply to relays that support 87L communications and have the corresponding bay card installed.

In the relay, serial port virtual terminal capability is available in MIRRORED BITS communications. You must have previously configured the serial port for MIRRORED BITS communications operation, set port setting MBNUM less than 8, and have at least one virtual terminal session available (set MBNUMVT to 0 or greater). Choosing MBNUMVT to 0 uses virtual terminal within the synchronization channel only. See *SEL MIRRORED BITS Communication on page 15.36* for information on the MIRRORED BITS communications protocol.

Table 14.109 PORT p Command

Command	Description	Access Level
PORT *p*[a]	Connect to a remote device through PORT p (over MIRRORED BITS communications virtual terminal mode).	1, B, P, A, O, 2

[a] Parameter p is 1, 2, 3, and F to indicate Communications PORT 1 – PORT 3 and PORT F, or BAY1 or BAY2 for 87L ports.

When the relay establishes a connection, the relay responds, `Transparent session to Port p established`. To quit the transparent connection, type the control string that you specify in port setting TERSTRN; the default is **<Ctrl+E>**. Only one transparent port connection to each MIRRORED BITS communications port is possible at one time. If you issue a **PORT *p*** command when the selected session is already active, the relay responds, `Transparent session already in use`.

If you issue the **PORT *p*** command to **PORT 1**, **PORT 2**, **PORT 3**, **PORT F**, **BAY 1**, or **BAY 2** (87L ports) and you have not properly configured the MIRRORED BITS communications port, the MBNUMVT is not set to 1 or larger, `Invalid destination port`.

PORT KILL n

It is possible to forcefully disconnect a transparent session from another port (a port not involved in the present transparent connection) by using the **PORT KILL *n*** command (shown in *Table 14.110*).

Table 14.110 PORT KILL n Command

Command	Description	Access Level
PORT KILL *n*[a]	Terminate the virtual terminal connection with a remote device through port *n* by using a port not involved in the connection.	P, A, O, 2

[a] Parameter n is 1, 2, 3, F, BAY1, or BAY2 (for 87L ports) to indicate Communications Ports 1, 2, 3, or F, BAY1, or BAY2; n is not the present port.

The port parameter *n* can refer to either of the ports involved in the session you want to kill. When you issue the **PORT KILL *n*** command, the relay responds, `Kill connection between ports m and n (Y/N)?` Answer **Y <Enter>** to terminate the connection. The relay sends a character sequence to the remote relay (to make sure the remote device is left in a known state) and responds, `Connection between ports m and n disconnected`.

PROFILE

Use the **PROFILE** command (**PRO**) to access the Signal Profile data for as many as 20 user selectable analog values.

Table 14.111 PRO Command (Sheet 1 of 2)

Command	Description	Access Level
PRO	Displays the first 20 rows of the profile report, with the oldest row at the top and the latest row at the bottom.	1, B, P, A, O, 2
PRO *m*	Displays the first *m* rows of the report, with the oldest row at the top and the latest row at the bottom.	1, B, P, A, O, 2
PRO *m n* (*m* > *n*)	Displays the row between *m* and *n*, (including *m* and *n*) with the oldest row at the top and the latest row at the bottom.	1, B, P, A, O, 2
PRO *date1*	Displays all the rows that were recorded on that date, with the oldest row at the top and the latest row at the bottom.	1, B, P, A, O, 2
PRO *date1 date2*	Displays all the rows that were recorded on and between (including) *date1* and *date2* (*date1* chronologically precedes *date2*, with the oldest row (*date1*) at the top and the latest row (*date2*) at the bottom.	1, B, P, A, O, 2
PRO *date2 date1*	Displays all the rows that were recorded on and between (including) *date1* and *date2* (*date2* chronologically precedes *date1*, with the oldest row (*date2*) at the top and the latest row (*date1*) at the bottom.	1, B, P, A, O, 2

Table 14.111 PRO Command (Sheet 2 of 2)

Command	Description	Access Level
PRO D	Displays, for each port, the maximum number of days data may be acquired with the present settings before data overwrite occurs.	1, B, P, A, O, 2
PRO C or R	Clears the signal profile data from nonvolatile memory on a per-port basis. The data are still visible to other ports and to file transfer accesses and is cleared independently for those points-of-view.	B, P, A, O, 2
PRO CA or RA	Completely clears all signal profile data from nonvolatile memory.	P, A, O, 2

PULSE

Use the **PULSE OUT*nnn*** command to pulse any of the relay control outputs for a specified time. This function aids you in relay testing and commissioning. If the output is open, the **PUL** command momentarily closes the output; if the output is closed, the **PUL** command momentarily opens the output. The control outputs are **OUT*nnn***, where *nnn* represents the 100-series, 200-series, 300-series, 400-series, and 500-series addresses.

Table 14.112 PUL OUTnnn Command

Command	Description	Access Level
PUL OUT*nnn*[a]	Pulse output OUT*nnn* for 1 second.	B, P, A, O, 2
PUL OUT*nnn s*[b]	Pulse output OUT*nnn* for *s* seconds.	B, P, A, O, 2

[a] Parameter nnn is a control output number.
[b] Parameter s is time in seconds, with a range of 1–30.

If the circuit breaker control enable jumper BREAKER is not in place, the relay aborts the command and responds, `Aborted: the breaker jumper is not installed`.

NOTE: The **PULSE** command does not update the OUTnnn Relay Word bit when it is used in other SELOGIC control equations. If the output Relay Word bit is assigned to another SELOGIC setting, the SER will report that OUTnnn asserted, but the corresponding SELOGIC setting will not be updated.

When you issue the **PUL** command and the breaker jumper is in place, the relay responds, `Pulse contact OUTnnn for s seconds (Y/N)?`. If you answer **Y <Enter>**, the relay asserts OUT*nnn* for the time you specify.

During the **PUL** operation, the Relay Word bit corresponding to the control output you specified (OUT*nnn*) asserts; Relay Word bit TESTPUL also asserts during any **PUL** command, so you can monitor pulse operation by programming TESTPUL into event triggers and alarm outputs.

QUIT

Use the **QUIT** command to revert to Access Level 0 (exit relay control).

Table 14.113 QUIT Command

Command	Description	Access Level
QUIT	Go to Access Level 0 (exit relay control).	0, 1, B, P, A, O, 2

Access Level 0 is the lowest access level; the relay performs no password check to descend to this level (or remain at this level).

In a Telnet session, **QUIT** terminates the connection.

RTC

Use the **RTC** command to display a description of all data being received on synchrophasor client channels. This report will list the analog quantity and Relay Word bits the data gets stored in locally, matched up with a label provided by the sending PMU. Use this information as aid to understanding the local values.

NOTE: Not all SEL-400 series relays support synchrophasors.

Table 14.114 RTC Command

Command	Description	Access Level
RTC	Display report of all configured synchrophasor client data labels.	1, B, P, A, O, 2

SER

The **SER** command retrieves SER records. The relay SER captures state changes of Relay Word bit elements and relay conditions. Relay conditions include startup, relay enable/disable, group changes, settings changes, memory queue overflow, and SER autoremoval/reinsertion. For more information on the SER, see *Sequential Events Recorder (SER) on page 9.28*.

SER

The default order of the **SER** command is oldest to newest from list top to list bottom. You can view the SER records in numerical or date order.

Table 14.115 SER Command

Command	Description	Access Level
SER	Return the 20 most recent records from the SER, with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list.	1, B, P, A, O, 2
SER *k*	Return the *k* most recent records from the SER, with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list.	1, B, P, A, O, 2
SER *m n*[a]	Return the SER records from *m* to *n*. If *m* is greater than *n*, records appear with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list. If *m* is less than *n*, records appear with the most recent (lowest number) at the top of the list and the oldest (highest number) at the bottom of the list.	1, B, P, A, O, 2
SER *date1*[b]	Return the SER records on date *date1*.	1, B, P, A, O, 2
SER *date1 date2*[b]	Return the SER records from *date1* at the top of the list, to *date2* at the bottom of the list.	1, B, P, A, O, 2

[a] Parameters m and n indicate an SER number, which the relay assigns at each SER trigger.
[b] Enter date1 and date2 in the same format as Global setting DATE_F.

SER C and SER R

The **SER C** and **SER R** commands clear/reset the SER records for the present port. Options **C** and **R** are identical.

Table 14.116 SER C and SER R Commands

Command	Description	Access Level
SER C	Clear/reset SER records on the present port.	1, B, P, A, O, 2
SER R	Clear/reset SER records on the present port.	1, B, P, A, O, 2

The relay prompts you with `Clear the sequential events recorder for this port. Are you sure (Y/N)?` when you issue the **SER C** or **SER R** command. If you answer **Y <Enter>**, the relay clears the particular port SER records.

SER CA and SER RA

The **SER CA** and **SER RA** commands clear all SER records from memory.

Table 14.117 SER CA and SER RA Commands

Command	Description	Access Level
SER CA	Clear SER data for all ports.	P, A, O, 2
SER RA	Clear SER data for all ports.	P, A, O, 2

If you issue the **SER CA** or **SER RA** command, the relay prompts you with `Clear the sequential events recorder for all ports. Are you sure (Y/N)?` commands. If you answer **Y <Enter>**, the relay clears all SER records in nonvolatile memory.

SER CV and SER RV

The **SER CV** and **SER RV** commands clear any SER data records that have been viewed from the present port. The two commands are equivalent.

Table 14.118 SER CV or SER RV Commands

Command	Description	Access Level
SER CV	Clear viewed SER data for this port.	1, B, P, A, O, 2
SER RV	Clear viewed SER data for this port.	1, B, P, A, O, 2

If you issue the **SER CV** or **SER R**V command, the relay prompts you with `Clear viewed SER records for this port. Are you sure (Y/N)?`. If you answer **Y <Enter>**, the relay clears all SER records viewed from this port. The data are still visible to other ports and to file transfer accesses, and they must be cleared independently for those ports. Data not yet viewed remain available.

SER D

The **SER D** command shows a list of SER items that the relay has automatically removed. These are “chattering” elements. You can automatically remove chattering SER elements in the SER Chatter Criteria category of the Report settings; the enable setting is ESERDEL.

Table 14.119 SER D Command

Command	Description	Access Level
SER D	List chattering SER elements that the relay is removing from the SER records.	1, B, P, A, O, 2

If you issue the **SER D** command and you have not enabled automatic removal of chattering SER elements (Report setting ESERDEL), the relay responds, `Automatic removal of chattering SER elements not enabled`.

SET

Use the **SET** command to change relay settings. The relay settings structure is ordered and contains these items (in structure order): classes, instances, categories, and settings. An outline of the relay settings structure is as follows:

Classes (Global, Group, Breaker Monitor, Protection, Automation, Outputs, Front Panel, Report, DNP3, and Ports)

Instances (some classes have instances: Group = 1–6; Protection = 1–6; Automation = 1–10; PORTs = 1–3, F, 5)

Categories (collections of similar settings)

Settings (specific relay settings with values)

The **SET** and **SHOW** commands contain these settings structure items, which you must specify in order from class to instance (if applicable) to setting. The order that specific settings appear in the relay settings structure is factory programmed.

SET

The **SET** command with no options or parameters accesses the relay settings Group class and the instance corresponding to the active group. To set a different instance, specify the instance number (1–6).

Table 14.120 SET Command Overview (Sheet 1 of 2)

Command[a]	Description	Access Level
SET	Set the Group relay settings, beginning at the first setting in the active group.	P, 2
SET *n*	Set the Group *n* relay settings, beginning at the first setting *n* each instance.	P, 2
SET *label*	Set the Group relay settings, beginning at the active group setting label *label*.	P, 2
SET *n label*	Set the Group n relay settings, beginning at setting label *label*.	P, 2
SET *c*	Set class *c*, using the default instance beginning at the first setting.	P,A,O,2

Table 14.120 SET Command Overview (Sheet 2 of 2)

Command[a]	Description	Access Level
SET *c i*	Set class *c*, instance *i*, beginning at the first setting.	P,A,O,2
SET *c i label*	Set class *c*, instance *i*, beginning at setting *label.*	P,A,O,2

[a] Parameter n = 1–6, representing Group 1–6.
c = settings class (relay specific).
i = class instance (choices depends on the class).

The specific classes and instances available depends on the relay. See the relay-specific instruction manual for the specific options that are available. The relay validates your settings entries as you enter each setting. At the end of a settings instance session, the relay responds with a readback of all the settings in the settings instance, then prompts you with `Save settings (Y,N)?`. If you answer **Y <Enter>**, the relay pulses the Relay Word bit SALARM, and responds, `Saving Settings, Please Wait..........` The relay saves the new settings, then responds, `Settings Saved`. If you answer **N <Enter>** to the save settings prompt, the relay responds, `Settings aborted`.

SET TERSE

Use the **TERSE** option to inhibit the relay from sending the settings class or instance readback when you end a settings session. SEL recommends that you use the **TERSE** option sparingly; you should review the readback information to confirm that you have entered the settings that you intended.

Table 14.121 SET TERSE Command Examples

Command	Description	Access Level
SET TERSE	SET Group relay settings for the active group, beginning at the first setting in this instance; omit settings readback.	P, 2
SET 3 TE[a] ***label***	SET Group 3 settings, beginning at the settings label *label*; omit settings readback.	P, 2
SET P *p label* TERSE	Set the communications port relay settings for **PORT** p, beginning at the settings label *label*; omit readback.	P, A, O, 2

[a] TERSE may be entered as TE, as shown in this example.

You can use the **TERSE** option in any **SET** command at any position after typing **SET**. When you end the settings edit session, the relay responds, `Save settings (Y,N)?`. If you answer **Y <Enter>**, the relay pulses the Relay Word bit SALARM, and responds, `Saving Settings, Please Wait...........` The relay saves the new settings, then responds, `Settings Saved`. If you answer **N <Enter>** to the save settings prompt, the relay responds, `Settings aborted`.

SHOW

The **SHOW** command shows the relay settings. When showing settings, the relay displays the settings label and the present value from nonvolatile memory.

The relay organizes settings in classes, instances, categories, and specific settings; see *SET on page 14.58* for information on settings organization. The relay displays each setting in the order specified in the settings tables. When you are using a terminal and you specify a setting in the middle of a settings category, the relay displays the category title, then proceeds with the class or instance settings from the setting that you specified.

Table 14.122 SHO Command Overview

Command[a]	Description	Access Level
SHO	Show the Group relay settings, beginning at the first setting in the active group.	1, B, P, A, O, 2
SHO *n*	Show the Group *n* relay settings, beginning at the first setting in each instance.	1, B, P, A, O, 2
SHO *label*	Show the Group relay settings, beginning at the active Group settings label *label*.	1, B, P, A, O, 2
SHO *n label*	Show the Group *n* relay settings, beginning at the settings label *label*.	1, B, P, A, O, 2
SHO *c*	Show class *c* using the default instance beginning at the first setting.	P, A, O, 2
SHO *c i*	Show class *c*, instance *i* beginning at the first setting.	P, A, O, 2
SHO *c i label*	Show class *c*, instance *i*, beginning at setting *label*.	P, A, O, 2

[a] Parameter n = 1–6, representing Group 1–6.
c = settings class (relay specific).
i = class instance (choices depends on the class).

SNS

In response to the **SNS** command, the relay sends the names of the SER elements. This is a comma-delimited string used to support the SEL Fast SER report.

Table 14.123 SNS Command

Command	Description	Access Level
SNS	Send the names of SER elements.	0, 1, B, P, A, O, 2

STATUS

The **STATUS** command reports relay status information that the relay derives from internal diagnostic routines and self-tests. See *Relay Self-Tests on page 10.19* for information on relay diagnostics.

STA

The **STA** command with no options displays a short-form relay status report. Items in the STA report are the header, failures, warnings, SELOGIC control equation programming environment errors, and relay operational status. See *Checking Relay Status on page 3.13* for information on relay status reports.

Table 14.124 STA Command

Command	Description	Access Level
STA	Return the relay status.	1, B, P, A, O
STA	Return the relay status and show a new hardware configuration prompt.	2

If you change an I/O interface board, the relay detects the new configuration and initiates a status warning. When you issue the **STA** command at Access Level 2, the relay responds to this situation with `Accept new hardware configuration (Y/N)?`. If you answer **Y <Enter>**, the relay responds, `New configuration accepted`. If you answer **N <Enter>**, the relay responds, `Command aborted`.

STA A

Use the **STA A** command to view the entire relay status report. Items in the full status report include the short-form status report items plus data on A/D (analog/digital) channel offsets, power supply voltages, temperature, communications interfaces, time-source synchronization, IEC 61850 Mode/Behavior, and IEC 61850 Simulation Mode.

Table 14.125 STA A Command

Command	Description	Access Level
STA A	Display all items of the status report.	1, B, P, A, O, 2

STA C and STA R

The **STA C** and **STA R** commands restart the relay. Thus, these commands clear a transient failure should this unlikely event occur. Options **C** and **R** are identical. Contact your Technical Service Center or the SEL Factory before using this command.

Table 14.126 STA C and STA R Command

Command	Description	Access Level
STA C	Reset the relay.	2
STA R	Reset the relay.	2

STA S

Use the **STA S** command to view all SELOGIC control equation storage and execution capacity and operating errors.

Table 14.127 STA S Command

Command	Description	Access Level
STA S	Display detailed SELOGIC control equation error information.	1, B, P, A, O, 2

STA SC and STA SR

The **STA SC** and **STA SR** commands clear/reset the SELOGIC control equation operating errors from the status report if the errors are no longer present. In addition, these commands reset the Automation SELOGIC Peak and Average Execution Cycle Time statistics.

Table 14.128 STA SC and STA SR Command

Command	Description	Access Level
STA SC	Clear SELOGIC control equation errors and reset SELOGIC cycle time statistics.	P, A, O, 2
STA SR	Clear SELOGIC control equation errors and reset SELOGIC cycle time statistics.	P, A, O, 2

STA T

NOTE: The **STA T** command is only available in TiDL relays that support T-Protocol.

In the **STA T** command, SEL-TMU type (1 or 2) is indicated. SEL-TMU type indicates the following:

1: 4CT/4PT SEL-TMU

2: 8CT SEL-TMU

Use the **STA T** command to view the status of the TiDL ports of your relay and connected SEL-TMUs.

Table 14.129 STA T Command

Command	Description	Access Level
STA T	Display TiDL system status	1, B, P, A, 0, 2

Table 14.130 shows the error messages that could be displayed and the appropriate action.

Table 14.130 STA T SEL-TMU Error Messages and User Action

Error Message	User Action
SFP NOT INSTALLED	Port is mapped but has no SFP transceiver installed. Install a compatible transceiver in that port.
SFP NOT COMPLIANT	An SFP transceiver is connected to a mapped port but could not be authenticated because it is not compatible. See *Table 15.7* or selinc.com/products/sfp for a list of compatible SFP transceivers.
TMU STREAM LOSS	Check the SEL-TMU and fiber connections. If the issue persists, issue the **VEC** command and contact SEL technical support.
WRONG TMU CONNECTED	The SEL-TMU connected to the port does not match what is expected according to the current commissioned system. Reconnect the appropriate SEL-TMU to this port.
TMU ERROR	Issue the **VEC** command, and contact SEL technical support.
BAD TMU DATA	Issue the **VEC** command, and contact SEL technical support.
CHANNEL DELAY EXCEEDED	Issue the **VEC** command, and contact SEL technical support.
TMU RX ERROR	Check the SEL-TMU and fiber connections. If the issue persists, issue the **VEC** command and contact SEL technical support.

SUMMARY

The **SUMMARY** command displays a summary event report. See *Event Summary on page 9.26* for information on summary event reports.

SUM

Use the **SUM** command to view the event summary reports in the relay memory.

Table 14.131 SUM Command

Command	Description	Access Level
SUM	Return the most recent event summary.	1, B, P, A, O, 2
SUM *n*[a]	Return an event summary for event *n*.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number; see the event history report (HIS on page 14.42 command).

When parameter *n* is 1–9999, *n* indicates the order of the event report. The most recent event report is 1, the next most recent report is 2, and so on. When parameter *n* is 10000–42767, *n* indicates the absolute serial number of the event report.

SUM ACK

Use **SUM ACK** to acknowledge an event summary that you recently viewed with the **SUM NEXT** command on the present communications port. Acknowledge the oldest summary (specify no event number).

Table 14.132 SUM ACK Command

Command	Description	Access Level
SUM ACK	Acknowledge the oldest unacknowledged event summary at the present communications port.	1, B, P, A, O, 2

If you attempt to acknowledge an event summary that you have not viewed on the present port with the **SUM NEXT** command, the relay responds, `Event summary number n has not been viewed with the NEXT option`.

SUM NEXT

Use the **SUM N** command to view the oldest (next) unacknowledged event summary.

Table 14.133 SUM N Command

Command	Description	Access Level
SUM N	View the oldest unacknowledged event summary at the present communications port.	1, B, P, A, O, 2

TARGET

The **TARGET** command displays the elements for a selected row in the Relay Word bit table.

TAR

Use the **TAR** command to view a row of Relay Word bit elements or aliases. When using the **TAR** command, you can specify the row number or element name.

Table 14.134 TAR Command

Command	Description	Access Level
TAR	Display target Row 0 or display the most recently viewed target row.	1, B, P, A, O, 2
TAR *n*	Display target Row *n*.	1, B, P, A, O, 2
TAR *n k*[a]	Display target Row *n* and repeat for *k* times; the repeat count *k* must follow the row number.	1, B, P, A, O, 2
TAR *name*	Display the target row with the element name *name*.	1, B, P, A, O, 2
TAR *name k*	Display the target row with the element name *name* and repeat for *k* times; the repeat count *k* can be before or after the name option.	1, B, P, A, O, 2

[a] Parameter k is the repeat count from 1–32767.

The relay memorizes the latest target row input conditioned by your present access level. The relay displays Row 0 if you have not specified a row since the relay was turned on, the access level has timed out, or you have issued the **QUIT** command.

If you specify the repeat count k at a number greater than 8, the relay displays the repeated target rows on the terminal screen in groups of eight, with the target row elements listed above each grouping.

TAR ALL

Use the **TAR ALL** command to display all of the relay targets.

Table 14.135 TAR ALL Command

Command	Description	Access Level
TAR ALL	Display all target rows.	1, B, P, A, O, 2

TAR R

The **TAR R** command has two functions. Use this command to reset any latched relay targets resulting from a tripping event. Also employ the **TAR R** command to reset to Row 0 the memorized target row that the relay reports when you issue a simple **TAR** command.

Table 14.136 TAR R Command

Command	Description	Access Level
TAR R	Reset latched targets and return memorized row to Row 0.	1, B, P, A, O, 2

TAR X

Use the **TAR X** command to view a different target row in the Relay Word bit table than the target row in the target row repeat memory. This function is useful for relay testing. See *Testing With Relay Word Bits on page 10.7* for more information.

Table 14.137 TAR X Command

Command[a]	Description	Access Level
TAR *n* X	Display target Row *n*, but do not memorize Row *n*.	1, B, P, A, O, 2
TAR X *n k*	Display target Row *n* and repeat for *k* times, but do not memorize Row *n*. The repeat count *k* must follow the row number.	1, B, P, A, O, 2
TAR *name* X	Display the target row with the element name *name*, but do not memorize the row *n*umber.	1, B, P, A, O, 2
TAR *name* X *k*	Display the target row with the element name *name* and repeat for *k* times, but do not memorize the row number. The repeat count *k* can be at any position in the command after **TAR**.	1, B, P, A, O, 2

[a] Parameter k is the repeat count from 1–32767.

You can place the **X** option at any position in the **TAR** command.

TEC

Enter the **TEC** (time-error calculation) command to display the present time-error estimate and the status of the time-error control equations, and to modify the time-error correction value.

NOTE: Not all SEL-400 series relays support the **TEC** command.

Table 14.138 TEC Command

Command	Description	Access Level
TEC	Display time-error data.	1, B, P, A, O, 2
TEC *n*	Preload time-error correction value *n*, where –30.000 <= *n* <= 30.000.	B, P, A, O, 2

Use the **TEC *n*** command to preload the time-error correction value, TECORR. If the value *n* is within range, the relay will prompt you with `Are you sure (Y/N)?`. If the prompt is acknowledged, the relay sets analog quantity TECORR = *n*, and asserts Relay Word bit PLDTE for approximately 1.5 cycles. The relay then displays the new TECORR value, along with the remaining **TEC** command data.

The TECORR value does not affect the TE (time-error) estimate until the LOADTE SELOGIC equation asserts.

TEST DB

The **TEST DB** command is used for testing access of the virtual device database used for Fast Message Data Access.

TEST DB

Use the **TEST DB** command to write temporary values to the virtual device database to verify the database values. The relay contains a database that describes the relay to external devices. When other devices access the relay via the Fast Message protocol, the relay appears as a virtual device described by the database. The relay is Virtual Device 1.

The virtual database is accessible to master stations of supported Fast Message protocol connected to the relay through serial communication or Ethernet network. You can therefore test the read functionality of the Fast Message protocol in the serial port or Ethernet interface with this command.

Use the **TEST DB 1** command to override any value in the relay database. You must understand the relay database structure to effectively use the **TEST DB** command. Use the **MAP** and **VIEW** commands to see the organization and contents of the database.

Values you enter in the relay database are override values. Use the **TEST DB** command to write override values in the database accessed through the Fast Message Data Access operations.

Table 14.139 TEST DB Command

Command	Description	Access Level
TEST DB	Display present override values by virtual device number and address.	1, B, P, A, O, 2
TEST DB 1 ***addr value1***	Write new data *value1* to the database at an address *addr*.	B, P, A, O, 2
TEST DB 1 ***addr value1 M D Y h m s***	Write new data value1 to the database at an address *addr* and include the provided date/time stamp *M D Y h m s*.	B, P, A, O, 2

The database address *addr* can be any legitimate decimal or hexadecimal address. (A hexadecimal address is a numeral with an “h” suffix or a “0x” prefix.)

You can enter the override value *value1* as an integer, a floating-point number (which overrides two registers), a character (which must be in single quotes), or a string (which must be in double quotes and overrides the number of registers corresponding to the length of the string).

If a date/time stamp is also provided (*M D Y h m s*), the relay will change the static state given and, for any bits being changed by this operation, queued entries will be pushed with the provided date/time stamp. If no queue is associated with the database region (determined by *addr*), the date/time stamp will be ignored.

The order that the date should be entered on the command line depends upon the DATE_F (Global) setting. For example, if DATE_F := DMY, you would enter **TEST DB 1** ***addr value D M Y h m s***.

While there are active test data, the relay asserts Relay Word bit TESTDB.

TEST DB OFF

Use the **TEST DB OFF** command to end the testing session and remove the override values. The relay returns the database registers to the pretest values.

Table 14.140 TEST DB OFF Command

Command	Description	Access Level
TEST DB OFF	Clear all override testing values from all virtual devices.	B, P, A, O, 2
TEST DB OFF 1	Clear all override testing values from Virtual Device 1 (the relay).	B, P, A, O, 2
TEST DB OFF 1 ***region***	Clear all override testing values from the region *region* in Virtual Device 1 (the relay).	B, P, A, O, 2

TEST DB2

The **TEST DB2** command is used to test DNP3 and IEC 61850 communications protocols.

TEST DB2

In addition to Fast Message Protocol, the communications protocols supported by the relay include DNP3, IEC 61850 MMS, and GOOSE. These data include both digital quantities and analog quantities.

Use the **TEST DB2** command to override any DNP3 or IEC 61850 value. The data that can be overridden include both digital and analog quantities.

Table 14.141 TEST DB2 Command

Command	Description	Access Level
TEST DB2	Display present analog and digital override names and values.	1, B, P, A, O, 2
TEST DB2 D *name1*[a] *value1*	Write the specified override value *value1* into the digital quantity *name1*.	B, P, A, O, 2
TEST DB2 A *name2*[b] *value2*	Write the specified override value *value2* into the analog quantity *name2*.	B, P, A, O, 2

[a] Digital name1 can be any Relay Word bits or additional binary input points in DNP3 map.
[b] The analog name2 is any analog available in the DNP3 reference map and any analog listed as a data source for IEC 61850 logical devices. This excludes the event summary analog inputs.

The override value *value1* can be logical 0 or logical 1 for digital and status elements. The analog *value2* can be an integer or a floating-point number.

The Relay Word bit TESTDB2 will be asserted while there are points in this test mode.

If IEC 61850 Mode/Behavior is not On, the relay will not process the **TEST DB2** command.

TEST DB2 OFF

Use the **TEST DB2 OFF** command to end the testing session and remove the override values. The relay returns the modified registers to the pretest values.

Table 14.142 TEST DB2 OFF Command

Command	Description	Access Level
TEST DB2 D OFF	Clear all digital override testing values.	B, P, A, O, 2
TEST DB2 D *name1*[a] OFF	Clear digital override testing value specified by name *name1*.	B, P, A, O, 2
TEST DB2 A OFF	Clear all analog override testing values.	B, P, A, O, 2
TEST DB2 A *name2*[b] OFF	Clear analog override testing value specified by name *name2*.	B, P, A, O, 2

[a] Digital name1 can be any Relay Word bits or additional binary input points in DNP3 map.
[b] See Section 12: Analog Quantities in the product-specific instruction manual for available analog name2.

When removing all existing digital override values, the relay responds, `Digital Overrides Removed`. If no digital override is ever configured, the `Overrides Not Found` message will be displayed. The analog override removal acknowledgment messages are similar.

If IEC 61850 Test Mode/Behavior changes from On, the **TEST DB2** command deactivates. All overrides clear and the TESTDB2 Relay Word bit deasserts.

TEST FM

NOTE: For the list of available bits to Fast Meter, see DNAME X on page 14.31.

The **TEST FM** command overrides normal Fast Meter quantities for testing purposes. You can override only “reported” Fast Meter values. For more information on Fast Meter and the relay, see *SEL Fast Meter, Fast Operate, Fast SER Messages, and Fast Message Data Access on page 15.34*.

TEST FM

Values you enter in Fast Meter storage are “override values.” Use the **TEST FM** command to display override values and write override values in the Fast Meter report.

Table 14.143 TEST FM Command

Command	Description	Access Level
TEST FM	Display present override values.	1, B, P, A, O, 2
TEST FM *label value1 value2*	Write new data *value1* and *value2* to the Fast Meter report at the item label *label*. Parameter *value2* is optional.	B, P, A, O, 2

When you display Fast Meter data overrides with the **TEST FM** command, the relay shows the item label, and override values.

To force a value, use the **TEST FM *label value1 value2*** command. The item label *label* is any analog channel label in the Fast Meter configuration (if available), any digital element label (from the **DNA** command), and any status element label (from the **BNA** command) except the TEST and FMTEST items.

The value *value1* can be logical 0 or logical 1 for digital and status elements, or a floating-point value for all meter quantities. For meter items that report a pair of values in the Fast Meter message, *value1* is the magnitude and *value2*, if provided, is the angle. If you do not specify *value2*, the relay uses an angle of 0.

When you have successfully added a new Fast Meter test value (for example, **TEST FM IA1 3.7 0.0**), the relay responds, `Override Added`.

The relay asserts Relay Word bit TESTFM while any Fast Meter override data are present in the relay.

Fast Meter Status Byte

Bits labeled TEST and FMTEST reside in the Fast Meter status byte. If any item within the Fast Meter message is in test mode, the relay sets the TEST bit. Similarly, if any item in any Fast Meter message is in test mode, the FMTEST is set in all three Fast Meter responses.

TEST FM DEM

Use the **TEST FM DEM** command to insert override values in Fast Meter demand metering.

NOTE: Not all SEL-400 series relays support demand metering. These relays will not support the **TEST FM DEM** command.

Table 14.144 TEST FM DEM Command

Command	Description	Access Level
TEST FM DEM *label value1*	Write new data value1 to the Fast Meter demand meter report at the item label *label*.	B, P, A, O, 2

TEST FM OFF

Use the **TEST FM OFF** command to remove override values. The relay returns the Fast Meter registers to the pretest values.

Table 14.145 TEST FM OFF Command

Command	Description	Access Level
TEST FM *label* OFF	Clear the override values for the Fast Meter item *label*.	B, P, A, O, 2
TEST FM OFF	Clear all override testing values from Fast Meter.	B, P, A, O, 2

When you have successfully removed a Fast Meter test value (for example, **TEST FM IA1 OFF**), the relay responds, `Override Removed`. When an attempt to remove an FM test value fails, the relay responds, `Override Not Found`. When removing all FM test values (for example, **TEST FM OFF**), the relay responds, `All Overrides Removed`.

TEST FM PEAK

Use the **TEST FM PEAK** command to insert override values in Fast Meter peak demand metering.

NOTE: Not all SEL-400 series relays support demand metering. These relays will not support the **TEST FM PEAK** command.

Table 14.146 TEST FM PEAK Command

Command	Description	Access Level
TEST FM PEAK *label value1*	Write new data *value1* to the Fast Meter peak demand meter report at the item label *label*.	B, P, A, O, 2

TEST SV

TEST SV (SEL SV Publisher)

NOTE: The **TEST SV** command is only available on SV subscriber or SV publisher models, with the exception of the SEL-487E-5 SV Publisher.

The **TEST SV** command is a SEL SV testing command. Do not confuse this with IEC 61850 Test Mode, which is enabled by PORT 5 setting E850MBC. The **TEST SV** command allows the SEL SV publisher to generate and publish test signals on all the configured SV publications. The **TEST SV** command provides a facility to test SV publishing functionality without the need for current and/or voltage sources present in the terminals of the SEL SV publisher.

Table 14.147 TEST SV Command in an SEL SV Publisher

Command	Description	Access Level
TEST SV[a]	Initiates the SV publication of test signals. When TEST SV Mode = ON, Relay Word bit SVPTST is asserted; SVPTST is deasserted otherwise.	B, P, A, O, 2
TEST SV OFF	Ends the SV publication of test signals. Relay Word bit SVPTST is cleared.	B, P, A, O, 2

[a] The test mode does not influence GOOSE or MMS functionality.

When you enable the TEST SV mode, a 15-minute timer starts. After 15 minutes, the SEL SV publisher automatically disables the TEST SV mode. This timer restarts each time the **TEST SV** command is entered. With the TEST SV mode enabled, the test bit in the quality attribute asserts in all outgoing SV publications. The mode of the device (LLN0.Mod) is not changed and it remains in normal operation mode. PubSim and Sim bits are also not modified.

Table 14.148 shows a detailed description of how the output values for the SEL SV publisher are calculated while in TEST SV mode.

Table 14.148 SV Output Values During TEST SV Mode

Physical Measurement	Description	Setting Source
CURRENT	The value for each Channel IA, IB, and IC is scaled from secondary values (Magnitude in *Table 14.149*) to primary values, in accordance with the CT ratio setting from the presently active Group settings. A-Phase starts at 0 degrees; the other phase angles are relative to the PHROT setting from the presently active Group settings. The value for Channel IN in each winding is the sum of IA, IB, and IC values.	CTRS, CTRT, CTRU, CTRW, CTRX, CTRY, CTRY1, CTRY2, CTRY3, ACTGRP, PHROT
VOLTAGE	The value for each Channel VA, VB, and VC is scaled from secondary values (Magnitude in *Table 14.149*) to primary values, in accordance with the PT ratio setting from the presently active Group settings. A-Phase starts at 0 degrees; the other phase angles are relative to the PHROT setting from the presently active Group settings. The value for Channel VN in each winding is the sum of VA, VB, and VC values.	PTRV, PTRY, PTRZ, ACTGRP, PHROT
FREQUENCY	The value for the frequency corresponds to the NFREQ setting.	NFREQ
PHASE ROTATION	The phase sequence corresponds to the PHROT setting.	PHROT

Table 14.149 shows the secondary values used while the SEL SV publisher is in TEST SV mode.

Table 14.149 Secondary Values Used During TEST SV Mode

IEC Notation	SEL Notation	Magnitude (RMS)		Angle (degrees)	
		5A	1A	ABC ROT	ACB ROT
I1	IA	5	1	0	0
I2	IB	5	1	–120	120
I3	IC	5	1	120	–120
I4	IN	0	0	0	0
V1	VA	67	67	0	0
V2	VB	67	67	–120	120
V3	VC	67	67	120	–120
V4	VN	0	0	0	0

When you enable or disable the SEL TEST SV mode, the SV publications are disabled momentarily, causing a brief interruption in the outgoing SV publications.

If the PORT 5 SV settings are not in use and no SV publications are configured in the CID file when the **TEST SV** command is issued, the relay responds with `Cannot enter test mode. No SV publications configured.`

You cannot use the **TEST SV** command if IEC 61850 Test Mode is enabled and active mode is not on.

TEST SV (SEL SV Subscriber)

The **TEST SV** command provides a facility to test SV functionality. The **TEST SV** command allows the SEL SV subscriber to accept SV test messages on all the configured SV subscriptions.

Table 14.150 TEST SV Command in an SEL SV Subscriber

Command	Description	Access Level
TEST SV[a]	Instructs the SEL SV subscriber to accept SV test messages. When TEST SV Mode = ON, Relay Word bit SVSTST is asserted; SVSTST is deasserted otherwise.	B, P, A, O, 2
TEST SV OFF	Instructs the SEL SV subscriber to reject the received SV messages with the test bit of the quality attribute asserted. Relay Word bit SVSTST is cleared.	B, P, A, O, 2

[a] The Test mode does not influence GOOSE or MMS functionality.

When you enable the TEST SV mode, a 15-minute timer starts. After 15 minutes, the SEL SV subscriber automatically disables the TEST SV mode. This timer restarts each time the **TEST SV** command is entered.

If the PORT 5 SV settings are not in use and no SV subscriptions are configured in the CID file when the **TEST SV** command is issued, the relay responds with `Cannot enter test mode. No SV subscriptions configured.`

Considerations for an SEL SV Subscriber During TEST SV Mode

The SEL SV subscriber will process and execute all the associated protection logic, operating in the same way as if the SEL SV subscriber were receiving valid SV messages.

The SEL SV subscriber will continue to accept incoming SV messages that do not have the TEST bit of the quality attribute asserted.

For TEST SV mode to function, the IEC 61850 Mode/Behavior must be On.

TIME

Use the **TIME** command to view and set the relay time clock. The ASCII interface is just one source by which you can set the internal clock. Other sources can override the ASCII **TIME** command; overriding occurs in HIRIG time mode, IRIG time mode, and when using DNP3. See *Section 11: Time and Date Management* for more information on configuring time functions.

TIME

The **TIME** command returns information about the internal relay clock. You can also set the clock to local time if you specify hours and minutes (seconds data are optional). Separate the hours, minutes, and seconds with colons, semicolons, spaces, commas, or slashes.

```
=>>TIME <Enter>
local: 16:48:33     UTC: 23:48:33     UTC Offset: -07.0 hrs
```

If a valid IRIG-B, PTP, or SNTP signal is connected to the relay, the **TIM** command cannot be used to set the relay time.

Table 14.151 TIME Command

Command	Description	Access Level
TIME	Display the present relay internal clock time, in three formats: local, UTC, and UTC offset.	1, B, P, A, O, 2
TIME *hh:mm*	Set the relay internal clock to *hh:mm*.	1, B, P, A, O, 2
TIME *hh:mm:ss*	Set the relay internal clock to *hh:mm:ss*.	1, B, P, A, O, 2

Use the **TIME *hh:mm*** and **TIME *hh:mm:ss*** commands to set the relay internal clock time. The value *hh* is for hours from 0–23, the value *mm* is for minutes from 0–59, and the value *ss* is for seconds from 0–59. If you enter a valid time, the relay updates and saves the time in the nonvolatile clock, and displays the time you just entered. If you enter an invalid time, the relay responds, `Invalid Time`.

TIME Q

The **TIME Q** command returns detailed information on the relay internal clock. Use this command to query the status of high-accuracy time source inputs and the present clock time mode.

Table 14.152 TIME Q Command

Command	Description	Access Level
TIME Q	Display detailed information about the internal relay clock; query relay time.	1, B, P, A, O, 2

When you issue the **TIME Q** command, the relay reports statistics on the relay time sources. These statistics include the present time source and the last time value update source (see *TIME Q Command on page 11.8*).

```
=>TIME Q <Enter>

Station A                                  Date: 03/17/2023  Time: 23:04:16.336
Relay 1                                    Serial Number: 1230769999


Time Source: HIRIG
Last Update Source: HIRIG

IRIG Time Quality:   0.000 ms

Time Mark Period:   999.990539 ms

Internal Clock Period:  20.000006 ns
```

Figure 14.18 Sample TIME Q Command Response With IRIG

```
=>>TIME Q <Enter>

Relay 1                                    Date: 03/17/2023  Time: 15:08:41.468
Station A                                  Serial Number: 1230769999


Time Source: HPTP
Last Update Source: HPTP

Grandmaster Clock Quality
    Clock Class : Synchronized with PTP timescale (6)
    Time Traceable : TRUE
    Clock Accuracy : Within 25 ns
    Offset Log Variance : 0

Time Mark Period:  1000.000061 ms

Internal Clock Period:  19.999935 ns
```

Figure 14.19 Sample Time Q Command Response With PTP

TIME DST

In response to the **TIME DST** command, the relay displays local time, UTC time and UTC Offset, followed by daylight-saving time rules and information.

```
=>>TIME DST <Enter>
local: 11:28:19     UTC: 18:28:19     UTC Offset: -07.0 hrs


Daylight Savings Time Begin Rule: 2nd Sunday of March at 02:00
Daylight Savings Time End Rule: 1st Sunday of November at 02:00


Daylight Savings Time Presently Active

Next Daylight Savings Time Beginning: 03/11/2012 02:00
Next Daylight Savings Time Ending: 11/06/2011 02:00
=>>
```

Table 14.153 TIME DST Command

Command	Description	Access Level
TIME DST	Daylight-saving time rules and information	1, B, P, A, O

TRIGGER

The **TRIGGER** command initiates data captures for high-resolution oscillography and event reports. For information on high-resolution oscillography and event reports see *Triggering Data Captures and Event Reports on page 9.7*.

Use the **TRI** command to trigger the relay to record data for high-resolution oscillography and event reports.

Table 14.154 TRI Command

Command	Description	Access Level
TRI	Trigger relay data capture.	1, B, P, A, O, 2

When you issue the **TRI** command, the relay responds, `Triggered`. If the event did not trigger within 1 second, the relay responds, `Did not trigger`.

VECTOR

The **VECTOR** command displays information useful to the factory for troubleshooting purposes.

Use the **VEC** command to view diagnostic information recorded by the relay. In TiDL relays, you can also view the diagnostic information of connected SEL-TMUs.

Table 14.155 VEC Command

Command	Description	Access Level
VEC	Report relay internal diagnostics information.	2

VERSION

The **VERSION** command displays the relay hardware and software configuration.

Use the **VER** command to list the part numbers, serial numbers, checksums, software release numbers, and other important relay configuration information.

Table 14.156 VER Command

Command	Description	Access Level
VER	Display the hardware and software configurations.	1, B, P, A, O, 2

When you issue the **VER** command, the relay displays the latest release numbers for various items, typically including:

- FID
- CID
- Part number
- Serial number
- SELBOOT BFID
- Main board memory types and sizes
- Front-panel hardware
- Analog inputs ratings
- Interface board inputs and outputs
- Bay cards
- Extended relay features list

A sample **VER** command response is shown in *Figure 14.20*.

```
=>VER <Enter>
FID=SEL-451-6-R404-V0-Z104102-D20230317
CID=XXXX
Part Number:  04516XX0X600XE9H4C4XXXXXX
Serial Number:  1230769999
SELboot:
    BFID= SLBT-4XX-R302-V0-Z001002-D20230317
    Checksum:  XXXX

Mainboard:
    Code FLASH Size:   12 MB
    Data FLASH Size:   52 MB
    RAM Size:          64 MB
    EEPROM Size:      128 kB

Front Panel: installed
Analog Inputs:
    W:  Currents:  5 Amp
    X:  Currents:  5 Amp
    Y:  Voltage:   67 Volts
    Z:  Voltage:   67 Volts

Interface Boards:
    Board 1:  24 inputs   8 outputs
    Board 2: not installed
    Board 3: not installed
    Board 4: not installed

Bay Cards:
    Bay 1:  not installed
    Bay 2:  not installed
    Bay 3:  Ethernet Configuration 9
             Port 5A: 1000BASE-SX (8131-01)
             Port 5B: 1000BASE-SX (8131-01)
             Port 5C: 100BASE-FX (8103-01)
             Port 5D: 100BASE-FX (8103-01)
             Port 5E: 100BASE-FX (8103-01)
    Bay 4:  RS-232 and IRIG-B

Extended Relay Features:
    IEC 61850

If the above information is not as expected, contact SEL for assistance.

=>>
```

Figure 14.20 Sample VER Command Response

If an item is not installed, the **VER** report indicates `Not installed` at the appropriate line. If a detected hardware configuration does not match the component part number, the relay adds the statement `Warning - hardware does not match part number` on the corresponding line.

VIEW

Use the **VIEW** command to examine data within the relay database. You can view these data in three ways:

- ➤ Region
- ➤ Register item
- ➤ Bit

The **VIEW** command in the relay is very similar to the **VIEW** command in SEL Communications Processors. See *Section 10: Communications Interfaces* in the product-specific instruction manual for more information on the relay database regions and data types.

Typical relay regions are LOCAL, METER, DEMAND, TARGET, HISTORY, BREAKER, STATUS, and ANALOGS; view this list with the **MAP 1** command.

The relay is Virtual Device 1; all commands begin with VIEW 1. In all database views, if a data item is in test mode (controlled by **TEST DB** command), the relay displays an asterisk (*) mark following the data value.

VIEW 1 Commands—Region

Use the commands in *Table 14.157* to view the contents of the database regions.

Table 14.157 VIEW 1 Commands—Region

Command	Description	Access Level
VIEW 1 *region*	Display the data in the relay database in the region *region*.	1, B, P, A, O, 2
VIEW 1 *region* BL	Display the data in the region *region* and include bit labels.	1, B, P, A, O, 2

VIEW 1 Commands—Register Item

Use the commands in *Table 14.158* to view register items in the relay database. Typical examples of register items in the METER region are IA1, I0_1, VB, and PF. Examples of register items in the LOCAL region are FID, SER_NUM, and PART_NUM.

Table 14.158 VIEW 1 Commands—Register Item (Sheet 1 of 2)

Command	Description	Access Level
VIEW 1 *addr*	Display the data in the relay database at register address *addr*.	1, B, P, A, O, 2
VIEW 1 *addr* NR *m*[a]	Display the data beginning at register address *addr* and continue for *m* registers.	1, B, P, A, O, 2
VIEW 1 *region item_label*	Display the data for the addresses in the *region item_label* area of the database.	1, B, P, A, O, 2
VIEW 1 *region item_label* NR *m*	Display the data for addresses in the *region item_label* area of the database; begin at the start of *item_label* and proceed for *m* registers.	1, B, P, A, O, 2

Table 14.158 VIEW 1 Commands—Register Item (Sheet 2 of 2)

Command	Description	Access Level
VIEW 1 *region offset*	Display the data for the address in the database region *region* at the offset *offset* from the beginning of the region.	1, B, P, A, O, 2
VIEW 1 *region offset* NR *m*	Display the data for the addresses in the database region *region*; begin at the offset *offset* from the beginning of the region and proceed for *m* registers.	1, B, P, A, O, 2

[a] Parameter m is an integer value representing the number of registers.

In the **VIEW 1 *addr*** commands, option *addr* is the register address. Use the **MAP 1 *region*** command to find the register address. You can specify register addresses as a decimal or hexadecimal number. (A hexadecimal address is a numeral with an "h" suffix or a "0x" prefix.) If you specify the data by address or by offset with the *addr* and *offset* options, the relay returns the data in hexadecimal number format. The **NR** option specifies the number of registers *m* that the relay includes in the data listing.

VIEW 1 Commands—Bit

Use commands in *Table 14.159* to inspect a specific bit in the relay database. The relay displays bit data as the bit label or number and the value logical 1 or logical 0. An example of a relay response for bit commands is `1:TARGET:ALTI = 0`, where `ALTI` is the bit label and `0` is the bit value.

Table 14.159 VIEW 1 Commands—Bit[a]

Command	Description	Access Level
VIEW 1 *addr bit*	Display the value at register address *addr* for the bit number *bit*.	1, B, P, A, O, 2
VIEW 1 *bit_label*	Display the value for the bit with the bit label *bit_label*.	1, B, P, A, O, 2
VIEW 1 *region bit_label*	Display the value for the particular bit with the bit label *bit_label* in the region *region*.	1, B, P, A, O, 2
VIEW 1 *region offset bit*[b]	Display the value for the bit *bit* in the region *region* that is offset from the beginning of the region by offset *offset*.	1, B, P, A, O, 2

[a] Parameter bit is a number from 0–15, with 0 as the LSB (least significant bit).
[b] Parameter offset is a decimal or hexadecimal number to indicate the offset.

The command option *bit* is the bit number. If you access bit data, the relay displays the bit label or number and the value (logical 0 or logical 1). If you reference the data by label with the **BL** and *bit_label* options, the relay returns the data according to the data type.

Use the **VIEW 1 *bit_label*** command as a shorthand method to inspect a specific data bit in the relay database. The relay searches the entire relay database structure for the bit label you specified; this process takes more time and processing than narrowing the search by using the **VIEW 1 *region*** command and the **VIEW 1 *addr*** command with the bit label option *bit_label*.

SECTION 15

Communications Interfaces

This section provides information on communications interface options for SEL-400 series relays. The following topics are discussed:

The relay collects, stores, and calculates a variety of data. These include electrical power system measurements, calculated quantities, diagnostic data, equipment monitoring data, fault oscillography, and sequential event reports. A communications interface is the physical connection on the relay that you can use to collect data from the relay, set the relay, and perform relay test and diagnostic functions.

The relay has three rear-panel serial ports and one front-panel serial port. These serial ports conform to the EIA-232 standard (often called RS-232). Several optional SEL devices are available to provide alternative physical interfaces, including EIA-485 and fiber-optic cable. The relay also has an Ethernet card to support a variety of communication protocols. TiDL relays also have a TiDL communications board that replaces the local CT/PT inputs.

Once you have established a physical connection, you must use a communications protocol to interact with the relay. A communications protocol is a language that you can use to perform relay operations and collect data. For information on protocols that you can use with the relay, see the instruction manual sections listed in *Table 15.1*.

Table 15.1 Relay Communications Protocols (Sheet 1 of 2)

Communications Protocol	Communications Interface	For More Information See
ASCII Commands	EIA-232[a] or Telnet using Ethernet	*Section 14: ASCII Command Reference*
High-Availability Seamless Redundancy (HSR) Protocol	Ethernet	*Network Connection by Using HSR Operating Mode on page 15.15*
Distributed Port Switch (LMD)	SEL-2885 EIA-232 to EIA-485 transceiver on an EIA-232 port	*SEL Distributed Port Switch Protocol (LMD) on page 15.43*
DNP3	EIA-232[a] or Ethernet	*Section 16: DNP3 Communication*
File Transfer Protocol (FTP)	Ethernet	*FTP on page 15.16*
HTTP	Ethernet	*HTTP (Hypertext Transfer Protocol) Server on page 15.20*

Table 15.1 Relay Communications Protocols (Sheet 2 of 2)

Communications Protocol	Communications Interface	For More Information See
IEC 61850	Ethernet	*Section 17: IEC 61850 Communication*
MIRRORED BITS Communications	EIA-232[a]	*SEL MIRRORED BITS Communication on page 15.36*
Phasor Measurement Protocols (IEEE C37.118 and SEL Fast Message)	EIA-232[a] Ethernet[b]	*Section 18: Synchrophasors*
Precision Time Protocol (PTP)	Ethernet	*Precision Time Protocol (PTP) on page 15.18*
Parallel Redundancy Protocol (PRP)	Ethernet	*Network Connection by Using PRP Operating Mode on page 15.12* and *Network Connection by Using PRP Operating Mode on page 15.14*
SEL Binary Protocols (Fast Meter, Fast Operate, Fast SER)	EIA-232[a] or Telnet using Ethernet	*SEL Fast Meter, Fast Operate, Fast SER Messages, and Fast Message Data Access on page 15.34*
SEL Fast Message RTD Protocol	EIA-232[a]	*SEL Fast Meter, Fast Operate, Fast SER Messages, and Fast Message Data Access on page 15.34*
SNTP	Ethernet	*SNTP on page 15.17*
Telnet	Ethernet	*Telnet on page 15.17*
T-Protocol	TiDL Communications	*TiDL (T-Protocol) on page 19.1*

[a] You can add converters to transform EIA-232 to other physical interfaces.
[b] Phasor Measurement over the Ethernet card is only available via IEEE C37.118 protocol.

Serial Communication

Each relay has four serial ports that you can use for serial communication with other devices.

EIA-232 Interfaces

The relay has four EIA-232 communications interfaces. The serial port locations for the 4U chassis are shown in *Figure 15.1* and *Figure 15.2*; other chassis sizes are similar. The port on the front panel is **PORT F** and the three rear-panel ports are **PORT 1**, **PORT 2**, and **PORT 3**.

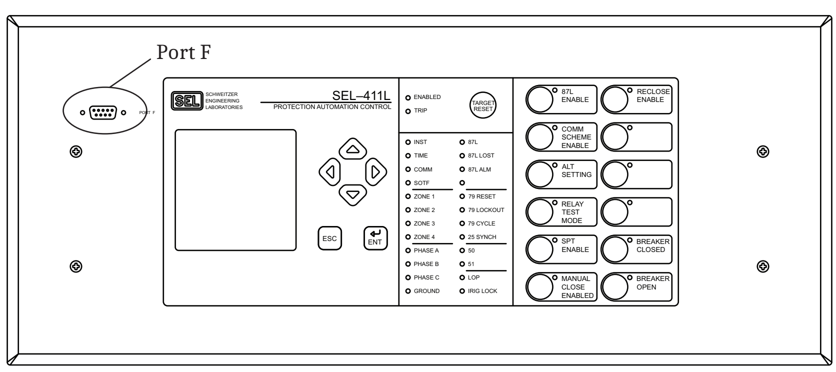

Figure 15.1 Relay 4U Chassis Front-Panel Layout

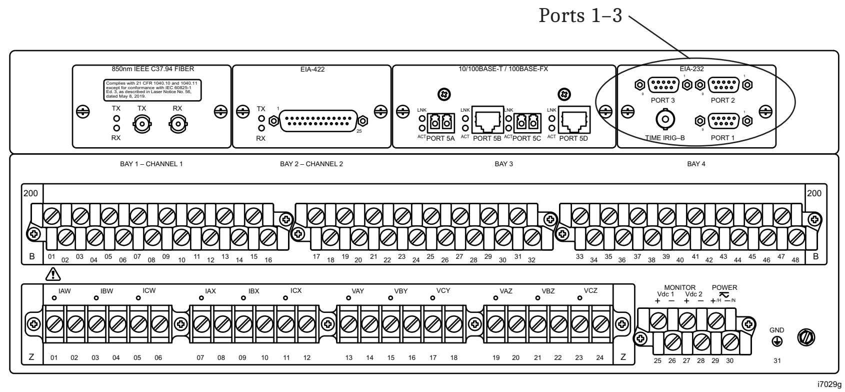

Figure 15.2 Example 4U Rear-Panel Layout in Relay With Bay Cards

The EIA-232 ports are standard female 9-pin connectors with the pin numbering shown in *Figure 15.3*. The pin functions are listed in *Table 15.2*. Pin 1 can provide power to an external device.

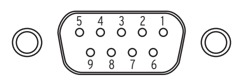

Figure 15.3 EIA-232 Connector Pin Numbers

NOTE: Pins 5 and 9 are not intended to provide a chassis ground connection.

Table 15.2 EIA-232 Pin Assignments

Pin	Signal Name	Description	Comments
1	5 Vdc	Modem power	Jumper selectable on **PORT 1**–**PORT 3**. No connection on **PORT F**.
2	RXD	Receive data	
3	TXD	Transmit data	
4	+IRIG-B	Time-code signal positive	**PORT 1** only. No connection on **PORT F**, **PORT 2**, and **PORT 3**.
5	GND	Signal ground	Also connected to chassis ground.
6	–IRIG-B	Time-code signal negative	**PORT 1** only. No connection on **PORT F**, **PORT 2**, and **PORT 3**.
7	RTS	Request to send	
8	CTS	Clear to send (input)	
8	TX/RX CLK (for SPEED := SYNC, only available when PROTO := MBA or MBB)	Transmit and receive clock (input)	Rear-panel serial ports only
9	GND	Chassis ground	

The +5 V serial port supply that is common to all three rear serial ports is monitored by the relay. If the +5 V supply is overloaded, the relay issues an HALARM warning (pulses HALARM bit for 5 seconds) and displays a port overload message in the relay status report. The serial port keeps working, regardless of this condition.

EIA-232 Communications Cables

For most installations, you can obtain information on the proper EIA-232 cable configuration from the SEL-5801 Cable Selector Program. Using the SEL-5801 software, you can choose a cable by application. The software provides the SEL cable number with wiring and construction information, so you can order the appropriate cable from SEL or construct one. If you do not see information for your application, please contact SEL and we will assist you. You can obtain a copy of the SEL-5801 software by contacting SEL or from selinc.com.

Severe power and ground problems can occur on the communications ports of this equipment as a result of using non-SEL cables. Never use standard null-modem cables with this equipment.

You can connect to a standard 9-pin computer port with an SEL-C234A cable for relay configuration and programming with a terminal program or with the ACSELERATOR QuickSet SEL-5030 software.

Fiber-Optic Interface

You can add transceivers to the EIA-232 ports to use fiber-optic cables to connect devices. We strongly recommend that you use fiber-optic cables to connect devices within a substation. Power equipment and control circuit switching can cause substantial interference with communications circuits. You can also experience significant ground potential differences during fault conditions that can interfere with communications and damage equipment. Fiber-optic cables provide electrical isolation that increases safety and equipment protection.

Use the SEL-2800 product series transceivers for multimode or single-mode fiber-optic communications. All of these transceivers are port powered, require no settings, and operate automatically over a broad range of data rates. SEL-2800 series transceivers operate over the same wide temperature ranges as SEL relays, providing reliable operations in extreme conditions.

EIA-485

There is no EIA-485 port integral to the relay. You can install an SEL-2885 or SEL-2886 transceiver to convert one of the rear-panel EIA-232 ports (**PORT 1–PORT 3**) on the relay to an EIA-485 port. The SEL-2885 and SEL-2886 are powered by the +5 Vdc output on Pin 1. These transceivers offer transformer isolation not found on most EIA-232-to-EIA-485 transceivers. See the transceiver product fliers for more information.

The SEL-2885 offers the SEL Distributed Port Switch Protocol (LMD). With this protocol you can selectively communicate with multiple devices on an EIA-485 network. You can communicate with other network nodes including EIA-232 devices with an SEL-2885 and SEL devices having integral EIA-485 ports. You can find more information about using SEL LMD in *SEL Distributed Port Switch Protocol (LMD) on page 15.43*.

Serial Port Hardware Protocol

The serial ports comply with the EIA-232 Standard (formerly known as RS-232). The serial ports support RTS/CTS hardware flow control. See also *Software Flow Control on page 15.32*.

Hardware Flow Control

Hardware handshaking is one form of flow control that two serial devices use to prevent input buffer information overflow and loss of characters. To support hardware handshaking, connect the RTS output pin of each device to the CTS input pin of the other device. To enable hardware handshaking, use the **SET P** command (or front-panel SET pushbutton sequence) to set RTSCTS := Y. Disable hardware handshaking by setting RTSCTS := N. *Table 15.3* shows actions the relay takes for the RTSCTS setting values and the conditions relevant to hardware flow control.

Table 15.3 Hardware Handshaking

Setting RTSCTS Value	Condition	Relay Action
N	All	Assert RTS output pin and ignore CTS input pin.
Y	Normal input reception	Assert RTS output pin.
Y	Local input buffer is close to full	Deassert RTS pin to signal remote device to stop transmitting.
Y	Normal transmission	Sense CTS input is asserted, transmit normally.
Y	Remote device buffer is close to full, so remote device deasserts RTS	Sense CTS input is deasserted, stop transmitting.

Note that the relay must assert the RTS pin to provide power for some modems, fiber-optic transceivers, and hardware protocol converters that are port powered. Check the documentation for any port-powered device to determine if the device supports hardware handshaking or if you must always assert RTS (RTSCTS := N) for proper operation.

Data Frame

The relay ports use asynchronous data frames to represent each character of data. Four port settings influence the framing: SPEED, DATABIT, PARITY, and STOPBIT. The time allocated for one bit is the reciprocal of the SPEED. For example, at 9600 bits per second, one bit-time is 0.104 milliseconds (ms).

The default port framing uses one start bit, eight data bits, no parity bit, and one stop bit. The transmitter asserts the TXD line for one data frame, as described in the following steps:

The TXD pin is normally in a deasserted state.

➤ To send a character, the transmitter first asserts the TXD pin for one bit time (start bit).

➤ For each data bit, if the bit is set, the transmitter asserts TXD for one bit time. If the bit is not set, it deasserts the pin for one bit time (data bits).

➤ If the PARITY setting is E, the transmitter asserts or deasserts the parity bit so that the number of asserted data bits plus the parity bit is an even number. If the PARITY setting is O, the transmitter asserts or deasserts the parity bit so that the number of asserted data bits plus the parity bit is an odd number. If the PARITY setting is N, the data frame does not include a parity bit.

➤ At the completion of the data bits and parity bit (if any), the transmitter deasserts the line for one bit time (stop bit). If STOPBIT is set to 2, the transmitter deasserts the line for one more bit time (stop bit).

➤ Until the relay transmits another character, the TXD pin will remain in the unasserted state.

Ethernet Communications

Ethernet Card

⚠CAUTION

The Ethernet card is not hot-swappable. To avoid equipment damage, remove power from the relay before removing or installing the Ethernet card.

The SEL-400 series relays support an Ethernet card. In some SEL-400 series devices, this is a daughter card to the main board, as shown in *Figure 15.4*. In others, it goes into **BAY 3**, as shown in *Figure 15.5* and *Figure 15.6*. The Ethernet card is optional except in relays configured for SV and TiDL. You can either field install the card or order the relay with the card installed at the factory. As with other SEL products, SEL has designed and tested SEL Ethernet cards for operation in harsh environments.

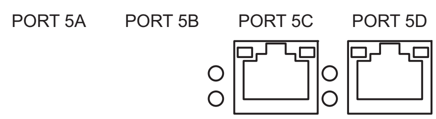

Figure 15.4 Example Two-Port Ethernet Card

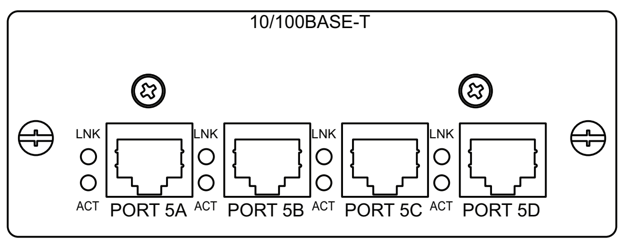

Figure 15.5 Example Four-Port Ethernet Card

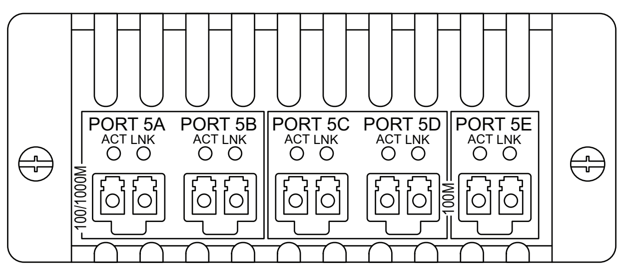

Figure 15.6 Five-Port Ethernet Card

In some relay models, the Ethernet card has two or four ports and is available with standard twisted-pair and fiber-optic physical interfaces. Other models support a five-port Ethernet card with small form-factor pluggable (SFP) ports, as shown in *Figure 15.6*. The Ethernet card includes redundant physical interfaces with the capability to automatically transfer communications to the backup interface in the event that the primary network fails. For information on substation integration architectures, see *Section 16: DNP3 Communication* and *Section 17: IEC 61850 Communication*.

Once installed in a relay, the settings needed for network operation and data exchange protocols, including DNP3 and IEC 61850, are available in the Port 5 settings.

Ethernet Network Operation

You should carefully design your Ethernet network to maximize reliability, minimize system administration effort, and provide adequate security. SEL recommends that you work with a networking professional to design your substation Ethernet network.

Use the network configuration settings shown in *Table 12.14* and *Table 12.28* to configure the relay for operation on an IP network and to set other parameters affecting the physical Ethernet network interface operation. Depending on the model and ordering selection, the relay is equipped with either two, four, or five Ethernet ports. See *Table 15.4* for information on what protocols are available on which ports for various Ethernet cards and configurations.

Table 15.4 Ethernet Protocol Options

Ethernet Card Type[a, b, c]	PORT 5A and PORT 5B	PORT 5C and PORT 5D	PORT 5E
Two-Port			
5A, 5B	PRP, PTP, GOOSE, IP	—	—
5C, 5D	—	PRP, GOOSE, IP	—
Four-Port			
Independent Bus Mode, Station Bus = (5A, 5B)	PRP, PTP, GOOSE, IP	GOOSE, SV	—
Independent Bus Mode, Station Bus = (5C, 5D)	PTP, GOOSE, SV	PRP, GOOSE, IP	—
Merged Bus Mode	PTP, GOOSE, SV, IP	—	—
Five-Port			
Independent Bus Mode	PRP, HSR, PTP[d], GOOSE, SV	PRP, HSR, PTP[d], GOOSE, IP	IP[e]
Merged Bus Mode	PRP, HSR, PTP[d], GOOSE, SV, IP	—	IP[e]

[a] IP refers to FTP, HTTP, Telnet, SNTP, MMS, DNP, and IEEE C37.118.
[b] The SEL-487B does not support IEEE C37.118.
[c] Some relay models do not support SV.
[d] PTP is not available on ports with HSR enabled.
[e] PORT E does not support SNTP.

The relay IP address setting uses Classless Inter-Domain Routing (CIDR) notation and a variable-length subnet mask (VLSM) to define its local network and host address.

An IP address consists of two parts: a prefix that identifies the network followed by a host address within that network. Early network devices used a subnet mask to define the network prefix of an associated host address. Within the mask, subnet boundaries were defined by the 8-bit segments of the 32-bit IP address. These boundaries constrained network prefixes to 8, 16, or 24 bits, defining Class A, B, and C networks, respectively.

This classful networking often created subnetworks that were not sized efficiently for actual requirements. CIDR allows more effective usage of a given range of IP addresses. In CIDR notation, you enter the IP address setting in the form a.b.c.d/p, where a.b.c.d is the host address in standard dotted decimal form and p is the network prefix expressed as the number of “1” bits in the mask. For example, if IPADDR := 192.168.1.2/24, the host address is 192.168.1.2 and the network prefix is the first 24 bits of the address, or 192.168.1. The network address is derived by applying the network prefix to the IP address and filling the remaining bits with zeros (in our example, it is 192.168.1.0). The broadcast address is derived similarly, but the remaining bits are filled with ones (192.168.1.255 for the example above). Neither the network (base) address nor the broadcast address can be used for any host or router addresses on the network.

Table 15.5 CIDR Notation

CIDR Value	Subnet Mask
/32	255.255.255.255
/31	255.255.255.254
/30	255.255.255.252
/29	255.255.255.248
/28	255.255.255.240
/27	255.255.255.224
/26	255.255.255.192
/25	255.255.255.128
/24	255.255.255.000
/23	255.255.254.000
/22	255.255.252.000
/21	255.255.248.000
/20	255.255.240.000
/19	255.255.224.000
/18	255.255.192.000
/17	255.255.128.000
/16	255.255.000.000
/15	255.254.000.000
/14	255.252.000.000
/13	255.248.000.000
/12	255.240.000.000
/11	255.224.000.000
/10	255.192.000.000
/9	255.128.000.000
/8	255.000.000.000
/7	254.000.000.000
/6	252.000.000.000
/5	248.000.000.000
/4	240.000.000.000
/3	224.000.000.000
/2	192.000.000.000
/1	128.000.000.000
/0	000.000.000.000

The relay uses the default router address setting to determine how to communicate with nodes on other local networks. The relay communicates with the default router to send data to nodes on other local networks. The default router must be on the same local network as the relay or the relay will reject the default router setting. You must also coordinate the default router with your general network implementation and administration plan. See *Table 15.6* for examples of how the IP address and subnet mask define the network and node and how these settings affect the default router setting.

If there is no router on the network, enter a null string (“”).

Table 15.6 Default Router Address Setting Examples

IP Address (CIDR)	Network Address	Broadcast Address	Default Router Range[a]
192.168.1.2/28	192.168.1.0	192.168.1.15	192.168.1.0–192.168.1.15
192.168.1.2/24	192.168.1.0	192.168.1.255	192.168.1.a[b]
192.168.1.2/20	192.168.0.0	192.168.15.255	192.168.0.a[b]–192.168.15.a[b]
192.168.1.2/16	192.168.0.0	192.168.255.255	192.168.a[b].b[b]
192.168.1.2/12	192.160.0.0	192.175.255.255	192.160.a[b].b[b]–192.175.a[b].b[b]
192.168.1.2/8	192.0.0.0	192.255.255.255	192.a[b].b[b].c[b]
192.168.1.2/4	192.0.0.0	207.255.255.255	192.a[b].b[b].c[b]–207.a[b].b[b].c[b]

[a] The Default Router cannot be the same as the IP Address, Network Address, or Broadcast Address.

[b] Value in the range 0–255.

NOTE: The ETCPKA setting applies to all TCP traffic on Ethernet ports, including Telnet, FTP, DNP3, IEC 61850 MMS, and IEEE C37.118.

The ETCPKA setting, along with the KAIDLE, KAINTV, and KACNT settings, can be used to verify that the computer at the remote end of a TCP connection is still available. If ETCPKA is enabled and the relay does not transmit any TCP data within the interval specified by the KAIDLE setting, the relay sends a keep-alive packet to the remote computer. If the relay does not receive a response from the remote computer within the time specified by KAINTV, the keep-alive packet is retransmitted as many as KACNT times. After this count is reached, the relay considers the remote device no longer available, so the relay can terminate the connection without waiting for the idle timer (TIDLE or FTPIDLE) to expire.

The relay monitors Manufacturing Message Specification (MMS) inactivity to identify and disconnect MMS clients that have stopped communicating with it. You can set it from 0 to 42000000 seconds via the IED Properties MMS Settings in ACSELERATOR Architect SEL-5032 Software. The MMS Inactivity default value is either 120 seconds or 900 seconds, depending on the relay. Setting this value to 0 disables the MMS Inactivity timer. If enabled, the relay starts a timer for an MMS session after it receives an MMS request from the client on that session. It resets the timer whenever it receives a new MMS request from that client. When the timer runs out, the relay disconnects the MMS session, making it available for other MMS clients.

This feature was implemented in addition to the TCP keep-alive timer to specifically handle MMS clients that do not disconnect properly. As there are a limited number of MMS sessions available, this ensures that misbehaving MMS clients do not take up multiple MMS sessions. Note that the MMS inactivity time-out can still disconnect an MMS session even if the relay receives TCP keep-alive messages from that MMS client.

The two-port and four-port Ethernet cards operate over either twisted-pair or fiber-optic media. Each Ethernet card is equipped with two or four network ports. You can select the medium for each port (10/100 Mbps twisted-pair or 100 Mbps fiber-optic).

The five-port Ethernet card uses SFP ports with compatible SFP transceivers. The transceivers are not included with the card and must be ordered separately. See *Table 15.7* or selinc.com/products/sfp/ for a list of compatible SFP transceivers.

Table 15.7 SFP Transceivers for the Five-Port Ethernet Card

Transceiver Part Number	Interface	Mode[a, b]	Type	Max. Distance	Wavelength	TX Power (dBm)	RX Sens. Max. (dBm)	RX Sens. Min. (dBm)
8131-01	1000BASE-SX	MM	Dual-fiber	300 m (62.5/125 µm) 550 m (50/125 µm)	850 nm	–2.5 to –9	0	–18
8103-01	100BASE-FX	MM	Dual-fiber	2 km	1310 nm	–14 to –24	–12	–31
8109-01	100BASE-FX	MM	Dual-fiber	2 km	1310 nm	–14 to –24	–12	–31
8130-01	1000BASE-LX	SM	Dual-fiber	10 km	1310 nm	–3 to –9.5	–3	–21
8130-02	1000BASE-LX	SM	Dual-fiber	20 km	1310 nm	–1 to –6	–3	–22
8130-03	1000BASE-LX	SM	Dual-fiber	30 km	1310 nm	0 to –5	–3	–24
8130-04	1000BASE-LX	SM	Dual-fiber	40 km	1310 nm	3 to –2	–3	–24
8130-05	1000BASE-XD	SM	Dual-fiber	50 km	1550 nm	0 to –5	–3	–24
8130-06	1000BASE-ZX	SM	Dual-fiber	80 km	1550 nm	5 to 0	–3	–24
8130-08	1000BASE-ZX	SM	Dual-fiber	160 km	1550 nm	5 to 1	–10	–36
8130-10	1000BASE-ZX	SM	Dual-fiber	200 km	1550 nm	8 to 5	–10	–36

[a] MM = multimode.
[b] SM = single-mode.

The five-port Ethernet card is only supported in certain products with a compatible firmware version. See *Appendix A: Firmware, ICD File, and Manual Versions* in the product-specific instruction manual for firmware that supports the five-port Ethernet card. Upgrading to this firmware while retaining an existing card will not impact your settings or functionality. Converting an existing card to the five-port Ethernet card will default the Port 5 settings.

Redundant Ethernet Ports (Two- or Four-Port Ethernet Card)

PORT 5A, **PORT 5B** and **PORT 5C**, **PORT 5D** are Ethernet port pairs. One port pair is for TCP/IP or UDP/IP Ethernet communications, including FTP, Telnet, DNP3 LAN/WAN, etc., and IEC 61850 GOOSE. You can configure these ports for redundant network architectures, or force the relay to use a single Ethernet port for these protocols. If the relay has four ports, the second port pair can be used for relay-specific functionality. PTP is only available on **PORT 5A** and **PORT 5B** when using the two- or four-port Ethernet card.

Redundant Ethernet Network by Using FAILOVER Operating Mode

The following settings are available in Port 5 to configure the relay for FAILOVER mode.

NOTE: The process bus on the four-port Ethernet card uses FAILOVER operating mode with no time-out delay.

- NETMODE := FAILOVER
- NETPORT := the preferred primary network port
- FTIME := desired time-out for the active port before failover to the backup port

Connect the relay to redundant networks as shown in *Figure 15.7*.

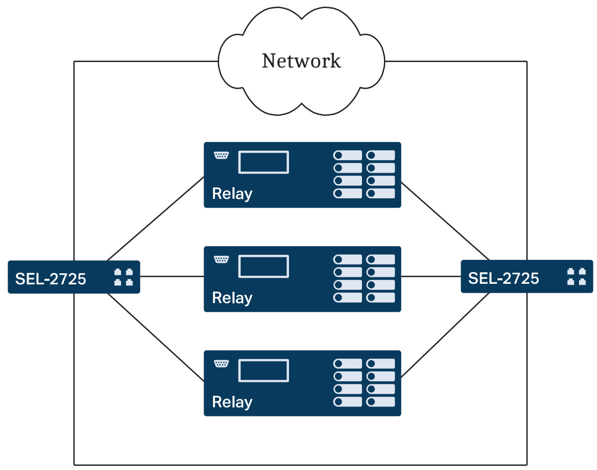

Figure 15.7 Failover Network Topology

NOTE: The TiDL relay Ethernet ports operate with a BUSMODE setting of INDEPEND. This allows for process bus GOOSE messages to be received by the relay on the non-IP ports. The non-IP ports operate in a fixed FAILOVER mode.

NOTE: For very small values of FTIME, or for a failover event on the process bus, the assertion or deassertion of LNKFAIL and LNKFL2 can be too short for a state change to register in the SER.

On startup, the relay communicates using the primary network port selected by the NETPORT setting. If the relay detects a link failure on the primary port, it asserts the LNKFAIL Relay Word bit. If the standby port's link is up, the relay activates the standby network port after time FTIME. If the link status on the primary port returns to normal before time FTIME, the failover timer resets and operation continues on the primary network port. Similarly, if the relay detects a link failure on the standby port and the primary port's link is up, the relay activates the primary network port after time FTIME.

The relay asserts the LNKFAIL Relay Word bit when it detects a link failure on the station bus. The relay asserts LNKFL2 when it detects a link failure on the process bus. LNKFAIL deasserts when at least one station bus port is active. LNKFL2 deasserts when at least one process bus port is active.

Network Connection by Using Isolated IP Operating Mode

The Isolated IP mode (NETMODE = ISOLATEIP) permits IEC 61850 GOOSE messages on two ports, but restricts IP traffic to just one port. This mode is useful for cases where it is desired to connect one port to a secured network (the IP port) but have the other port leave the security perimeter.

NOTE: If NETMODE = ISOLATEIP, Precision Time Protocol (PTP) is only supported on the port designated as the IP port.

The NETPORT setting selects which port will be the IP port. The other port will only support GOOSE traffic. IP transmissions will only go out the IP port. IP receptions will only be processed from the IP port. GOOSE publications will go out both ports. GOOSE subscriptions will be accepted from either port. Any non-GOOSE traffic received on the non-IP port will be ignored. No traffic will go from one external port to the other.

Network Connection by Using SWITCHED Operating Mode

Make Port 5 setting NETMODE = SWITCHED to activate the internal Ethernet switch. The internal switch connects a single Ethernet stack inside the relay to two external Ethernet ports. The combination of relay and internal switch operate the same as if a single Ethernet port on a relay were connected to an external unmanaged Ethernet switch. Use the internal switch to add devices to a network, as shown in *Figure 15.8*.

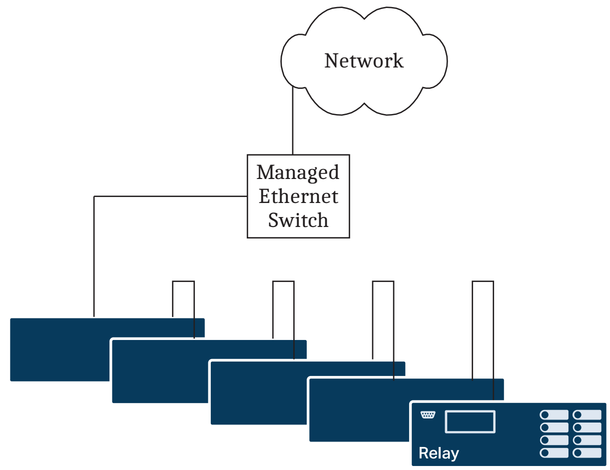

Figure 15.8 Using Internal Ethernet Switch to Add Networked Devices

Using this topology, the internal network switch of the relay supports connecting Ethernet devices in series. Each relay in the chain acts as a network hub. Network traffic originating from a relay is forwarded to the adjacent relay, and so on, until the traffic reaches its destination. In this SWITCHED mode, each relay is forced to process and filter traffic not intended for it, which results in a reduced overall network performance. This configuration is only recommended for temporary use. Note that PTP functionality is not available in SWITCHED operating mode.

When using this switched mode, do not to connect the last device back to the Managed Ethernet Switch, thereby creating a loop or ring.

In switched mode, the internal Ethernet switch of the relay is an unmanaged Ethernet switch and does not provide RSTP functionality. You will experience very large RSTP healing times in such a network.

Network Connection by Using Fixed Operating Mode

Force the relay to use a single station bus Ethernet port by making setting NETMODE := FIXED. When NETMODE := FIXED, only the port selected by NETPORT is active. The other port is disabled.

Network Connection by Using PRP Operating Mode

PRP is part of an IEC standard for high availability automation networks (IEC 62439-3). The purpose of the protocol is to provide seamless recovery from any single Ethernet network failure.

The basic concept is that the Ethernet network and all traffic are fully duplicated with the two copies operating in parallel.

The following settings are available in Port 5 to configure the relay for PRP mode.

- ➤ NETMODE := PRP
- ➤ PRPTOUT := desired time-out for PRP frame entry
- ➤ PRPINTV := desired supervision frame transmit interval
- ➤ PRPADDR := PRP supervision frame’s destination MAC address least significant byte

When NETMODE is not set to PRP, the PRP settings are hidden.

Enabling PRP doubles the number of Ethernet packets received on the station bus. You may need to reduce the number of incoming GOOSE subscriptions so that you do not exceed the relay's incoming GOOSE buffers, which are sized to accommodate a maximum of 128 GOOSE messages.

Redundant Ethernet Ports (Five-Port Ethernet Card)

The five-port Ethernet card includes many of the same capabilities and settings as the two- and four-port Ethernet cards. It also provides new and enhanced capabilities such as PRP, HSR, and fast failover on both the station bus and process bus. PORT 5A and PORT 5B are reserved for process bus network. PORT 5C and PORT 5D are reserved for the station bus network. PORT 5E operates on an isolated network with a unique IP address making it ideal for engineering and data access. PORT 5E supports IP protocols including FTP, HTTP, Telnet, MMS, DNP, and IEEE C37.118. PTP is available on either port pair PORT 5A, PORT 5B or PORT 5C, PORT 5D. All ports support 100 Mbps speeds. PORT 5A and PORT 5B also support 1 Gbps speeds to satisfy potentially large traffic requirements on the process bus. Use the enable interface setting, EINTF, to enable the network interfaces required for your application. If a network interface is not included in EINTF setting, the relay hides the settings associated with that interface.

Redundant Ethernet Network by Using FAILOVER Operating Mode

The following settings are available in Port 5 to configure port pairs PORT 5A, PORT 5B and PORT 5C, PORT 5D for FAILOVER mode.

- NETMODP := FAILOVER (for the process bus)
- NETPORP := the preferred primary network port for the process bus
- NETMODE := FAILOVER (for the station bus)
- NETPORT := the preferred primary network port for the station bus
- FTIME := desired time-out for the active port before failover to the backup port for the station bus

NOTE: For a 1000BASE-X connection, auto-negotiation is supported.

For a 100BASE-FX connection, the far-end fault feature is supported to detect asymmetric link failures.

Connect the relay to a redundant network like the one shown in *Figure 15.7*. On startup, the relay communicates using the primary network ports selected by the NETPORT and NETPORP settings. If the relay detects a link failure on the primary port and the standby port's link is up, the relay activates the standby network port. The failover time on the process bus is immediate (less than 100 microseconds) and will drop no more than one SV sample. The failover time on the station bus occurs after time FTIME. If the link status on the primary port on the station bus returns to normal before time FTIME, the failover timer resets and operation continues on the primary network port. Similarly, if the relay detects a link failure on the standby port on the station bus and the primary port's link is up, the relay activates the primary network port after time FTIME.

NOTE: For very small values of FTIME, or for a failover event on the process bus, the assertion or deassertion of LNKFAIL and LNKFL2 can be too short for a state change to register in the SER.

The relay asserts the LNKFAIL Relay Word bit when it detects a link failure on the station bus. The relay asserts LNKFL2 when it detects a link failure on the process bus. LNKFAIL deasserts when at least one station bus port is active. LNKFL2 deasserts when at least one process bus port is active.

Network Connection by Using Fixed Operating Mode

The following settings are available in Port 5 to configure ports **PORT 5A**, **PORT 5B** and **PORT 5C**, **PORT 5D** for FIXED mode.

- NETMODP := FIXED (for the process bus)
- NETPORP := the preferred primary network port for the process bus
- NETMODE := FIXED (for the station bus)
- NETPORT := the preferred primary network port for the station bus

Only the ports selected by NETPORT and NETPORP are active. **PORT 5E** is not affected by these settings.

Network Connection by Using PRP Operating Mode

PRP is part of an IEC standard for high availability automation networks (IEC 62439-3). The purpose of the protocol is to provide seamless recovery from any single Ethernet network failure.

The basic concept is that the Ethernet network and all traffic are fully duplicated with the two copies operating in parallel.

The following settings are available in Port 5 to configure port pairs **PORT 5A**, **PORT 5B** and **PORT 5C**, **PORT 5D** for PRP mode.

- NETMODP := PRP (for the process bus)
- PRPINTP := desired supervision frame transmit interval for the process bus
- PRPADDP := PRP supervision frame's destination MAC address least significant byte for the process bus
- NETMODE := PRP (for the station bus)
- PRPINTV := desired supervision frame transmit interval for the station bus
- PRPADDR := PRP supervision frame's destination MAC address least significant byte for the station bus
- PRPTOUT := desired time-out for PRP frame entry

Enabling PRP on a port pair doubles the number of Ethernet packets received on that interface. You may need to reduce the number of incoming GOOSE subscriptions on the port pairs so that you do not exceed the relay's incoming GOOSE buffers which are sized to accommodate a maximum of 128 GOOSE messages.

Configure the PTHDLY setting to **P2P** to cause the relay to synchronize both the primary and standby ports. This allows the relay to seamlessly maintain PTP synchronization during a failover operation. This does not apply when PTHDLY is set to E2E.

The relay provides PRP supervision bits for GOOSE and SV. See *COM PRP on page 14.14* for more information.

Figure 15.9 shows an example PRP/HSR network with an SEL-421-7 and SEL-401. The five-port Ethernet cards in the relays allow for PRP on both the station bus and process bus, as well as a separate network for engineering access.

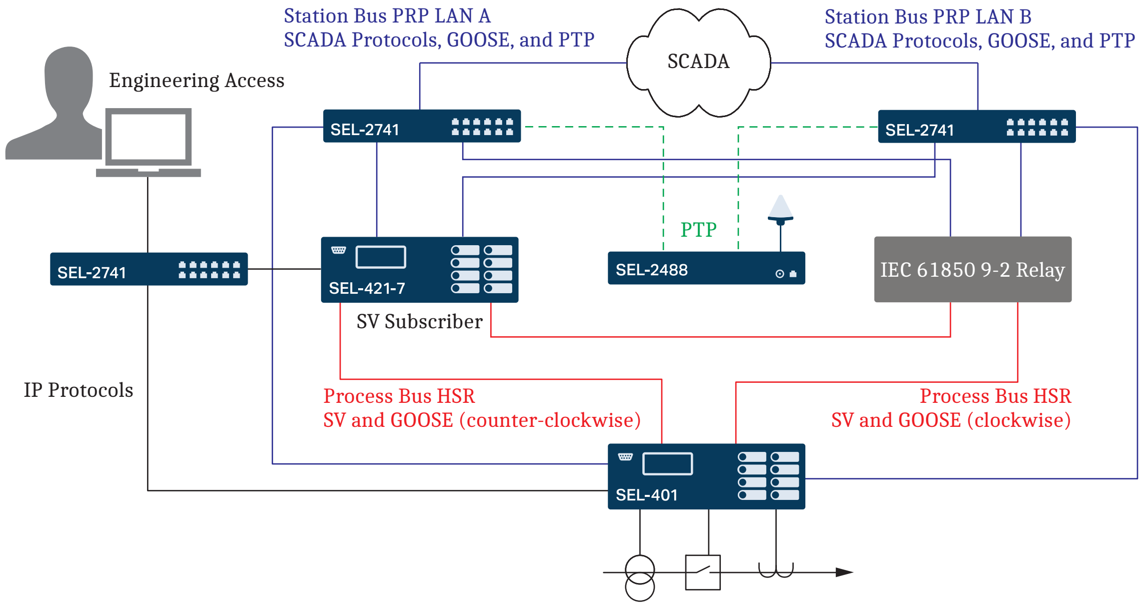

Figure 15.9 Example PRP/HSR Network Using SEL-400 Series Relays With Five-Port Ethernet Cards

Network Connection by Using HSR Operating Mode

HSR, similar to PRP, is part of the IEC standard for high-availability automation networks (IEC 62439-3). The purpose of the protocol is to ensure seamless recovery from any single device failure within an HSR ring. This is achieved by fully duplicating the messages and sending it in both clockwise and counter-clockwise directions around the ring. Messages received from other devices in the ring are simply forwarded to the next device, unless they originate from the device itself or are intended solely for that device. Non-HSR capable devices can be attached to the HSR ring through a Redundancy Box (RedBox). The SEL-400 series products support Mode H according to the IEC 62439-3 standard.

The following settings are available in Port 5 to configure port pairs **PORT 5A**, **PORT 5B** and **PORT 5C**, **PORT 5D** for HSR mode.

- ➤ NETMODP := HSR (for the process bus)
- ➤ HSRADDP := HSR supervision frame's destination MAC address least significant byte for the process bus
- ➤ NETMODE := HSR (for the station bus)
- ➤ HSRADDR := HSR supervision frame's destination MAC address least significant byte for the station bus

The relay provides supervision bits and logical nodes that monitor the status of the HSR ring. See *COM HSR on page 14.14* for more information.

The five-port Ethernet card in the relay allows for HSR on both the station bus and process bus. However, PTP is not supported on the process bus or station bus ports when they are configured to use HSR operating mode.

For best performance and minimal latency, SEL recommends limiting the number of devices in the ring to 18.

Refer to the following general guidelines to reduce HSR ring latency:

- ➤ Use 1 Gbit/s SFPs
- ➤ Use devices that operate in cut-through mode
- ➤ Use smaller GOOSE frame sizes, typically less than 200 bytes.

Figure 15.9 shows an example HSR network for a process bus and a PRP with PTP for the station bus network that uses an SEL-421-7 and SEL-401.

Ethernet Protocols

NOTE: The relay prioritizes processing IEC 61850 GOOSE data over the data access protocols listed above. With GOOSE enabled, high GOOSE traffic to and from the relay sustained over long periods may cause slowed responsiveness to data transfer requests via TCP/IP protocols.

Access data by using either the standard TCP/IP Telnet and FTP interfaces or, optionally, through the (Web) HTTP Server, DNP3 LAN/WAN or IEC 61850 interface. You cannot access all data through all interfaces. See the appropriate interface section below for details on data access.

FTP

FTP is a standard application-level protocol for exchanging files between computers over a TCP/IP network. The relay Ethernet card operates as an FTP server, presenting files to FTP clients. The relay Ethernet card supports one FTP connection at a time. Subsequent requests to establish FTP sessions will be denied. If your FTP client does not work properly, be sure to set your client to use a single session.

Table 12.15 and *Table 12.29* list lists the settings that affect FTP server operation.

File Structure

The basic file structure is organized as a directory and subdirectory tree similar to that used by Unix, DOS, Windows, and other common operating systems. See *Virtual File Interface on page 15.21* for information on the basic file structure.

Access Control

The standard FTP logins consist of the three-character access level command (e.g., ACC, BAC) with their respective passwords. For example, with default passwords, if you use the username of 2AC and password of TAIL, you will connect with Access Level 2 privileges.

The relay validates FTP clients and controls access by limiting failed password attempts. If a user attempts to log into the relay with three consecutive invalid login attempts within a 1-minute period, the relay disables login requests for 30 seconds and pulses the SALARM and BADPASS Relay Word bits.

FTP settings control anonymous file access features. The special FTP username “anonymous” does not require a password. It has the access rights of the access level selected by the FTPAUSR setting. For example, if FTPAUSR is set to 1 (for Access Level 1), the FTP anonymous user has Access Level 1 rights.

SEL advises against enabling anonymous FTP logins (FTPANMS = Y) except under test conditions. The Ethernet card does not require a password for the special FTP username “anonymous”. If you enable anonymous FTP logins, you are allowing unrestricted access to the relay and host files.

Telnet

Telnet is part of the TCP/IP protocol suite. A Telnet connection provides access to the relay user interface. The relay supports as many as three Telnet connections at a time. When you connect with Telnet and log in to the relay, you can use all of the ASCII and Compressed ASCII commands described in *Section 14: ASCII Command Reference* to configure and interact with the relay. You can also use the SEL binary Fast Meter and Fast Operate commands described in *SEL Fast Meter, Fast Operate, Fast SER Messages, and Fast Message Data Access on page 15.34*.

Use a Telnet client or QuickSet on the host PC to communicate with the relay. To terminate a Telnet session, use the **EXI** command from any access level.

Table 12.17 and *Table 12.31* list the settings that affect Telnet operation.

SNTP

When SNTP is enabled (Port 5 setting ESNTP is not OFF), the relay internal clock conditionally synchronizes to the time of day served by a Network Time Protocol (NTP) server. The relay uses a simplified version of NTP called the SNTP. SNTP is not as accurate as IRIG-B or PTP. The relay can use SNTP as a less accurate primary time source, or as a backup to the higher accuracy IRIG-B or PTP time sources.

If an IRIG-B time source is connected and either Relay Word bits TSOK or TIRIG assert, then the relay synchronizes the internal time-of-day clock to the incoming IRIG-B time-code signal, even if SNTP is configured in the relay and an NTP server is available. If the IRIG-B source is disconnected (TIRIG deassert) then the relay synchronizes the internal time-of-day clock to the NTP server if available. In this way an NTP server acts as either the primary time source, or as a backup time source to the more accurate IRIG-B time source. The above is also true if the relay is connected to an accurate PTP time source, but TPTP (not TIRIG) will deassert when the PTP time source is disconnected.

Three SEL application notes available from the SEL website describe how to create an NTP server.

- AN2009-10: Using an SEL-2401, SEL-2404, or SEL-2407 to Serve NTP Via the SEL-3530 RTAC
- AN2009-38: Using SEL Satellite-Synchronized Clocks With the SEL-3332 or SEL-3354 to Output NTP
- AN2010-03: Using an SEL-2401, SEL-2404, or SEL-2407 to Create a Stratum 1 Linux NTP Server

Configuring SNTP Client in the Relay

To enable SNTP in the relay, set Port 5 setting ESNTP to UNICAST, MANYCAST, or BROADCAST. *Table 12.25* lists the settings associated with SNTP.

SNTP Operation Modes

The following sections explain the setting associated with each SNTP operation mode (UNICAST, MANYCAST, and BROADCAST).

ESNTP = UNICAST

In unicast mode of operation the SNTP client in the relay requests time updates from the primary (IP address setting SNTPPIP) or backup (IP address setting SNTPBIP) NTP server at a rate defined by setting SNTPRAT. If the NTP server does not respond with the period defined by the sum of setting SNTPTO and SNTPRAT then the relay tries the other SNTP server. When the relay successfully synchronizes to the primary NTP time server, Relay Word bit TSNTPP asserts. When the relay successfully synchronizes to the backup NTP time server, Relay Word bit TSNTPB asserts.

ESNTP = MANYCAST

In manycast mode of operation the relay initially sends an NTP request to the broadcast address contained in setting SNTPPIP. The relay continues to broadcast requests at a rate defined by setting SNTPRAT. When a server replies, the relay considers that server to be the primary NTP server, and switches to UNICAST mode, asserts Relay Word bit TSNTPP, and thereafter requests updates from the primary server. If the NTP server stops responding for time SNTPTO, the relay deasserts TSNTPP and begins to request time from the broadcast address again until a server responds.

ESNTP = BROADCAST

Setting SNTPPIP = 0.0.0.0 while ESNTP = BROADCAST, the relay will listen for and synchronize to any broadcasting NTP server. If setting SNTPPIP is set to a specific IP address while setting ESNTP = BROADCAST, then the relay will listen for and synchronize to only NTP server broadcasts from that address. When synchronized the relay asserts Relay Word bit TSNTPP. Relay Word bit TNSTPP deasserts if the relay does not receive a valid broadcast within the SNTPT0 setting value after the period defined by setting SNTPRAT.

SNTP Accuracy Considerations

SNTP time synchronization accuracy is limited by the accuracy of the SNTP Server and by the networking environment. The highest degree of SNTP time synchronization can be achieved by minimizing the number of switches and routers between the SNTP Server and the relay.

When installed on a network with low burden configured with one Ethernet switch between the relay and the SNTP Server, and when using ESNTP = UNICAST or MANYCAST, the relay time synchronization error to the SNTP server is typically less than ±1 millisecond.

Precision Time Protocol (PTP)

NOTE: PTP is not supported when ports are configured in HSR operating mode.

The two-port and four-port Ethernet cards support PTP on port pair **PORT 5A**, **PORT 5B**. The five-port Ethernet card supports PTP on either port pair **PORT 5A**, **PORT 5B** or **PORT 5C**, **PORT 5D**. The relay supports Precision Time Protocol version 2 (PTPv2) as a slave-only clock as defined by IEEE-1588-2008. PTP provides high accuracy timing over an Ethernet network, eliminating the need for a separate IRIG-B cable and connection. To achieve the best accuracy (<1 µs), it is necessary to have one or more PTP master clocks and that all intervening equipment (e.g., Ethernet switches) need to be 1588-aware (i.e., all intervening network devices need to be transparent or boundary clocks).

NOTE: The SEL-2488 with the PTP option is a PTP grandmaster clock capable GPS receiver.

In PTP, a clock that provides time to other devices, typically based on GPS input, is a master clock. The intervening switches are transparent clocks. It is also possible to connect networks together and pass time from one network to another by using boundary clocks. Transparent and boundary clocks are important because they provide time correction in the PTP messages that pass through them, whereas devices that are not 1588-aware would not provide this correction. Because it is possible for a network to have multiple master clocks, PTP clocks implement algorithms to select the best available clock. The one selected for use by an end device is the grandmaster clock. A complete description of possible PTP networking configurations is beyond the scope of this manual. You can learn more about configuring a PTP network in these application guides:

> "Using the SEL-2488 to Provide IEEE 1588 Version 2 Grandmaster Functionality in a Redundant Network Topology" (AN2015-07)

> "Using the SEL-2488 to Provide IEEE 1588 Version 2 Grandmaster Functionality to Isolated Ethernet Networks" (AN2015-06)

NOTE: See Appendix A: Firmware, ICD File, and Manual Versions in the product-specific instruction manual for firmware that supports PTP over PRP.

To configure PTP, update the Port 5 PTP settings as described in *Table 12.26* and *Table 12.33*. By default, PTP is disabled in the relay. Enable PTP to make the other PTP settings available.

Within PTP, there are multiple clock profiles available. A profile defines the set of PTP features available in a specific application domain. SEL-400 series relays support three profiles: Default, Power System profile (C37.238-2011), and Power Utility Automation profile (IEC/IEEE 61850-9-3-2016).

The Power profile provides predictable performance and the highest accuracy with compensation for network inaccuracies. This Power profile also allows for unique identification of grandmaster clocks, providing better security when operating in local clock mode.

The Power profile is only supported on Layer 2 networks and exclusively uses the peer-to-peer Delay Mechanism. All messages must be sent at 1-second intervals, must have 802.1Q VLAN tags, and Announce messages must include grandmaster ID and (maximum) inaccuracy fields. Transparent clocks are mandatory in a power profile network; boundary clocks are not allowed. For a network with less than 16 hops between Grandmaster and IED, the Power profile can deliver time with better accuracy than 1 µs. Select the profile by using the PTPPRO setting.

The Default profile has many optional features. It was intended to address common applications, so has been implemented by most PTP-capable devices. The Default profile supports both UDP or Layer 2 (802.3) Ethernet transport, and can use either end-to-end (E2E) or peer-to-peer (P2P) Delay Mechanism. Grandmaster clocks can send Announce, Sync, and Delay request messages over a wide range of intervals. A Default profile network can consist of boundary clocks or transparent clocks anywhere between the grandmaster and the end devices. A well-designed Default profile network with an accurate grandmaster can achieve better than 1 µs accuracy

The 61850-9-3 Power Utility Automation profile is only supported on Layer 2 networks and exclusively uses the peer-to-peer delay mechanism. Grandmaster clocks can send Announce and Sync messages over a wide range of intervals. A 61850-9-3 profile network can consist of boundary clocks or transparent clocks anywhere between the grandmaster and the end devices. The performance requirements for this profile are listed in the IEC 61850 standard part 9-3 documentation. This profile does not account for network time inaccuracy calculations, but a well-designed network can achieve better than 1 µs accuracy.

PTP defines a logical grouping of clocks in a network as a clock domain. This allows a logical separation between clocks that participate in different application domains to coexist on the same network. Domains are identified by domain numbers. The domain number for the relay is selected by the DOMNUM setting. Set DOMNUM to match the domain number configured in the master clocks the relay should synchronize with.

The relay supports transport of PTP messages over UDP or layer 2 (Ethernet). Use the PTPTR setting to select the PTP transport mechanism. This needs to match the transport mechanism used in the master clocks. Layer 2 Ethernet transport is available with both the Default and Power System profiles. If operating in a UDP network, PTP will operate on port 320. Except for peer delay messages, the relay sets the time allowed to live (TTL) value in the UDP/IP header of PTP messages to 64. This allows the possibility of synchronizing relay time through routers across a WAN to a PTP master. High-accuracy synchronization may not be achievable across the WAN, so it is left to the user to determine if the accuracy meets the needs of their application.

When using the Power System profile, use the VLAN number and priority settings PVLAN and PVLANPR to set the VLAN ID and priority, respectively, of the Ethernet frames. Be sure to set PVLAN unique from other VLANs used within the relay.

NOTE: For the five-port Ethernet card, configure the PTHDLY setting to **P2P** to cause the relay to synchronize both the primary and standby ports. This allows the relay to seamlessly maintain PTP synchronization during a failover operation. This does not apply when PTHDLY is set to E2E or when using the two- or four-port Ethernet card.

PTP defines two methods for calculating and correcting for the communications path delay between the relay and the master clock: end-to-end (Delay Request-Response) and peer-to-peer (Peer Delay Request-Response). The end-to-end mechanism calculates the total path delay between the relay and the master clock. The peer-to-peer mechanism calculates the total path delay in a piecemeal fashion between each device in the path. Peer-to-peer is the more accurate method and is recommended for use in SEL relays. The relay periodically initiates path delay calculations. Use the PTHDLY and PDINT settings to configure the path delay method and the path delay request rate. If PTHDLY is set to OFF, then the relay will not calculate and correct for path delay. Only the peer-to-peer mechanism is available for Power System profile and 61850-9-3.

By default, the relay will synchronize to any clock on the network that it evaluates to be the best clock based on the Best Master Clock Algorithm (BMCA). Use the Acceptable Master Table settings to specify a list of master (grandmaster or boundary) clocks to which the relay may synchronize. The relay will not synchronize to any master clock that is not in the list. It is recommended to use this feature for additional security. The AMNUM setting selects the number of master clocks you will list in this table. The default value is OFF, which means the relay will synchronize to any master clock on the network. If AMNUM is set to a value other than OFF, that number of allowable masters must be identified in accordance with the PTP transport chosen, i.e., MAC address for 802.3 or IP address for UDP transport.

If the PTP transport (PTPTR) is set to UDP, use the AMIP*n* settings to specify the IP addresses of the clocks the relay is permitted to synchronize to. If PTP transport is set to layer 2, use the AMMAC*n* settings to specify the MAC addresses of the clocks the relay is permitted to synchronize to.

NOTE: The Acceptable Master Table feature may not work for transport over Layer 2 if the intervening Ethernet switch(es) modify the source MAC address of Announce messages passing through them. With transport over Layer 2, the relay uses the source MAC address to identify if an Announce message is coming from a master clock in the table.

If the ALTPRI*n* (alternate priority 1 for master *n*) setting is set to a positive value, the priority1 value in received Announce messages from the corresponding master clock will be replaced by the ALTPRI*n* value before applying the BMCA. The ALTPRI*n* values reprioritize the master clocks locally. A discussion of reasons to apply alternative priorities is beyond the scope of this manual. If you are not familiar with the Best Master Clock Algorithm, leave the setting set to 0.

HTTP (Hypertext Transfer Protocol) Server

The relay provides an HTTP (Web) server to provide read-only access to selected settings, metering, and reports. The HTTP server supports as many as four sessions at a time. *Table 12.16* and *Table 12.30* list the settings that affect HTTP server operation.

When enabled, the HTTP server opens TCP/IP Port 80 by default. Set HTTPPOR to configure any other port as needed.

The relay validates HTTP server access by limiting failed password attempts. If a user attempts to log into the relay with three consecutive invalid login attempts within a 1-minute period, the relay disables login requests for 30 seconds and pulses the SALARM and BADPASS Relay Word bits.

Virtual File Interface

You can retrieve and send data as files through the virtual file interface of the relay. Devices with embedded computers can also use the virtual file interface. When using serial ports or virtual terminal links, use the FILE DIR command. When you use an Ethernet card, the FTP protocol supported by Ethernet presents the file structure and sends and receives files.

The relay has a two-level file structure. There are a few files at the root level and three or more subdirectories or folders. Some SEL-400 series relays support directories in addition to those listed here. *Table 15.8* shows the directories and the contents of each directory.

Table 15.8 Virtual File Structure

Directory	Usage	Access Level
Root	CFG.TXT file, CFG.XML[a] file, SWCFG.ZIP file and the following directories	1
SETTINGS	Relay Settings	1
REPORTS	SER, circuit breaker, protection and history reports	1
EVENTS	EVE, CEV, COMTRADE, and history reports	1
SYNCHROPHASORS[b]	Synchrophasor recording files	1
UPGRADE[c]	Digitally signed firmware upgrades	2

[a] Present only if the Ethernet card is installed.
[b] Only present in SEL-400 series relays that support synchrophasors.
[c] Only present in SEL-400 series relays running SELBOOT R300 or newer and relay firmware that supports firmware upgrades over Ethernet. Directory is not available if Port 5 settings EETHFWU := N.

System Data Format

Settings files and the CFG.TXT file use the system data format (SDF) unless otherwise specified. The files may contain keywords to aid external support software (ESS) parsing. A keyword is defined as a string surrounded by the open and close bracket characters, followed by a carriage return and line feed. Only one keyword is allowed per line in the file. For example, the keyword INFO would look like this in the file: [INFO]<CR><LF>.

Records are defined as comma-delimited text followed by a carriage return and line feed. One line in a text file equals one record. Fields are defined as comma-delimited text strings.

Comma-Delimited Text Rules

Field strings are separated by commas or spaces and may be enclosed in optional double quotation marks. Double quotes within the field string are repeated to distinguish these double quotes from the quotes that surround the field string. Delimiters are spaces and commas that are not contained within double quotes. Two adjacent commas indicate an empty string, but spaces that appear next to another delimiter are ignored. Consider the following examples for converting a list of fields to comma-delimited text. Consider the following list of fields.

Stri,ng 1

Stri"ng 2

String 3

String4

The translation to comma-delimited text is as follows:

"Stri,ng 1","Stri""ng 2","String 3","String4"

Root Directory

The root directory contains three or more subdirectories and two or three files (CFG.TXT, CFG.XML, and SWCFG.ZIP). CFG.XML is only present if an Ethernet card is installed. SWCFG.ZIP is for internal use.

CFG.TXT File (Read-Only)

The CFG.TXT file contains general configuration information about the relay and each setting class. ESS retrieves the CFG.TXT file to interact automatically with the connected relay.

CFG.XML File (Read-Only)

Present only in units with an Ethernet card installed, the CFG.XML file is supplementary to the CFG.TXT file. The CFG.XML file describes the IED configuration and includes firmware identification, settings class names, and configuration file information.

SWCFG.ZIP File (Read/Write)

The SWCFG.ZIP file is a compressed file used to store ESS settings. It is readable at Access Level 1 and above, and writable at Access Level 2 and above.

Settings Directory

You can access the relay settings through files in the SETTINGS directory. We recommend that you use support software to access the settings files, rather than directly accessing them via other means. External settings support software reads settings from all of these files to perform its functions. The relay only allows you to write to the individual SET_*cn* files, where c is the settings class code and *n* is the settings instance. Except for the SET_61850 CID file, changing settings with ESS involves the following steps:

Step 1. The PC software reads the CFG.TXT and SET_ALL.TXT files from the relay.

Step 2. You modify the settings at the PC. For each settings class that you modify, the software sends a SET_*cn*.TXT file to the relay.

Step 3. The PC software reads the ERR.TXT file. If it is not empty, the relay detects errors in the SET_*cn*.TXT file.

Step 4. For any detected errors, modify the settings and send the settings until the relay accepts your settings.

Step 5. Repeat *Step 2–Step 4* for each settings class that you want to modify.

Step 6. Test and commission the relay.

SET_ALL.TXT File (Read-Only)

The SET_ALL.TXT file contains the settings for all of the settings classes in the relay.

SET_cn.TXT Files (Read and Write)

There is a file for each instance of each setting class. *Table 15.9* summarizes the typical settings files. The exact list of settings files depends on the specific settings classes available in each relay model. The settings class is designated by *c*, and the settings instance number is *n*.

BAY_SCREEN.TXT

NOTE: Not all SEL-400 series relays support bay mimic screens.

The BAY_SCREEN.TXT file describes the content of the custom bay mimic screen that can be selected for display on the HMI. This file is generated by QuickSet and may be downloaded to the relay when Bay Control settings are changed.

ERR.TXT (Read-Only)

The ERR.TXT file contents are based on the most recent SET_cn.TXT or SET_61850.CID file written to the relay. If there were no errors, the file is empty. If errors occurred, the relay logs these errors in the ERR.TXT file.

SET_61850.CID

Present if ordered with the IEC 61850 protocol option, the SET_61850.CID file contains the IEC 61850 Configured IED Description (CID) in XML. This file is generated by Architect and downloaded to the relay. See *Section 17: IEC 61850 Communication* for more information on the SET_61850.CID file.

Table 15.9 Typical Settings Directory Files (Sheet 1 of 2)

Settings Class	Filename	Settings Description	Read Access Level	Write Access Level
A	SET_A*n*.TXT	Automation; *n* in range 1–10 For relay-0, *n* = 1	1, B, P, A, O, 2	A, 2
B	SET_B1.TXT	Bay Control	1, B, P, A, O, 2	P, A, O, 2
D	SET_D*n*.TXT	DNP3 remapping; *n* in range 1–5	1, B, P, A, O, 2	P, A, O, 2
F	SET_F1.TXT	Front panel	1, B, P, A, O, 2	P, A, O, 2
G	SET_G1.TXT	Global	1, B, P, A, O, 2	P, A, O, 2
L	SET_L*n*.TXT	Protection logic; *n* in range 1–6	1, B, P, A, O, 2	P, 2

Table 15.9 Typical Settings Directory Files (Sheet 2 of 2)

Settings Class	Filename	Settings Description	Read Access Level	Write Access Level
M	SET_SM.TXT	Breaker monitor settings	1, B, P, A, O, 2	P, 2
N	SET_N1.TXT	Notes	1, B, P, A, O, 2	P, A, O, 2
O	SET_O1.TXT	Contact outputs	1, B, P, A, O, 2	O, 2
P	SET_P*n*.TXT	Port; *n* in range 1, 2, 3, 5, F	1, B, P, A, O, 2	P, A, O, 2
R	SET_R1.TXT	Report	1, B, P, A, O, 2	P, A, O, 2
S	SET_S*n*.TXT	Group *n*; *n* in range 1–6	1, B, P, A, O, 2	P, 2
T	SET_T1.TXT	Alias settings	1, B, P, A, O, 2	P, A, O, 2
All	SET_ALL.TXT	All instances of all setting classes	1, B, P, A, O, 2	N/A
All	ERR.TXT	Error log for most recently written settings file	1, B, P, A, O, 2	N/A
NA	SET_61850.CID	IEC 61850 configured IED description file	1, B, P, A, O, 2	2
NA	BAY_SCREEN.TXT	Custom bay mimic screen content	1, B, P, A, O, 2	P, A, O, 2

Reports Directory

Use the REPORTS directory to retrieve files that contain the reports shown in *Table 15.10*. Note that the relay provides a report file that contains the latest information each time you request the file.

NOTE: Not all SEL-400 series relays support breaker monitoring and corresponding breaker files.

Table 15.10 REPORTS Directory Files

File[a]	Usage: All Are Read-Only Files
SER.TXT[b]	SER report
CSER.TXT[b]	Compressed ASCII SER report
BRE_*n*.TXT	BRE *n* H report, *n* is the breaker reference
BRE_S*n*.TXT	BRE S*n* report, *n* is the breaker reference
CBRE.TXT	Compressed ASCII breaker monitor report
HISTORY.TXT	History file
CHISTORY.TXT	Compressed ASCII History file
PRO.TXT[b]	Profiling report
CPRO.TXT[b]	Compressed ASCII profiling report
TFE.TXT[b, c]	Through-fault event report
THE.TXT[b, c]	Thermal report
THE_D.TXT[b, c]	Daily thermal report
THE_H.TXT[b, c]	Hourly thermal report
VSS.TXT[b, c]	Voltage sag swell report

[a] Report files are read-only
[b] Report clears/resets when retrieved though use of a serial port.
[c] Not available on all SEL-400 series relays. See the product-specific instruction manual for availability.

Events Directory

NOTE: Most SEL-400 series relays provide large resolution event reports of 8 samples/cycle. The SEL-487B provides large resolution event reports of 12 samples/cycle. The SEL-400G provides all event reports in IEEE C37.111-2013 COMTRADE format. Filtered event reports use a 2.5 millisecond sample rate.

The relay provides history, event reports, and oscillography files in the EVENTS directory. Event reports are available in a variety of formats. Depending on the relay, these may include SEL ASCII 4- or 8-samples/cycle reports and Compressed ASCII 4- or 8-samples/cycle reports. The size of each event report file is determined by the LER setting in effect at the time the event is triggered. Higher resolution oscillography is available in binary COMTRADE (IEEE C37.111-1999 and C37.111-2013) format at the sample rate (SRATE) and length (LER) settings in effect at the time the event is triggered.

The 4- and 8-samples/cycle report files (files with names that begin with E or C) are text files with the same format as the **EVENT** and **CEVENT** command responses. Event file names start with the prefix E4_, E8_, E12, C4_, C8_, C12, or HR_, followed by a unique event serial number. For example, if one event is triggered, with serial number of "10001", the EVENTS directory contains the files shown in *Table 15.13*. Event oscillography in COMTRADE format consists of three files (.CFG, .DAT, and .HDR).

The file names for the C37.111-1999 COMTRADE event files have the following format:

pq_nnnnn.rrr

Table 15.11 C37.111-1999 COMTRADE Event File Names

Variable	Description
pq	One of the following: HR (indicating high-resolution event file) HF (indicating high-impedance fault event reports, if supported by the relay) TW (indicating traveling-wave event reports, if supported by the relay)
nnnnn	The unique serial number associated with the event file
rrr	CFG (indicating configuration file) or DAT (indicating data file) or HDR (indicating header file)

The file names for the C37.111-2013 COMTRADE event files have the following format:

yymmdd,hhMMssmmm,0T,aaaaa,bbbbb,ccccc,pq,nnnnn.rrr

Table 15.12 C37.111-2013 COMTRADE Event File Names (Sheet 1 of 2)

Variable	Description
yy	Last two digits of year
mm	The month (01 to 12)
dd	The day (01 to 31)
hh	The hour (00 to 23)
MM	The minute (00 to 59)
ss	The second (00 to 59)
mmm	The millisecond (000 to 999)
aaaaa	The last five characters of the SID setting (after removing spaces)
bbbbb	The last five characters of the RID setting (after removing spaces)
ccccc	The CONAM setting

Table 15.12 C37.111-2013 COMTRADE Event File Names (Sheet 2 of 2)

Variable	Description
pq	One of the following: HR (indicating high-resolution event file) LR (indicating low-resolution event file, if supported by the relay) DR (indicating disturbance recording event files, if supported by the relay) HF (indicating high-impedance fault event reports, if supported by the relay) TW (indicating traveling-wave event reports, if supported by the relay)
nnnnn	The unique serial number associated with the event file
rrr	CFG (indicating configuration file) or DAT (indicating data file) or HDR (indicating header file)

the *yymmdd* and *hhMMss* values are based on the SOC (second of century) of the first triggered data point as specified in the COMTRADE C37.111 standard.

Spaces and characters **? " / \ < > * | : ; [ ] $ % { }** are not supported in the RID or SID used in the C37.111-2013 filenames, and the relay will automatically remove them.

Table 15.13 EVENTS Directory Files (for Event 10001)

File	Usage
HISTORY.TXT	History file; read-only
CHISTORY.TXT	Compressed ASCII history file; read-only
C4_10001.TXT	4-samples/cycle Compressed ASCII event report; read-only
C8_10001.TXT[a]	8-samples/cycle Compressed ASCII event report; read-only
E4_10001.TXT	4-samples/cycle event report; read-only
E8_10001.TXT[b]	8-samples/cycle event report; read-only
HR_10001.CFG	Sample/second C37.111-1999 COMTRADE configuration file; read-only
HR_10001.DAT	Sample/second C37.111-1999 COMTRADE binary data file; read-only
HR_10001.HDR	Sample/second C37.111-1999 COMTRADE header file; read-only
yymmdd,hhMMssmmm,0T,aaaaa,bbbbb,ccccc,pq,nnnnn.CFG[c]	Sample/Second C37.111-2013 COMTRADE configuration file, read-only
yymmdd,hhMMssmmm,0T,aaaaa,bbbbb,ccccc,pq,nnnnn.DAT	Sample/Second C37.111-2013 data file, read-only
yymmdd,hhMMssmmm,0T,aaaaa,bbbbb,ccccc,pq,nnnnn.HDR	Sample/Second C37.111-2013 COMTRADE header file, read-only

[a] In the SEL-487B, this is replaced with C1210001.TXT, which provides a 12-samples/cycle Compressed ASCII event report.
[b] In the SEL-487B, this is replaced with E1210001.TXT, which provides a 12-samples/cycle event report.
[c] See the filename descriptions in Figure 15.12 for an explanation of the variable names used in the C37.111-2013 COMTRADE format.

Synchrophasors Directory

Table 15.14 shows an example SYNCHROPHASORS directory. Synchrophasor data recording is enabled when synchrophasors are enabled and EPMDR := Y. The filename includes a time stamp based on the first data frame in the file. The data in the file conforms to the IEEE C37.118 data format.

Table 15.14 SYNCHROPHASORS Directory File Sample

File	Description
080528,160910,0,ONA,1,ABC.PMU	080528 = date 160910 = time 0 = GMT (no time offset) ONA = Last three letter (spaces removed) of the PMSTN setting 1 = PMID setting ABC = CONAM setting (company name) PMU = file name extension indicating synchrophasor recording file

Upgrade Directory

Table 15.15 shows the file contents of the UPGRADE directory. The UPGRADE directory is only available via FTP at Access Level 2 and above on relays that support Ethernet firmware upgrades. The directory is not available if the Port 5 setting EETHFWU := N. The RELAY.ZDS and SELBOOT.ZDS are write-only files, whereas the ERR.TXT is a read-only file.

NOTE: The UPGRADE directory is not available via FTP if FTPANM := Y.

Table 15.15 UPGRADE Directory File Sample

File	Description
ERR.TXT	Digitally signed firmware upgrade error file, read-only
RELAY.ZDS	Digitally signed firmware upgrade file, write-only
SELBOOT.ZDS	SELBOOT firmware digitally signed upgrade file, write-only

Batch File Access

You can access files as a batch by using the supported wildcard characters ***** or **?**. Use ***** to match any sequence of characters and **?** to match any single character.

FTP and MMS Wildcard Usage

Table 15.16 shows examples using supported wildcards. Note that these wildcards may be appended to a directory path (e.g., /specified_directory/*.txt).

Table 15.16 FTP and MMS Wildcard Usage Examples

Usage	Description	Example	Note
**xyz*	Lists all files and/or subdirectories, within a specified directory, whose names (including extension) end with *xyz*.	/*.TXT	List all files with the .TXT extension
*abc**	Lists all files and/or subdirectories, within a specified directory, whose names begin with *abc*.	/SETTINGS/SET*	List all settings files that start with SET
mno	Lists all files and/or subdirectories, within a specified directory, whose names contain *mno*.	/EVENTS/*_100*	List all events that contain _100 in the ID number
abc?.xyz[a]	Lists all files, within a specified directory, whose names begin with *abc* and whose names (including extension) end with *xyz* and have any one single character following the letter *c*.	/EVENTS/C?_10007.CEV	Retrieves both the filtered and raw compressed event reports pertaining to the unique event number 10007

[a] Only available for FTP.

Ymodem Wildcard Usage

NOTE: Ymodem protocol only supports wildcard file retrieval operations for event files.

NOTE: Wildcards cannot be used in the last five digits of the file name when retrieving event reports.

Event, report, synchrophasor, and settings files can be accessed as a batch by using wildcards.

Table 15.17 Ymodem Wildcard Usage Examples

Usage	Description	Example	Note
**xyz*	Selects all files whose names (including extension) end with *xyz*.	FILE DIR EVENTS *.CFG	Lists all COMTRADE.CFG files
*abc**	Selects all files whose names begin with *abc*.	FILE READ EVENTS HR_10007*	Retrieves all of the three files for the COMTRADE event 10007 (HR_10007.CFG, HR_10007.DAT, and HR_10007.HDR)
mno	Selects all files whose names contain *mno*.	FILE READ EVENTS *10007*	Retrieves all event files pertaining to the unique event number 10007 (including both the filtered and raw compressed event reports and all three comtrade files)
abc?.xyz	Selects all files whose names begin with *abc* and whose names (including extension) end with *xyz* and have any one single character following the letter c.	FILE DIR SETTINGS SET_D?.TXT	Lists all of the DNP settings files (SET_D1.TXT–SET_D5.TXT)

Software Protocol Selections

The relay supports the protocols and command sets shown in *Table 15.18*.

Table 15.18 Supported Serial Command Sets

PROTO Setting Value	Command Set	Description
SEL	SEL ASCII	Commands and responses
SEL	SEL Compressed ASCII	Commands and comma-delimited responses
SEL	SEL Fast Meter	Binary meter and digital element commands and responses
SEL	SEL Fast Operate	Binary operation commands
SEL	SEL Fast Message	Fast Message database access, binary SER commands and responses
MBA, MBB, MBGA, or MBGB	SEL MIRRORED BITS communications	Binary high-speed control commands
PMU	Phasor Measurement Unit	Binary Synchrophasor Protocol, as selected by Port Setting PMUMODE and Global Setting MFRMT (see *Section 18: Synchrophasors*).
RTD	SEL Fast Message protocol for resistance temperature detector (RTD) data	As many as 12 analog temperature readings from the SEL-2600A.
DNP	DNP3 Level 2 Outstation	Binary commands and responses (see *Section 16: DNP3 Communication*).

NOTE: Not all SEL-400 series relays support MBGA and MBGB protocol.

NOTE: Not all SEL-400 series relays support synchrophasors (the PMU protocol choice).

NOTE: Not all SEL-400 series relays support RTD communications with the SEL-2600A.

Virtual Serial Ports

Actual serial ports are described in *Serial Port Hardware Protocol on page 15.4*. In addition to actual serial ports, the relay supports several virtual serial ports. A virtual serial port does the following:

- ➤ Transmits and receives characters through a different mechanism than the physical serial port
- ➤ "Encapsulates" characters in virtual terminal messages of a different protocol
- ➤ Simulates an actual serial port with setting PROTO := SEL
- ➤ May have restrictions imposed by the protocol that encapsulates the virtual serial data

You can set the relay to use virtual serial ports encapsulated in SEL MIRRORED BITS communications links, DNP3 links, and through Telnet over Ethernet.

SEL Protocol

This section describes the command sets that are active when the port setting PROTO := SEL. You can also access these protocols through virtual serial ports that simulate ports with PROTO := SEL.

SEL ASCII Commands

SEL originally designed the SEL ASCII commands for communication between the relay and a human operator via a keyboard and monitor or a printing terminal. A computer with a serial port can also use the SEL ASCII protocol to communicate with the relay, collect data, and issue commands.

The ASCII character set specifies numeric codes that represent printing characters and control characters. The complete ASCII command set is shown in *Section 14: ASCII Command Reference*. *Table 15.19* shows the subset of the ASCII control characters used in this section.

Table 15.19 Selected ASCII Control Characters

Decimal Code	Name	Usage	Keystroke(s)
13	CR	Carriage return	**<Enter>** or **<RETURN>** or **<Ctrl+M>**
10	LF	Line feed	**<Ctrl+J>**
02	STX	Start of transmission	**<Ctrl+B>**
03	ETX	End of transmission	**<Ctrl+C>**
24	CAN	Cancel	**<Ctrl+X>**
17	XON	Flow control on	**<Ctrl+Q>**
19	XOFF	Flow control off	**<Ctrl+S>**

The **<Enter>** key on standard keyboards sends the ASCII character CR for a carriage return. This manual instructs you to press the **<Enter>** key after commands to send the proper ASCII code to the relay. A correctly formatted command transmitted to the relay consists of the command, including optional parameters, followed by either a CR character (carriage return) or CR and LF characters (carriage return and line feed). The following line contains this information in the format this manual uses to describe user input:

<command> <Enter> or <command> <Enter> <CR>

You may truncate commands to the first three characters. For example, **EVENT 1 <Enter>** is equivalent to **EVE 1 <Enter>**. You may use upper- and lowercase characters without distinction, except in passwords.

In response to a command, the relay may respond with an additional dialog line or message. The relay transmits dialog lines in the following format:

```
<DIALOG LINE ><CR><LF>
```

The relay transmits messages in the following format:

```
<STX><MESSAGE LINE 1><CR><LF>
<MESSAGE LINE 2><CR><LF>
…
<LAST MESSAGE LINE><CR><LF>< ETX>
```

Each message begins with the start-of-transmission character, STX, and ends with the end-of-transmission character, ETX. Each line of the message ends with a carriage return, CR, and line feed, LF.

Send the CAN character to the relay to abort a transmission in progress. For example, if you request a long report and want to terminate transmission of this report, depress the **<Ctrl>** and **<X>** keys (**<Ctrl+X>**) to terminate the report.

SEL Compressed ASCII Commands

The relay supports a subset of SEL ASCII commands identified as Compressed ASCII commands. Each of these commands results in a comma-delimited message that includes a checksum field. Most spreadsheet and database programs can directly import comma-delimited files. Devices with embedded processors connected to the relay can execute software to parse and interpret comma-delimited messages without expending the customization and maintenance labor needed to interpret nondelimited messages. The relay calculates a checksum for each line by numerically summing all of the bytes that precede the checksum field in the message. The program that uses the data can detect transmission errors in the message by summing the characters of the received message and comparing this sum to the received checksum.

Most commands are available only in SEL ASCII format. Selected commands have versions in both standard SEL ASCII and Compressed ASCII formats. Compressed ASCII reports generally have fewer characters than conventional SEL ASCII reports, because the compressed reports reduce blanks, tabs, and other white space between data fields to a single comma.

Compressed ASCII Message Format

Each message begins with the start-of-transmission character, STX, and ends with the end-of-transmission character, ETX:

```
<STX><MESSAGE LINE 1><CR><LF>
<MESSAGE LINE 2><CR><LF>
...
<LAST MESSAGE LINE><CR><LF><ETX>
```

Each line in the message consists of one or more data fields, a checksum field, and a CRLF. Commas separate adjacent fields. Each field is either a number or a string. Number fields contain base-10 numbers that use the ASCII characters 0–9, plus (+), minus (-), and period (.). String fields begin and end with quote marks and contain standard ASCII characters. Hexadecimal numbers are contained in string fields.

The checksum consists of four ASCII characters that are the hexadecimal representation of the two-byte binary checksum. The checksum value is the sum of the first byte on a line (first byte following <STX>, <CR>, or <CR><LF>) through the comma preceding the checksum.

If you request data with a Compressed ASCII command and these data are not available, (in the case of an empty history buffer or invalid event request), the relay responds with the following Compressed ASCII format message:

<STX>"No Data Available","0668"<CR><ETX>

where:

No Data Available is a text string field.

0668 is the checksum field, which is a hexadecimal number represented by a character string.

Table 15.20 lists the typical Compressed ASCII commands and contents of the command responses. The Compressed ASCII commands are described in *Section 14: ASCII Command Reference*.

Table 15.20 Typical Compressed ASCII Commands

Command	Response	Access Level
BNAME	ASCII names of Fast Meter status bits	0
CASCII	Configuration data of all Compressed ASCII commands available at access levels > 0	0
CBREAKER	Circuit breaker data	1
CEVENT	Event report	1
CHISTORY	List of events	1
CPR	Displays the first 20 rows of the profile report, with the oldest row at the bottom and the latest row at the top	
CSER	Sequential Events Recorder report	1
CSTATUS	Self-diagnostic status	1
CSUMMARY	Summary of an event report	1
DNAME	ASCII names of digital I/O reported in Fast Meter	0
ID	Relay identification	0
SNS	ASCII names for SER data reported in Fast Meter	0

CASCII Configuration Message for Compressed ASCII Commands

The CASCII message provides a block of data for each of the Compressed ASCII commands supported by an SEL device. The block of data for each command provides message description information to allow automatic data extraction. The relay arranges items in the Compressed ASCII configuration message in a predefined order. For the purpose of improving products and services, SEL sometimes changes the items and item order. The information presented below explains the message and serves as a guide to the items in Compressed ASCII configuration messages.

NOTE: Compressed ASCII is self-describing and may vary with the firmware version of your relay. Before you program a master device to send and parse Compressed ASCII commands and responses, you should perform a **CASCII** command on your relay or contact SEL for more detailed information.

A Compressed ASCII command can require multiple header and data configuration lines. The general format of a Compressed ASCII configuration message is the following:

```
<STX>"CAS",n,"yyyy"<CR><LF>
"COMMAND 1",ll,"yyyy"<CR><LF>
"#H","xxxxx","xxxxx",......,"xxxxx","yyyy"<CR><LF>
"#D","ddd","ddd","ddd","ddd",......,"ddd","yyyy"<CR><LF>
.
.
.

"COMMAND n",ll,"yyyy"<CR><LF>
"#H","xxxxx","xxxxx",......,"xxxxx","yyyy"<CR><LF>
"#D","ddd","ddd","ddd","ddd",......,"ddd","yyyy"<CR><LF><ETX>
```

Definitions for the items and fields in a Compressed ASCII configuration message are the following:

- `n` is the number of Compressed ASCII command descriptions to follow.
- `COMMAND` is the ASCII name for the Compressed ASCII command that the requesting device (terminal or external software) sends. The naming convention for the Compressed ASCII commands is a C character preceding the typical command. For example, **CSTATUS**, abbreviated to **CST**, is the Compressed ASCII **STATUS** command.
- `#H` identifies a header line to precede one or more data lines; the # character represents the number of subsequent ASCII names. For example, 21H identifies a header line with 21 ASCII labels.
- `xxxxx` is an ASCII name for corresponding data on following data lines. Maximum ASCII name width is ten characters.
- `#D` identifies a data format line; the # character represents the maximum number of data lines in command response.
- `ddd` identifies a format field containing one of the following type designators:
  - I—Integer data
  - F—Floating-point data
  - *z*S—String of maximum *z* characters (for example, enter 10S for a 10-character string)
- *yyyy* is the 4-byte hex ASCII representation of the checksum. Every checksum is followed by a new line indication (<CR><LF>).

Software Flow Control

Software handshaking is a form of flow control that two serial devices use to prevent input buffer overflow and loss of characters. The relay uses XON and XOFF control characters to implement software flow control for ASCII commands.

The relay transmits the XOFF character when the input buffer is more than 75 percent full. The connected device should monitor the data it receives for the XOFF character to prevent relay input buffer overflow. The external device should suspend transmission at the end of a message in progress when it receives the XOFF character. When the relay has processed the input buffer so that the buffer is less than 25 percent full, the relay transmits an XON character. The external device should resume normal transmission after receiving the XON character.

The relay also uses XON/XOFF flow control to delay data transmission to avoid overflow of the input buffer in a connected device. When the relay receives an XOFF character during transmission, it pauses transmission at the end of the message in progress. If there is no message in progress when the relay receives the XOFF character, it blocks transmission of any subsequent message. Normal transmission resumes after the relay receives an XON character.

Automatic Messages

If you enable automatic messages, **AUTO = Y**, the relay issues a message any time the relay turns on, asserts a self-test, changes to another settings group, or triggers an event. For virtual ports, the relay issues automatic messages only if the connection is active. Automatic messages contain the following information:

- Power-up: When you turn on the relay, the message provides the terminal ID and the present date and time.
- Self-test failure: When the relay detects an internal failure, the automatic message is the same as the relay response to the **STATUS** command.
- Group switch: Whenever a settings group change occurs, the message contains the relay ID, terminal ID, present date and time, and the selected settings group.
- Events: When the relay triggers an event, the automatic message is the same as the relay response to the **SUMMARY** command.

Time-Out

Use the TIMEOUT setting to set the idle time for each port. Idle time is the period when no ASCII characters are transmitted and received (interleaved Fast Messages do not affect the idle time). When the idle time exceeds the TIMEOUT setting, the following takes place:

- The access level changes to Access Level 0.
- The front-panel targets reset to TAR 0 if the port had previously remapped the targets.
- Virtual connections are disconnected.
- The software flow control state changes to XON.

When set to OFF, the port never times out.

Interleaved ASCII and Binary Messages

SEL relays have two separate data streams that share the same physical serial port. Human data communications with the relay consist of ASCII character commands and reports that you view using a terminal or terminal emulation package. The binary data streams can interrupt the ASCII data stream to obtain information; the ASCII data stream continues after the interruption. This mechanism uses a single communications channel for ASCII communication (transmission of an event report, for example) interleaved with short bursts of binary data to support fast acquisition of metering data. The device connected to the other end of the link requires software that uses the separate data streams to exploit this feature. However, you do not need a device to interleave data streams to use the binary or ASCII commands. Note that XON, XOFF, and CAN operations operate on only the ASCII data stream.

An example of using these interleaved data streams is when the relay communicates with an SEL communications processor. The communications processor performs autoconfiguration by using a single data stream and SEL Compressed

ASCII and binary messages. In subsequent operations, the communications processor uses the binary data stream for Fast Meter, Fast Operate, and Fast SER messages to populate a local database and to perform SCADA operations. At the same time, you can use the ASCII data stream for commands and responses.

SEL Fast Meter, Fast Operate, Fast SER Messages, and Fast Message Data Access

NOTE: For the list of available bits to Fast Meter, see DNAME X on page 14.31.

SEL Fast Meter is a binary message that you solicit with binary commands. Fast Operate is a binary message for control. The relay can also send unsolicited Fast SER messages and unsolicited synchrophasor messages automatically. If the relay is connected to an SEL communications processor, these messages provide the mechanism that the communications processor uses for SCADA or DCS functions that occur simultaneously with ASCII interaction.

This section summarizes the binary commands and messages and includes our recommendation for using Fast Commands and Compressed ASCII configuration information to communicate with the relay. You need this information to develop or specify the software an external device uses to communicate using Fast Messages with the relay. To support this type of development, you will also need to contact SEL for Fast Message protocol details.

Table 15.21 lists the two-byte Fast Commands and the actions the relay takes in response to each command.

NOTE: Not all SEL-400 series relays support demand metering and the corresponding fast commands.

Table 15.21 Fast Commands and Response Descriptions

Command (Hex)	Name	Response Description
A5B9h	Status acknowledge message	Clears Fast Meter status byte and sends current status.
A5C0h	Relay Fast Meter definition block	Defines available Fast Meter messages and general relay configuration information.
A5C1h	Fast Meter configuration block	Defines contents of Fast Meter data message.
A5C2h	Demand Fast Meter configuration block	Defines contents of demand Fast Meter data message.
A5C3h	Peak demand Fast Meter configuration block	Defines contents of peak demand Fast Meter data message.
A5CEh	Fast Operate configuration block	Defines available circuit breaker, remote bits, and associated commands.
A5D1h	Fast Meter data message	Defines present values of analog and digital data.
A5D2h	Demand Fast Meter data message	Defines values of most recently completed demand period.
A5D3h	Peak demand Fast Meter data message	Defines values for peak demands as of end of most recently completed demand periods.

Fast Operate commands use one of the two-byte command types shown in *Table 15.22*. Each Fast Operate command also includes additional bytes that specify a remote bit or circuit breaker bit.

Table 15.22 Fast Operate Command Types

Command (Hex)	Name	Description
A5E0h	Fast Operate command for remote bits	Sends command code that will change the state of a remote bit, if setting FASTOP :=Y for this port.
A5E3h	Fast Operate command for circuit breaker bits	Sends command code that will change the state of a circuit breaker control bit, if setting FASTOP :=Y for this port.

The Fast Operate messages transfer control commands through the binary data stream. You must enable Fast Operate messages for a port before the relay accepts these messages on that port. In the port settings, when the protocol is set to SEL, the FASTOP setting is visible. Set FASTOP :=Y to enable Fast Operate commands or to N to disable Fast Operate commands.

General Fast Messages have a two-byte identifier (A546h) and a function code. Fast SER messages are general Fast Messages that transport Sequential Event Recorder report information. The Fast SER messages include function codes to accomplish different tasks. *Table 15.23* lists the Fast SER function codes and the actions the relay takes in response to each command.

Table 15.23 Fast Message Command Function Codes Used With Fast Messages (A546 Message) and Relay Response Descriptions

Function Code (Hex)	Function	Relay Action
00h	Fast Message definition block request	Relay transmits Fast Message definition request acknowledge (Function Code 80).
01h	Enable unsolicited transfers	Relay transmits Fast SER command acknowledged message (Function Code 81) and sets relay element bit FSERx. Relay will transmit subsequent SER events (Unsolicited SER broadcast, Function Code 18).
02h	Disable unsolicited transfers	Relay sends Fast SER command acknowledged message (Function Code 82) and clears relay element bit FSERx. Relay will not transmit subsequent SER messages.
05h	Ping—determine channel is operable	Relay aborts unsolicited message in progress and transmits ping acknowledge message (Function Code 85).
98h	Fast SER Message acknowledge	Relay completes dialog processing for unsolicited message sequence.
30h	Device description request	Relay sends summary of data blocks available (Function Code B0h).
31h	Data format request	Relay sends description of requested data block, including data labels and types (Function Code B1h).
33h	Bit label request	Relay sends set of bit labels for specific data item (Function Code B3h).
10h	Data request	Relay responds with set of requested data (Function Code 90h).

The SEL Fast Message Synchrophasor Protocol is described in *Section 18: Synchrophasors*.

Recommended Use of Relay Self-Description Messages for Automatic Configuration

Compressed ASCII and Fast Message commands provide information to allow an external computer-based device to adapt to the special messages for each relay. The SEL communications processors use the self-description messages to configure a database and name the elements in the database.

Table 15.24 lists commands and command usage in the recommended order of execution for automatic configuration.

Table 15.24 Commands in Recommended Sequence for Automatic Configuration

Command ASCII or hexadecimal (h suffix)	Response	Usage
ID	Relay identification	ID and FID
A5C0h	Relay Fast Meter definition block	Defines available Fast Meter messages and general relay configuration information
A5C1h, A5C2h, A5C3h	Fast Meter configuration blocks	Defines contents of Fast Meter data messages
BNAME	Binary names	ASCII names of status bits
DNAME	Digital I/O name	ASCII names of digital I/O points
SNS	SER names	ASCII names for SER data points
CASCII	Compressed ASCII configuration block	Configuration data for Compressed ASCII commands with access levels > 0
A5CEh	Fast Operate configuration block	Defines available circuit breaker and remote bits, and associated commands, if setting FASTOP :=Y for this port

SEL MIRRORED BITS Communication

With SEL-patented MIRRORED BITS communications protocol, protective relays and other devices can directly exchange information quickly, securely, and with minimal cost. Use MIRRORED BITS communications for remote control, remote sensing, or communications-assisted protection schemes such as permissive overreaching transfer trip (POTT) and directional comparison blocking (DCB).

SEL products support several variations of MIRRORED BITS communications protocols. Through port settings, you can set the relay for compatible operation with SEL-300 series relays, the SEL-2505 or SEL-2506 Remote I/O Modules, and the SEL-2100 Protection Logic Processors. These devices use MIRRORED BITS communications to exchange the states of eight logic bits. You can also use settings to select extensions of the MIRRORED BITS communications protocols, available only in SEL-400 series relays, to exchange analog values, synchronize clocks, and engage in virtual terminal dialogs. *Table 15.25* summarizes MIRRORED BITS communications features.

Table 15.25 MIRRORED BITS Communications Features (Sheet 1 of 2)

Feature	Compatibility
Transmit and receive logic bits	SEL-300 series relays, SEL-2505, SEL-2506, SEL-2100, SEL-400 series relays
Transmit and receive analog values	SEL-400 series relays
Synchronize time	SEL-400 series relays

Table 15.25 MIRRORED BITS Communications Features (Sheet 2 of 2)

Feature	Compatibility
Send and receive virtual serial port characters	SEL-400 series relays
Support synchronous communications channel	SEL-400 series relays

Communications Channels and Logical Data Channels

The relay supports two MIRRORED BITS communications channels, designated A and B. Use the port setting PROTO to assign one of the MIRRORED BITS communications channels to a serial port: PROTO := MBA or MBGA for MIRRORED BITS communications Channel A or PROTO := MBB or MBGB for MIRRORED BITS communications Channel B.

Transmitted bits include TMB1A–TMB8A and TMB1B–TMB8B. The last letter (A or B) designates with which channel the bits are associated. These bits are controlled by SELOGIC control equations. Received bits include RMB1A–RMB8A and RMB1B–RMB8B. You can use received bits as arguments in SELOGIC control equations. The channel status bits are ROKA, RBADA, CBADA, LBOKA, ROKB, RBADB, CBADB, LBOKB, DOKA, ANOKA, DOKB, and ANOKB. You can also use these bits as arguments in SELOGIC control equations. Use the **COM** command for additional channel status information.

Within each MIRRORED BITS communications message for a given channel (A or B), there are eight logical data channels (1–8). In operation compatible with other SEL products, you can use the eight logical data channels for TMB1–TMB8. If you use fewer than eight transmit bits, Data Channel 8 is reserved to support data framing and time synchronization features. You can assign the eight logical data channels as follows:

- Logic bits: Setting MBNUM controls the number of channels used for logic bits, TMB1–TMB8, inclusive.
  - If you set MBNUM to 8, then you cannot use channels for any of the following features.
  - If you set MBNUM to less than 8, you can use the remaining channels (as many as eight total) for the features listed below.
- Message and time synchronization: If MBNUM is less than 8, the relay dedicates a logical data channel to message framing and time synchronization. This feature is enabled by the MBTIME setting.
- Analog channels: Setting MBNUMAN controls the number of analog channels. It is not guaranteed that multiple analog quantities will come from the same relay sampling interval.
  - If MBNUM := 8, all channels are used for logic bits and MBNUMAN is forced to 0.
  - If MBNUM := 7, seven channels are used for logic bits and one channel is used for message and time synchronization.
  - If MBNUM is less than 7, you can use the remaining channels for analog channels by setting the desired number of channels in MBNUMAN (1 to 7 – MBNUM).

  Note: Analog quantities are converted to Integer values for transmission via MIRRORED BITS. Because of this, they will lose any fractional value they may have had. To maintain a fixed resolution, multiply the analog quantity by a set value before transmission, and divide by the same quantity upon reception. To maintain accuracy, add 0.5 to the analog quantity after any scaling.

- Virtual terminal sessions: Setting MBNUMVT controls the number of additional channels available for the virtual terminal session.
  - If MBNUMVT := OFF, the relay does not dedicate any additional channels to the virtual terminal session.
  - If there are spare channels (7 – MBNUM – MBNUMAN > 0), you can use MBNUMVT to dedicate these additional channels to the virtual terminal session.
  - With MBNUM = 7 or less and MBNUMVT = 0, virtual terminal is still possible because the relay uses the eighth element for time synchronization and virtual terminal.

  The virtual terminal session uses channels differently than other data exchange mechanisms. There can be only one active virtual terminal session across a MIRRORED BITS link. One channel, included in the synchronization data, is always dedicated to this virtual terminal session. If you assign additional channels to the virtual terminal session (set MBNUMVT > 0), you will improve the performance of the virtual terminal session. The relay uses the additional channels to exchange data more quickly.

Operation

MBG Protocol

The MBG protocol selection allows the user to move the MIRRORED BITS Transmit equations to the Group settings for more flexibility in bus transfer schemes. Using MBG will allow the MIRRORED BITS settings to transfer with a Group Switch when it occurs.

NOTE: The MBG protocol option is only available in some SEL-400 series relays.

To enable the MBG protocol, set the Port setting PROTO := MBGA to enable Channel A MIRRORED BITS, or PROTO := MBGB for Channel B MIRRORED BITS. Next, the protocol will need to be enabled in the Group settings.

Under Group settings, enable the MBG protocol for Channel A by setting EMBA := Y. When this setting is enabled, the transmit equation settings TX_IDA, RX_IDA, and TMB*n*A will be available in the Group settings and will be hidden from the Port settings.

The MBG protocol can also be enabled for Channel B by setting EMBB := Y. When this setting is enabled, the transmit equation settings TX_IDB, RX_IDB, and TMB*n*B will be available in the Group settings and will be hidden from the Port settings.

MB8

While the relay does not have a setting for the MB8 protocol implemented in some SEL products, you can configure the relay to communicate with devices set to MB8A or MB8B (such as the SEL-351S or SEL-2505). Set the protocol setting PROTO to MBA or MBB. Set the STOPBIT setting to 2. Set all other settings to match those in the other device.

Message Transmission

The relay transmits a MIRRORED BITS communications message as fast as it can for the configured data rate. At 9600 bps, this is approximately one message every 1/4-cycle. At 19200 bps, it is approximately every 1/8-cycle. At 38400 bps, it is approximately two every 1/8-cycle. However, if pacing is enabled, it slows to one message every 3 ms at 19200 and 38400 bps (see *Table 15.28*). Each message contains the most recent values of the transmit bits. If you enabled any of the extended features through the settings, note that the relay transmits a portion of the extended data in each message.

If you have specified virtual terminal data channels for this port, the designated data channels are normally idle. If you use the **PORT** command to open a virtual terminal session for this port and type characters, the relay transmits these characters through the virtual terminal logical data channels.

Message Reception Overview

When the devices are synchronized and the MIRRORED BITS communications channel is in a normal state, the relay decodes and checks each received message. If the message is valid, the relay performs the following operations:

- ➤ Sends each received logic bit (RMB*n*) to the corresponding pickup and dropout security counters, that in turn set or clear the RMB*nc* relay element bits.
- ➤ Accumulates the analog data, and every 18th message, updates the received analog quantities.
- ➤ Accumulates the virtual terminal information, and every 18th message, makes the received character or characters available to the virtual terminal.

NOTE: c represents the MIRRORED BITS channel (A or B), n represents the MIRRORED BITS data channel data number (1–8).

Message Decoding and Integrity Checks

The relay provides indication of the status of each MIRRORED BITS communications channel, with element bits ROKA and ROKB. During normal operation, the relay sets the ROK*c* bit. The relay clears the bit upon detecting any of the following conditions:

- ➤ Parity, framing, or overrun errors
- ➤ Receive data redundancy error
- ➤ Receive message identification error
- ➤ No message received in the time three messages have been sent

The relay will assert ROK*c* only after successful synchronization as described below and two consecutive messages pass all of the data checks described above. After ROK*c* is reasserted, received data may be delayed while passing through the security counters described below.

While ROK*c* is not set, the relay does not transfer new RMB data to the pickup-dropout security counters described below. Instead, the relay sends one of the user-definable default values to the security counter inputs. For each RMB*n*, specify the default value with setting RMB*n*FL, as follows:

- ➤ 1
- ➤ 0
- ➤ P (to use last valid value)

Individual pickup and dropout security counters supervise the movement of each received data bit into the corresponding RMB*n* element. You can set each pickup/dropout security counter from 1 to 8. A setting of 1 causes a security counter to pass every occurrence, while a setting of 8 causes a counter to wait for eight consecutive occurrences in the received data before updating the data bits. The pickup and dropout security count settings are separate. Control the security count settings with the settings RMB*n*PU and RMB*n*DO.

A pickup/dropout security counter operates identically to a pickup/dropout timer, except that the counter uses units of counted received messages instead of time. An SEL relay communicating with another SEL relay typically sends and receives MIRRORED BITS communications messages eight times per power system cycle. Therefore, a security counter set to two counts will delay a bit by approximately 1/4 of a power system cycle. Reference *Table 15.28* for the message rates based on the settings. You must consider the impact of the security counter settings in the receiving device to determine the channel timing performance.

Channel Synchronization

When an SEL relay detects a communications error, it deasserts ROKA or ROKB. The relay transmits an attention message until it receives an attention message that includes a match to the TX_ID setting value. If the attention message is successful, the relay has properly synchronized and data transmission will resume. If the attention message is not successful, the relay will repeat the attention message until it is successful.

Loopback Testing

Use the **LOOP** command to verify the communications channel. In this mode, the relay expects the transmitted data to be looped back to the relay to test the data transmissions, including communications data. At the remote end, jumper the send and receive communications channels to complete the path for the test. While in loopback mode, ROK*c* is deasserted, and LBOK*c* asserts and deasserts based on the received data checks.

Channel Monitoring

Based on the results of data checks (described above), the relay collects information regarding the 255 most recent communications errors. Each record contains at least the following fields:

- Dropout Time/Date
- Pickup Time/Date
- Time elapsed during dropout
- Reason for dropout

Use the **COM** command to generate a long or summary report of the communications errors.

NOTE: Combine error conditions including RBADA, RBADB, CBADA, and CBADB with other alarm conditions by using SELOGIC control equations. You can use these alarm conditions to monitor and report a communications channel failure.

There is a single record for each outage, but an outage can evolve. For example, the initial cause could be a data disagreement, but framing errors can extend the outage. If the channel is presently down, the COMM record will only show the initial cause, but the COMM summary will display the present cause of failure.

When the duration of an outage on Channel A or B exceeds a user-definable threshold, the relay will assert a user-accessible flag, RBADA or RBADB. When channel unavailability exceeds a user-definable threshold for Channel A or B, the relay asserts a user-accessible flag, CBADA or CBADB.

MIRRORED BITS Communications Protocol for the Pulsar 9600-BPS Modem

NOTE: The MBT9600 modem requires +5 Vdc from pin 1 of the DB 9 connector. A rear serial port can supply this voltage if its jumper is set. See Serial Port Jumpers in the product-specific instruction manual for more information.

NOTE: You must consider the idle time in the calculations of data transfer latency through a Pulsar MBT modem system.

To use a Pulsar MBT modem, set setting MBT := Y. Setting MBT := Y hides setting SPEED and forces it to 9600, and hides setting RTSCTS and forces it to a value of N. The relay also injects a delay (idle time) of 3 ms between messages.

The relay sets RTS to a negative voltage at the EIA-232 connector to signify that MIRRORED BITS communications matches this specification.

Settings

The port settings associated with MIRRORED BITS communications are shown in *Table 15.26* and *Table 15.27*.

Set PROTO := MBA or MBGA to enable the MIRRORED BITS communications protocol Channel A on this port. Set PROTO := MBB or MBGB to enable the MIRRORED BITS communications protocol Channel B on this port.

Table 15.26 General Port Settings Used With MIRRORED BITS Communications

Name	Description	Range	Default
PROTO	Protocol	None, SEL, DNP, MBA, MBB, MBGA, MBGB, RTD, PMU	SEL
MBT	Enable Pulsar 9600 modem	Y, N	N
SPEED	Data speed. Hidden and set to 9600 if MBT := Y	300, 600, 1200, 2400, 4800, 9600, 19200, 38400, SYNC	9600
STOPBIT	Stop bits. Hidden and set to 1 if MBT := Y	1, 2	1

Setting SPEED := SYNC (available only on the rear-panel serial ports for which PROTO := MBA, MBB, MBGA, or MBGB) places the serial port in synchronous (or externally clocked) mode. The serial port hardware will synchronize transmit and receive data (TX/RX) to a clock signal applied to the Pin 8 input at any effective data rate as high as 64000. This setting choice will suit certain synchronous communications networks.

The relay uses the RBADPU setting to determine how long a channel error must persist before the relay asserts RBADA or RBADB. The relay deasserts RBADA and RBADB when it no longer detects a channel error. RBADA and RBADB update immediately in the MIRRORED BITS protocol but may take several milliseconds to update for SELOGIC control equations. It is recommended to use RBADA and RBADB in SELOGIC control equations for monitoring purposes only.

The relay uses the CBADPU setting to determine when to assert CBADA and CBADB. If the short-term channel downtime ratio exceeds CBADPU, the relay asserts the appropriate CBAD bit.

The TXMODE setting provides compatibility with SEL devices that are not SEL-400 series relays. The relay can send messages more quickly than the SEL-300 series relays and other SEL devices can process these messages. This could lead to loss of data and a failure to communicate properly. When you set TXMODE to P, the relay sends new MIRRORED BITS messages every 3 ms even if the selected data speed (SPEED setting) would allow more frequent messages.

As a function of the settings for SPEED, TXMODE, and MBT, the message transmission periods are shown in *Table 15.28*.

Table 15.27 MIRRORED BITS Communications Protocol Settings

Name	Description	Range
TX_ID	MIRRORED BITS communications ID of this device	1–4
RX_ID	MIRRORED BITS communications ID of device connected to this port	1–4 (must be different than TX_ID)
RBADPU	Outage duration to set RBAD	1–10000 seconds
CBADPU	Channel unavailability to set CBAD	1–100000 parts per million
TXMODE	Transmission mode[a]	N (normal), P (paced)
MBNUM	Number of MIRRORED BITS communications data channels used for logic bits	0–8
RMB1FL[b]	RMB1 channel fail state	0, 1, P
RMB1PU[b]	RMB1 pickup message count	1–8
RMB1DO[b]	RMB1 dropout message count	1–8
• • •	• • •	
RMB8FL[b]	RMB8 channel fail state	0, 1, P
RMB8PU[b]	RMB8 pickup message count	1–8
RMB8DO[b]	RMB8 dropout message count	1–8
MBTIME	MIRRORED BITS time synchronize enable	Y, N
MBNUMAN	Number of analog data channels (hidden and set to 0 if MBNUM := 7 or 8)	0–*n*, *n* = 7–MBNUM
MBANA1[c]	Selection for analog Channel 1	Analog quantity label
MBANA2[c]	Selection for analog Channel 2	Analog quantity label
MBANA3[c]	Selection for analog Channel 3	Analog quantity label
MBANA4[c]	Selection for analog Channel 4	Analog quantity label
MBANA5[c]	Selection for analog Channel 5	Analog quantity label
MBANA6[c]	Selection for analog Channel 6	Analog quantity label
MBANA7[c]	Selection for analog Channel 7	Analog quantity label
MBNUMVT	Number of virtual terminal channels	OFF, 0–*n*, *n* = 7–MBNUM–MBNUMAN

[a] Must be P for connections to devices that are not SEL-400 series relays.
[b] Hidden based on MBNUM setting.
[c] Hidden based on MBNUMAN setting.

Table 15.28 MIRRORED BITS Communications Message Transmission Period

Speed in Bits per Second	TXMODE := NORMAL MBT := N	TXMODE := PACED MBT := N	MBT :=Y
38400	1.0 ms	3.0 ms	N/A
19200	2.0 ms	3.0 ms	N/A
9600	4.0 ms	4.0 ms	7.0 ms
4800	8.0 ms	8.0 ms	N/A

Set the RX_ID of the local relay to match the TX_ID of the remote relay. In a three-terminal case, Relay X transmits to Relay Y, Relay Y transmits to Relay Z, and Relay Z transmits to Relay X. *Table 15.29* lists the MIRRORED BITS communications ID settings for Relays X, Y, and Z.

Table 15.29 MIRRORED BITS Communications ID Settings for Three-Terminal Application

Relay	TX_ID	RX_ID
X	1	3
Y	2	1
Z	3	2

SEL Distributed Port Switch Protocol (LMD)

The relay does not have built-in LMD protocol, but you can connect the relay to an SEL-2885 EIA-232 to EIA-485 Transciever and connect the SEL-2885 to an EIA-485 multidrop network. See the *SEL-2885 EIA-232 to EIA-485 Transceiver* product flyer for more information on the settings, configuration, and application of the SEL-2885. Application Guide AG94-03 provides additional details for applying this protocol and is available at selinc.com.

SEL-2600A RTD Module Operation

The SEL-2600A RTD Module Protocol (RTD) enables communication with an SEL-2600A via an SEL-2800 (EIA-232 to Fiber-Optic) Transceiver.

NOTE: Not all SEL-400 series relays support communication with SEL-2600A RTD Modules.

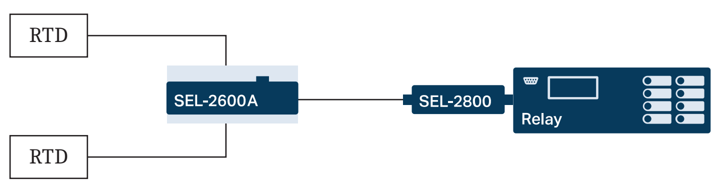

Figure 15.10 SEL-2600A RTD Module and the Relay

This protocol supports data acquisition of as many as 12 temperature channels and places the results directly into predefined analog quantities (RTD01–RTD12) inside the relay for use in freeform SELOGIC applications. For more information on the SEL-2600A or SEL-2800, contact your local technical service center, the SEL factory, or visit the SEL website at selinc.com for a copy of the SEL-2600A and SEL-2800 product fliers.

Initialization

Perform the following steps to prepare the relay for communicating with an SEL-2600A RTD module:

Step 1. Set the desired port to RTD protocol.

Step 2. Set the port setting RTDNUM to the number of RTDs attached to the SEL-2600A.

Step 3. Set the RTD type settings (RTD*nn*TY) to the appropriate RTD type.

Step 4. Connect the SEL-2600A RTD Module to the port via the SEL-2800 (EIA-232 to Fiber-Optic) Transceiver.

Operation

The SEL-2600A RTD module sends all temperature measurements to the relay every 0.5 seconds. The relay places the received temperature measurements into analog quantities RTD01–RTD12 for use in freeform SELOGIC applications. The data range is from –50 to +250 °C.

NOTE: When a channel status bit is not asserted, the data in the respective analog quantity is the last valid temperature, not the current temperature.

If the relay stops receiving valid analog quantities from a certain channel, the temperature stored in the relay freezes at the last received value. Fifteen status bits help supervise decisions based on temperature measurements. *Table 15.30* describes how to interpret the status bits.

Table 15.30 RTD Status Bits

RTD Status Bit	Description
RTDFL	Asserts if the SEL-2600A experiences an internal problem.
RTDCOMF	Asserts if the relay does not receive a valid measurement from the SEL-2600A for 1.25 seconds.
RTD01ST–RTD12ST	Assert when an RTD is attached to a channel and the SEL-2600A is able to read RTD.
RTDIN	SEL-2600 input status bit. Asserts when the SEL-2600 is healthy and the received data indicates the assertion of the input.

NOTE: In some SEL-400 series relays, you must use **MET RTD** instead of **MET T**.

To view the temperature measurements received from the SEL-2600A, issue the **MET T** command, as depicted in *Figure 15.11*.

```
=>>MET T <Enter>
Relay 1                                    Date: 03/17/2023  Time: 13:42:13.220
Station A                                  Serial Number: 1230769999
RTD Input Temperature Data (deg. C)
RTD  1 = -48

RTD  2 = Channel Failure
RTD  3 =   0
RTD  4 =  24
RTD  5 = Channel Not Used
RTD  6 =  72
RTD  7 = Channel Failure
RTD  8 = 120

RTD  9 = Channel Not Used
RTD 10 = 168
RTD 11 = 192
RTD 12 = 216
```

Figure 15.11 MET T Command Response

The **MET T** command displays the following messages:

- `Channel Failure`: This message is displayed for each channel whose channel status bit is not asserted.
- `Channel Not Used`: This message is displayed for each channel whose channel type is set to NA.

When there is a status problem with the SEL-2600A RTD module, the **MET T** command will respond with an informational message, as shown in *Figure 15.12*.

```
=>>MET T
SEL-2600 Failure
```

Figure 15.12 MET T Command Response for Status Problem

The four possible messages for status problems, with their interpretation, are indicated in *Table 15.31*.

Table 15.31 MET T Command Status Messages

Message	Interpretation
SEL-2600 Failure	RTDFL status bit asserted
Communication Failure	RTDCOMF status bit asserted
No data available	Port Protocol not set to RTD
Channel Failure	RTD*xx*ST status bit deasserted

Direct Networking Example

This example demonstrates direct networking to the relay through use of the Ethernet card. *Figure 15.13* shows the Ethernet network topology. This examples uses an SEL-421, but the same concepts apply to any SEL-400 series relay.

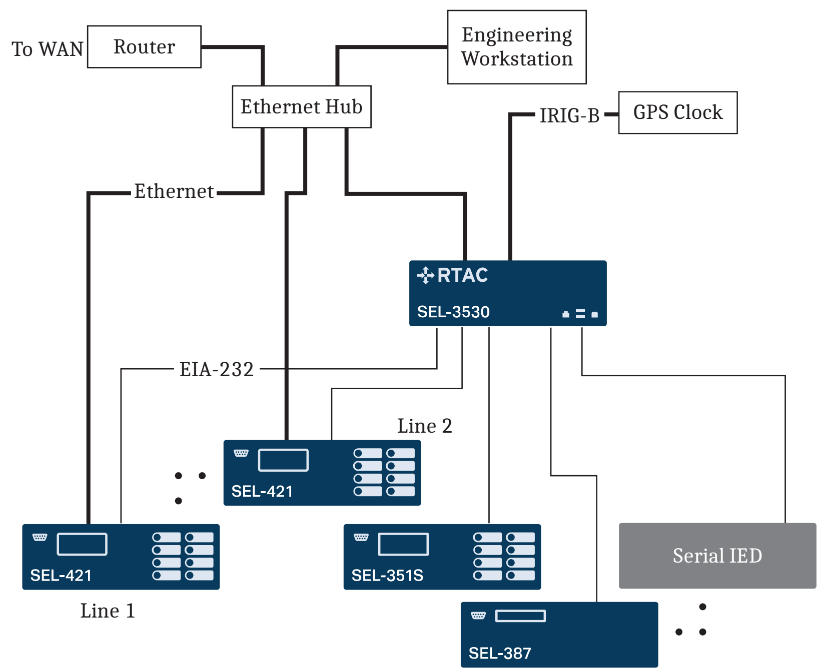

Figure 15.13 Example Direct Networking Topology

Application

The Ethernet network is used primarily for an engineering connection to the devices in the substation either across the WAN or from the local computer. The engineer can use FTP to collect settings, oscillography, and other file data directly from the SEL-421 Relays. The engineer can also use Telnet to establish a terminal connection to the SEL-421 Relays or through the SEL-3530 to one of the serial IEDs to configure these devices or obtain diagnostic information. The SEL-3530 provides IRIG-B time synchronization to all the IEDs via a serial connection.

Settings

This example focuses on the relay labeled Line 1 shown in *Figure 15.13*. Port 5 settings for the SEL-421 configure the Ethernet card. Port 5 settings for this example are shown in *Table 15.32*.

Table 15.32 SEL-421 Port 5 Direct Networking Settings

Setting Name	Setting	Description
BUSMODE[a]	INDEPEND	Bus operating mode
EINTF[a]	CD	Enable interface
IPADDR	10.201.0.112/16	IP network address
DEFRTR	10.201.0.1	Default router
ETCPKA	N	Disable TCP keep-alive functionality
KAIDLE	10	Length of time to wait with no detected activity before sending a keep-alive packet (must be greater than or equal to KAINTV)
KAINTV	1	Length of time to wait between sending keep-alive packets after receiving no response for the prior keep-alive packet (must be less than or equal to KAIDLE)
KACNT	6	Maximum number of keep-alive packets to send
NETPORT	C	Primary network port selected to **PORT 5C**
NETCSPD[b]	A	Automatically detect network speed on **PORT C**
FTPSERV	Y[c]	Enabled FTP server
FTPCBAN	FTP SERVER:	FTP connect banner
FTPIDLE	5	FTP connection time-out in minutes
FTPANMS	N	Anonymous login disabled so that passwords are required for all FTP users
FTPAUSR	“”	Host user from which anonymous FTP client inherits access rights—not used in this application
ETELNET	Y[c]	Enable Telnet server
TCBAN	HOST TERMINAL SERVER:	Host Telnet connect banner
TPORT	23	Host Telnet TCP/IP port
TIDLE	5	Telnet connection time-out in minutes

[a] Five-port Ethernet card only.
[b] Not applicable for fiber ports.
[c] Set to CD when using the five-port Ethernet card.

FTP Session

Figure 15.14 is a screen capture of an FTP session with the relay. The FTP client used for this example is included with the Windows operating system and accessible through a command prompt window. The operator connects to the relay, moves to the SETTINGS directory, and collects the Port 5 settings. *Figure 15.14* shows a portion of the Port 5 settings in the SET_P5.TXT file.

```
C:\>ftp 10.201.0.112 <Enter>
Connected to 10.201.0.112.
220 FTP SERVER:
User (10.201.0.112:(none)): 2AC
331 User name okay, need password.
Password:
230 User logged in, proceed.
ftp> ls
200 PORT Command okay.
150 File status okay; about to open data connection.
CFG.TXT
CFG.XML
EVENTS
REPORTS
SETTINGS
SWCFG.ZIP
SYNCHROPHASORS
226 Closing data connection.
ftp: 72 bytes received in 0.00Seconds 72.00Kbytes/sec.
ftp> cd SETTINGS
250 CWD  requested file action okay, completed.
ftp> ls
200 PORT Command okay.
150 File status okay; about to open data connection.
BAY_SCREEN.TXT
ERR.TXT
SET_A1.TXT
SET_A10.TXT
SET_A2.TXT
SET_A3.TXT
SET_A4.TXT
SET_A5.TXT
SET_A6.TXT
SET_A7.TXT
SET_A8.TXT
SET_A9.TXT
SET_ALL.TXT
SET_B1.TXT
SET_D1.TXT
SET_D2.TXT
SET_D3.TXT
SET_D4.TXT
SET_D5.TXT
SET_F1.TXT
SET_G1.TXT
SET_L1.TXT
SET_L2.TXT
SET_L3.TXT
SET_L4.TXT
SET_L5.TXT
SET_L6.TXT
SET_N1.TXT
SET_O1.TXT
SET_P1.TXT
SET_P2.TXT
SET_P3.TXT
SET_P5.TXT
SET_PF.TXT
SET_R1.TXT
SET_S1.TXT
SET_S2.TXT
SET_S3.TXT
SET_S4.TXT
SET_S5.TXT
SET_S6.TXT
SET_SM.TXT
SET_T1.TXT
UPGRADE_RPT.TXT
226 Closing data connection.
ftp: 536 bytes received in 0.01Seconds 53.60Kbytes/sec.
ftp> get SET_P5.TXT
200 PORT Command okay.
150 File status okay; about to open data connection.
226 Closing data connection.
ftp: 3853 bytes received in 0.01Seconds 428.11Kbytes/sec.
ftp> quit
221 Goodbye.

C:\>
```

Figure 15.14 Example FTP Session

```
[INFO]
RELAYTYPE=SEL
FID=SEL-421-X045-V0-Z001001-D20010106
BFID=SLBT-CFS-X000
PARTNO=SEL-400H1234
[IOBOARDS]
[COMCARDS]
, SEL-2701-X061-V0-Z000000-D20010117, SLBT-2701-X021-V0-Z000000-D20010109, 1
[P5]

"TIMEOUT",5
"AUTO",Y
"FASTOP",N
"TERTIM1",1
"TERSTRN","\005"
"TERTIM2",0

"IPADDR","10.201.0.112"
"SUBNETM","255.255.0.0"
"DEFRTR","10.201.0.1"
"NETPORT","C"
"FAILOVR","N"

"FTIME",5
"NETCSPD","A"
"NETDSPD","A"
"FTPSERV","Y"

"FTPCBAN","FTP SERVER:"
"FTPIDLE",5
"FTPANMS","N"
"FTPAUSR","ACC"

"T1CBAN","HOST TERMINAL SERVER:"
"T1INIT","N"
"T1RECV","Y"
"T1PNUM",23

"T2CBAN","CARD TERMINAL SERVER:"
"T2RECV","Y"
"T2PNUM",1024
"TIDLE",5
Remaining settings not shown
```

Figure 15.15 Partial Contents of SET_P5.TXT

Telnet Session

This section contains screen captures of a Telnet session with the Line 1 SEL-421. The Telnet application is included with the Windows operating system. *Figure 15.16* shows the login dialog box and the entries required to connect to the SEL-421.

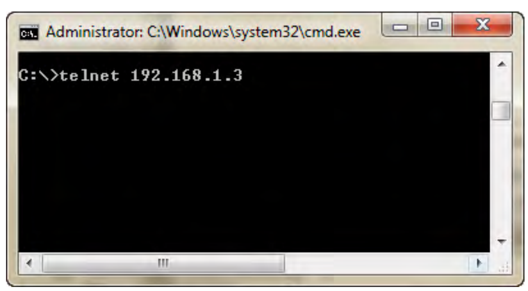

Figure 15.16 Telnet Connection Dialog Box

Figure 15.17 is a screen capture of a Telnet session with the relay. The operator connects to the relay, and displays the Port 5 settings. Only a portion of the Port 5 settings are shown.

```
TERMINAL SERVER:
=ACC <Enter>

Password: ?OTTER <Enter>

Relay 1                                     Date: 03/17/2023  Time: 01:17:08.142
Station A                                   Serial Number: 1230769999

Level 1

=>2AC <Enter>

Password: ?TAIL <Enter>

Relay 1                                     Date: 03/17/2023  Time: 01:17:23.082
Station A                                   Serial Number: 1230769999

Level 2

=>>SHO P 5 <Enter>
Port 5

Protocol Selection

EPORT   := Y        EPAC    := N        MAXACC  := C

SEL Protocol Settings

AUTO    := Y        FASTOP  := N        TERTIM1 := 1
TERSTRN := "\005"
TERTIM2 := 0

Fast Message Read Data Access

FMRENAB := Y        FMRLCL  := N        FMRMTR  := Y        FMRDMND := Y
FMRTAR  := Y        FMRHIS  := N        FMRBRKR := N        FMRSTAT := N
FMRANA  := Y

IP Configuration

IPADDR  := 10.201.0.112/16
DEFRTR  := "10.201.0.1"
ETCPKA  := Y        KAIDLE  := 10       KAINTV  := 1        KACNT   := 6
NETMODE := FIXED    NETPORT := C        NETASPD := AUTO     NETBSPD := AUTO
NETCSPD := AUTO     NETDSPD := AUTO

FTP Configuration

FTPSERV := N

HTTP Server Configuration

EHTTP   := N

Telnet Configuration

ETELNET := Y
TCBAN   := "TERMINAL SERVER:"
TPORT   := 23       TIDLE   := 15

DNP Configuration

EDNP    := 0

Phasor Measurement Configuration

EPMIP   := N

SNTP Protocol Selection

ESNTP   := OFF

PTP Settings

EPTP    := N
=>>QUI <Enter>
```

Figure 15.17 Example Telnet Session

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SECTION 16

DNP3 Communication

The relay provides a DNP3-2009 Level 2 outstation interface for direct network connections to the relay. This section covers the following topics:

Introduction to DNP3

A SCADA manufacturer-developed DNP3 from the lower layers of IEC 60870-5. Originally designed for use in telecontrol applications, version 3 of the protocol has also become popular for local substation data collection. DNP3 has been standardized as IEEE 1815.

Rather than wiring individual input and output points from the station RTU to the station IEDs, many stations use DNP3 to convey measurement and control data over a single serial or Ethernet cable to the RTU. The RTU then forwards data to the offsite master station. By using a data communications protocol rather than hard wiring, designers have reduced installation, commissioning, and maintenance costs while increasing remote control and monitoring flexibility.

The DNP User's Group maintains and publishes DNP3 standards in cooperation with IEEE. See the DNP User's Group website (www.dnp.org) for more information on DNP3 standards, implementers of DNP3, and tools for working with DNP3.

DNP3 Specifications

DNP3 is a feature-rich protocol with many ways to accomplish tasks. The *Interoperability* section of IEEE 1815 defines four levels of subsets to help improve interoperability. The levels are listed in *Table 16.1*.

Table 16.1 DNP3 Implementation Levels

Level	Description	Equipment Types
1	Simple: limited communications requirements	Meters, simple IEDs
2	Moderately complex: monitoring and metering devices and multifunction devices that contain more data	Protective relays, RTUs
3	Sophisticated: devices with great amounts of data or complex communications requirements	Large RTUs, SCADA masters
4	Enhanced: additional data types and functionality for more complex requirements	Large RTUs, SCADA masters

Each level is a proper superset of the next lower-numbered level. A higher level device can act as a master to a lower level device, but can only use the data types and functions implemented in the lower level device. For example, a typical SCADA master is a Level 3 device and can use Level 2 (or lower) functions to poll a Level 2 (or lower) device by using only the data types and functions that the lower-level device uses. A lower-level device can also poll a higher-level device, but the lower level device can only access the features and data available to its level.

Data Handling Objects

DNP3 uses a system of data references called object types, commonly referred to as objects. Each subset level specification requires a minimum implementation of objects and also recommends several optional objects. DNP3 objects are specifications for the type of data the object carries. An object can include a single value or more complex data. Some objects serve as shorthand references for collections of data or even all data within the DNP3 device.

Each instance of the object includes an index that makes it unique. For example, each binary status point (Object 1) has an index. If there are 16 binary status points, these points are Object 1, Index 0 through Object 1, Index 15. Note that index numbers are 0-based.

Each object also includes multiple versions called variations. For example, Object 1 has three variations: 0, 1, and 2. Variation 0 is used to request Object 1 data from a DNP3 device by using its default variation. Variation 1 is used to specify binary input values only and Variation 2 is used to specify binary input values with status information.

Each DNP3 device has both a list of objects and a map of object indices. The list of objects defines the available objects, variations, and qualifier codes. The map defines the indices for objects that have multiple instances and what data or control points correspond with each index.

A master initiates all DNP3 message exchanges except unsolicited data. DNP3 terminology describes all points from the perspective of the master. Binary points for control that move from the master to the outstation are called binary outputs, while binary status points within the outstation are called binary inputs.

Function Codes

Each DNP3 message includes a function code. Each object has a limited set of function codes that a master may use to manipulate the object. The object listing for the device shows the permitted function codes for each type of object. The most common DNP3 function codes are listed in *Table 16.2*.

Table 16.2 Selected DNP3 Function Codes

Function Code	Function	Description
1	Read	Request data from the outstation
2	Write	Send data to the outstation
3	Select	First part of a select-before-execute operate
4	Execute	Second part of a select-before-execute operate
5	Direct operate	One-step operation with acknowledgment
6	Direct operate, no ack.	One-step operation with no acknowledgment

Qualifier Codes and Ranges

DNP3 masters use qualifier codes and ranges to make requests for specific objects by index. Qualifier codes specify the style of range, and the range specifies the indices of the objects of interest. DNP3 masters use qualifier codes to compose the shortest, most concise message possible when requesting points from a DNP3 remote device.

For example, the qualifier code 01 specifies that the request for points will include a start address and a stop address. Each of these two addresses uses two bytes. An example request using qualifier code 01 might have the four-hexadecimal byte range field, 00h 04h 00h 10h, that specifies points in the range 4–16.

Access Methods

DNP3 has many features that help it obtain maximum possible message efficiency. DNP3 Masters send requests with the least number of bytes by using special objects, variations, and qualifiers that reduce the message size. Other features eliminate the continual exchange of static (unchanging) data values. These features optimize use of bandwidth and maximize performance over a connection of any speed.

DNP3 event data collection eliminates the need to use bandwidth to transmit values that have not changed. Event data are time-stamped records that show when observed measurements changed. For binary points, the outstation device logs changes from logical 1 to logical 0 and from logical 0 to logical 1. For analog points, the remote device logs changes that exceed a deadband. DNP3 outstation devices collect event data in a buffer that either the master can request or the device can send to the master without a request message. Data sent from the outstation to the master without a polling request are called unsolicited data.

DNP3 data fit into one of four event classes: 0, 1, 2, or 3. Class 0 is reserved for reading the present value (static data). Classes 1, 2, and 3 are event data classes. The meaning of Classes 1 to 3 is arbitrary and defined by the application at hand. With remotes that contain great amounts of data or in large systems, the three event classes provide a framework for prioritizing different types of data. For example, you can poll once a minute for Class 1 data, once an hour for Class 2 data, and once a day for Class 3 data.

Class 0 polling is also known as static polling, or simple polling of the present value of data points within the outstation. By combining event data polls, unsolicited messaging, and static polling, you can operate your system in one of the four access methods shown in *Table 16.3*.

The access methods listed in *Table 16.3* are in order of increasing communications efficiency. With various tradeoffs, each method is less demanding of communications bandwidth than the previous one. For example, unsolicited report-by-exception consumes less communications bandwidth because of the elimination of polling messages from the master required by polled report-by-exception. You must also consider overall system size and the volume of data communication expected to properly evaluate which access method provides optimum performance for your application.

Table 16.3 DNP3 Access Methods

Access Method	Description
Polled static	Master polls for present value (Class 0) data only.
Polled report-by-exception	Master polls frequently for event data and occasionally for Class 0 data.
Unsolicited report-by-exception	Remote devices send unsolicited event data to the master, and the master occasionally polls for Class 0 data.
Quiescent	Master never polls and relies on unsolicited reports only.

Binary Control Operations

DNP3 masters use the Object 12 control relay output block to perform binary control operations. The control relay output block has both a trip/close selection and a code selection. The trip/close selection allows a single index to operate two related control points, such as trip and close or raise and lower. Trip/close pair operation is not recommended for new DNP3 devices, but is often included for interoperability with older DNP3 master implementations.

The control relay output block code selection specifies either a latch or pulse operation on the point. In many cases, DNP3 outstations have only a limited subset of the possible combinations of the code field. Sometimes, DNP3 outstations assign special operation characteristics to the latch and pulse selections.

Conformance Testing

In addition to the protocol specifications, the DNP User's Group has approved conformance testing requirements for all levels of outstation devices. Some implementers perform their own conformance specification testing, while some contract with independent companies to perform conformance testing.

Conformance testing does not always guarantee that a master and remote will be fully interoperable (work together properly for all implemented features). Conformance testing does help to standardize the testing procedure and move the DNP3 implementers toward a higher level of interoperability.

DNP3 Serial Network Issues

You can build a DNP3 network by using either a multidrop or star topology. Each DNP3 network has one or more DNP3 masters and DNP3 outstations. *Figure 16.1* shows the DNP3 multidrop network topology.

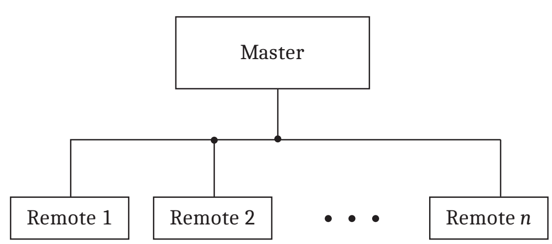

Figure 16.1 DNP3 Multidrop Network Topology

Figure 16.2 shows the DNP3 star network topology.

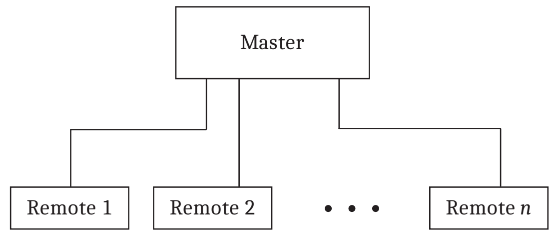

Figure 16.2 DNP3 Star Network Topology

DNP3 multidrop networks that are used within substations often use an EIA-485 physical layer. The multidrop network is vulnerable to the failure of a single transmitter. If any one transmitter fails in a state that disrupts signals on the network, the network will fail. The DNP3 star network topology eliminates the network transmitters and other single points of failure related to the physical medium.

If you are planning either a DNP3 star or multidrop network topology, you should consider the benefits of including an SEL communications processor such as the SEL-2032 or SEL-3530 RTAC in your design. A network with a communications processor is shown in *Figure 16.3*. A DNP3 network that includes a communications processor has a lower data latency and shorter scan time than comparable networks through two primary mechanisms. First, the communications processor collects data from all remotes in parallel rather than one-by-one. Second, the master can collect all data with one message and response, drastically reducing message overhead.

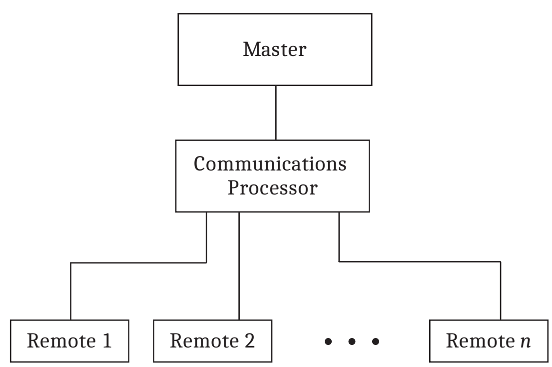

Figure 16.3 DNP3 Network With Communications Processor

In the communications processor DNP3 network, you can also collect data from devices that do not support the DNP3 protocol. SEL communications processors can collect data and present it to the master as DNP3 data regardless of the protocol between the SEL communications processor and the remote device.

Data Link Layer Operation

DNP3 employs a three-layer version of the seven-layer OSI (open systems interconnect) model called the enhanced performance architecture. The layer definition helps to categorize functions and duties of various software components that make up the protocol. The middle layer, the data link layer, includes several functions for error checking and media access control.

A feature called data link confirmation is a mechanism that provides positive confirmation of message receipt by the receiving DNP3 device. While this feature helps you recognize a failed device or failed communications link quickly, it also adds significant overhead to the DNP3 conversation. Consider for your individual application whether you require this link integrity function at the expense of overall system speed and performance.

The DNP3 specification recommends against using data link confirmations because these processes can add to traffic in situations where communications are marginal. The increased traffic will reduce connection throughput further, possibly preventing the system from operating properly.

Network Medium Contention

When more than one device requires access to a single network medium, you must provide a mechanism to resolve the resulting network medium contention. For example, unsolicited reporting results in network medium contention if you do not design your network as a star topology of point-to-point connections or use carrier detection on a multidrop network.

To avoid collisions among devices trying to send messages, DNP3 includes a collision avoidance feature. Before sending a message, a DNP3 device listens for a carrier signal to verify that no other node is transmitting data. The device transmits if there is no carrier or waits for a random time before rechecking for a carrier signal. However, if two nodes both detect a lack of carrier at the same instant, these two nodes could begin simultaneous transmission of data and cause a data collision. If your network allows for spontaneous data transmission including unsolicited event data transmissions, you also must use application confirmation to provide a retry mechanism for messages lost as a result of data collisions.

DNP3 LAN/WAN Considerations

The main process for carrying DNP3 over an Ethernet network (LAN/WAN) involves encapsulating the DNP3 data link layer data frames within the transport layer frames of the IP suite. This allows the IP stack to deliver the DNP3 data link layer frames to the destination in place of the original DNP3 physical layer. The DNP User’s Group Technical Committee has recommended the following guidelines for carrying DNP3 over a network:

- DNP3 shall use the IP suite to transport messages over a LAN/WAN
- Ethernet is the recommended physical link, though others may be used
- TCP must be used for WANs
- TCP is strongly recommended for LANs
- UDP may be used for highly reliable single segment LANs
- UDP is necessary if broadcast messages are required
- The DNP3 protocol stack shall be retained in full
- Link layer confirmations shall be disabled

The Technical Committee has registered a standard port number, 20000, for DNP3 with the Internet Assigned Numbers Authority (IANA). This port is used for either TCP or UDP.

The Committee recommends the selection of TCP or UDP protocol as per the guidelines in *Table 16.4*.

Table 16.4 TCP/UDP Selection Guidelines

Use in the case of...	TCP	UDP
Most situations	X	
Non-broadcast or multicast	X	
Mesh Topology WAN	X	
Broadcast		X
Multicast		X
High-reliability single-segment LAN		X
Pay-per-byte, non-mesh WAN, for example, Cellular Digital Packet Data (CDPD)		X
Low-priority data, for example, data monitor or configuration information		X

DNP3 in the Relay

The relay is a DNP3-2009 Level 2 outstation device. The relay DNP3 interface has the capabilities summarized in *Table 16.5*.

Table 16.5 Relay DNP3 Feature Summary

Feature	Application
DNP3 event data reporting	More efficient polling through event collection or unsolicited data
Time-tagged events	Time-stamped SER data
Control output relay blocks	Operator-initiated control
Write analog set point	Change the active protection settings group
Time synchronization	Set the relay time from the master station or automatically request time synchronization from the master
Custom mapping	Increase communications efficiency by organizing data and reducing available data to what you need for your application
Modem support	Reduce the cost of the communications channel by either master dialing to relay or relay dialing to master
Analog deadband settings per session	Deadbands may be set to different values per session depending on desired application
Virtual Terminal	Provides engineering access for configuration, diagnostics, and other tasks over the existing DNP3 connection
TEST DB2 command	Test DNP3 protocol interface without disturbing protection
Support for Object 0 Device Attributes	Provides Device Attributes (Device ID, Number of binary, analog and counter points, Manufacturer information, etc.) for the device specific to the current connected DNP3 session in use
XML DNP3 Device Profile Document	The DNP3 Device Profile document contains the complete information on DNP3 Protocol support in the relay. This information is available in XML format.

Data Access

You can use any of the data access methods listed in *Table 16.6*. *Table 16.6* also lists the relay DNP3 settings. You must configure the DNP3 master for the data access method you select.

NOTE: Because unsolicited messaging only operates properly in some situations, for maximum performance and minimum risk of configuration problems, SEL recommends the polled report-by-exception access method.

Table 16.6 DNP3 Access Methods

Access Method	Master Polling	Relay Settings
Polled static	Class 0	Set ECLASSB, ECLASSC, ECLASSA, ECLASSV to OFF, UNSOL to N.
Polled report-by-exception	Class 0 occasionally, Class 1, 2, 3 frequently	Set ECLASSB, ECLASSC, ECLASSA, ECLASSV to the desired event class, UNSOL to N.
Unsolicited report-by-exception	Class 0 occasionally, optional Class 1, 2, 3 less frequently, mainly relies on unsolicited messages	Set ECLASSB, ECLASSC, ECLASSA, ECLASSV to the desired event class, set UNSOL to Y and PUNSOL to Y or N.
Quiescent	Class 0, 1, 2, 3 never, relies completely on unsolicited messages	Set ECLASSB, ECLASSC, ECLASSA, ECLASSV to the desired event class, set UNSOL and PUNSOL to Y.

In both the unsolicited report-by-exception and quiescent polling methods shown in *Table 16.6*, you must make a selection for the PUNSOL setting. This setting enables or disables unsolicited data reporting when you turn the relay on. If your master can send the DNP3 message to enable unsolicited reporting from the relay, you should set PUNSOL to No.

NOTE: The DNP3 LAN/WAN settings have names similar to the serial port settings above, but include the session number n as a suffix ranging from 1 to 6 (for example, CLASSB1, UNSOL1, PUNSOL1). All settings with the same numerical suffix comprise the complete DNP3 LAN/WAN session configuration.

While automatic unsolicited data transmission on power-up is convenient, problems can result if your master is not prepared to start receiving data immediately when you turn on the relay. If the master does not acknowledge the unsolicited data with an application confirm, the relay will resend the data until it is acknowledged. On a large system, or in systems where the processing power of the master is limited, you may have problems when several outstations simultaneously begin sending data and waiting for acknowledgment messages.

Collision Avoidance

If your application requires unsolicited reporting from multiple devices on a single (serial) network medium, you must select a half-duplex medium or a medium that supports carrier detection to avoid data collisions. EIA-485 two-wire networks are half-duplex. EIA-485 four-wire networks do not provide carrier detection.

The relay uses application confirmation messages to guarantee delivery of unsolicited event data before erasing the local event data buffer. Data collisions are typically resolved when messages are repeated until confirmed.

The relay pauses for a random delay between the settings MAXDLY and MINDLY when it detects a carrier through data on the receive line or the CTS pin. If you use the settings of 0.10 seconds for MAXDLY and 0.05 seconds for MINDLY, the relay will insert a random delay of 50 to 100 ms (milliseconds) between the end of carrier detection and the start of data transmission.

Transmission Control

If you use a media transceiver (for example, EIA-232 to EIA-485) or a radio system for your serial DNP3 network, you may need to adjust data transmission properties. Use the PREDLY and POSTDLY settings to provide a delay between RTS signal control and data transmission. For example, an EIA-485 transceiver typically requires 10–20 ms to change from receive to transmit. If you set the predelay to 30 ms, you will avoid data loss resulting from data transmission beginning at the same time as RTS signal assertion.

Event Data

DNP3 event data objects contain change-of-state and time-stamp information that the relay collects and stores in a buffer. You can configure the relay to either report the data without a polling request from the master (unsolicited data) or hold the data until the master requests it with an event poll message.

With the event class settings ECLASSB, ECLASSC, ECLASSA, and ECLASSV you can set the event class for binary, counter, analog, and virtual terminal information. You can use the classes as a simple priority system for collecting event data. The relay does not treat data of different classes differently with respect to unsolicited messages, but the relay does allow the master to perform independent class polls.

NOTE: Most RTUs that act as substation DNP3 masters perform an event poll that collects event data of all classes simultaneously. Confirm that the polling configuration of your master allows independent polling for each class before implementing separate classes in the relay.

For event data collection you must also consider and enter appropriate settings for deadband and scaling operation on analog points shown in *DNP3 Settings—Custom Maps on page 12.19*. You can either set and use default deadband and scaling according to data type or use a custom data map to select deadbands on a point-by-point basis. See *Configurable Data Mapping on page 16.23* for a discussion of how to set scaling and deadband operation on a point-by-point basis.

The serial port settings ANADBA, ANADBV, and ANADBM (ANADBA*n*, ANADBV*n*, and ANADBM*n* for Ethernet port settings on session *n*) control default deadband operation for the specified data type. Because DNP3 Objects 30 and 32 use integer data by default, you can use scaling to send digits after the decimal point and avoid truncating to a simple integer value.

With no scaling, the value of 12.632 would be sent as 12. With a scaling setting of 1, the value transmitted is 126. With a scaling setting of 3, the value transmitted is 12632. You must make certain that the maximum value does not exceed 32767 if you are polling the default 16-bit variations for Objects 30 and 32, but you can send some decimal values by using this technique. You must also configure the master to perform the appropriate division on the incoming value to display it properly.

Set the default analog value scaling with the DECPLA, DECPLV, and DECPLM settings (DECPLA*n*, DECPLV*n*, and DECPLM*n* for Ethernet port settings on session *n*). Application of event reporting deadbands occurs after scaling in the DECPLA, DECPLV, and DECPLM. For example, if you set DECPLA to 2 and ANADBA to 10, a measured current of 10.14 amperes would be scaled to the value 1014 and would have to increase to more than 1024 or decrease to less than 1004 (a deadband of 0.2 amperes) for the relay to report a new event value.

The relay uses the NUMEVE and AGEEVE settings (NUMEVE*n* and AGEEVE*n* Ethernet port settings for session *n*) to decide when to send unsolicited data to the master. The relay sends an unsolicited report when the total number of events accumulated in the event buffer reaches NUMEVE. The relay also sends an unsolicited report if the age of the oldest event in the buffer exceeds AGEEVE. The relay has the buffer capacities listed in *Table 16.7*.

Table 16.7 Relay Event Buffer Capacity

Type	Maximum Number of Events
Binary	1024
Analog	One event per analog input in the DNP3 Map
Counters	One event per counter input in the DNP3 Map
Virtual Terminal Objects	5

Binary Controls

The relay provides more than one way to control individual points within the relay. The relay maps incoming control points either to remote bits within the relay or to internal command bits that cause circuit breaker operations.

NOTE: The port setting DNPCL (or DNPCLn for DNP3 LAN/WAN session n) must be set to Y to enable binary controls for the DNP3 session. Binary Output Status requests (Object 10, Variation 2) and Class 0 requests will have no Binary Outputs in the response unless DNPCL := Y.

A DNP3 technical bulletin (*Control Relay Output Block Minimum Implementation 9701-002*) recommends that you use one point per Object 12, control block output relay. You can use this method to perform pulse on, latch on, and latch off operations on selected remote bits.

If your master does not support the single-point-per-index messages or single-operation database points, you can use the trip/close operation or use the code field in the DNP3 message to specify operation of the points shown in *Control Point Operation on page 16.20*.

Time Synchronization

The accuracy of DNP3 time synchronization is insufficient for most protection and oscillography needs. DNP3 time synchronization provides backup time synchronization in the event the relay loses primary synchronization through the IRIG-B TIME input or some other high-accuracy source.

Enable time synchronization with the TIMERQ setting (TIMERQ*n* for DNP3 LAN/WAN Session *n*) and use Object 50, Variation 1, and Object 52, Variation 2 (Object 50, Variation 3 for DNP3 LAN/WAN), to set the time via a DNP3 master.

TIMERQ can be set in one of three ways:

- A numeric setting of 1–32767 minutes specifies the rate at which the relay shall request a time synchronization.
- A setting of M disables the relay from requesting a time synchronization, but still allows the relay to accept and apply time synchronization messages from the master.
- A setting of I disables the relay from requesting a time synchronization, and sets the relay to ignore time synchronization messages from the master.

Effective January 1, 2008, the DNP3 standard requires that DNP3 time correspond to Coordinated Universal Time (UTC). To help ease into the transition to this standard, you can use the DNPSRC Global setting to determine whether the relay will use local or UTC time for DNP3.

When requesting time synchronization with DNPSRC := UTC, the relay will treat incoming DNP3 time-set messages as UTC time. All DNP3 event timestamps (binary input changes with time, analog input changes with time, etc.) will be in UTC time.

When requesting time synchronization with DNPSRC := LOCAL, the relay will treat incoming time set by the DNP3 master as local time. All DNP3 event timestamps will be in local time.

When setting the time with local time, there is an ambiguity during the last hour of daylight-saving time (DST) and to resolve this ambiguity, if the relay accepts a Time Set request in this hour, it will assume the time is in DST.

Modem Support

The relay DNP3 implementation includes modem support. Your DNP3 master can dial-in to the relay and establish a DNP3 connection. The relay can automatically dial out and deliver unsolicited DNP3 event data. When the relay dials out, it waits for the CONNECT message from the local modem and for assertion of the relay CTS line before continuing the DNP3 transaction. This requires a connection from the modem DCD to the relay CTS line.

NOTE: Contact SEL for information on serial cable configurations and requirements for connecting your relay to other devices.

NOTE: RTS/CTS hardware flow control is not available for a DNP3 modem connection. You must set the port data speed slower than the effective data rate of the modem.

Either connect the modem to a computer and configure it before connecting it to the relay, or program the appropriate modem setup string in the modem startup string setting MSTR. Use the PH_NUM1 setting to set the phone number that you want the relay to dial. The relay will automatically send the ATDT modem dial command and then the contents of the PH_NUM1 setting when dialing the modem. PH_NUM1 is a text setting that must conform to the AT modem command set dialing string standard. Use a comma (,) for a pause of four seconds. You may need to include a nine to reach an outside line or a one if the number requires long distance access. You can also insert other special codes your telephone service provider designates for block call waiting and other telephone line features.

The relay supports backup dial-out to a second phone number. If PH_NUM2 is set, the RETRY1 setting is used to configure the number of times the relay tries to dial PH_NUM1 before dialing PH_NUM2. Similarly, the RETRY2 setting configures the number of times the relay tries to dial PH_NUM2 before trying PH_NUM1. MDTIME sets the length of time from initiating the call to declaring it failed because of no connection, and MDRET sets the time between dial-out attempts.

DNP3 Settings

DNP3 configuration involves both Global (SET G) and Port (SET P) settings. The Global settings govern behavior for all DNP3 sessions, serial or LAN/WAN. The Port settings apply to specific DNP3 sessions only.

There are two Global settings that directly configure DNP3. These settings, EVELOCK and DNPSRC, define the behavior of Fault Summary event retrieval and the DNP3 session time base. See *Reading Relay Event Data on page 16.21* for more information on EVELOCK. The DNPSRC setting can be either LOCAL or UTC (default). See *Time Synchronization on page 16.10* for more information on the DNPSRC setting.

The DNP3 protocol settings are shown in *Table 12.9* and *Table 12.23*. The DNP3 protocol settings are in the port settings for the port that you select for the DNP3 protocol. You can use DNP3 on any of the serial ports (**PORT F** and **PORT 1–PORT 3**) or Ethernet port (**PORT 5**), but you can only enable DNP3 on one serial port at a time. You may enable as many as six DNP3 sessions over Ethernet, independent of the number of serial DNP3 sessions enabled.

Warm Start and Cold Start

The DNP3 function codes for warm start and cold start reset the relay serial port or DNP3 Ethernet session. These function codes do not interrupt protection processes within the relay.

Testing

NOTE: The **TEST DB2** command will override the state of all instances of the forced bit or value for all active protocols. This includes DNP3 serial and LAN/WAN and IEC 61850 GOOSE and Manufacturing Message Specification (MMS). Before using the command, take precautions to ensure against unintended operations from inadvertent messages sent as the result of a **TEST DB2** override, for example, a bit used to trip a breaker on a remote relay via IEC 61850 GOOSE.

Use the **TEST DB2** command to test the data mapping from the relay to your DNP3 master. You can use the **TEST DB2** command to force DNP3 values by object type and label. Although the relay reports forced values to the DNP3 host, these values do not affect protection processing within the relay. The **TEST DB2** command operates by object type and label, so it works equally well with custom mapping and the default DNP3 maps. See *TEST DB2 on page 14.66* for more information.

When you are using the **TEST DB2** command to test DNP3 operation, the Relay Word bit TESTDB2 will be asserted to indicate that test mode is active. The DNP3 status bit will also show forced status for any object variations that include status.

DNP3 Documentation

Object List

Table 16.8 lists the objects and variations with supported function codes and qualifier codes available in the relay. The list of supported objects conforms to the format laid out in the DNP3 specifications and includes both supported and unsupported objects. Those that are supported include the function and qualifier codes. The objects that are not supported are shown without any corresponding function and qualifier codes.

Table 16.8 Relay DNP3 Object List (Sheet 1 of 6)

Obj.	Var.	Description	Request[a]		Response[a]	
			Funct. Codes	Qual. Codes	Funct. Codes	Qual. Codes
0	211	Device attributes—User-specific sets of attributes	1	0	129	0, 17
0	212	Device attributes—Master data set prototypes	1	0	129	0, 17
0	213	Device attributes—Outstation data set prototypes	1	0	129	0, 17
0	214	Device attributes—Master data sets	1	0	129	0, 17
0	215	Device attributes—Outstation data sets	1	0	129	0, 17
0	216	Device attributes—Max. binary outputs per request	1	0	129	0, 17
0	219	Device attributes—Support for analog output events	1	0	129	0, 17
0	220	Device attributes—Max. analog output index	1	0	129	0, 17
0	221	Device attributes—Number of analog outputs	1	0	129	0, 17
0	222	Device attributes—Support for binary output events	1	0	129	0, 17
0	223	Device attributes—Max. binary output index	1	0	129	0, 17
0	224	Device attributes—Number of binary outputs	1	0	129	0, 17
0	225	Device attributes—Support for frozen counter events	1	0	129	0, 17
0	226	Device attributes—Support for frozen counters	1	0	129	0, 17
0	227	Device attributes—support for counter events	1	0	129	0, 17
0	228	Device attributes—Max. counter index	1	0	129	0, 17
0	229	Device attributes—Number of counters	1	0	129	0, 17
0	230	Device attributes—Support for frozen analog inputs	1	0	129	0, 17
0	231	Device attributes—Support for analog input events	1	0	129	0, 17

Table 16.8 Relay DNP3 Object List (Sheet 2 of 6)

Obj.	Var.	Description	Request[a]		Response[a]	
			Funct. Codes	Qual. Codes	Funct. Codes	Qual. Codes
0	232	Device attributes—Max. analog input index	1	0	129	0, 17
0	233	Device attributes—Number of analog inputs	1	0	129	0, 17
0	234	Device attributes—Support for double-bit events	1	0	129	0, 17
0	235	Device attributes—Max. double-bit binary index	1	0	129	0, 17
0	236	Device attributes—Number of double-bit binaries	1	0	129	0, 17
0	237	Device attributes—Support for binary input events	1	0	129	0, 17
0	238	Device attributes—Max. binary input index	1	0	129	0, 17
0	239	Device Attributes—Number of binary inputs	1	0	129	0, 17
0	240	Device attributes—Max. transmit fragment size	1	0	129	0, 17
0	241	Device attributes—Max. receive fragment size	1	0	129	0, 17
0	242	Device attributes—Device manufacturer's software version	1	0	129	0, 17
0	243	Device attributes—Device manufacturer's hardware version	1	0	129	0, 17
0	245	Device attributes—User-assigned location name	1	0	129	0, 17
0	246	Device attributes—User-assigned ID code/number	1	0	129	0, 17
0	247	Device attributes—User-assigned device name	1	0	129	0, 17
0	248	Device attributes—Device serial number	1	0	129	0, 17
0	249	Device attributes—DNP3 subset and conformance	1	0	129	0, 17
0	250	Device attributes—Device manufacturer's product name and model	1	0	129	0, 17
0	252	Device attributes—Device manufacturer's name	1	0	129	0, 17
0	254	Device attributes—Non-specific all attributes request	1	0, 6	129	0, 17
0	255	Device attributes—List of attribute variations	1	0, 6	129	0, 17
1	0	Binary input—All variations	1	0, 1, 6, 7, 8, 17, 28		
1	1	Binary input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
1	2[a]	Binary input with status	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
2	0	Binary input change—All variations	1	6, 7, 8		
2	1	Binary input change without time	1	6, 7, 8	129	17, 28
2	2	Binary input change with time	1	6, 7, 8	129, 130	17, 28
2	3	Binary input change with relative time	1	6, 7, 8	129	17, 28
10	0	Binary output—All variations	1	0, 1, 6, 7, 8		
10	1	Binary output				
10	2[a]	Binary output status	1	0, 1, 6, 7, 8	129	0, 1
12	0	Control block—All variations				
12	1	Control relay output block	3, 4, 5, 6	17, 28	129	echo of request
12	2	Pattern control block	3, 4, 5, 6	7	129	echo of request
12	3	Pattern mask	3, 4, 5, 6	0, 1	129	echo of request

Table 16.8 Relay DNP3 Object List (Sheet 3 of 6)

Obj.	Var.	Description	Request[a]		Response[a]	
			Funct. Codes	Qual. Codes	Funct. Codes	Qual. Codes
20	0	Binary counter—All variations	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28		
20	1	32-Bit binary counter	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28		
20	2	16-Bit binary counter	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28		
20	3	32-Bit delta counter				
20	4	16-Bit delta counter				
20	5	32-Bit binary counter without flag	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	6[a]	16-Bit binary counter without flag	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	7	32-Bit delta counter without flag				
20	8	16-Bit delta counter without flag				
21	0	Frozen counter—All variations				
21	1	32-Bit frozen counter				
21	2	16-Bit frozen counter				
21	3	32-Bit frozen delta counter				
21	4	16-Bit frozen delta counter				
21	5	32-Bit frozen counter with time of freeze				
21	6	16-Bit frozen counter with time of freeze				
21	7	32-Bit frozen delta counter with time of freeze				
21	8	16-Bit frozen delta counter with time of freeze				
21	9	32-Bit frozen counter without flag				
21	10	16-Bit frozen counter without flag				
21	11	32-Bit frozen delta counter without flag				
21	12	16-Bit frozen delta counter without flag				
22	0	Counter change event—All variations	1	6, 7, 8		
22	1	32-Bit counter change event without time	1	6, 7, 8	129	17, 28
22	2[a]	16-Bit counter change event without time	1	6, 7, 8	129, 130	17, 28
22	3	32-Bit delta counter change event without time				
22	4	16-Bit delta counter change event without time				
22	5	32-Bit counter change event with time	1	6, 7, 8	129	17, 28
22	6	16-Bit counter change event with time	1	6, 7, 8	129	17, 28
22	7	32-Bit delta counter change event with time				
22	8	16-Bit delta counter change event with time				
23	0	Frozen counter event—All variations				
23	1	32-Bit frozen counter event without time				
23	2	16-Bit frozen counter event without time				
23	3	32-Bit frozen delta counter event without time				
23	4	16-Bit frozen delta counter event without time				

Table 16.8 Relay DNP3 Object List (Sheet 4 of 6)

Obj.	Var.	Description	Request[a] Funct. Codes	Request[a] Qual. Codes	Response[a] Funct. Codes	Response[a] Qual. Codes
23	5	32-Bit frozen counter event with time				
23	6	16-Bit frozen counter event with time				
23	7	32-Bit frozen delta counter event with time				
23	8	16-Bit frozen delta counter event with time				
30	0	Analog input—All variations	1	0, 1, 6, 7, 8, 17, 28		
30	1[b]	32-Bit analog input with flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	2[b]	16-Bit analog input with flag	1	0, 1, 6, 7, 8, 17, 28	129, 130	0, 1, 17, 28
30	3[b]	32-Bit analog input without flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	4[b]	16-Bit analog input without flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	5[b]	Single-precision floating-point analog input with flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	6[b]	Double-precision floating-point analog input with flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
31	0	Frozen analog input—All variations				
31	1	32-Bit frozen analog input				
31	2	16-Bit frozen analog input				
31	3	32-Bit frozen analog input with time of freeze				
31	4	16-Bit frozen analog input with time of freeze				
31	5	32-Bit frozen analog input without flag				
31	6	16-Bit frozen analog input without flag				
32	0	Analog change event—All variations	1	6, 7, 8		
32	1[b]	32-Bit analog change event without time	1	6, 7, 8	129	17, 28
32	2[b]	16-Bit analog change event without time	1	6, 7, 8	129, 130	17, 28
32	3	32-Bit analog change event with time	1	6, 7, 8	129	17, 28
32	4	16-Bit analog change event with time	1	6, 7, 8	129	17, 28
32	5[b]	Single-precision floating-point analog change event without time	1	6, 7, 8	129	17, 18
32	6[b]	Double-precision floating-point analog change event without time	1	6, 7, 8	129	17, 18
32	7[b]	Single-precision floating-point analog change event with time	1	6, 7, 8	129	17, 28
32	8[b]	Double-precision floating-point analog change event with time	1	6, 7, 8	129	17, 28
33	0	Frozen analog event—All variations				
33	1	32-Bit frozen analog event without time				
33	2	16-Bit frozen analog event without time				
33	3	32-Bit frozen analog event with time				
33	4	16-Bit frozen analog event with time				

Table 16.8 Relay DNP3 Object List (Sheet 5 of 6)

Obj.	Var.	Description	Request[a]		Response[a]	
			Funct. Codes	Qual. Codes	Funct. Codes	Qual. Codes
34	0	Analog input deadband—All variations	1	0, 1, 6, 7, 8, 17, 28		
34	1	16-Bit analog input deadband	1, 2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
34	2[a]	32-Bit analog input deadband	1, 2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
34	3	Single-precision floating-point analog input deadband	1, 2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
40	0	Analog output status—All variations	1	0, 1, 6, 7, 8		
40	1	32-Bit analog output status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
40	2[a]	16-Bit analog output status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
40	3	Single-precision floating-point analog output status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
40	4	Double-precision floating-point analog output status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
41	0	Analog output block—All variations				
41	1	32-Bit analog output block	3, 4, 5, 6	17, 28	129	echo of request
41	2	16-Bit analog output block	3, 4, 5, 6	17, 28	129	echo of request
41	3	Single-precision floating-point analog output block	3, 4, 5, 6	17, 28	129	echo of request
41	4	Double-precision floating-point analog output block	3, 4, 5, 6	17, 28	129	echo of request
50	0	Time and date—All variations				
50	1	Time and date	1, 2	7, 8 index = 0	129	07, quantity = 1
50	2	Time and date with interval				
50	3	Time and date at last recorded time	2	7 quantity = 1	129	
51	0	Time and date CTO—All variations				
51	1	Time and date CTO			129	07, quantity = 1
51	2	Unsynchronized time and date CTO			129	07, quantity = 1
52	0	Time delay—All variations				
52	1	Time delay, coarse				
52	2	Time delay, fine			129	07, quantity = 1
60	0	All classes of data	1, 20, 21, 22	6, 7, 8		
60	1	Class 0 data	1, 22	6, 7, 8		
60	2	Class 1 data	1, 20, 21, 22	6, 7, 8		
60	3	Class 2 data	1, 20, 21, 22	6, 7, 8		
60	4	Class 3 data	1, 20, 21, 22	6, 7, 8		
70	1	File identifier				
80	1	Internal indications	2	0, 1 index = 4, 7		

Table 16.8 Relay DNP3 Object List (Sheet 6 of 6)

Obj.	Var.	Description	Request[a]		Response[a]	
			Funct. Codes	Qual. Codes	Funct. Codes	Qual. Codes
81	1	Storage object				
82	1	Device profile				
83	1	Private registration object				
83	2	Private registration object descriptor				
90	1	Application identifier				
100	1	Short floating point				
100	2	Long floating point				
100	3	Extended floating point				
101	1	Small packed binary—Coded decimal				
101	2	Medium packed binary—Coded decimal				
101	3	Large packed binary—Coded decimal				
112	All	Virtual terminal output block	2	6		
113	All	Virtual terminal event data	1	6	129, 130	17, 28
N/A		No object required for the following function codes: 13 cold start 14 warm start 23 delay measurement	13, 14, 23			

[a] Default variation.
[b] Setting AIVAR determines default variation.

Device Profile

The DNP3 Device Profile document, available as a download from the SEL website, contains the standard device profile information for the relay. This information is also available in XML format. Please refer to this document for complete information on DNP3 Protocol support in the relay.

Reference Data Map

Table 16.9 shows the common portions of the relay DNP3 reference data map. See *Section 10: Communications Interfaces* in the product-specific instruction manual for a complete DNP3 reference map for that relay. You can use the default map or the custom DNP3 mapping functions of the relay to include only the points required by your application.

The entire Relay Word bit table (see *Section 11: Relay Word Bits* in the product-specific instruction manual) is part of the DNP3 reference map. You may include any label in the Relay Word bit table as part of a DNP3 custom map.

The relay scales analog values by the indicated settings or fixed scaling. Analog inputs for event (fault) summary reporting use a default scale factor of 1 and deadband of ANADBM. Per-point scaling and deadband settings specified in a custom DNP3 map will override defaults.

Table 16.9 Relay DNP3 Reference Data Map (Sheet 1 of 2)

Object	Label	Description
Binary Inputs		
01, 02	RLYDIS	Relay disabled
01, 02	STFAIL	Relay diagnostic failure
01, 02	STWARN	Relay diagnostic warning
01, 02	STSET	Settings change or relay restart
01, 02	UNRDEV	New relay event available
01, 02	NUNREV	An unread event exists, newer than the event in the event summary AIs
01, 02	LDATPFW	Leading true power factor A-Phase, Terminal W (1 if leading, 0 if lagging or zero)
01, 02	LDBTPFW	Leading true power factor B-Phase, Terminal W (1 if leading, 0 if lagging or zero)
01, 02	LDCTPFW	Leading true power factor C-Phase, Terminal W (1 if leading, 0 if lagging or zero)
01, 02	LD3TPFW	Leading true power factor three-phase, Terminal W (1 if leading, 0 if lagging or zero)
01, 02	Relay Word	Relay Word bit label
Binary Outputs		
10, 12	RB01–RB*nn*	Remote bits RB01–RB*nn*[a]
10, 12	RB01:RB02 RB03:RB04 RB05:RB06 • • • RB*mm*:RB*nn*	Remote bit pairs RB01–RB*nn*[a]
10, 12	OC*m*	Pulse open Circuit Breaker *m* command[b]
10, 12	CC*m*	Pulse close Circuit Breaker *m* command[b]
10, 12	OC*m*:CC*m*	Open/close pair for Circuit Breaker *m*[b]
10, 12	89OC01–89OC*dd*	Open Disconnect Switch Control 1–*dd*[c]
10, 12	89CC01–89CC*dd*	Close Disconnect Switch Control 1–*dd*[c]
10, 12	89OC01:89CC01 89OC02:89CC02 89OC03:89CC03 • • • 89OC*dd*:89CC*dd*	Open/close Disconnect Switch Control Pair 1–*dd*[c]
10, 12	RST_DEM	Reset demands[d]
10, 12	RST_PDM	Reset demand peaks[d]
10, 12	RST_ENE	Reset energies[d]
10, 12	RSTMML	Reset min/max metering data for the line[d]
10, 12	RSTMMB*m*	Reset min/max metering data for Circuit Breaker *m*[d]
10, 12	RST_BK*m*	Reset Breaker *m* monitor data[d]
10, 12	RST_BAT	Reset battery monitor data[d]
10, 12	RST_79C	Reset recloser shot counter[d]
10, 12	RSTFLOC	Reset fault location data[d]
10, 12	RSTTRGT	Reset front-panel targets[d]

Table 16.9 Relay DNP3 Reference Data Map (Sheet 2 of 2)

Object	Label	Description
10, 12	RSTDNPE	Reset (clear) DNP3 event summary AIs[d]
10, 12	NXTEVE	Load next fault event into DNP3 event summary AIs
Binary Counters		
20, 22	ACTGRP	Active settings group
NOTE: Additional binary counters are relay-specific. See the relay instruction manual to see what counter objects are available.		
Analog Inputs		
NOTE: The analog inputs available is relay dependent. See the relay instruction manual to determine what analog inputs are available.		
Analog Outputs		
40, 41	ACTGRP0	Active settings group
40, 41	TECORR[e]	Time-error preload value
40, 41	RA001–RA256	Remote analogs

[a] The number of remote bits available, nn, depends on the specific relay. See the relay instruction manual to see how many are available.

[b] The number of breakers to control and their designations, m, depends on the specific relay. See the relay instruction manual to determine which breakers are available.

[c] The number of disconnect controls, dd, available depends on the relay. See the relay instruction manual to determine how many disconnects are supported. Not all SEL-400 series relays support disconnect controls.

[d] Not all SEL-400 series relays support all of these resets. See the relay instruction manual to see which specific controls are available.

[e] In milliseconds, $-30000 \leq \text{time} \leq 30000$. When writing to this value, the Relay Word bit PLDTE asserts for approximately 1.5 cycles.

Device Attributes (Object 0)

Table 16.8 includes the supported Object 0 device attributes and variations. In response to Object 0 requests, the relay will send attributes that apply to that particular DNP3 session. Because the relay supports custom DNP3 maps, these values will likely be different for each session.

The relay uses its internal settings for the following variations:

- Variation 245—SID Global setting
- Variation 246—DNPID port setting
- Variation 247—RID Global setting

Binary Inputs

Binary inputs (Objects 1 and 2) are supported as defined by *Table 16.8*. The default variation for both static and event inputs is 2. Only the Read function code (1) is allowed with these objects. The relay will respond to an Object 2, Variation 3 request, but the response will contain no data.

The relay scans binary inputs approximately twice per second to generate DNP3 change events. When time is reported with these event objects, it is the time at which the scanner observed the bit change. This may be significantly delayed from when the original source changed and should not be used for sequence-of-events determination. Binary inputs registered with SER are derived from the SER process and carry the time stamp of actual occurrence. Some additional binary inputs are available to DNP3, most without SER time stamps. For example, RLYDIS is derived from the relay status variable, STWARN and STFAIL are derived from the diagnostic task data, and UNRDEV and NUNREV are derived from the event queue. Another binary input, STSET, is derived from the SER and carries the time stamp of actual occurrence.

Binary Outputs

Binary output status (Object 10, Variation 2) is supported as defined by *Table 16.8*. Static reads of points RB01–RB*nn*, OC*m*, CC*m*, 89OC01–89OC*dd*, and 89CC01–89CC*dd* respond with the online bit set and the state of the requested bit. Reads from control-only binary output points (such as the data reset controls RSTTRGT and RSTDNPE) respond with the online bit set and a state of 0.

The relay supports control relay output block objects (Object 12, Variation 1). The control relays correspond to the remote bits and other functions as shown above. Each DNP3 control message contains a trip/close code (TRIP, CLOSE, or NUL) and an operation type (PULSE ON, LATCH ON, LATCH OFF, or NUL). The trip/close code works with the operation type to produce set, clear, and pulse operations.

Control operations differ slightly for single-point controls compared to paired outputs. Paired outputs correspond to the complementary two-output model, and single-point controls follow the complementary latch or activation model. In the complementary two-output model, paired points only support close or trip operations, which, when issued, will pulse on the first or second point in the pair, respectively. Latch commands and pulse operations without a trip code are not supported. An operation in progress may be canceled by issuing a NUL trip/close code with a NUL operation type. Single output points support both pulse and latch operations. See *Control Point Operation on page 16.20* for details on control operations.

The status field is used exactly as defined. All other fields are ignored. A pulse operation is asserted for a single processing interval. You should exercise caution if sending multiple remote bit pulses in a single message (i.e., point count > 1), because this may result in some of the pulse commands being ignored and the return of an already active status message. The relay will only honor the first ten points in an Object 12, Variation 1 request. Any additional points in the request will return the DNP3 status code `TOO_MANY_OBJS`.

The relay also supports pattern control blocks (Object 12, Variations 2 and 3) to control multiple binary output points. Variation 2 defines the control type (trip/close, set/clear, or pulse) and the range of points to operate. Variation 3 provides a pattern mask that indicates which points in that range should be operated. Object 12, Variations 2 and 3 define the entire control command: the DNP3 master must send both for a successful control. For example, the DNP3 master sends an Object 12, Variation 2 message to request a trip of the range of indices 0–7. The DNP3 master then sends an Object 12, Variation 3 message with a hexadecimal value of “BB” as the pattern mask (converted to binary notation: 10111011). Read right to left in increasing bit order, the pattern block control command will result in a TRIP of indexes 0, 1, 3 to 5, and 7.

Control Point Operation

Use the trip and close, latch on/off and pulse on operations with Object 12 control relay output block command messages to operate the binary output points. See *Section 10: Communications Interfaces* in the product-specific instruction manual for a complete table of object 12 controls available in that relay. Pulse operations provide a pulse with duration of one protection processing interval. Cancel an operation in progress by issuing a NUL trip/close code with a NUL operation type.

Analog Inputs

Analog inputs (Objects 30 and 32) are supported as defined by *Table 16.8*. The default variation for both static and event inputs is defined by the AIVAR (AIVAR*n* for DNP3 LAN/WAN session *n*) setting. Only the Read function code (1) is allowed with these objects.

NOTE: Sequence current quantities are forced to 0 if the value is below 0.5 percent of I_{NOM}.

Unless otherwise indicated, analog values are reported in primary units. Voltage magnitudes below 0.10 volts secondary and current magnitudes below 0.5 percent of I_{NOM} are forced to 0, as are their corresponding angles. Default scaling is indicated in the product-specific instruction manual, but default scaling can be overridden by per-point scaling in a custom DNP3 map. The DECPLA, DECPLV, and DECPLM settings are the default scaling factors (in powers of 10) for current magnitudes, voltage magnitudes, and miscellaneous magnitudes, respectively. See *Configurable Data Mapping on page 16.23* for more information.

Default deadbands are also indicated in the product-specific instruction manual and may be overridden by per-point deadband configuration. In general, the ANADBA, ANADBV, and ANADBM settings are the default deadbands for current magnitudes, voltage magnitudes, and miscellaneous magnitudes, respectively. Deadbands are applied after any custom or default scaling factors. Events are generated when values exceed deadbands.

Reading Relay Event Data

The relay provides protective relay event history information in one of two modes: single-event or multiple-event access. Each DNP3 session begins in the mode specified by Port setting EVEMOD*n* (where *n* = 1–6 for Ethernet sessions and not present for serial sessions). The selected mode is entered when the relay is first enabled, when there is a DNP3 settings change, a DNP3 map change, or an SER settings change. When EVEMOD*n* = SINGLE, the relay powers up in single-event mode. When EVEMOD*n* = MULTI, the relay powers up in multiple-event mode. A DNP3 session will switch to multiple-event mode if the session DNP3 master sends a control to the NXTEVE binary output control point. The DNP3 session will revert to the default mode after a power cycle or relay restart.

When a relay event occurs, (TRIP asserts, ER asserts, or TRI asserts) whose fault location is in the range of MINDIST to MAXDIST, the data shall be made available to DNP3. If MINDIST is set to OFF, then there is no minimum. Similarly, if MAXDIST is set to OFF, there is no maximum.

In either mode, DNP3 events for all event summary analog inputs will be generated if any of them change beyond their deadband value after scaling (usually whenever a new relay event occurs and is loaded into the event summary analog inputs). Events are detected approximately twice a second by the scanning process.

The specific fault data available and its encoding is relay-specific. See *Section 10: Communications Interfaces* in the product-specific instruction manual for information on the relay reports fault data.

Single-Event Mode

Single-event mode provides the most recent tripping event. When a relay event occurs and FLOC is in range of MINDIST and MAXDIST, these data regions are copied to the DNP3 fault summary analog inputs, generating appropriate DNP3 events. The relay shall then ignore any subsequent events for EVELOCK (Global setting) time. When the EVELOCK setting is zero, single-event mode effectively acts as a zero-buffer FIFO queue. In this mode, relay events are presented to generate DNP3 events for the fault summary analog inputs as they occur. Fault summary analog inputs shall be reset to 0 on a rising edge of RSTDNPE (Global SELOGIC equation result). The relay element EVELOCK shall be set when a relay event is triggered and reset when EVELOCK time expires.

Multiple-Event Mode

Relay multiple-event summary data can be read in two ways: first in, first out (FIFO); or last in, first out (LIFO).

See *FIFO on page 16.22* and *LIFO on page 16.22* below for procedures to retrieve relay events that occur when FLOC is in range of MINDIST and MAXDIST. Event retrieval as shown below is a manual monitor, control, and poll process. A DNP3 master can collect relay event summaries by using event data rather than the static data polling described below. For best results, the master must control the NXTEVE binary output no faster than once every two seconds to load a new event into the event summary analog inputs. If the NXTEVE binary output is controlled at a faster rate, some DNP3 events may not be recognized and processed by the DNP3 event scanner.

FIFO

Multiple-event FIFO mode shall be initiated if the DNP3 session master operates the NXTEVE (next event) control. The master should monitor the UNRDEV binary input point, which will be asserted when there is an unread relay event summary. The NUNREV bit will also be asserted as long as there remain any unread events newer than the currently loaded event summary. To read the oldest unread relay event summary, the master should send a close, latch on, or pulse on control to the NXTEVE binary output point. This will load the relay event summary analogs with information from the oldest relay event summary, discarding the values from the previous load.

After reading the analogs, the master should again check the UNRDEV binary input point, which will be on if there is another unread relay event summary. The master should continue this process until the UNRDEV binary input point deasserts. If the master attempts to load values by controlling the NXTEVE output point when the UNRDEV binary input point is deasserted, the relay event type analog (FTYPE) will be loaded with zero. With the FIFO method, the relay event summaries will always be collected in chronological order.

LIFO

Multiple-event LIFO mode event summary retrieval is similar to FIFO retrieval, with the following difference: to read the newest unread relay event summary, the master should send a latch off control to the NXTEVE binary output point. As with FIFO retrieval, the master should monitor the UNRDEV binary input to determine if there are any unread events. Users must be aware of one caveat with LIFO retrieval: if an event occurs while in the process of reading the newest event(s) event collection will no longer continue in reverse chronological order. The next event read will be the newest event, and will proceed with the next newest, but any events that have already been read shall be skipped. The NUNREV bit will be asserted if this happens, signifying that the currently loaded event summary is no longer the newest event.

Analog Outputs

Analog outputs (Objects 40 and 41) are supported as defined by *Table 16.8*. The default variation for both static and event inputs is Variation 2. If an invalid value is written, the relay will ignore the value without generating an error.

The relay will only honor the first ten points in a request. Any additional points in the request will be ignored without generating an error.

Counters

Counters (Object 20 and 22) are supported as defined by *Table 16.8*. The default variation for Object 20 is Variation 6, and Variation 2 is the default for Object 22. Counters shall only support the Read function code (1). A Read of Object 21 will receive a Null response. The default deadband is 0, which may be overridden by a per-point deadband in a custom map. Scaling for counters is always 1.

Default Data Map

See *Section 10: Communications Interfaces* in the product-specific instruction manual to see the relay default map. If the default maps are not appropriate, you can also use the custom DNP3 mapping commands **SET D *n*** and **SHOW D *n***, where *n* is the map number, to edit or create the map required for your application.

Configurable Data Mapping

One of the most powerful features of the relay DNP3 implementation is the ability to remap DNP3 data and, for analog and counter inputs, specify per-point scaling and deadbands. Remapping is the process of selecting data from the default or reference map and organizing it into a data set optimized for your application. The relay uses point labels rather than point indexes in a reference map to streamline the remapping process. This enables you to quickly create a custom map without having to search for point indexes in a large reference map.

You may use any of the five available DNP3 maps to exchange data with any DNP3 master. Each map is initially populated with default data points, as described in the Default DNP3 Map. You may remap the points in a default map to create a custom map with as many as:

- 400 binary inputs
- 160 binary outputs
- 20 counters
- 200 analog inputs
- 100 analog outputs

Use the settings Class D to access the relay DNP3 map settings shown in *DNP3 Settings—Custom Maps on page 12.19*. There are five DNP3 maps available to customize, or leave as default.

The mapping settings are entered in a line-based freeform format. An example of these settings is shown in *Figure 16.4*. You can program a custom scaling and deadband for each point where indicated. If you do not specify a custom scaling or deadband, the relay will use the default for the type of value you are mapping. For example, if you enter the label 3P_F in Row 1 of the custom analog map with no other parameters, the power in MW will be available as Objects 30 and 32, Index 0 and the relay will use the default scaling DECPLM and default deadband of ANADBM.

You can use the **SHOW D *x*** command to view the DNP3 data map settings, where *x* is the DNP3 map number from 1 to 5. See *Figure 16.4* for an example display of Map 1.

```
=>>SHO D 1 <Enter>
DNP 1

DNP Object Default Map Enables

MINDIST := OFF      MAXDIST := OFF


Binary Input Map
(Binary Input Label)

1: EN_RLY
2: TRIPLED
.
.
.
13: RB04
14: RB05
15: RB06


Binary Output Map
(Binary Output Label)

1: RB01
2: RB02
.
.
.
5: RB05
6: RB06


Counter Map
(Counter Label, Deadband)

1: ACTGRP

Analog Input Map
(Analog Input Label, Scale Factor, Deadband)

1: IAWFMC
2: IAWFAC
.
.
.
15: 3SWFC
16: VDC1


Analog Output Map
(Analog Output Label)

1: ACTGRP
```

Figure 16.4 Sample Response to SHO D Command

You can use the **SET D *x*** command (where *x* is the map number), to edit or create custom DNP3 data maps. You can also use QuickSet, which is recommended for this purpose.

See the Reference Map to determine the available choices for each object type.

For binary inputs, a value of 0 or 1 may be used instead of a label; this will cause the relay to report that value for that point. Similarly, for counters and analog inputs, a value of 0 may be used instead of a label, which will cause the relay to report 0 for that point. A NOOP can be used as a placeholder for binary or analog outputs-control of a point with this label does not change any relay values nor respond with an error message. Duplicate point labels are not allowed within a map, except for the values 0 or 1 or NOOP.

You can customize the DNP3 analog input map with per-point scaling and deadband settings. Class scaling (DECPLA*n*, DECPLV*n*, and DECPLM*n*) and deadband settings (ANADBA*n*, ANADBV*n*, and ANADBM*n*) are applied to indices that do not have per-point entries. Per-point scaling overrides any class scaling and deadband settings. Unlike per-point scaling, class-level scaling is specified by an integer in the range 0–3 (inclusive), which indicates the number of decimal place shifts. In other words, you should select 0 to multiply by 1, 1 for 10, 2 for 100, or 3 for 1000.

NOTE: The settings above contain the DNP3 LAN/WAN session suffix n. This suffix is not present in serial port DNP3 settings.

Scaling factors allow you to overcome the limitations imposed, by default, of the integer nature of Objects 30 and 32. For example, DNP3, by default, truncates a value of 11.4 A to 11 A. You may use scaling to include decimal point values by multiplying by a power of 10. For example, if you use 10 as a scaling factor, 11.4 A will be transmitted as 114. You must divide the value by 10 in the master to see the original value including one decimal place.

You can also use scaling to avoid overflowing the 16-bit maximum integer value of 32767. For example, if you have a value that can reach 157834, you cannot send it using DNP3 16-bit analog object variations. You could use a scaling factor of 0.1 so that the maximum value reported is 15783. You can then multiply the value by 10 in the master to see a value of 157830. You will lose some precision as the last digit is dropped in the scaling process, but you can transmit the scaled value by using the default variations for DNP3 Objects 30 and 32.

If your DNP3 master has the capability to request floating-point analog input variations, the relay will support them. These floating-point variations, 5 and 6 for Object 30 and 5–8 for Object 32, allow the transmission of 16- or 32-bit floating-point values to DNP3 masters. When used, these variations eliminate the need for scaling and maintain the resolution of the relay analog values. Note that this support is greater than DNP3 Level 4 functionality, so you must confirm that your DNP3 master can work with these variations before you consider using floating-point analog variations.

The following example describes how to create a custom DNP3 map by point type. The example demonstrates the **SET D** command for analog inputs. Alternatively, you can use the QuickSet software to simplify custom data map creation. The example uses quantities available in the SEL-411L, but similar operations can be performed on any SEL-400 series relay.

Consider a case where you want to set the analog input points in a map as shown in *Table 16.10*.

Table 16.10 Sample Custom DNP3 Analog Input Map

Point Index	Description	Label	Scaling	Deadband
0	Fundamental IA magnitude	LIAFM	Default	Default
1	Fundamental IB magnitude	LIBFM	Default	Default
2	Fundamental IC magnitude	LICFM	Default	Default
3	Fundamental IC magnitude	LIAFM	Default	Default
4	Fundamental three-phase power	3P_F	5	Default
5	Fundamental A-Phase magnitude	VAFM	Default	Default
6	Fundamental A-Phase angle	VAFA	1	15
7	Frequency	FREQ	0.01	1

To set these points as part of custom map 1, you can use the **SET D 1 TERSE** command as shown in *Figure 16.5*.

```
=>>SET D 1 TERSE <Enter>
DNP 1

DNP Object Default Map Enables


Min Fault Location to Capture (OFF,-10000 - 10000)   MINDIST := OFF    ?
Max Fault Location to Capture (OFF,-10000 - 10000)   MAXDIST := OFF    ?

Analog Input Map
(Analog Input Label, Scale Factor, Deadband)
1:
? LIBFM <Enter>
2:
? LICFM <Enter>
3:
? LIAFM <Enter>
4:
? 3P_F,5 <Enter>

5:
? VAFM <Enter>
6:
? VAFA,1,15 <Enter>
7:
? FREQ,.01,1 <Enter>
8:
? END
Save settings (Y,N) ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved
```

Figure 16.5 Sample Custom DNP3 Analog Input Map Settings

DNP3 Serial Application Example

Application

This example uses an SEL-421 connected to an RTU over an EIA-485 network. The RTU collects basic metering information from the relay and other devices. The network for this example is shown in *Figure 16.6*.

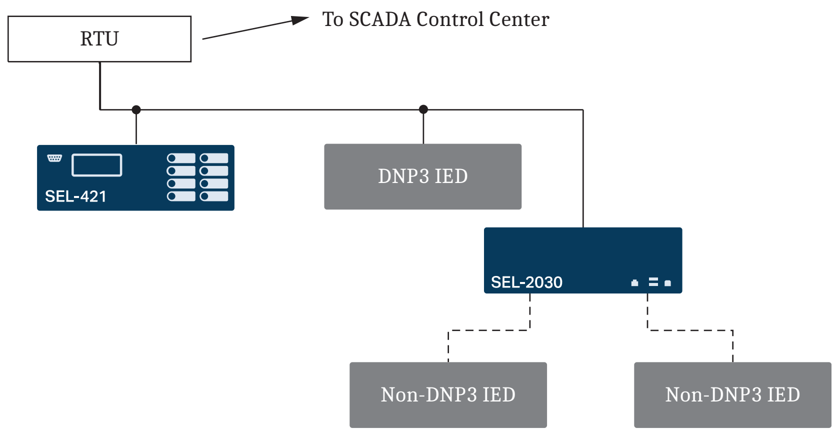

Figure 16.6 DNP3 Application Network Diagram

The metering and status data that the RTU collects from the relay are listed in *Table 16.11*.

Table 16.11 DNP3 Application Example Data Map

Label	Object	Custom Map Index	Description
EN	1, 2	0	Relay enabled
TRIPLED	1, 2	1	Circuit Breaker tripped
IN101	1, 2	2	Relay Discrete Input 1
IN102	1, 2	3	Relay Discrete Input 2
IN103	1, 2	4	Relay Discrete Input 3
IN104	1, 2	5	Relay Discrete Input 4
SALARM	1, 2	6	Relay software alarm
HALARM	1, 2	7	Relay hardware alarm
TESTDB2	1, 2	8	Test mode enabled
RB01	10, 12	0	Remote Bit 1
RB02	10, 12	1	Remote Bit 2
RB03	10, 12	2	Remote Bit 3
RB04	10, 12	3	Remote Bit 4
RB05	10, 12	4	Remote Bit 5
RB06	10, 12	5	Remote Bit 6
OC1:CC1	10, 12	6	Circuit Breaker 1 trip/close pair
LIAFM	30, 32	0	IA magnitude
LIAFA	30, 32	1	IA angle
LIBFM[a]	30, 32	2	IB magnitude
LIBFA[b]	30, 32	3	IB angle
LICFM[a]	30, 32	4	IC magnitude
LICFA[b]	30, 32	5	IC angle
VAFM[c]	30, 32	6	VAY magnitude
VAFA[b]	30, 32	7	VAY angle
VBFM[c]	30, 32	8	VBY magnitude
VBFA[b]	30, 32	9	VBY angle
VCFM[c]	30, 32	10	VCY magnitude
VCFA[b]	30, 32	11	VCY angle
3P_F[d]	30, 32	12	Three-phase real power in MW
3Q_F[d]	30, 32	13	Three-phase reactive power in MVAR
DC1[e]	30, 32	14	DC1 voltage multiplied by 100
ACTGRP	40	0	Active settings group

[a] Assume the largest expected current is 2000 A and scale the analog value by a factor of 10 to provide a resolution of 0.1 A and a maximum current of 3276.7 A. Report change events on a change of 5 A.

[b] Angles are scaled to 1/100 of a degree. Report change events on a change of 2 degrees.

[c] For a nominal voltage of 230 kV, scale the analog value by a factor of 100 to provide a resolution of 10 V and a maximum value of 327.67 kV. Report 1 kV for change event reporting.

[d] For a maximum load of 800 MW (or 800 mVar), scale the power by a factor of 40 to provide a resolution of 0.025 MW and a maximum value of 819.175 MW. Report 1 MW for change event reporting.

[e] VDC1 is scaled by a factor of 1/100 of a volt. Report change events on a change of 2 V.

Settings

Figure 16.7 shows how to enter the new map into the relay. Use the **SET D** command and enter N at the prompts shown in *Figure 16.7* to allow changes to the existing maps. Press **<Enter>** at the empty line prompt to advance to the next map. For example, press **<Enter>** at line 10 of the Binary Input Map to advance to the Binary Output Map. If the prompt contains an entry, you can enter the greater-than symbol (>) and press **<Enter>** to advance to the next step.

```
=>>SET D 1 TERSE <Enter>
DNP 1

DNP Object Default Map Enables

Min Fault Location to Capture (OFF,-10000 - 10000)   MINDIST := OFF    ? <Enter>
Max Fault Location to Capture (OFF,-10000 - 10000)   MAXDIST := OFF    ? <Enter>


Binary Input Map
(Binary Input Label)

1: RLYDIS
?  DELETE 100 <Enter>
1:
?  EN <Enter>
2:
?  TRIPLED <Enter>
3:
?  IN101 <Enter>
4:
?  IN102 <Enter>
5:
?  IN103 <Enter>
6:
?  IN104 <Enter>
7:
?  SALARM <Enter>
8:
?  HALARM <Enter>
9:
?  TESTDB2 <Enter>
10:
? <Enter>


Binary Output Map
(Binary Output Label)

1: RB01
?  DELETE 100 <Enter>
1:
?  RB01 <Enter>
2:
?  RB02 <Enter>
3:
?  RB03 <Enter>
4:
?  RB04 <Enter>
5:
?  RB05 <Enter>
6:
?  RB06 <Enter>
7:
?  OC1:CC1 <Enter>
8:
? <Enter>


Counter Map
(Counter Label, Deadband)

1: ACTGRP
?
2: BKR1OPA
? DELETE 100 <Enter>
2:
? <Enter>
```

Figure 16.7 SEL-421 Example DNP Map Settings

```
Analog Input Map
(Analog Input Label, Scale Factor, Deadband)

1: LIAFM
?  <Enter>
2: LIAFA
?  LIAFA,1,200 <Enter>
3: LIBFM
? <Enter>
4: LIBFA
?  LIBFA,1,200 <Enter>
5: LICFM
? <Enter>
6: LICFA
?  LICFA,1,200 <Enter>
7: B1IAFM
?  VAFM <Enter>
8: B1IAFA
?  VAFA,1,200 <Enter>
9: B1IBFM
?  VBFM <Enter>
10: B1IBFA
?  VBFA,1,200 <Enter>
11: B1ICFM
?  VCFM <Enter>
12: B1ICFA
?  VCFA,1,200 <Enter>
13: B2IAFM
?  3P_F,40,40 <Enter>
14: B2IAFA
?  3Q_F,40,40 <Enter>
15: B2IBFM
?  DC1,,200 <Enter>
16: B2IBFA
?  DELETE 200 <Enter>
16:
? <Enter>


Analog Output Map
(Analog Output Label)

1: ACTGRP
? <Enter>
2:
? <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
=>>
```

Figure 16.7 SEL-421 Example DNP Map Settings (Continued)

Table 16.12 lists the settings for PORT 3 for this example. The physical connection between the relay and the DNP3 master is an EIA-485 network. An SEL-2884 interface converter on the relay PORT 3 provides conversion from EIA-232 to EIA-485. Unsolicited reporting has been disabled because the network is wired as a four-wire connection and does not provide carrier detection or the opportunity to monitor for data traffic on the network.

Table 16.12 SEL-421 PORT 3 Example Settings (Sheet 1 of 2)

Setting Name	Setting	Description
EPORT	Y	Enable port
EPAC	N	Enable port access control
MAXACC	2	Maximum access level for virtual terminal sessions
PROTO	DNP	DNP3 protocol
SPEED	9600	Data speed
PARITY	N	No parity bit
STOPBIT	1	1 stop bit
TIMEOUT	5	Time out virtual terminal session after 5 minutes
TERTIM1	1	Check for termination after 1 second idle time

Table 16.12 SEL-421 PORT 3 Example Settings (Sheet 2 of 2)

Setting Name	Setting	Description
TERSTRN	"\005"	Virtual terminal termination string
TERTIM2	0	No delay before accepting termination string
DNPADR	101	DNP3 address = 101
DNPID	"RELAY1-DNP"	DNP ID for Object 0 self-description
DNPMAP	1	Use DNP3 Map 1
ECLASSB	1	Event Class 1 for binary event data
ECLASSC	1	Event Class 1 for counter event data
ECLASSA	1	Event Class 1 for analog event data
ECLASSV	OFF	Disable virtual terminal event data (this feature is not supported by the DNP3 master)
TIMERQ	I	Ignore time-set request because IRIG-B is used for time synchronization
DECPLA	1	Scale current, multiplying by 10 to send amperes and tenths of an ampere. The relay would report a value of 10.4 as 104, which would remain unscaled at the master.
DECPLV	2	Scale voltage, multiplying by 100 to send kilovolts, tenths, and hundredths of a kilovolt
DECPLM	2	Scale miscellaneous analog data, multiplying by 100 to send whole numbers and hundredths. The relay would report a value of 5.25 as 525, which would remain unscaled at the master.
STIMEO	10.0	10 second select before operate time-out
DRETRY	OFF	Turn off data link retries
MINDLY	0.05	Minimum delay from DCD to TX
MAXDLY	0.10	Maximum delay from DCD to TX
PREDLY	0.025	Settle time from RTS on to TX to allow EIA-485 transceiver to switch to transmit mode
PSTDLY	0.00	Settle time from TX to RTS off—not required in this application
DNPCL	Y	Enable controls for DNP3
AIVAR	2	Default AI variation
ANADBA	50	Analog reporting deadband for currents, 5 A based on DECPLA scaling factor
ANADBV	100	Analog reporting deadband for voltages, 1 kV based on DECPLV scaling factor
ANADBM	100	Miscellaneous analog value deadband, based on DECPLM scaling factor
ETIMEO	10	Event Message Confirm Time-Out, 10 seconds
UNSOL	N	Unsolicited reporting disabled (data retrieval method is polled report-by-exception)
MODEM	N	No modem connected to port

In this example, the polling method employed by the RTU DNP3 master is polled report-by-exception. The master device normally polls for events only. Once every 25 event polls, the master polls for Class 0 data (status of all points). This polling method allows the master to collect data efficiently from the IEDs by not continuously polling and receiving data that are not changing.

DNP3 LAN/WAN Application Example

Application

This example uses an SEL-487E connected to an RTU over an Ethernet (TCP) network. The RTU collects basic metering information from the relay. The network for this example is shown in *Figure 16.8*.

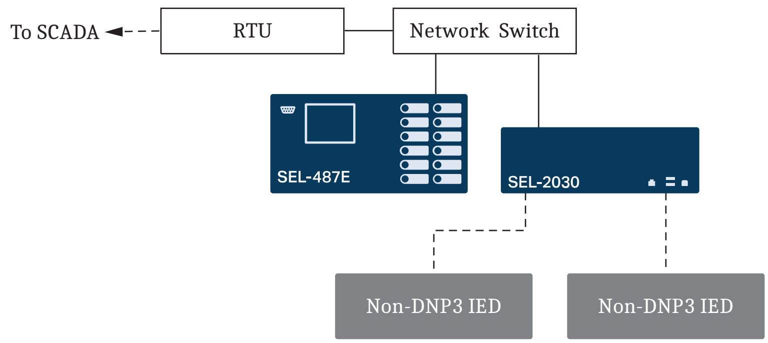

Figure 16.8 DNP3 LAN/WAN Application Example Ethernet Network

The polling method employed by the RTU DNP3 master is polled report-by-exception, so it normally only does event polls. Once every 25 event polls, the master polls for Class 0 data (status of all points). This polling method allows the master to collect data efficiently from the IEDs by only polling and receiving data that has changed.

The RTU, which will act as the DNP3 master to the SEL-487E outstation, has an IP address of 192.9.0.3 and a DNP3 address of 12. The SEL-487E should be assigned an IP address of 192.9.0.2, default router of 192.9.0.1, and DNP3 address of 101.

All event data (analog, binary, counter) should be assigned to CLASS 1. All Binary Inputs should have SOE-quality time stamps.

The desired DNP3 data map is shown in *Table 16.13*.

Table 16.13 DNP3 Application Example Data Map (Sheet 1 of 2)

Label	Object	Custom Map Index	Description
EN	1, 2	0	Relay enabled
TRIPLED	1, 2	1	Circuit Breaker tripped
IN101	1, 2	2	Relay Discrete Input 1
IN102	1, 2	3	Relay Discrete Input 2
IN103	1, 2	4	Relay Discrete Input 3
IN104	1, 2	5	Relay Discrete Input 4
SALARM	1, 2	6	Relay software alarm
HALARM	1, 2	7	Relay hardware alarm
TESTDB2	1, 2	8	Test mode enabled
RB01	10, 12	0	Remote Bit 1
RB02	10, 12	1	Remote Bit 2
RB03	10, 12	2	Remote Bit 3
RB04	10, 12	3	Remote Bit 4

Table 16.13 DNP3 Application Example Data Map (Sheet 2 of 2)

Label	Object	Custom Map Index	Description
RB05	10, 12	4	Remote Bit 5
RB06	10, 12	5	Remote Bit 6
OCS:CCS	10, 12	6	Circuit Breaker S trip/close pair
IASFMC	30, 32	0	A-Phase Current magnitude
IASFAC	30, 32	1	A-Phase Current angle
IBSFMC[a]	30, 32	2	B-Phase Current magnitude
IBSFAC[b]	30, 32	3	B-Phase Current angle
ICSFMC[a]	30, 32	4	C-Phase Current magnitude
ICSFAC[b]	30, 32	5	C-Phase Current angle
VAVFMC	30, 32	6	VA Phase Voltage magnitude, Terminal V
VAVFAC[b]	30, 32	7	VA Phase Voltage angle, Terminal V
VBVFMC[c]	30, 32	8	VB Phase Voltage magnitude, Terminal V
VBVFAC[b]	30, 32	9	VB Phase Voltage angle, Terminal V
VCVFMC[c]	30, 32	10	VC Phase Voltage magnitude, Terminal V
VCVFAC[b]	30, 32	11	VC Phase Voltage angle, Terminal V
VDC[d]	30, 32	12	VDC voltage multiplied by 100
ACTGRP	40	0	Active settings group

[a] Assume the largest expected current is 2000 A, scale the analog value by a factor of 10 to provide a resolution of 0.1 A and a maximum current of 3276.7 A. Report change events on a change of 5 A.

[b] Angles are scaled to 1/100 of a degree. Report change events on a change of 2 degrees.

[c] For a nominal voltage of 230 kV, scale the analog value by a factor of 100 to provide a resolution of 10 V and a maximum value of 327.67 kV. Report 1 kV for change event reporting.

[d] VDC1 is scaled by a factor of 1/100 of a volt. Report change events on a change of 2 V.

Settings

Use SEL Grid Configurator to enter the DNP3 protocol settings and new data map into the relay.

Table 16.14 DNP3 LAN/WAN Application Example Protocol Settings (Sheet 1 of 2)

Setting Name	Setting	Description
EPORT	Y	Enable Ethernet port
IPADDR	192.9.0.2/16	Relay IP address and network in classless inter-domain routing (CIDR) notation
DEFRTR	192.9.0.1	Default router
EDNP	1	Enable DNP3 LAN/WAN Session 1
DNPADR	101	DNP3 address for relay is 101
DNPPNUM	20000[a]	DNP3 port number for TCP
DNPID	RELAY1DNP	DNP3 ID for Object 0 self-description
DNPIP1	192.9.0.3	DNP3 Master (RTU) IP address
DNPTR1	TCP	Use TCP transport
DNPMAP1	1	Use DNP3 Map 1 for DNP3 LAN/WAN Session 1
CLASSB1	1	Binary event data = Class 1
CLASSC1	1	Counter event data = Class 1

Table 16.14 DNP3 LAN/WAN Application Example Protocol Settings (Sheet 2 of 2)

Setting Name	Setting	Description
CLASSA1	1	Analog event data = Class 1
TIMERQ1	1	Ignore time synchronization requests from DNP3 Master
DECPLA1	2	Scale analog current data, multiplying by 10 to send whole numbers and tenths. The relay would report a value of 5.25 as 525, which would remain unscaled at the master. (10^2 = 100)
DECPLV1	2	Scale analog voltage data, multiplying by 10 to send whole numbers and tenths. The relay would report a value of 5.25 as 525, which would remain unscaled at the master. (10^2 = 100)
DECPLM1	2	Scale analog miscellaneous data, multiplying by 10 to send whole numbers and tenths. The relay would report a value of 5.25 as 525, which would remain unscaled at the master. (10^2 = 100)
STIMEO1	1.0[a]	1.0 second to select before operate time-out
DNPINA1	120[a]	Wait 120 seconds to send inactive heartbeat
DNPCL1	Y	Allow DNP3 controls for this session
AIVAR1	2	Default AI variation
ANADBA1	200	Analog deadband counts, set to 2 engineering units, based on DECPLA scaling factor
ANADBV1	200	Analog deadband counts, set to 2 engineering units, based on DECPLV scaling factor
ANADBM1	200	Analog deadband counts, set to 2 engineering units, based on DECPLM scaling factor
ETIMEO1	2[a]	Event message confirm time-out (2 s)
UNSOL1	N	Disable unsolicited reporting for Master 1

[a] Default value.

To meet the requirement for SOE-quality time stamps, enter all binary inputs into the SER report. See *Figure 16.9* for a screenshot of the process.

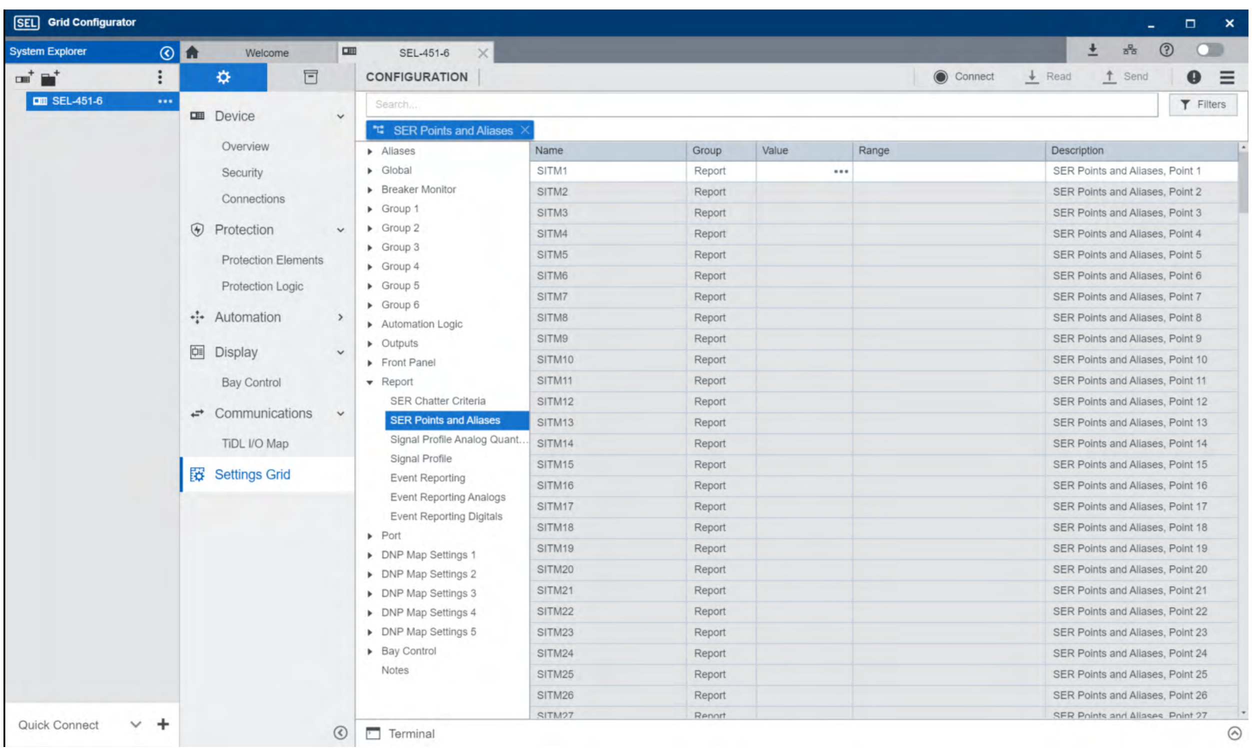

Figure 16.9 Add Binary Inputs to SER Point List

SECTION 17

IEC 61850 Communication

The relay supports the following features using Ethernet and IEC 61850.

- **SCADA**—Connect as many as seven simultaneous IEC 61850 Manufacturing Message Specification (MMS) client sessions. The relay also supports as many as seven buffered and seven unbuffered report control blocks. See *Table 17.34* for logical node mapping that enables SCADA control (including Setting Group Switch) via a MMS browser. Controls support the Direct Normal Security and Enhanced Security (Direct or Select Before Operate) control models.

NOTE: The CID file contains only the necessary data for the required data sets, reports, GOOSE/SV publications, subscriptions, and supervisions. This helps prevent a CID file from exceeding its allocated memory. Refer to Section 10: Testing, Troubleshooting, and Maintenance for more information.

NOTE: Not all SEL-400 series relays support SV publication or subscription.

- **Peer-to-Peer Real-Time Status and Control**—Use GOOSE with as many as 128 incoming (receive) and 8 outgoing (transmit) messages. Virtual Bits (VB001–VB256) and remote analogs (RA001–RA256) can be mapped from incoming GOOSE messages. Remote analog outputs (RAO01–RAO64) provide peer-to-peer real-time analog data transmission.
- **Sampled Values—**Use Sampled Values (SV) to replace the traditional copper wiring between instrument transformers and the relay. Connect an SEL SV publisher to CTs and VTs to publish SV. Use SV subscribers to subscribe to these SV messages. SEL-400 series SV products are compliant to the UCA 61850 9-2LE guidelines. In accordance with the guideline, each publication includes one application service data unit (ASDU), with four current and four voltage channels. Supported publication rates are 4.8 kHz for a 60 Hz power system and 4 kHz for a 50 Hz power system. SEL SV publishers support as many as seven SV streams. SEL SV subscribers support subscribing to as many as seven streams.

NOTE: The relay ships with a default CID file installed, which supports basic IEC 61850 functionality. A new CID file should be loaded if a change in the relay configuration is required. If an invalid CID file is transferred, the relay will reject the file and revert to the previous valid CID file.

- **Configuration**—Use File Transfer Protocol (FTP) client software or ACSELERATOR Architect SEL-5032 Software to transfer the Substation Configuration Language (SCL) Configured IED Description (CID) file to the relay. SEL-400 series SV products also support SV configuration via PORT 5 settings.
- **Commissioning and Troubleshooting**—Use software such as MMS Object Explorer and AX-S4 MMS from Sisco, Inc., to browse the relay logical nodes and verify functionality.

This section presents the information you need to use the IEC 61850 features of the relay.

Introduction to IEC 61850

In the early 1990s, the Electric Power Research Institute (EPRI) and the Institute of Electrical and Electronics Engineers, Inc. (IEEE) began to define a Utility Communications Architecture (UCA). They initially focused on inter-control center and substation-to-control center communications and produced the Inter-Control Center Communications Protocol (ICCP) specification. This specification, later adopted by the IEC as 60870-6 TASE.2, became the standard protocol for real-time exchange of data between databases.

In 1994, EPRI and IEEE began work on UCA 2.0 for Field Devices (simply referred to as UCA2). In 1997, they combined efforts with Technical Committee 57 of the IEC to create a common international standard. Their joint efforts created the current IEC 61850 standard.

The IEC 61850 standard, a superset of UCA2, contains most of the UCA2 specification, plus additional functionality. The standard describes client/server and peer-to-peer communications, substation design and configuration, testing, and project standards.

The IEC 61850 standard consists of the parts listed in *Table 17.1*. The original parts were first published between 2001 and 2004 and are often referred to as IEC 61850 Edition 1 (Ed1). Selected parts of these standards were updated in 2011 and tagged as Edition 2 (Ed2). The current edition, Edition 2, Amendment 1 (Ed2.1), was published in 2020. Refer to the product-specific manual to identify edition compliance.

It is possible and even likely that an installation will have a mixture of devices that conform to different editions. The standard generally supports backward compatibility, i.e., Ed2 devices can send and receive messages to and from Ed1 devices. However, there are important considerations to be made when adding Ed2 or Ed2.1 devices to an existing Ed1 system. Refer to *Potential Client and Automation Application Issues With Ed2 and Ed2.1 Upgrades on page 17.94* for more information.

Table 17.1 IEC 61850 Document Set (Sheet 1 of 2)

IEC 61850 Sections	Definitions
IEC 61850-1	Introduction and overview
IEC 61850-2	Glossary
IEC 61850-3	General requirements
IEC 61850-4	System and project management
IEC 61850-5	Communication requirements
IEC 61850-6	Configuration description language for substation IEDs
IEC 61850-7-1	Basic communication structure for substations and feeder equipment—Principles and models
IEC 61850-7-2	Basic communication structure for substations and feeder equipment—Abstract communication service interface (ACSI)
IEC 61850-7-3	Basic communication structure for substations and feeder equipment—Common data classes (CDCs)
IEC 61850-7-4	Basic communication structure for substations and feeder equipment—Compatible logical node (LN) classes and data classes
IEC 61850-8-1	SCSM—Mapping to Manufacturing Messaging Specification (MMS) (ISO/IEC 9506-1 and ISO/IEC 9506-2 over ISO/IEC 8802-3)

Table 17.1 IEC 61850 Document Set (Sheet 2 of 2)

IEC 61850 Sections	Definitions
IEC 61850-9-1	SCSM—Sampled values over serial multidrop point-to-point link
IEC 61850-9-2	SCSM—Sampled values over ISO/IEC 8802-3
IEC 61850-10	Conformance testing

The IEC 61850 document set, available directly from IEC at www.iec.ch, contains information necessary for successful implementation of this protocol. SEL strongly recommends that anyone involved with the design, installation, configuration, or maintenance of IEC 61850 systems be familiar with the appropriate sections of this standard.

IEC 61850 Operation

IEC 61850 and Ethernet networking model options are available when ordering a new relay and may also be available as field upgrades to relays equipped with the Ethernet card. In addition to IEC 61850, the Ethernet card provides support protocols and data exchange, including FTP and Telnet, to SEL devices. Access the relay PORT 5 settings to configure all of the Ethernet settings, including the IEC 61850 network settings.

The relay supports IEC 61850 services, including transport of logical node objects, over TCP/IP. The relay can coordinate a maximum of seven concurrent IEC 61850 MMS sessions.

Object Models

The IEC 61850 standard relies heavily on the Abstract Communication Service Interface (ACSI) models to define a set of services and the responses to those services. In terms of network behavior, abstract modeling enables all IEDs to act identically. These abstract models are used to create objects (data items) and services that exist independently of any underlying protocols. These objects are in conformance with the CDC specification IEC 61850-7-3, which describes the type and structure of each element within a logical node. CDCs for status, measurements, controllable analogs and statuses, and settings all have unique CDC attributes. Each CDC attribute belongs to a set of functional constraints that groups the attributes into specific categories such as status (ST) and description (DC). Functional constraints, CDCs, and CDC attributes are used as building blocks for defining logical nodes. *Table 17.2* shows the CDCs supported in SEL-400 series relays.

Table 17.2 Relay Common Data Classes (Sheet 1 of 2)

CDC Name	Description
Status Information	
SPS	Single point status
DPS	Double point status
INS	Integer status
ENS	Enumerated status
ACT	Protection activation information
ACD	Directional protection activation information

Table 17.2 Relay Common Data Classes (Sheet 2 of 2)

CDC Name	Description
BCR	Binary counter reading
VSS	Visible string status
Measurand Information	
MV	Measured value
CMV	Complex measured value
SAV	Sampled value
WYE	Phase-to-ground/neutral-related measured values of a three-phase system.
DEL	Phase-to-phase-related measured values of a three-phase system
SEQ	Sequence
Status Settings	
SPG	Single point setting
ING	Integer status setting
ENG	Enumerated status setting
ORG	Object reference setting
TSG	Time setting group
CUG	Currency setting group
VSG	Visible string setting
Analog Settings	
ASG	Analog setting
CURVE	Setting curve
Description Information	
DPL	Device name plate
LPL	Logical node name plate
Controls	
SPC	Controllable single point
DPC	Controllable double point
ENC	Controllable enumerated status
INC	Controllable integer status
BSC	Binary controlled step position information
ISC	Integer controlled step position information
APC	Controllable analog process value
BAC	Binary controlled analog process value

The standard describes elements of the power system that use semantic representations. A physical device contains one or more logical devices that contain many logical nodes. A logical node represents a group of data (controls, status, measurements, etc.) associated with a particular function. For example, the MMXU logical node (polyphase measurement unit) contains nonrevenue grade measurement data and other points associated with three-phase metering. Each IED may contain many functions such as protection, metering, and control. Multiple logical nodes represent the functions in multifunction devices.

IEC 61850 devices are capable of self-description. Clients can request descriptions of the data available in an IEC 61850 server. Simply run an MMS browser to query devices on an IEC 61850 network and discover what data are available. Self-description also shows extensions to both standard and custom data models. Instead of having to look up data in a profile stored in its database, an IEC 61850 client can query an IEC 61850 device and receive a description of all logical devices, logical nodes, and available data.

Unlike other SCADA protocols that present data as a list of addresses or indices, IEC 61850 presents data with descriptors in a composite notation made up of components. *Table 17.3* shows how the A-Phase current magnitude expressed as MMXUAphsA$cVal.mag.f is broken down into its component parts.

Table 17.3 Example IEC 61850 Descriptor Components

Component		Description
MMXU	Logical Node	Polyphase measurement unit
A	Data Object	Phase-to-ground amperes
PhsA	Subdata Object	A-Phase
cVal	Data Attribute	Complex value
mag	Subdata Attribute	Magnitude
f	Data type	Float32

Functional Naming

NOTE: Functional naming is not supported by all MMS clients and GOOSE subscribers. Verify support for this feature before configuring functional names in a publishing IED. Earlier SEL-400 series relays firmware that do not support functional naming can subscribe to GOOSE and SV publications from IEDs that use functional naming.

Substation design typically starts with a one-line diagram and progresses down to the assignment of functions to IEDs. In this top-down approach, the functions are identified and named independently from the IEDs to which they are assigned. Because a logical device is a grouping of logical nodes that perform a certain high-level function at a substation, the associated name often indicates the assigned function. The functional naming feature allows users to name a logical device based on the function it provides independent of the name of the IED to which the function is assigned. The alternative is product naming, which prepends the IED name to the logical device instance to create the logical device name. The functional name is used on the communications interface for all references to data in the logical device.

SEL-400 series relays support functional naming of logical devices. You can add functional names in Architect for supported Ed2 relays. To enable it in Architect, navigate to **Edit > Project Settings** and select the **Enable functional name editing on Server Model tab of supporting IEDs** check box, as shown in *Figure 17.1*.

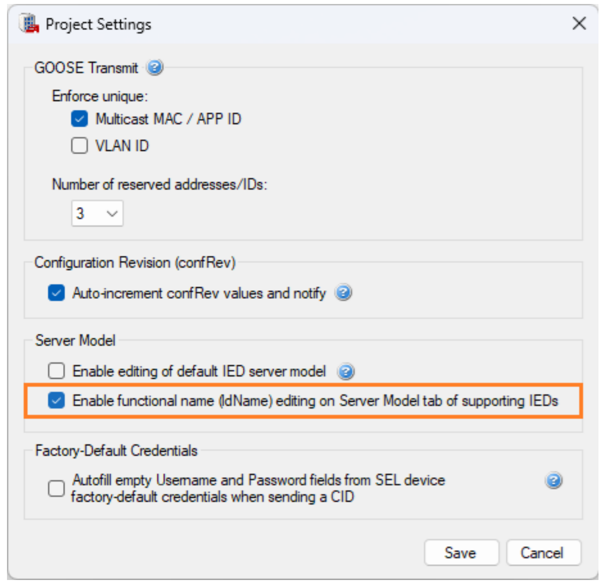

Figure 17.1 Enabling Functional Naming in Architect

To provide functional names to the logical devices, navigate to the Server Model tab for the IED. Because data sets and control blocks are in the CFG logical device, any functional name given to the CFG logical device instance is used in data set references, control block references, and published GOOSE messages, as shown in *Figure 17.2*. The IED Server Model also allows the user to change the default logical node prefix and instance values.

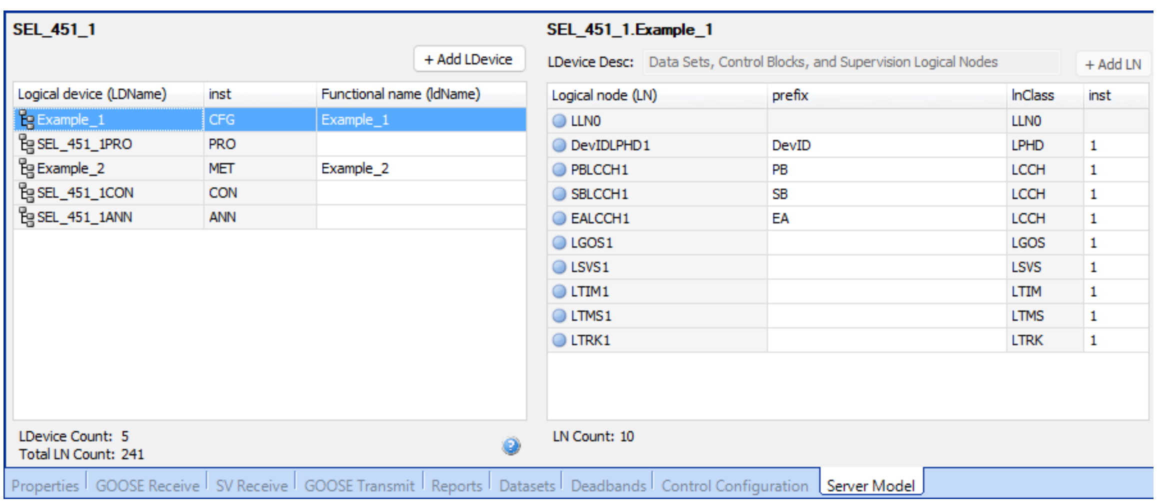

Figure 17.2 Configure Functional Naming in Architect

Data Mapping

Device data are mapped to IEC 61850 LN according to rules defined by SEL. Refer to IEC 61850-5:2013(E) and IEC 61850-7-4:2010(E) for the mandatory content and usage of these LNs. The relay logical nodes are grouped under Logical Devices for organization based on function. See *Table 17.4* for descriptions of the logical devices in a relay. See *Logical Nodes on page 17.53* for a description of the LNs that make up these logical devices.

Table 17.4 Relay Logical Devices

Logical Device	Description
CFG	Configuration elements—data sets and report control blocks
PRO	Protection elements—protection functions and breaker control
MET	Metering or Measurement elements—currents, voltages, power, etc.
CON	Control elements—remote bits
ANN	Annunciator elements—alarms, status values
MU[a]	Merging unit elements—voltage and current channels

[a] This only applies to merging units.

Architect Flexible Server Model (FSM)

Architect provides an interface to build custom ICD files for Ed2.1 devices that have ICD files ClassFileVersion 010 or later. SEL devices have a default ICD file available in Architect, but you may need to add IEC 61850 optional objects to the default logical nodes or add additional logical nodes based on your application.

You may need to customize the SCL server model of a device to model functions configured in SELOGIC control equations, and then make them available through MMS or GOOSE. Various functions, such as automatic tap changer control, gas alarm for GIS, etc., can be configured in SELOGIC programming but require specific customization to implement in IEC 61850.

For example, the SIML logical node models insulation medium supervision (liquid). Transformers or tap changers use oil as an insulator, and sensors or measuring devices can be wired to relay contact inputs. Because the connection of these sensors to a device are application-specific, they are not included in the default ICD file. The FSM provides an interface to add and customize the SIML logical node.

Begin by adding a device to the Project Editor in Architect and selecting an existing ICD file (ClassFileVersion 010 or later). Select the **Server Model** tab to view the logical devices, logical nodes, and data objects that exist in the default ICD file. Although logical nodes can be added to an existing logical device, SEL recommends adding a new logical device for custom logical nodes. If SEL releases new logical nodes or features in the future, the merge operation between default and custom files is less prone to the inadvertent removal of the custom logical nodes.

The default ICD file in this example contains five logical devices: CFG, PRO, MET, CON, and ANN. To add a logical device, select the **+ Add LDevice** button in the logical device pane. Provide an instance name for the new logical device. The new logical device is named XFMR, as shown in *Figure 17.3*.

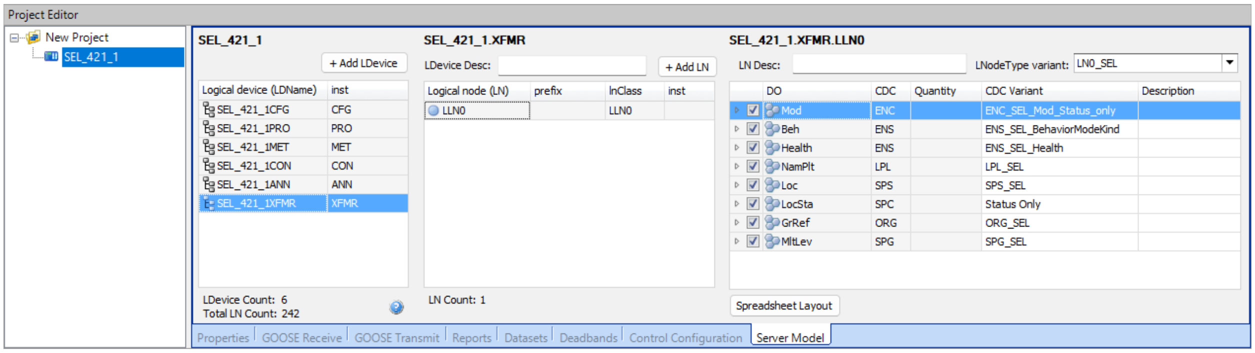

Figure 17.3 Server Model View in Architect

Every logical device contains an LLN0 or common logical node that provides common information. To add another logical node, either right-click in the logical node pane or select the **+ Add LN button**. This opens a pop-up window that contains a list of logical nodes that are present in the Architect Library. There may be more than one variant of each logical node, where each variant may have different data objects included. In this case, only one SIML logical node is added to this file (see *Figure 17.4*).

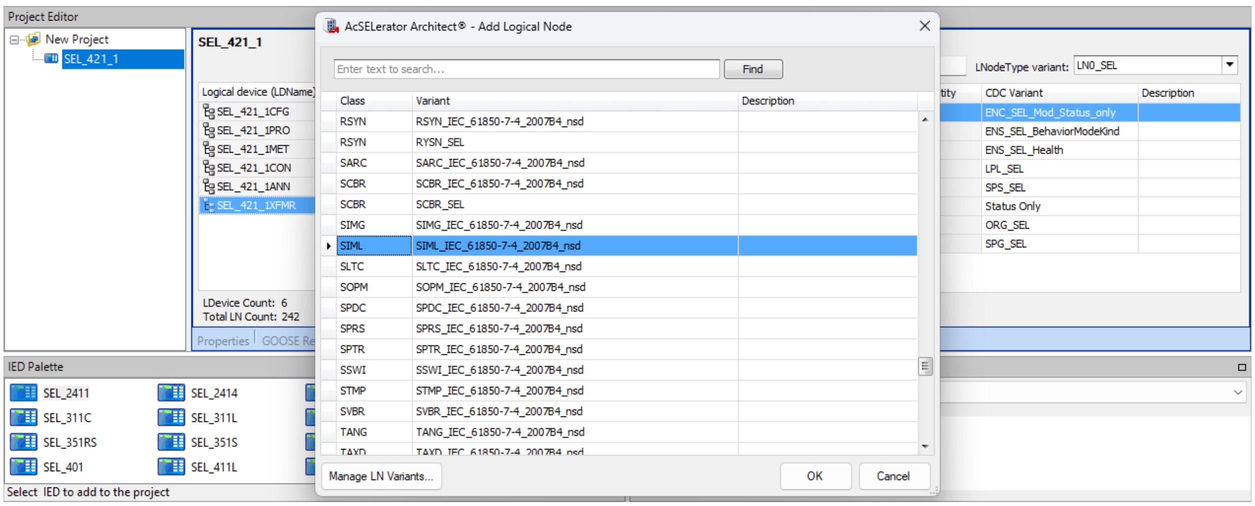

Figure 17.4 Add a Logical Node From the Architect Library

Once the logical node is added to the logical device, select the logical node, which will display the data objects available in the data object pane (see *Figure 17.5*). Add the TmpAlm and GasInsAlm objects by selecting the box to the left of the attribute name. Each object conforms to a particular CDC defined for that object in the IEC 61850 standard. In this example, both TmpAlm and GasInsAlm are single point status (SPS) data objects. *Table 17.2* lists the CDCs supported by the SEL-400 series relays.

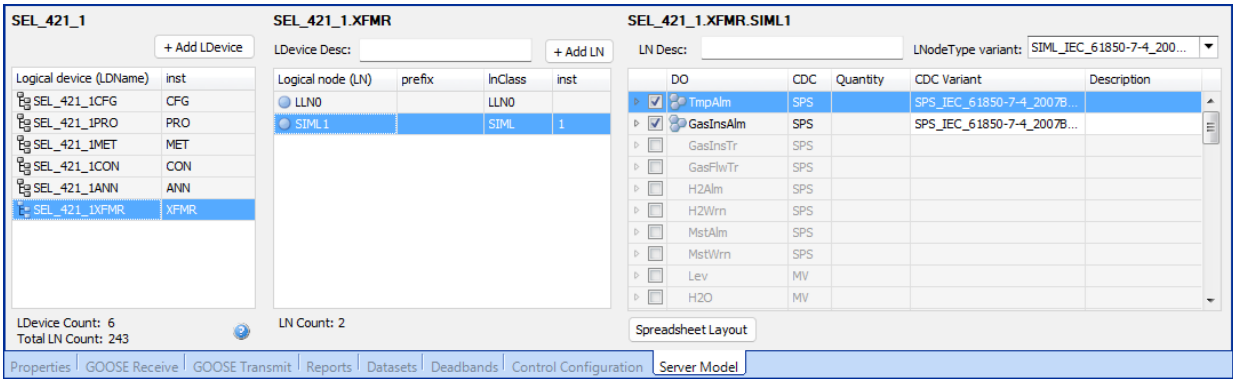

Figure 17.5 Add Data Objects to a Logical Node

Each object contains a list of attributes. TmpAlm, when expanded, lists the associated attributes. In this example, the temperature alarm is wired to Input 6 on I/O Card 2, which is represented by Relay Word bit IN206. The association between the TmpAlm.stVal (status value) and IN206 must be made by entering the Relay Word bit name after the db prompt in the RWB/AQ column, as shown in *Figure 17.6*.

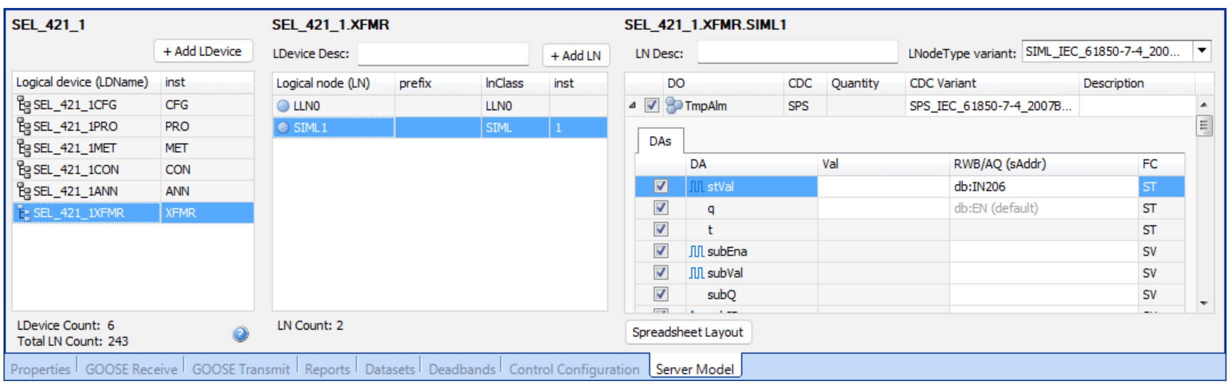

Figure 17.6 Associate a Data Attribute's Value to a Relay Variable

If desired, other logical nodes can be added to the new XFMR logical device. Save the configuration of the project and device. The new logical node objects and attributes are available to add to data sets that may be sent in a GOOSE message or added to a report, as shown in *Figure 17.7*.

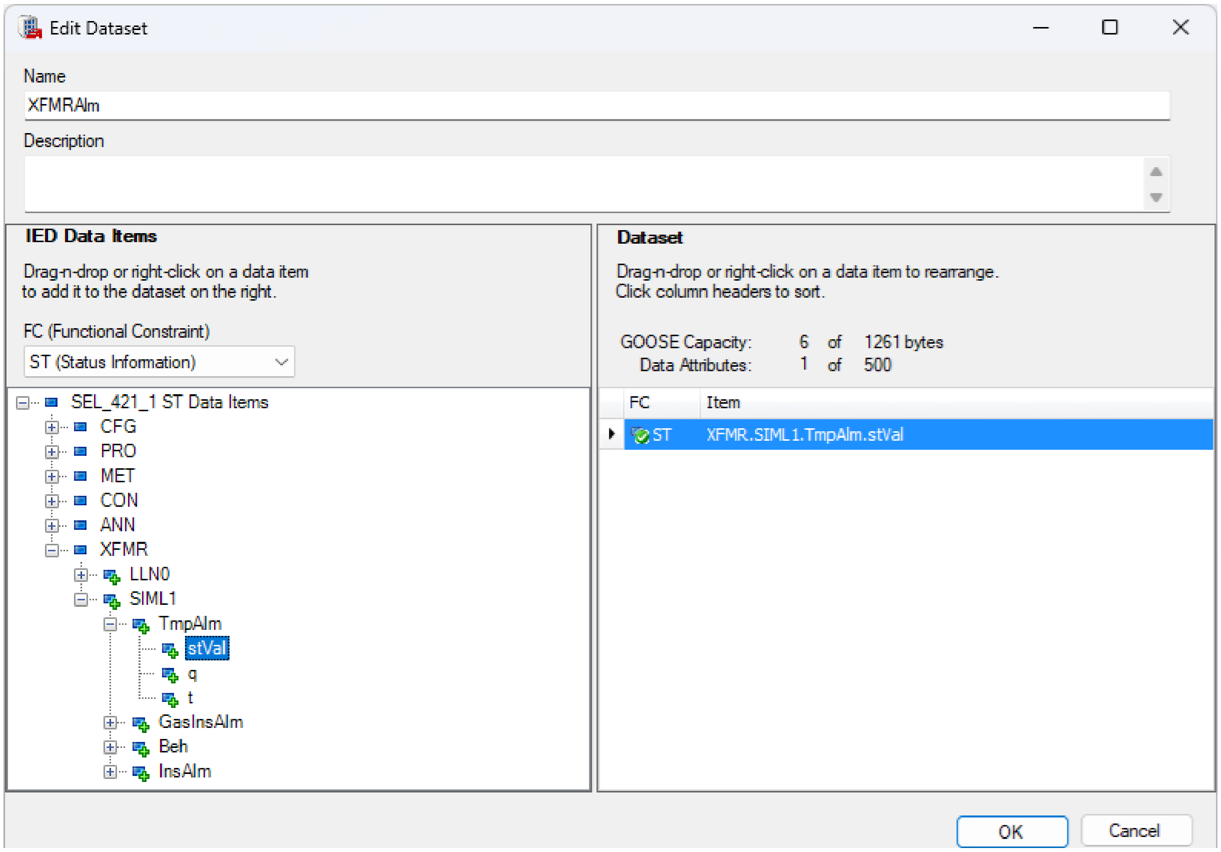

Figure 17.7 Data Set Mapping From an FSM Created Attribute

MMS

MMS provides services for the application-layer transfer of real-time data within a substation LAN. MMS was developed as a network-independent data exchange protocol for industrial networks in the 1980s and standardized as ISO 9506.

In theory, you can map IEC 61850 to any protocol. However, it can become unwieldy and quite complicated to map objects and services to a protocol that only provides access to simple data points via registers or index numbers. MMS supports complex named objects and flexible services that enable mapping to IEC 61850 in a straightforward manner. This was why the UCA users group used MMS for UCA from the start and why IEC chose to keep it for IEC 61850. MMS associations are discussed within IEC61850-8-1, Clause 10 of the Ed1 standard.

If MMS authentication is enabled, the device will authenticate each MMS association by requiring the client to provide the password authentication parameter with a value that is equal to the Access Level 2 password of the relay.

- ➤ If the correct password authentication parameter value is not received, the device will return a not authenticated error code. If a user attempts to log in to the relay with three consecutive invalid login attempts within a 1-minute period, the relay will disable login requests for 30 seconds and pulse the SALARM and BADPASS Relay Word bits.
- ➤ If the correct password authentication parameter value is received, the device will provide a successful association response. The device will allow access to all supported MMS services for that association.

Control

IEC 61850 Controls

An IEC 61850 server may allow a client to manipulate data related to its outputs, external devices, or internal functions. This is accomplished by the IEC 61850 control model, which provides services to execute control commands. The control models are defined in IEC 61850-7-2 and the mapping to the MMS application protocol is defined in IEC 61850-8-1. The former describes control functionality while the latter maps the IEC 61850 control primitives to MMS.

The SEL-400 series relays support four different control models for all controllable CDCs defined in IEC 61850-7-3:

- Status only
- Direct with Normal Security
- Direct with Enhanced Security
- SBO with Enhanced Security

One control model must be selected during the initial IED configuration in Architect and be applied throughout the CID file. This control model applies to all controls in the IED. For CID files created from an ICD file with ClassFileVersion 010 or later, Architect allows modifying the control model on a per-control basis if a different control model is required other than the one selected during initial IED configuration.

Firmware that supports Ed2.1 and ClassFileVersion 010 or later supports pulsing the SPC and DPC control models as defined in IEC 61850-7-3 by configuring pulseConfig attributes cmdQual, onDur, offDur, and numPls.

Direct Control Models

The direct control models provide the simplest means to initiate actions on the server. In these models, the client issues a control request via MMS and the server validates the request. Once validated, the server attempts to act upon the request. Note that if multiple clients try to perform control actions, the server does nothing to prevent the simultaneous control actions.

SBO Control Model

The SBO control model supports the SelectWithValue Service and can be used to prevent multiple clients from performing simultaneous control actions. In this mode, a client has to “reserve” the control object by sending a “select” control command. Once an object is selected, only the client that made the selection is allowed to perform control actions on it. If that client does not send a valid operate request for the object by the time the select time-out runs out, the object becomes available for selection again. The relay supports as many as ten pending control object selections at any time.

NOTE: When an IED is configured with the SBO with Enhanced Security control model, the sboTimeout attribute of the controllable CDCs in the CID file is set to ten seconds. This time-out is not configurable via Architect.

The attribute stSeld (selected status) of the controllable CDC is set to TRUE when a client successfully selects the control object. The attribute is reset to FALSE when either the control (operate) command is successfully executed, an error occurs, or no operate command is received within the select time-out period. The stSeld attribute may trigger a report just like any data attribute with trigger option.

Security in Control Models

"Security" in the control model context refers to additional supervision of the status value by the control object. The enhanced security models report additional error information on failed operations to the requesting client unlike the models with normal security. Enhanced security control models provide a command termination report indicating if the control actually reached the new state as commanded within a configurable time-out period.

NOTE: The maximum time required for a control operation to be completed should be less than the configured time-out period to avoid erroneous command termination reports indicating failure.

The time-out period between the execution of a control and the generation of a command termination report indicating failure has a default value of 1 s and is configurable via the CID file. This time out is not configurable via Architect.

Optional Control Configurations

The SEL-400 series relays that support Ed2.1 and ClassFileVersion 010 or later support the pulse configuration option specified in Clause 6.7 of IEC 61850-7-3. For relays that do not support Ed2.1, some control logical nodes are available that pulse the control for one processing interval.

Controls that can be configured for pulse operations, such as the SPCSO data objects in the RBGGIO logical nodes, contain a pulseConfig constructed data attribute type.

The cmdQual data attribute of an SPC control defines whether the control will be persistent or pulsed. For DPC, only the pulse operation is supported.

- If cmdQual = pulse (0), the control object pulses according to the onDur, offDur and numPls attributes. The control object pulses for one processing interval when cmdQual = pulse, onDur = 0, offDur = 0, and numPls = 1.

  Figure 17.8 shows an example of how onDur, offDur, and numPls are used when the control is pulsed.

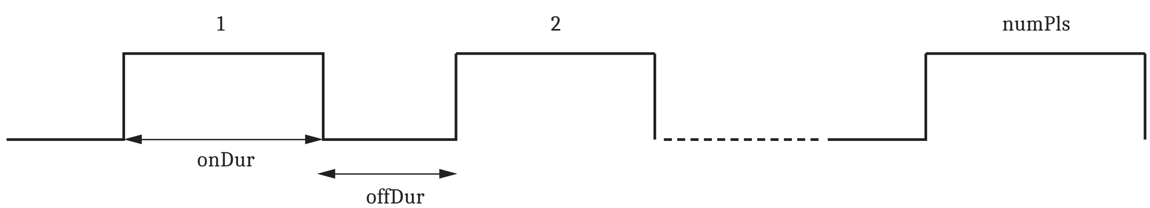

Figure 17.8 Pulse Behavior in Control Operations

- If cmdQual = persistent (1), the control object sets when the command writes TRUE and clears when it writes FALSE.
- cmdQual = persistent-feedback (2) is not supported.

Use Architect to configure a control to pulse by selecting a controllable data object (such as a remote bit), selecting the Control Configuration tab, and setting the pulseConfig.cmdQual to pulse (see *Figure 17.9*). Setting pulseConfig.cmdQual allows changes to the onDur, offDur, and numPls attributes.

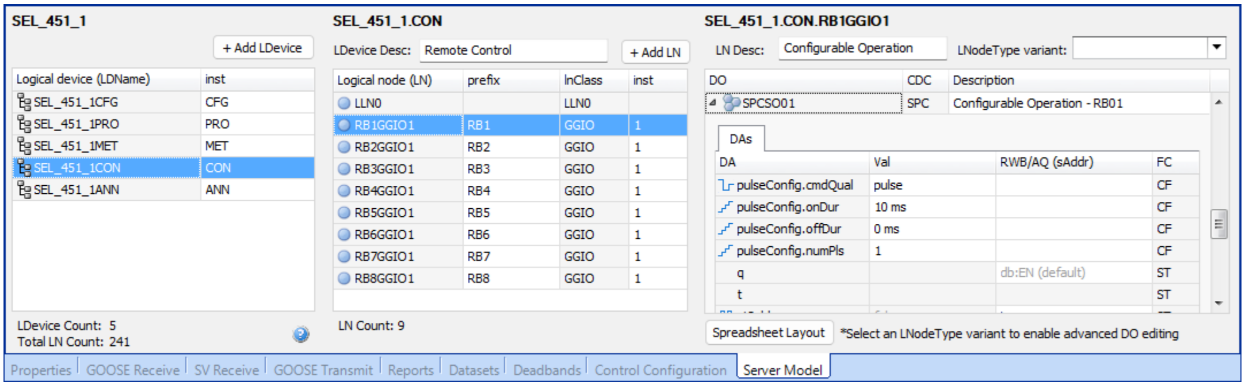

Figure 17.9 Configure Pulse Control Attributes

Control Interlocking

The IEC 61850 standards make provision for control object interlocking, and the IEC 61850-7-4 standard explains how this is performed using the CILO logical node. The CILO logical node has two data objects, namely Enable Open (EnaOpn) and Enable Close (EnaCls), for each breaker or disconnect control object.

NOTE: The IEC 61850 CILO interlocking function does not affect controls sent by any other protocols or local front-panel operations.

The SEL-400 series relays use control interlocking to supervise the open and close control commands from MMS clients. The relay accomplishes this by checking each CSWI logical node control object against an associated CILO logical node data object. When the associated CILO logical node EnaCls and EnaOpn data objects are not asserted, the relay blocks the control operation and sends the AddCause "Blocked-by-interlocking" to the MMS client.

Table 17.5 defines how control interlocking is implemented in the CILO logical node.

Table 17.5 CILO Logical Node EnaOpn and EnaCls Equations

CILO LN Data Object	Data Source	Data Source Equation
EnaCls	BKENC*n*[a]	NOT SCBK*n*BC[a]
EnaOpn	BKENO*n*[a]	NOT SCBK*n*BO[a]
EnaCls	89ENC*mm*[b]	NOT (89CBL*mm* OR 89OPE*mm*)[b]
EnaOpn	89ENO*mm*[b]	NOT (89OBL*mm* OR 89CLS*mm*)[b]

[a] n = Breaker terminal.
[b] mm = Disconnect switch number.

SCBK*n*BO and SCBK*n*BC are SELOGIC control equations. Program these equations in the Protection SELOGIC setting (SET L) to block breaker operation. Program the 89CBL*mm* and 89OBL*mm* SELOGIC control equations in the Bay settings (SET B) to block disconnect operation.

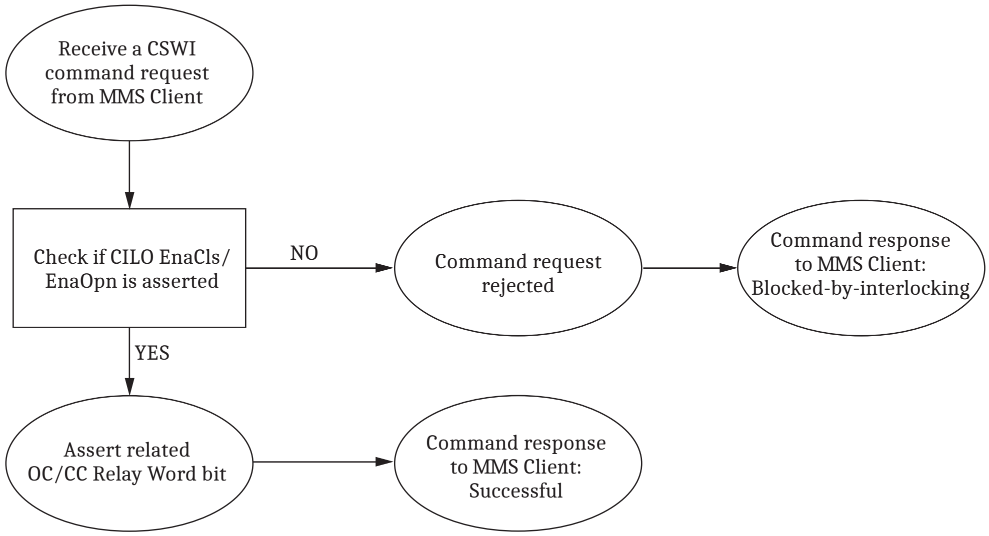

Figure 17.10 CSWI Logical Node Direct Operate Command Request

Figure 17.10 shows how the relay responds to CSWI logical node command requests from MMS Clients when IEC 61850 control interlocking is applied. The SBO control model performs the same check when the select control command is received and again when the operate control is received.

Local/Remote Control Authority

Control commands at a substation originate from one of three levels: remote (network control center), station, or bay. Under certain operational conditions (e.g., during maintenance), you may need to block control commands from one or more of these levels. The local/remote control feature allows you to enable or disable control authority at any of the three levels. The level at which a control command originates is determined by the value of the origin.orCat (originator category) attribute in the command. *Table 17.6* describes the different orCat values defined in IEC 61850-7-2.

Table 17.6 Originator Categories

Originator Category	Value
not-supported	0
bay-control	1
station-control	2
remote-control	3
automatic-bay	4
automatic-station	5
automatic-remote	6
maintenance	7
process	8

The SEL-400 series relays support the local/remote control feature defined in IEC 61850-7-4. The feature is supported at the IED level and the logical node level with identical and configurable attributes in the LLN0 logical node in each logical device and in CSWI logical nodes. *Table 17.7* describes the attributes and their data sources in various logical nodes.

Table 17.7 Control Authority Attributes

Logical Node	Attribute	Data Source	Description
LLN0	Loc.stVal	LOC	Control authority of the IED at local (bay) level
	LocKey.stVal	NOOP	Physical key or toggle switch indication for switching IED in local mode
	LocSta.stVal	LOCSTA	Control authority of the IED at station level
	MltLev.setVal	MLTLEV	Multi-level control authority
CSWI	Loc.stVal	LOC	Control authority of the switch controller at local (bay) level
	LocKey.stVal	NOOP	Physical key or toggle switch indication for switching switch controller LN in local mode
	LocSta.stVal	LOCSTA	Control authority of the switch controller at station level
XCBR/XSWI	Loc.stVal	LOCAL	Switchgear local/remote status
	LocKey.stVal	NOOP	Physical key or toggle switch indication for switchgear local mode

You can control the Relay Word bits LOC, LOCAL, LOCSTA, and MLTLEV through SELOGIC control equations. LOCSTA is set to True when the SELOGIC control equation SC850LS asserts and is set to False when SC850LS deasserts. LOCSTA can also be controlled through MMS, but if LOCSTA is set to True through SELOGIC control equations, it cannot be set to False through MMS. The LocKey data objects are set to NOOP by default as a placeholder. The data source of the LocKey data object can be changed depending on application requirements.

The IED-level local/remote behavior can be changed using the following methods:

- The value of the LOC Relay Word bit is changed through a SELOGIC control equation.
- If the system is equipped with a physical key or a toggle switch for controlling the local/remote status of the entire IED, the data source of CFG.LLN0.LocKey.stVal can be configured to indicate the binary input to which the physical key is wired.

Similarly, the switchgear local/remote behavior can be changed using the following methods:

- The value of the LOCAL Relay Word bit is changed through a SELOGIC control equation. Asserting the LOCAL Relay Word bit changes the XCBR and XSWI logical nodes to local mode. This blocks all control commands to the associated CSWI logical nodes.
- If a switchgear has a physical local/remote control switch, the data source of XCBR.LocKey.stVal can be configured to indicate the binary input to which the physical key is wired.

The MLTLEV SELOGIC control equation allows you to define whether multiple levels of control authority are allowed. If MLTLEV is FALSE, only one level of control authority is allowed to control the switchgear, as shown in *Table 17.8*.

Table 17.8 Control Authority Settings-MLTLEV Set to FALSE[a] (Sheet 1 of 2)

Switchgear Local/ Remote Behavior	Local Control Behavior	Control Authority at Station Level	orCat Value		
XCBR.Loc XSWI.Loc	CSWI.Loc	CSWI.LocSta	Bay (1 or 4)	Station (2 or 5)	Remote (3 or 6)
T	X	X	NA	NA	NA
F	T	X	AA	NA	NA

Table 17.8 Control Authority Settings-MLTLEV Set to FALSE[a] (Sheet 2 of 2)

Switchgear Local/ Remote Behavior	Local Control Behavior	Control Authority at Station Level	orCat Value		
XCBR.Loc XSWI.Loc	**CSWI.Loc**	**CSWI.LocSta**	**Bay (1 or 4)**	**Station (2 or 5)**	**Remote (3 or 6)**
F	F	T	NA	AA	NA
F	F	F	NA	NA	AA

[a] T = True (asserted)
F = False (deasserted)
X = Do not care (True or False)
AA = Command is allowed
NA = Command is not allowed

If MLTLEV is TRUE, multiple levels of control authority are allowed to control the switchgear, as shown in *Table 17.9*.

Table 17.9 Control Authority Settings-MLTLEV Set to TRUE[a]

Switchgear Local/ Remote Behavior	Local Control Behavior	Control Authority at Station Level	orCat Value		
XCBR.Loc XSWI.Loc	**CSWI.Loc**	**CSWI.LocSta**	**Bay (1 or 4)**	**Station (2 or 5)**	**Remote (3 or 6)**
T	X	X	NA	NA	NA
F	T	X	AA	NA	NA
F	F	T	AA	AA	NA
F	F	F	AA	AA	AA

[a] T = True (asserted)
F = False (deasserted)
X = Do not care (True or False)
AA = Command is allowed
NA = Command is not allowed

Control Requests

IEC 61850 control services are implemented by reading and writing to pseudo-variables in the relay in response to MMS requests. Similar to how client requests are generated and mapped to MMS read or write service requests, server actions are also mapped to internal commands, read and write actions, and MMS information report messages. In the case of an unsuccessful control request, the relay sends the appropriate response PDU indicating that there was a problem and an MMS information report that contains more detailed information about the problem that occurred.

When writing controls, the client must select and write the entire Oper, SBOw or Cancel structure to the relay. See *Figure 17.11* for the attributes of the CON logical device and the ST and CO functional constraints (FC) of LN RBGGIO1 used for control of RB01 through RB08.

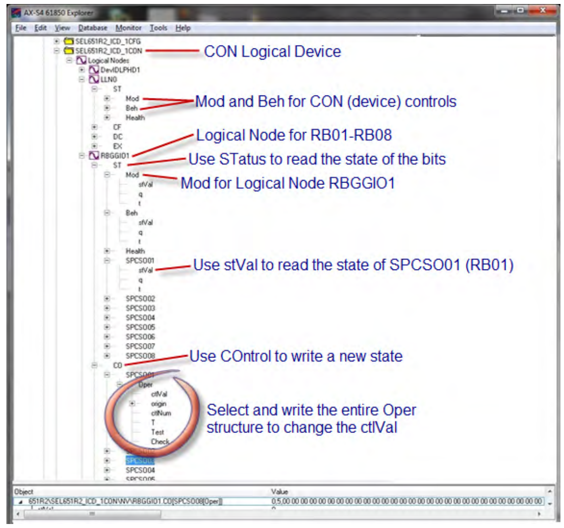

Figure 17.11 MMS Client View of the CON Logical Device

Control Error Messages

If a control request results in an error condition, the relay responds with an AddCause value in an MMS information report. See Clause 20.5.2.9 of IEC 61850-7-2 for additional information on the AddCause values.

The SEL-400 series relays support the AddCause values in *Table 17.10* as part of the LastApplError information report.

Table 17.10 AddCause Descriptions

AddCause Enumeration	AddCause Description	Error Condition
0	Unknown	No other AddCause value defined within this section applies
2	Blocked-by-switching-hierarchy	Logical node is set to local mode, i.e., Loc.stVal = true
3	Select-failed	Originator category not allowed to issue control commands or SelectWithValue operation fails
4	Invalid-position	For controls with enhanced security, an AddCause of “Invalid-position” (4) will be sent if the control status changes to an unexpected value. If no control status change is detected after the operate time-out period, an AddCause of “Time-limit-over” (16) will be sent.
5	Position-reached	Control status is already at the desired state
6	Parameter-change-in-execution	Control object is already selected by the client, and 1. Logical node is set to local mode i.e., Loc.stVal = true, or 2. Originator category not allowed to issue control commands
8	Blocked-by-mode	Mode of logical device or node is not ON
10	Block-by-interlocking	Selection of switch device failed due to interlock check
12	Command-already-in-execution	Execution of a previous control is not completed
13	Blocked-by-health	Health of logical device or node is not OK
16	Time-limit-over	CommandTermination gives a negative response. (The control failed to reach its intended state prior to time-out.)
18	Object-not-selected	Cancel operation fails
20	No-access-authority	Control action is blocked due to lack of access authority

Any AddCause value not specified above is not supported. Control CDC data attributes that are associated with unsupported AddCause values and are not part of a control structure will be accepted but ignored. For example, the attribute CmdBlk.stVal, which is associated with the AddCause value "blocked-by-command" and is not part of a SBOw, Oper, or Cancel structure, will be ignored.

Group Switch Via MMS

The group switch feature in IEC 61850 is primarily a convenience feature for users so that they can institute a settings group switch from an IEC 61850 client without having to revert to the command line or some other tool. However, this has great potential for integration with IEC 61850 SCADA systems that would be able to control setting groups through IEC 61850 MMS.

The IEC 61850 specification outlines a method for switching the current settings group to another preconfigured settings group. The setting group control block, or SGCB, contains the SettingControl element that enables settings group control. The SEL-400 series relays require the minimum versions of the firmware and ICD files to enable the SGCB. Refer to Appendix A in the product-specific manuals for supported firmware and ICD versions. In the IEC 61850 standard, SGCB class includes an attribute for the active settings group, or ActSG, as a read/write attribute. The ActSG is a read-only attribute in SEL-400 series relays. Adding the ActSG attribute with a value to the SettingControl element of the ICD file results in the relay ignoring the value and continuing to use the existing active settings group when the ICD file is downloaded.

When the IEC 61850 functions of the relay are enabled, the selectActiveSG service allows an MMS client to request that the relay change the active setting group. The MMS client can request a group switch by writing a valid setting group number to ActSG. The relay updates the ActSG value under the following conditions:

- ➤ The value written to ActSG is valid and not the current active group
- ➤ There is no group switch in progress
- ➤ The setting of the active group was successful.

Note that if the value written to ActSG is the same as the current group, the relay will not attempt to switch settings groups. Refer to *Multiple Setting Groups on page 12.4* for more information on Group settings.

Service Tracking

The IEC 61850 standard defines many services to be provided by an IED (server). These services include control services, reporting services, logging services, and group switch control services. IEC 61850 Ed2 defines the service tracking feature to allow these services to be reported or logged, whether they succeed or fail.

SEL-400 series relays support the service tracking feature for control commands, report control block edits, and group switch selection. You can report these services.

Tracking of these services is enabled by data objects in the service tracking logical node LTRK. *Table 17.11* lists the service tracking data objects. Their data attributes mirror those in the service request or in the control block that was the target of the service request.

Table 17.11 Service Tracking Data Objects

Data Object	CDC	Description
SpcTrk	CTS	Tracks control service requests targeted at a controllable single-point object
DpcTrk	CTS	Tracks control service requests targeted at a controllable double-point object
EncTrk	CTS	Tracks control service requests targeted at a controllable enumerated status object
UrcbTrk	UTS	Tracks unbuffered report control block edits
BrcbTrk	BTS	Tracks buffered report control block edits
SgcbTrk	STS	Tracks active settings group selection

Refer to *Table 17.28* for information regarding the available attributes in each tracking data object.

Each tracking data object includes the data attributes objRef, serviceType, and errorCode. The attribute objRef provides the reference to the control object or control block instance that was the target of the service request. The attribute serviceType provides an enumerated value for the specific service requested or executed. *Table 17.12* defines the service type enumerations.

Table 17.12 IEC 61850 Service Type Enumeration

Service Type	Service Name	Description
16	SelectActiveSG	Active settings group switch request
24	SetBRCBValues	Write request on one or more of the following buffered report control block attributes: RptID, RptEna, OptFlds, BufTm, TrgOps, IntgPd, PurgeBuf, EntryID, or GI
26	SetURCBValues	Write request on one or more of the following unbuffered report control block attributes: RptID, RptEna, OptFlds, BufTm, TrgOps, IntgPd, Resv, or GI
44	SelectWithValue	Select control request
45	Cancel	Cancel control request
46	Operate	Operate control request
47	CommandTermination	Control processing completed on a control object configured with enhanced security control model
54	InternalChange	Report control block has been automatically disabled, i.e., RptEna is set to False after a loss of association with the client

The attribute errorCode provides the error code that indicates whether the service was successful or unsuccessful. The codes are listed in *Table 17.13* together with the corresponding ACSI errors.

Table 17.13 IEC 61850 ACSI Service Error (Sheet 1 of 2)

Error Code	ACSI Error
0	no-error
1	instance-not-available
3	access-violation
5	parameter-value-inappropriate
6	parameter-value-inconsistent
7	class-not-supported
8	instance-locked-by-other-client
10	type-conflict

Table 17.13 IEC 61850 ACSI Service Error (Sheet 2 of 2)

Error Code	ACSI Error
11	failed-due-to-communications-constraint
12	failed-due-to-server-constraint

When creating data sets to track the services through information reporting, it is important to include the tracking data objects as a whole object (FCD—functionally constrained data), and not as individual data attributes (FCDA—functional constrained data attribute). Only the objRef attribute has a trigger option (dupd—data update) and can trigger a report. The dupd trigger option must also be enabled in the report control block that is reporting changes in the tracking data objects.

File Services

The Ethernet file system allows reading or writing data as files. The file system supports FTP and MMS file transfer. The file system provides:

- A means for the device to transfer data as files.
- A hierarchal file structure for the device data.

The relay supports MMS file transfer with or without authentication. Note that the MMS File Transfer service will still be supported even if the relay contains an invalid CID file. The service is intended to support:

- Settings file download and upload
- CID file download and upload
- Event report retrieval

MMS File Services are enabled or disabled via the PORT 5 settings, EMMSFS. Permissions for the Access Level 2 apply to MMS File Services requests. All files and directories that are available at the Access Level 2 via any supported file transfer mechanism (FTP, file read/write, etc.) are also available for transfer via MMS File Services.

SCL Files

Substation Configuration Language (SCL) is an XML-based configuration language used to support the exchange of database configuration data between different tools, which may come from different manufacturers. There are four types of SCL files:

- IED Capability Description (.ICD) file
- System Specification Description (.SSD) file
- Substation Configuration Description (.SCD) file
- Configured IED Description (.CID) file

The ICD file describes the capabilities of an IED, including information on LN and GOOSE support. The SSD file describes the single-line diagram of the substation and the required LNs. The SCD file contains information on all IEDs, communications configuration data, and a substation description. The CID file, of which there may be several, describes a single instantiated IED within the project and includes address information.

Reports

IEC 61850 provides two classes of reporting services, unbuffered and buffered, that a client can use to receive event data from a server. The unbuffered report service provides event data on a best-effort basis only while the client is connected. In contrast, the buffered report service keeps an internal buffer of events, which ensures that clients can receive a sequence of events even after reconnecting following a lost connection. The relay supports unbuffered and buffered report control blocks in the report model as defined in IEC 61850-8-1:2020.

IEC 61850 servers can deliver the same event data to multiple clients. IEC 61850 Ed1 proposed two different approaches that a server could use to accomplish this: association-based (non-indexed) reports and indexed reports. As of Ed2.1, SEL-400 series relays support both methods. The relay supports as many as 14 report control blocks (7 each of unbuffered and buffered reports). Reports can be either configured as association-based reports or indexed reports. Configuring a mix of association-based reports and indexed reports is not allowed, and such a configuration will be rejected by the IED. SEL devices with ClassFileVersion 009 or earlier support only association-based reports. Devices that are ClassFileVersion 010 or later support association-based reports as well as indexed reports.

ICD files with ClassFileVersion 009 or earlier only support dynamic report reservations. Writing to ResvTms of the buffered report control block (BRCB) or Resv of the unbuffered report control block (URCB) causes the client to dynamically obtain a reservation. ICD files with ClassFileVersion 010 support both preconfigured report reservations and dynamic reservations.

Reports are serviced at a 2 Hz rate. The client can set the IntgPd to any value with a resolution of 1 ms. However, the integrity report is only sent when the period has been detected as having expired. The report service rate of 2 Hz results in a report being sent within 500 ms of expiration of the IntgPd. The new IntgPd begins at the time that the current report is serviced.

When you are configuring unbuffered and buffered reports that contain only analog values, a data change report only is triggered when there is a change in the magnitude value in excess of the deadband setting. When you are configuring unbuffered and buffered reports that contain a combination of digital and analog values, any digital value change triggers a data change report, which contains the current value of the analogs contained in the report at the time of the trigger.

Unbuffered Reports

By using Architect, you can define if the URCB should be association-based or indexed. You can allocate data within each report data set to present different data attributes for each report. For unbuffered reports, connected clients may edit the report parameters shown in *Table 17.14*.

Table 17.14 Unbuffered Report Control Block Client Access (Sheet 1 of 2)

RCB Attribute	User Changeable (Report Disabled)[a]	User Changeable (Report Enabled)	Default Values
RptID	YES		URep01–URep07
RptEna	YES	YES	FALSE

Table 17.14 Unbuffered Report Control Block Client Access (Sheet 2 of 2)

RCB Attribute	User Changeable (Report Disabled)[a]	User Changeable (Report Enabled)	Default Values
Resv	YES		Association-based reports: Resv = FALSE for all URCB instances if none is preconfigured for any client Resv = TRUE for all URCB instances if one or more are preconfigured for a client Indexed reports: Resv = FALSE for the specific URCB instance if it is not preconfigured for any client Resv = TRUE for the specific URCB instance if it is preconfigured for a client
OptFlds	YES		seqNum
			timeStamp
			dataSet
			reasonCode
BufTm	YES		250
TrgOps	YES		dchg
			qchg
			period
IntgPd	YES		0
GI		YES[b]	FALSE
Owner			If the ReportControl has a single preconfigured client and its IP address can be found in the SCL, the IP address of the client is used as the default value for Owner; otherwise, the default value is NULL.

[a] The report must be actively reserved by setting Resv to 1 before the attribute values can be changed.
[b] Exhibits a pulse behavior. Write a one to issue the command. Once command is accepted will return to zero. Always read as zero.

Resv indicates the report reservation for unbuffered reports. Clients must actively reserve the URCB by setting Resv to 1 before the report can be enabled. This is applicable to preconfigured SCL clients as well. A successful write to Resv results in the Owner attribute being updated to the IP address of the client that performed the write operation. When the MMS client disables the URCB by setting RptEna to FALSE and actively unreserves it by setting Resv to 0, the report is immediately available for write operations.

Association-Based (Non-Indexed) URCBs

In association-based URCBs, the relay provides a unique URCB instance for each client association. Each client sees a different instance, although all instances have the same URCB name. This results in multiple client associations for that URCB. Once enabled, each client has independent access to an instance of that URCB. The server automatically ensures that a URCB instance is available to each client. SEL first offered association-based URCB support in the IEC 61850 Ed1 release of the relay.

The relay supports 7 association-based URCBs and 7 simultaneous clients, resulting in a total of 49 URCB instances, because each client views a different instance.

For example, if an association-based URCB is named UrcbA, seven clients can get independent access to UrcbA.

Indexed URCBs

In indexed URCBs, the server provides multiple URCB instances with all instances visible to all clients. Because all clients can see all instances, each instance must have a unique name. The report name is appended with a two-digit number *nn*, where *nn* ranges from 01 to the maximum number of instances supported for that control block. This allows a client to view all instances of a report control block, unlike association-based reports, where each client can only view the instance to which it is connected. Clients can reserve an instance by using the URCB Resv attribute. To prevent conflicts between clients, Ed2 introduced the concept of pre-configured reservations.

The relay added support for as many as 49 indexed URCB instances as a part of the IEC 61850 Ed2.1 release of the relay.

Each report control block has seven instances available to connect to when a URCB is configured as indexed. For example, if UrcbA is configured as indexed, a client can connect to any of the instances named UrcbA*xx*, where *xx* = 01–07.

Buffered Reports

By using Architect, you can define if the BRCB should be association-based or indexed. You can allocate data within each report data set to present different data attributes for each report. For buffered reports, connected clients can edit the report parameters shown in *Table 17.15*.

Table 17.15 Buffered Report Control Block Client Access (Sheet 1 of 2)

RCB Attribute	User Changeable (Report Disabled)[a]	User Changeable (Report Enabled)	Default Values
RptID	YES		BRep01–BRep07
RptEna	YES	YES	FALSE
OptFlds	YES		seqNum
			timeStamp
			dataSet
			reasonCode
			entryID
BufTm	YES		500
TrgOps	YES		dchg
			qchg
			period
IntgPd	YES		0
GI	YES[b, c]	YES[a]	0
PurgeBuf	YES[b]		FALSE
EntryId	YES		0

Table 17.15 Buffered Report Control Block Client Access (Sheet 2 of 2)

RCB Attribute	User Changeable (Report Disabled)[a]	User Changeable (Report Enabled)	Default Values
ResvTms	YES		–1 if the BRCB instance is preconfigured for a specific client in the SCL 0 if the BRCB instance is not reserved 60 if the report has been reserved with a write value of 0
Owner			NULL if the BRCB instance is not preconfigured or the IP address of the client in the SCL if it is preconfigured or dynamically assigned

[a] The report must be actively reserved by setting ResvTms > 0 before the attribute values can be changed.

[b] Exhibits a pulse behavior. Write a one to issue the command. Once command is accepted will return to zero. Always read as zero.

[c] When disabled, a GI will be processed and the report buffered if a buffer has been previously established. Buffered reports begin buffering at startup.

ResvTms indicates the report reservation time for buffered reports. Clients must actively reserve the BRCB by setting ResvTms to a value greater than 0 before the report can be enabled. This is applicable to preconfigured SCL clients as well. A successful write to ResvTms results in the Owner attribute being updated to the IP address of the client that performed the write operation. When the MMS client disables the BRCB by setting RptEna to FALSE and actively unreserves it by setting ResvTms to 0, the report is immediately available for write operations. After the ResvTms duration elapses, ResvTms reverts to 0 for dynamic associations, indicating the control block is available to other clients.

Association-Based (Non-Indexed) BRCBs

When a BRCB is configured as association-based or non-indexed, only one client can enable the BRCB at a time, which results in a client association for that BRCB. Once enabled, the associated client has exclusive access to the BRCB until the connection is closed or the BRCB is unreserved. Once enabled by a client, all unassociated clients have read-only access to the BRCB. SEL first offered association-based BRCB support in the IEC 61850 Ed1 release of the relay. For example, if an association-based BRCB is named BrcbA, a client can connect to the report with name BrcbA.

Indexed BRCBs

In indexed BRCBs, the server provides multiple BRCB instances with all instances visible to all clients. The report name is appended with a two-digit number *nn*, where *nn* ranges from 01 to the maximum number of instances supported for that control block. This allows a client to view all instances of a report control block. Clients can reserve an instance by using the BRCB ResvTms attribute.

The relay supports seven indexed BRCB instances as part of the IEC 61850 Ed2.1 release of the relay.

Only one instance of the report control block is available to connect to when a BRCB is configured as indexed. For example, if BrcbA is configured as indexed in Architect, a client connects to the report with name BrcbA01.

Data Sets

IEC 61850 data sets are lists of references to DataObject attributes for the purpose of efficient observation and transmission of data. Use Architect to configure data sets to be used to transfer data via GOOSE messages, SV messages, or MMS reports.

- ➤ GOOSE: You can create data sets for outgoing GOOSE transmission.
- ➤ SV: Predefined data sets are provided. Each data set includes three phase currents and the neutral current as well as three phase voltages and the neutral voltage.
- ➤ Reports: You can create data sets that are linked to buffered and unbuffered reports.

Deadband

Analog values of the MV, CMV, APC, and BAC CDCs defined in IEC 61850-7-3 have associated deadbands that determine when the analog values should be updated. The MV and CMV analog objects contain attributes that reflect the instantaneous value of the magnitude (instMag) and the value of the magnitude (mag), which is updated based on the deadband calculation.

Deadband calculations in Ed1 and Ed2 use a percent multiplier and the maximum range. The percent multiplier, a number between 0 and 100,000, is multiplied by 0.001 percent to determine the percentage of the maximum range to use as a deadband. Architect handles these calculations in the background, enabling users to configure the deadbands using nominal values. *Figure 17.12* displays the view from the Deadband tab in Architect for both Ed1 and Ed2 implementations.

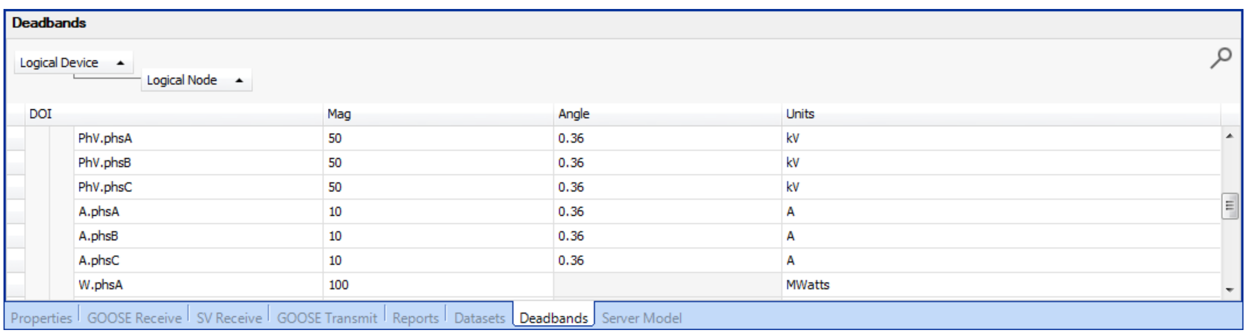

Figure 17.12 Deadband Configuration View for Ed1 and Ed2

Ed2.1 introduced deadband-related attributes, dbRef, dbAngRef, zeroDb, and zeroDbRef to explicitly expose the deadband behavior. The attribute dbRef may have a value of 0, which means the value db is used as the percentage of the last transmitted value in units of 0.001 percent. If the dbRef value is less than 0, it means db represents the percentage of dbRef in units of 0.001 percent and is appropriate for values with constant or small-changing values, for example frequency. The zeroDb attribute is the configuration parameter used to calculate the range around zero where the deadbanded value mag is forced to zero. The value of zeroDb represents the percentage of zeroDbRef in units of 0.001 percent.

For ICD files with ClassFileVersion 010 or higher, use Architect to view and configure the deadbands for analog values. The configuration values for the parameters shown in *Figure 17.13* are editable, and Architect displays the resulting deadband value.

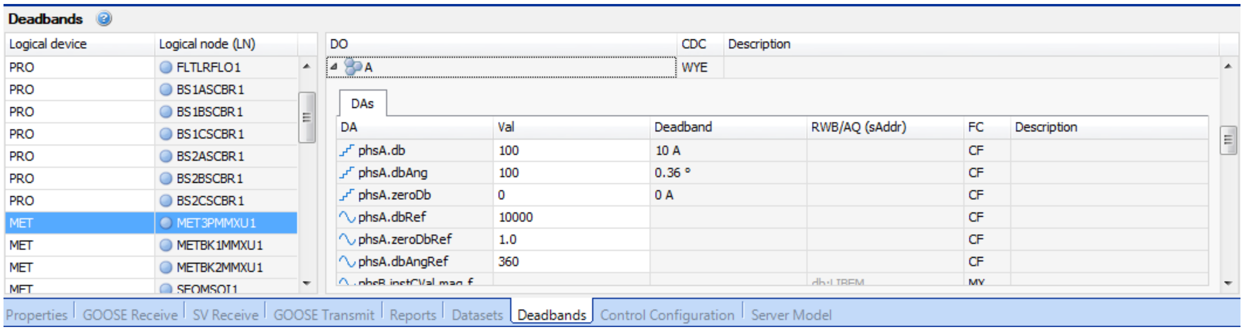

Figure 17.13 Deadband Configuration View for Ed2.1

Supplemental Software Support

Examine the data structure and values of the supported IEC 61850 LNs with an MMS browser such as MMS Object Explorer and AX-S4 61850 from Sisco, Inc.

The settings needed to browse the relay with an MMS browser are shown below.

OSI-PSEL (Presentation Selector)	00000001
OSI-SSEL (Session Selector)	0001
OSI-TSEL (Transport Selector)	0001

Time Stamps and Quality

In addition to the various data values, the two attributes quality and t (time stamp) are available at any time. The time stamp is determined when data or quality change is detected. A change in the quality attribute can also be used to issue an internal event.

The time stamp is applied to all data and quality attributes (Boolean, Bstrings, analogs, etc.) in the same fashion when a data or quality change is detected. However, there is a difference in how the change is detected between the different attribute types. For points in a data set that are also listed in the SER, the change is detected by the SER process. For all other Booleans or Bstrings, the change is detected via the scanner, which compares the last state against the previous state to detect the change. For analogs, the scanner looks at the amount of change relative to the deadband configured for the point to indicate a change and apply the time stamp. In all cases, these time stamps are used for the reporting model.

LN data attributes listed in the SER will have SER time stamps of 1 ms accuracy for data change events. All other LN data attributes are scanned on a 1/2-second interval for data change and have 1/2-second time-stamp accuracy.

The relay uses GOOSE quality attributes to indicate the quality of the data in its transmitted GOOSE messages. Under normal conditions, all attributes are zero, indicating good quality data. *Figure 17.14* shows the GOOSE quality attributes available to devices that subscribe to GOOSE messages from relay data sets that contain them. Internal status indicators provide the information necessary for the device to set these attributes. For example, if the device becomes disabled, as shown via status indications (e.g., an internal self-test failure), the relay will set the Validity attribute to INVALID and the Failure attribute to TRUE. Note that the relay does not set any of the other quality attributes. These attributes will always indicate FALSE (0). See the Architect online help for additional information on GOOSE quality attributes.

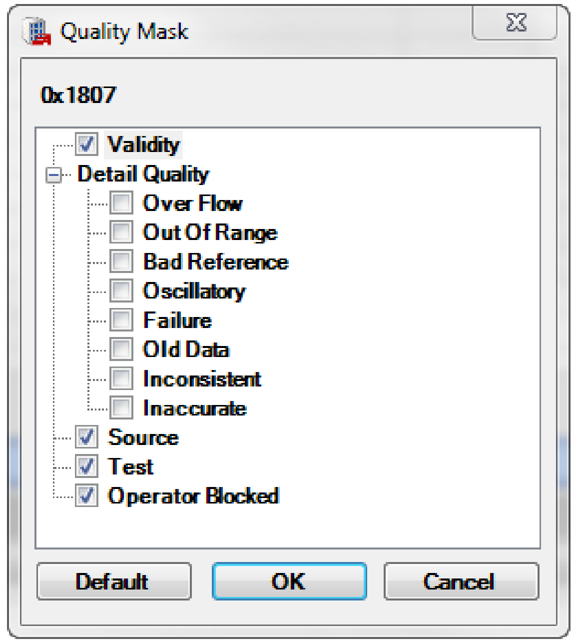

Figure 17.14 GOOSE Quality Attributes

GOOSE

The Generic Object Oriented Substation Event (GOOSE) object within IEC 61850 is for high-speed control messaging. IEC 61850 GOOSE automatically broadcasts messages containing status, controls, and measured values onto the network for use by other devices. IEC 61850 GOOSE sends the message several times, increasing the likelihood that other devices receive the messages.

IEC 61850 GOOSE objects can quickly and conveniently transfer status, controls, and measured values between peers on an IEC 61850 network. Configure SEL devices to respond to GOOSE messages from other network devices with Architect. Also, configure outgoing GOOSE messages for SEL devices in Architect. See the Architect online help for more information.

Each IEC 61850 GOOSE sender includes a text identification string (GOOSE Control Block Reference) in each outgoing message and an Ethernet multicast group address. Devices that receive GOOSE messages use the text identification and multicast group to identify and filter incoming GOOSE messages.

Virtual bits (VB001–VB256) are control inputs that you can map to values from incoming GOOSE messages by using the Architect software. See the VB*nnn* bits in *Table 17.28*, *Table 17.29*, and *Table 17.30* for details on which logical nodes and names are used for these bits. This information can be useful when searching through device data with MMS browsers. If you intend to use any relay virtual bits for controls, you must create SELOGIC control equations to define these operations. The relay is capable of receiving and sending analog values via peer-to-peer GOOSE messages. Remote analogs (RA001–RA256) are analog inputs that you can map to values from incoming GOOSE messages. Remote analog outputs (RAO01–RAO64) can be used to transmit analog values via GOOSE messages. You must create SELOGIC control equations to assign internal relay values to RAO points to transmit them via GOOSE.

GOOSE Processing

SEL devices support GOOSE processing as defined by IEC 61850-7-1:2011(E), IEC 61850-7-2:2010(E), and IEC 61850-8-1:2011(E) via the installed Ethernet port.

Outgoing GOOSE messages are processed in accordance with the following constraints.

- ➤ The user can define as many as eight data sets for outgoing GOOSE messages consisting of any data attribute (DA) from any logical node. A single DA can be mapped to one or more outgoing GOOSE data sets, or one or more times within the same outgoing GOOSE data set. A user can also map a single GOOSE data set to multiple GOOSE control blocks. The number of unique Boolean variables is limited to a combined total of 512 digital bits across all eight outgoing messages.
- ➤ High-speed GOOSE messaging (as defined under GOOSE Performance) is available for GOOSE messages that contain either all Boolean data or a combination of Boolean data and remote analog output (RAO01–RAO64) data.
- ➤ The relay will transmit all configured GOOSE immediately upon successful initialization. If a GOOSE message is not retriggered, then following the initial transmission, the relay shall retransmit that GOOSE message based on the Min. Time and Max. Time configured for that GOOSE message. The first transmission shall occur immediately upon triggering of an element within the GOOSE data set. The second transmission shall occur Min. Time later. The third shall occur Min. Time after the second. The fourth shall occur twice Min. Time after the third. All subsequent transmissions shall occur at the Max. Time interval. For example, a message with a Min. Time of 4 ms and Max. Time of 1000 ms, will be transmitted upon triggering, then retransmitted at intervals of 4 ms, 4 ms, 8 ms, and then at 1000 ms indefinitely or until another change triggers a new GOOSE message (see IEC 61850-8-1, Sec. 18.1).
- ➤ Each outgoing GOOSE message includes communications parameters (VLAN, priority, and multicast address) and is transmitted entirely in a single network frame.
- ➤ The relay maintains the configuration of outgoing GOOSE messages through a power cycle and device reset.

Incoming GOOSE messages are processed in accordance with the following constraints.

- ➤ The user can configure the relay to subscribe to as many as 128 incoming GOOSE messages.
- ➤ Control bits in the relay get data from incoming GOOSE messages which are mapped to virtual bits (VB*nnn*). Virtual bits are volatile and are reset to zero when a new CID file is loaded, the device is restarted, or they are overwritten by data from a subscribed GOOSE message.
- ➤ The relay recognizes incoming GOOSE messages as valid based on the following content:
  - ➢ Source Broadcast MAC Address
  - ➢ Data Set Reference*
  - ➢ Application ID*
  - ➢ GOOSE Control Reference*

NOTE: Options marked with * are configurable via tools such as Architect. The relay, by default, checks against this parameter.

Any GOOSE message that fails these checks shall be rejected. You can find the default quality check in the quality mask in Architect. See Figure 17.24 for an example.

    - ➢ Configuration Revision*
    - ➢ Needs Commissioning*
    - ➢ Quality Test*
- ➤ Every received and validated GOOSE message that indicates a data change, by an incremented status number, is evaluated as follows:
    - ➢ Data within the received GOOSE data set that are mapped to host data bits are identified.
    - ➢ Mapped bits are compared against a local version of the available host data bits.
    - ➢ If the state of the received bits is different than the local version:
        - ➢ Update the local version with the new state for that bit.
        - ➢ Pass the new state for the bit to the relay.
- ➤ Rejection of all DA contained in an incoming GOOSE message, based on the presence of the following error indications created by inspection of the received GOOSE message:
    - ➢ Configuration Mismatch: The configuration number of the incoming GOOSE message changes.
    - ➢ Needs Commissioning: This Boolean parameter of the incoming GOOSE message is true.
    - ➢ Decode Error: The format of the incoming GOOSE messageis not as configured.
- ➤ Reject DAs with quality indicating test if the subscriber is On or On-blocked mode.
- ➤ Upon a transition of Mod/Beh, the received GOOSE messages are evaluated to determine if the message will be processed according to IEC 61850-7-4 Appendix A.
- ➤ The relay discards incoming GOOSE under the following conditions:
    - ➢ After a permanent (latching) self-test failure
    - ➢ When EGSE is set to No

Link-layer priority tagging and virtual LAN is supported as described in Annex C of IEC 61850-8-1:2011.

GOOSE Performance

For outgoing high-speed data (as identified under GOOSE Processing), transmission of GOOSE begins within 2 ms of transition of digital data within the relay. Note that you can include RAO points in outgoing GOOSE for high-speed transmission. Only the transition of a digital point will trigger the transmission within 2 ms. For all other data contained in outgoing GOOSE, transmission of GOOSE begins within 500 ms of transition of data within the relay. For incoming GOOSE data with an included change of state, the corresponding mapped virtual bit states update within two processing intervals.

Sampled Values

NOTE: Not all SEL-400 series products support SV.

IEC 61850 9-2, also known as Sampled Values (SV), describes a service that brings digital samples of analog signals from the substation yard to the control house. Multiple components are essential to successful implementation of such a service. SV publishers, also known as merging units, locally sample and convert analog signals to digital time-stamped samples. They then publish these samples with minimum delays via an Ethernet connection. Ethernet connections are established between SV publishers and SV subscribers for transmitting SV samples and GOOSE messages. This network is also called the process bus network. The information exchange between the SV publisher and the SV-subscribing relays is based on a publisher/subscriber mechanism that is similar to GOOSE messaging. The SV subscribing relay receives the time-stamped SV messages and checks the timeliness of the samples. Messages are buffered and then used by the relays.

To promote interoperability and fast deployment of SV, UCA International Users Group released "Implementation Guideline for Digital Interface to Instrument Transformers Using IEC 61850-9-2" and described a subset of IEC 61850-9-2, also known as UCA 61850 9-2LE or simply 9-2LE. The SEL-400 series SV products are compliant with the 9-2LE guideline, also known as the 9-2LE profile in this manual.

You can configure the SEL-400 series SV products via Architect or by using **PORT 5** settings. See *IEC 61850 Configuration on page 17.47* for more information on SV product configuration.

SV Processing

SV Publication

An SV publisher is an interface to the non-conventional instrument transformers (NCIT) and traditional instrument transformers. When an SV publisher is connected to a traditional instrument transformer, it is also called a standalone merging unit. The SV publisher samples the analog data at 8 kHz and downsamples to 4.8 kHz/4.0 kHz when the nominal frequency is 60 Hz/50 Hz. A time stamp representation, known as smpCnt, is encoded with each published SV message. Given the sampling rate and the need to maintain the time coherence of samples from multiple merging units, merging units must be time-synchronized to high-accuracy time source. See *Section 11: Time and Date Management* for time-synchronization methods. The difference between the time encoded by the smpCnt in an SV message and the time that the message is published at the Ethernet interface is the merging unit processing delay. This delay and the transmitting delay over a process bus network is the total network delay. See *SV Network Delays on page 17.33* for more about network delay.

SV Data Set

NOTE: SV publications are not supported for measurements that use delta-connected CTs or PTs. Any SV stream that includes data from a delta-connected CT or PT is marked as questionable/inaccurate.

SEL SV publishers can transmit multiple SV data streams. Each SV message includes four currents and four voltages. For example, the SEL-401 Protection, Automation, and Control Merging Unit has inputs for 12 analog measurements (6 currents and 6 voltages). This means that the merging unit function requires at least two streams to send all available voltage/current inputs. Merging units support as many as seven output streams, allowing unmatched flexibility with measurement channel assignment and precise routing of duplicate streams.

Primary/Secondary Scale Factor

The analog measurements inside SV messages represent the primary side of the instrument transformer. When connecting a standalone merging unit to a conventional transformer, a scale factor should be applied such that the measured secondary quantity is scaled to primary values. SEL recommends matching the transformer ratios between SV publishers and subscribers to ensure consistent pickup settings when protection elements are enabled in both.

Time Synchronization

SmpCnt is a representation of the time stamp, which is encoded in each SV message. If SV messages from multiple merging units are used for an application, the smpCnt from these merging units must represent the same time instance to correctly align the data. High-accuracy time synchronization is critical. SEL-400 series relays can be synchronized with high-quality IRIG-B or high-quality Precision Time Protocol (PTP). The quality of smpCnt at the time the sample was taken is indicated by the SmpSynch value included in each SV message. When a merging unit is not time synchronized to any time source, its sample time error is unknown. Without time synchronization, the relay sets the smpSynch to 0. When the merging unit is synchronized to a high-quality local time source (TLOCAL = 1), the smpSynch is set to 1. When the merging unit is synchronized to a high-quality global time source (TGLOBAL = 1), the smpSynch is set to 2. TLOCAL and TGLOBAL are indicators of the time-synchronization source. See *Section 11: Time and Date Management* for information about TLOCAL and TGLOBAL. During the synchronization process to a time source, SEL merging units may set the quality attribute validity as questionable and detailQual attribute as inaccurate in the SV message.

SEL merging units use the information in *Table 17.16* and *Table 17.17* to determine the quality of sample timing and the smpSynch values. See *Table 17.16* and *Table 17.17* for smpSynch values.

When high-quality IRIG-B is the current time source (CUR_SRC = BNC_IRIG or CUR_SRC = SER_IRIG):

Table 17.16 Mechanism of Determining smpSynch Values With an IRIG-B Time Source

Time Synchronization Status	smpSynch Value
TGLOBAL = 1	2
TLOCAL = 1	1
TGLOBAL = 0 TLOCAL = 0	0

When high-quality PTP is the current time source (CUR_SRC = PTP):

Table 17.17 Mechanism of Determining smpSynch Values With a PTP Time Source

Profile	MU Sync State	smpSynch Value
IEEE C37.238, IEC 61850-9-3, or Default Profile	TGLOBAL = 1	2
IEEE C37.238	TLOCAL = 1	GMID[a]
IEC 61850-9-3 or Default Profile	TLOCAL = 1	1
IEEE C37.238, IEC 61850-9-3, or Default Profile	TGLOBAL = 0 TLOCAL = 0	0

[a] Grand Master ID

SV Subscription

An SEL SV relay can receive one or more SV streams from one or more merging units. SEL SV relays only support receiving 9-2LE-compliant SV messages. Once messages are received, samples are buffered to ensure that samples used to calculate protection elements are from the same time. The SV message attribute, smpCnt, is used to check and align samples. SV messages can be published at different frequencies based on the nominal frequency. The SEL SV relay nominal frequency setting must match the merging unit nominal frequency.

Primary/Secondary Scale Factor

SV messages provide current and voltage measurements in terms of the primary side of the instrument transformers. SEL SV relay protection calculations are based on traditional secondary quantities. Thus, the received digital samples must be scaled to the secondary properly. For example, if the SV stream comes from a merging unit that is connected to a 1200/5 CT, the SEL SV relay CT ratio settings should be 240.

Current Summation

NOTE: Use caution when externally summing CT currents for differential protection. Because the resulting restraint current can be lower than expected, this can have implications for protection security.

To provide a similar function to sum currents by connecting copper wires together, SEL-400 series relays provide current summation via SV subscriptions. You can map as many as three SV current channels (UCA 9-2LE-compliant) to the same SV subscriber analog channel. You can enable this function by clearing **Hide current summation rows** in Architect in the **SV Receive** tab.

Example 17.1 Current Summation Via SV Subscription

In this example, a transmission line connects to a line reactor. The line current is the sum of the two breaker currents minus the reactor current. Merging unit Bay1MU #1 current transformer logical nodes TCTR1 and TCTR2 are both mapped to Terminal W on the SEL-421-7 Protection, Automation, and Control System With Sampled Values. SEL-421-7 Current Channel IAW has current measurements summed from Bay1MU #1...TCTR1.Amp.instMag.i and Bay1MU #1...TCTR2.Amp.instMag.i. The reactor current published from Bay1MU #2 is mapped to Terminal X on the SEL-421-7. The Terminal W and Terminal X currents are then combined by setting LINEI := COMB in Global settings.

Example 17.1 Current Summation Via SV Subscription (Continued)

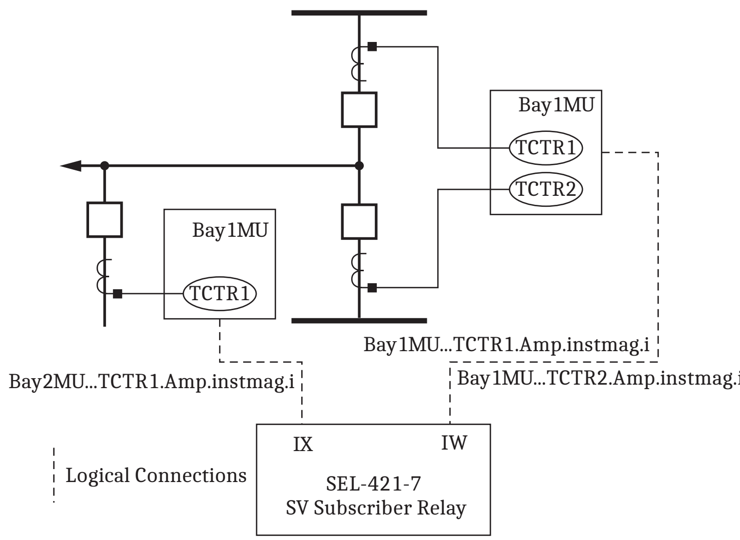

Figure 17.15 Example Current Summation

The corresponding configuration is shown in *Figure 17.16*.

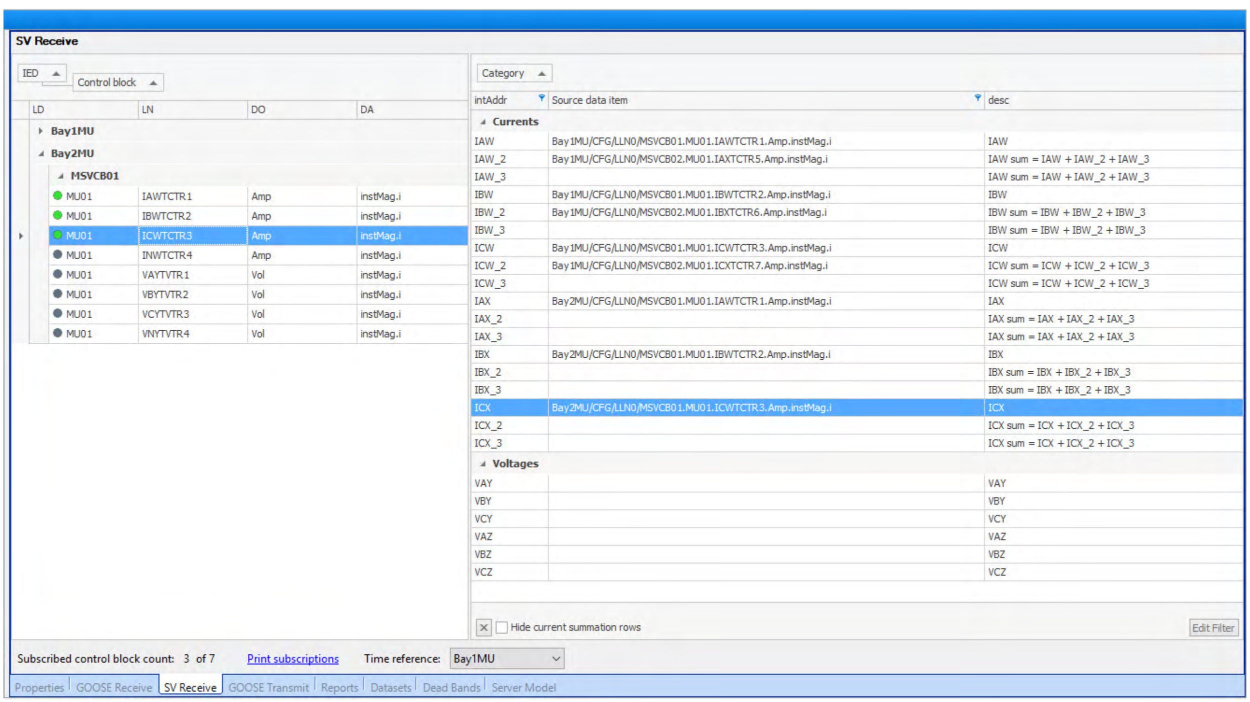

Figure 17.16 Example Current-Summation Configuration

SV Network Delays

The SV merging unit and process bus network act as the data acquisition system for an SV relay. There are time delays introduced by DSS. The delays of an SV stream include the merging unit processing delay and the process bus network delay. The sum of these is called the network delay. SEL SV relays measure and report this network delay. The measured network delay for each SV subscription is stored as an analog quantity and reported via the **COM SV** ASCII command. See *Section 9: ASCII Command Reference* in the product-specific instruction manual for more detailed information.

SEL SV relays account for a network delay by buffering SV samples. The buffer length is controlled by the CH_DLY setting. Set the CH_DLY setting to the following value:

$$\text{CH\_DLY} = \text{MAX}(\text{SVND}mm) + (\text{N} + 1) \cdot (\text{Sample Period})$$

Equation 17.1

where:

MAX(SVND*mm*) is the maximum network delay out of all received streams

N is the number of lost packets you want the relay to ride through by interpolating data

N = 3 is a good choice for typical applications because it allows the relay to ride through a loss of three packets. The allowable range for N is 1–3. The CH_DLY setting is specified in milliseconds (ms), and the SVND*mm* value is reported in milliseconds (ms), both in the **COM SV** command response and as a user-accessible analog quantity. Convert the last part of the channel delay equation to milliseconds by treating a sample period as 0.2083 ms for a 60 Hz system, or 0.25 ms for a 50 Hz system.

SEL SV relays wait to start resampling until samples arrive for the configured CH_DLY. This design also provides a consistent delay (CH_DLY) to protection and control operations, which overcomes the non-deterministic delays caused by the Ethernet process bus network.

If SV messages of the first SV subscription, which is listed first in the **COM SV** command response, are delayed by more than CH_DLY, they are considered lost. If less than three consecutive messages are delayed or missing, the SEL SV relay interpolates for these delayed or lost messages. If more than three samples are delayed or missing, the SEL relay ASCII command **COM SV** reports `SV STREAM LOST` for this scenario.

The protection and control operation times are delayed by the configured CH_DLY. Use caution when setting the relay coordination times to account for this added delay.

Coupled Clocks Mode

The SV relay operates in coupled clocks mode when both it and the merging unit configured as the time reference are synchronized to either a high-quality global time source or the same high-quality local time source. The relay evaluates its operation in this mode by using the local smpSynch and the smpSynch value from the first subscribed SV stream. The SVCC Relay Word bit asserts when the relay is operating in coupled clocks mode and can calculate the network delay for incoming SV streams. These delays are stored in analog quantities SVND*mm*, where *mm* is the subscription number, and are also reported in the **COM SV** command response.

Freewheeling Mode

When the relay is not operating in coupled clocks mode, it operates in freewheeling mode. In this mode, only the data from the reference stream are used; all other SV streams are discarded. The SVCC Relay Word bit remains deasserted in this mode and the network delay statistics are not reported.

Subscription Reference Stream

SEL SV relays store the smpSynch of each subscribed SV stream in analog quantities SV*mm*SNC, where *mm* is the subscription number. If a CID file is used, the first subscription stream in the CID file is used as the smpSynch reference. If the **PORT 5** SV setting is used, the subscription with the subscribed MAC address set by SVRADR1 is the first subscription and is used as the smpSynch reference. In coupled clocks mode, any subsequent streams that do not have the same smpSynch as the time reference are discarded. If the relay stops receiving data for the first subscription stream, the last smpSynch value received from the first subscription stream continues to remain as the time reference. If the smpSynch value of the first subscription stream is zero, only the first subscription stream is accepted.

Station Bus and Process Bus (Four-Port Ethernet Card)

NOTE: The MERGED BUSMODE is not recommended for long-term operations, as the large amount of process bus traffic can adversely affect station bus functions when the buses are combined.

The SEL SV publishers and subscribers allow flexible station bus and process bus configurations when using the four-port Ethernet card. If BUSMODE := INDEPEND, station bus traffic (typically MMS and GOOSE) will only be transmitted out on the station bus ports, and process bus traffic (typically SV and GOOSE) will only be transmitted on process bus ports. If BUSMODE := MERGED, all communications use **PORT 5A** and **PORT 5B**, with process bus and station bus traffic merged on the same physical network, and the process bus ports are disabled. The designation of station bus and process bus is controlled by NETPORT settings. The station bus port is the same as the primary port, as specified by NETPORT settings. If NETPORT := A or NETPORT := B, then **PORT 5A** and **PORT 5B** are used for station bus communication and **PORT 5C** and **PORT 5D** are used for process bus communication. If NETPORT := C or NETPORT := D, then **PORT 5C** and **PORT 5D** are used for station bus communication and **PORT 5A** and **PORT 5B** are used for process bus communication. IEEE 1588-based time synchronization is only available on **PORT 5A** and **PORT 5B** when using the four-port Ethernet card. If you want PTP time synchronization on the process bus, use **PORT 5A** and **PORT 5B** for process-bus communications. *Figure 17.17* shows some common network configurations, including the NETPORT and BUSMODE settings used.

Figure 17.17 shows an independent bus mode network schematic with PTP time synchronization on the process bus. In this schematic, the merging unit has settings BUSMODE := INDEPEND and NETPORT := C.

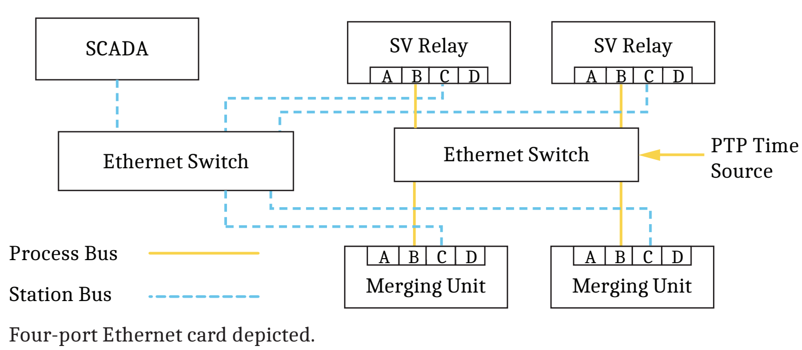

Figure 17.17 Independent Bus Mode With PTP Time Synchronization on the Process Bus

Figure 17.18 shows an independent bus mode network schematic with PTP time synchronization on the station bus. In this schematic, the merging unit has settings BUSMODE := INDEPEND and NETPORT := A.

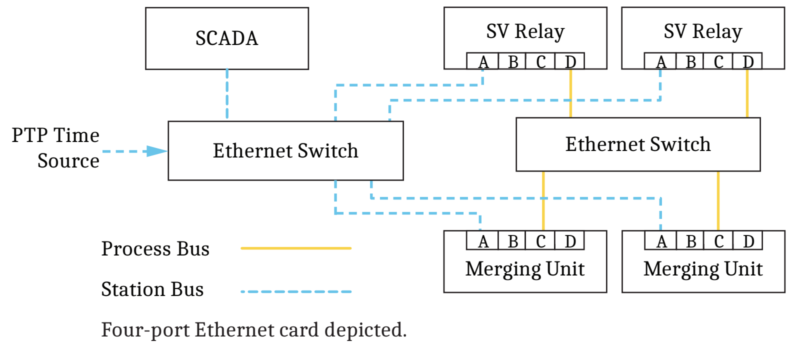

Figure 17.18 Independent Bus Mode With PTP Time Synchronization on the Station Bus

Figure 17.19 shows an independent bus mode network schematic with local IRIG time source. In this schematic, the merging unit has settings BUSMODE := INDEPEND and NETPORT := A.

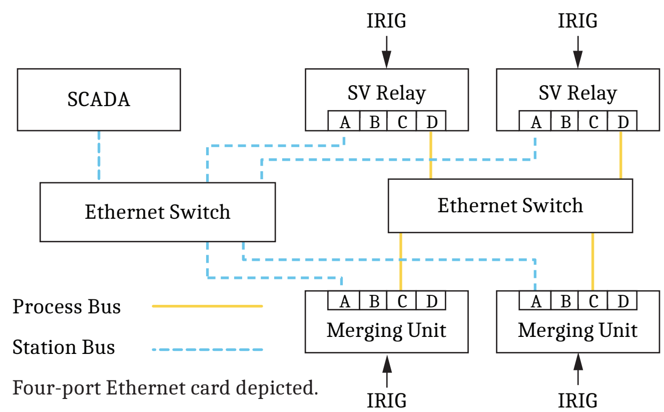

Figure 17.19 Independent Bus Mode With IRIG Time Synchronization

Figure 17.20 shows a merged bus mode network schematic with PTP time synchronization. Process bus and station bus traffic are all processed in PORT A. In this schematic, the merging unit has settings BUSMODE := MERGED and NETPORT := A.

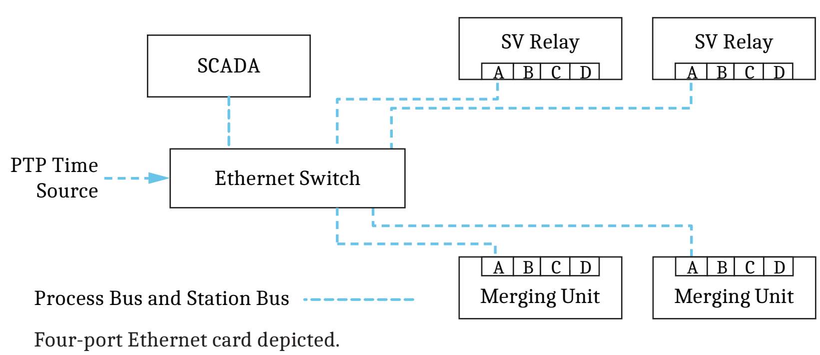

Figure 17.20 Merged Bus Mode With PTP Time Synchronization

Station Bus and Process Bus (Five-Port Ethernet Card)

When using the five-port Ethernet card, the station bus and process bus designations are fixed. If BUSMODE := INDEPEND, the process bus is assigned to PORT 5A and PORT 5B, and the station bus is assigned to PORT 5C and PORT 5D. If

BUSMODE := MERGED, traffic is processed on PORT 5A and PORT 5B, and PORT 5C and PORT 5D are disabled. The engineering access port (PORT 5E) is not associated with the BUSMODE setting; therefore, its designation and functionality remain the same. The card uses three source MAC addresses. The first MAC address is applied to the process bus. The second MAC address is applied to the station bus. The third MAC address is applied to the engineering access port. IEEE 1588-based time synchronization is available on either the process bus or station bus when using the five-port Ethernet card.

IEC 61850 Messaging (Four-Port Ethernet Card)

The SEL-400 series relays publish and subscribe GOOSE messages on both the station bus and the process bus ports when using the four-port Ethernet card. GOOSE subscription error out of sequence may be reported if GOOSE messages from station bus and process bus are not isolated properly via network management. For example, *Figure 17.21* shows an SEL merging unit publishing two GOOSE messages from the station bus and process bus. Without proper GOOSE messages routing on the Ethernet switch, the SV relay receives GOOSE messages #1 and #2 from the process bus and the station bus, and out-of-sequence error is reported for GOOSE messages #1 and #2 subscriptions. Proper management and segregation of GOOSE messages from the station bus and the process resolves this. For example, if GOOSE message #1 is designed for the process bus only, engineers can configure the station bus Ethernet switch to only forward GOOSE message #2 and the process bus Ethernet switch to only forward GOOSE message #1 via VLAN management.

SEL recommends using an SEL software-defined network (SDN) Ethernet switch to engineer each Ethernet traffic flow. Engineers can plan the network path for process bus GOOSE messages to flow through the process bus SDN switch only and discard the station bus GOOSE messages.

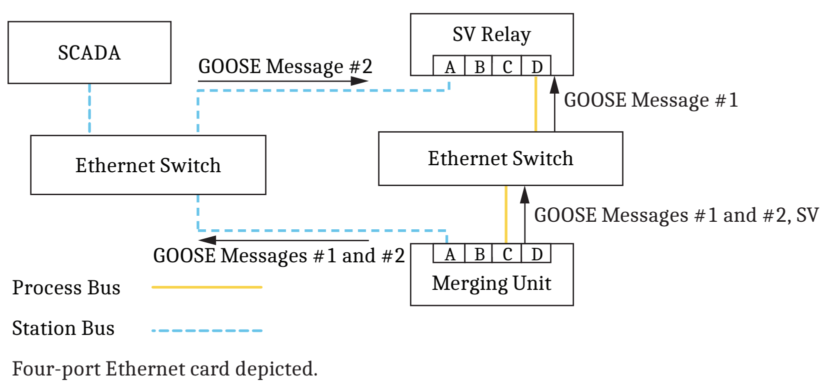

Figure 17.21 Use Ethernet Switch to Engineer Network Path for GOOSE Messages

IEC 61850 Messaging (Five-Port Ethernet Card)

To configure IEC 61850 messaging in the five-port Ethernet card, download a ClassFileVersion 007 CID file to the relay. This file provides multiple access points to differentiate between the process bus, station bus, and engineering access networks, as well as to define which services are available on those networks. Use Architect to configure communications for each network. For example, to publish a GOOSE message on process bus PORT 5A and PORT 5B, select interface **P1** in the address dropdown menu in the GOOSE transmit editor, as shown in *Figure 17.22*.

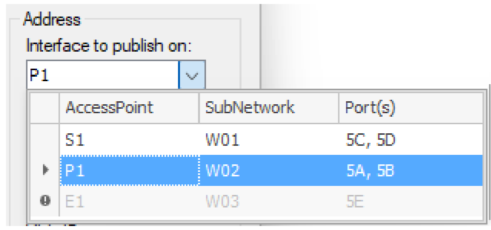

Figure 17.22 GOOSE Transmit Interface Selection (Five-Port Ethernet Card)

The five-port Ethernet card supports two levels of GOOSE message VLAN prioritization: high and low. GOOSE messages with VLAN tags priorities from 0–3 are processed as low priority. GOOSE messages with VLAN priorities tags from 4–7 are processed as high priority. GOOSE messages without VLAN tags are processed as low priority.

IEC 61850 Simulation Mode

NOTE: SV simulation is only applicable in IEDs with SV subscription capability.

The SEL-400 series relays (including the SEL-401) can be configured to operate in simulation mode. In this mode, the SEL-400 series relays continue to process normal SV or GOOSE messages until a simulated SV or GOOSE message is received for a subscription. Once a simulated SV or GOOSE message is received, only simulated SV or GOOSE messages are processed for that subscription. Simulated mode only terminates when LPHDSIM is returned to FALSE. When the relay is not in simulation mode, only normal SV or GOOSE messages are processed for all subscriptions.

A user can place the SEL-400 series relays in IEC 61850 simulation mode by setting LPHDSIM (CFG.DevIDLPHD1.Sim.stVal) to true via MMS messaging.

Alternatively, you can use SELOGIC variable SC850SM to set LPHDSIM. The rising edge of SC850SM sets LPHDSIM, and the falling edge of SC850SM clears LPHDSIM. When you use SC850SM to enter simulation mode, the relay rejects MMS attempts to enter or exit simulation mode until SC850SM deasserts.

IEC 61850 Mode/Behavior

NOTE: IEC 61850 Mode/Behavior is only available in IEDs with IEC 61850 Ed2 support.

The IEC 61850-7-4:2010 standard defines behaviors of different modes to facilitate testing. SEL-400 series relays support the following modes:

- On
- Blocked
- Test
- Test/Blocked
- Off

IEC 61850 Behavior is jointly determined by the logical device mode and its logical node mode according to the IEC 61850 standard. For SEL-400 series relays, the selected IEC 61850 Mode/Behavior applies to the entire IED, including all its logical devices and all logical nodes. The behavior of the IED is always the same as the selected mode.

Table 17.18 describes the available services based on the mode/behavior of the IED.

Table 17.18 IEC 61850 Services Available Based on Mode/Behavior

Mode	MMS	GOOSE Publication and Subscription	SV Publication and Subscription
On	Available	Available	Available
Blocked	Available	Available	Available
Test	Available	Available	Available
Test/Blocked	Available	Available	Available
Off	No services[a]	Publication[b]	Publication[b]

[a] All MMS control requests to change the mode with Test = false will be processed.
[b] GOOSE and SV publication in mode Off are disabled if EOFFMTX = N.

The analog quantity I850MOD is an enumerated number that corresponds to mode and behavior, as shown in *Table 17.19*.

Table 17.19 Analog Quantity I850MOD Status Based on the Selected IEC 61850 Mode/Behavior

I850MOD	IEC 61850 Mode/Behavior
1	On
2	Blocked
3	Test
4	Test/Blocked
5	Off
0	Not Supported

Mode/Behavior Control

Enable Mode/Behavior Control

IEC 61850 Mode/Behavior, by default, is disabled on SEL-400 series relays. To enable IEC 61850 Mode/Behavior, you must set PORT 5 setting E61850 to **Y**. To enable IEC 61850 Mode/Behavior control, you must set port setting E850MBC to **Y** and the CID file setting controllableModeSupported to **True**. You can set the controllableModeSupported setting by selecting **Enable control of IEC 61850 Mode/Behavior** when adding an IED into an Architect project, as shown in *Figure 17.23*.

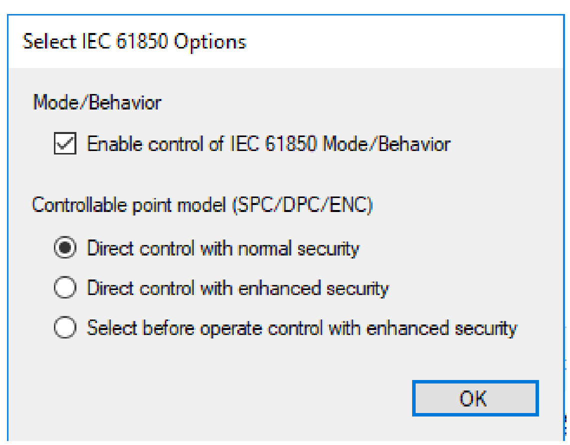

Figure 17.23 Set controllableModeSupported = True

Enhanced Secure Mode Control

Relay setting E850MBC and CID file setting controllableModeSupported provide security to prevent accidental switching into an unplanned IEC 61850 Mode/Behavior during normal operations. For example, following IED testing, a technician can disable unplanned switching of IEC 61850 Mode/Behavior by setting E850MBC to N after switching the relay back to On mode.

Change Mode Via MMS or SELOGIC

If IEC 61850 Mode/Behavior is set as controllable, you can control the IEC 61850 Mode/Behavior via MMS writes to the LLN0 logical node mode data object (Mod.Oper.ctlVal) in logical device CFG. Note that Mod.Oper.ctlVal in other logical devices does not accept MMS writes.

Write Values to Mod.Oper.ctlVal in Logical Device CFG	Selected IEC 61850 Mode/Behavior
1	On
2	Blocked
3	Test
4	Test/Blocked
5	Off

You can also control IEC 61850 Mode/Behavior through use of the **SET L** command with protection SELOGIC variables SC850TM and SC850BM on the left side of protection logic equations. These variables are the SELOGIC controls for the Test mode and the Blocked mode, respectively.

NOTE: The variables SC850TM and SC850BM are not protection settings.

SC850TM	SC850BM	Selected IEC 61850 Mode/Behavior
0	0	See Note[a]
1	0	Test
0	1	Blocked
1	1	Test/Blocked
See Note[b]	See Note[b]	Off

[a] **Note:** The SELOGIC controls have higher priority than MMS clients in controlling the Test mode and Blocked mode. When SC850TM and SC850BM both evaluate to 0 (false), IEC 61850 Mode/Behavior control is available to MMS clients. If either SC850TM or SC850BM evaluates to 1 (true), SELOGIC determines the IEC 61850 Mode/Behavior of the IED regardless of MMS control values.

[b] **Note:** You cannot control Off mode by using SC850TM and SC850BM. When an MMS client causes the IED to be in Off mode, the SELOGIC controls are disabled and SC850TM and SC850BM are not evaluated.

Example 17.2 Change Mode Via SELOGIC

In this example, pushbuttons PB1 and PB2 control SC850TM. Pushbuttons PB3 and PB4 control SC850BM. If you press PB1, the relay enters Test mode. If you press PB3, the relay transitions from Test mode into Test/Blocked mode. Press PB2 and PB4 to reset Test mode and Blocked mode, respectively.

Example 17.2 Change Mode Via SELogic (Continued)

```
=>>SHO L
Protection 1

1: PLT01S := PB1
2: PLT01R := PB2
3: SC850TM := PLT01
4: PLT02S := PB3
5: PLT02R := PB4
6: SC850BM := PLT02
```

You can read the current IEC 61850 Mode/Behavior through an MMS client or by using the **STA A** commands.

Mode Indications on HMI

If the Mode/Behavior is Test, Blocked, or Test/Blocked, the relay toggles the **ENABLED** LED on the front panel approximately every half a second to alarm users that the relay is not in On mode. When the relay is placed in Off mode, the relay is disabled and the relay **ENABLED** LED is solid red.

Incoming Messages Processing

IEC 61850 incoming data processing is jointly determined by quality validity, test, and operatorBlocked. SEL-400 series relays, by default, check if the quality operatorBlocked = False; if not, the relays treat the messages as invalid. You can disable the default check by changing the quality mask of GOOSE subscriptions. *Figure 17.24* illustrates the default quality check for GOOSE subscription on SEL-400 series relays.

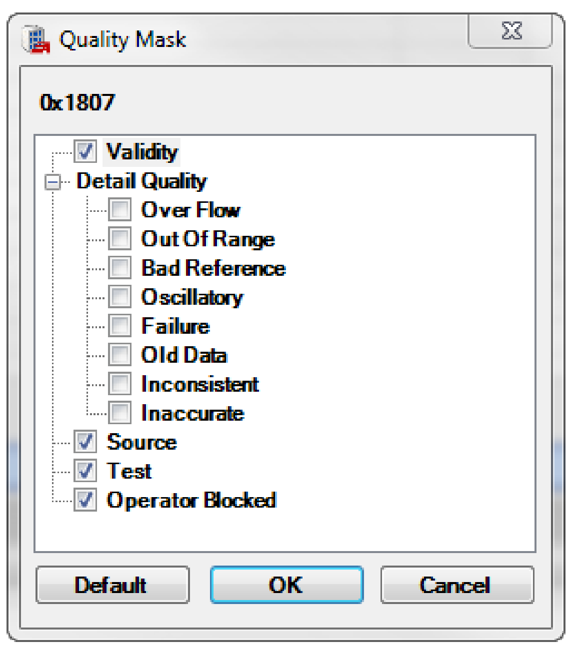

Figure 17.24 Default Quality Check on GOOSE Subscription if Quality Is Present

Relay Operation for Different IEC 61850 Modes/Behaviors

Refer to *Section 10: Testing, Troubleshooting, and Maintenance* for information on how to use the various modes in testing.

Mode: On

In On mode, the relay operates as normal; it reports IEC 61850 Mode/Behavior status as On and processes all inputs and outputs as normal. If the quality of the subscribed SV messages satisfies *Table 14.46*, the relay processes the received SV messages as valid. If the quality of the subscribed GOOSE messages satisfies the GOOSE processing (see *GOOSE Processing on page 17.28*), the relay processes the received GOOSE messages as valid.

NOTE: An IEC 61850 IED determines the processing of GOOSE messages based on the received quality of the GOOSE data and its current mode. If a GOOSE message does not contain quality information, the relay always processes it as valid. To use the IEC 61850 Mode/Behavior, SEL recommends including quality attributes in GOOSE messages.

Table 17.20 IEC 61850 Incoming Message Handling in On Mode

IEC 61850 Messages	Incoming Message With Quality Test Bit Set to False (0)	Incoming Message With Quality Test Bit Set to True (1)
MMS	Processed	Processed as invalid
GOOSE	Processed	Processed as invalid
SV[a]	Processed	Processed as invalid

[a] IEC SV subscribers only.

Table 17.21 IEC 61850 Outgoing Message Handling in On Mode

IEC 61850 Messages	Outgoing Message Quality Test Bit Status
MMS	False
GOOSE	False
SV[a]	False

[a] IEC SV publishers only.

Figure 17.25 illustrates the mode/behavior.

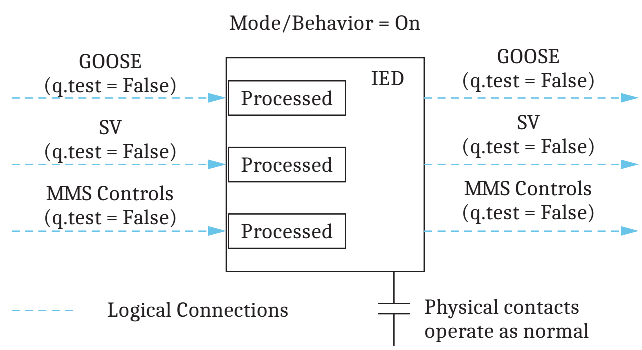

Figure 17.25 Relay Operations in On Mode

Mode: Blocked

The relay operates in Blocked mode similarly to how it operates in On mode, except that it does not operate any physical contact outputs in this mode. It does continue to operate control bits such as remote bits and output contact bits.

NOTE: In Blocked mode, the physical output contacts are frozen in the state they were in prior to entering Blocked mode.

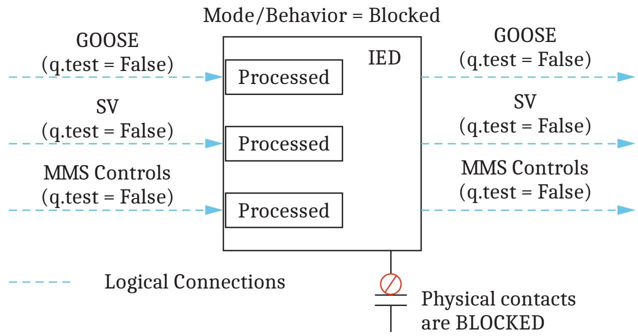

Figure 17.26 Relay Operations in Blocked Mode

Mode: Test

In Test mode, the relay processes valid incoming test signals or normal messages and operates physical contact outputs if triggered. In this mode/behavior, outgoing MMS, GOOSE, and SV messages have the quality test bit set to True if the quality test bit is present. If the quality of the subscribed SV messages satisfies *Table 14.46* (regardless of whether the quality test bit is set to True or False), the relay processes the received SV messages as valid. If the quality of the subscribed GOOSE messages satisfies the user-defined quality type definition (regardless of whether the quality test bit is set to True or False—see *GOOSE Processing on page 17.28*), the relay processes the received GOOSE messages as valid.

NOTE: An IEC 61850 IED determines the processing of GOOSE messages based on the received quality of the GOOSE data and its current mode. If a GOOSE message does not contain quality information, the relay always processes it as valid. To use the IEC 61850 Mode/Behavior, SEL recommends including quality attributes in GOOSE messages.

Table 17.22 IEC 61850 Incoming Message Handling in Test Mode

IEC 61850 Messages	Incoming Message With Quality Test Bit Set to False (0)	Incoming Message With Quality Test Bit Set to True (1)
MMS	Not Processed	Processed
GOOSE	Processed	Processed
SV[a]	Processed	Processed

[a] IEC SV subscribers only.

Table 17.23 IEC 61850 Outgoing Message Handling in Test Mode

IEC 61850 Messages	Outgoing Message Quality Test Bit Status
MMS	True
GOOSE	True
SV[a]	True

[a] IEC SV publishers only.

Figure 17.27 illustrates the mode/behavior.

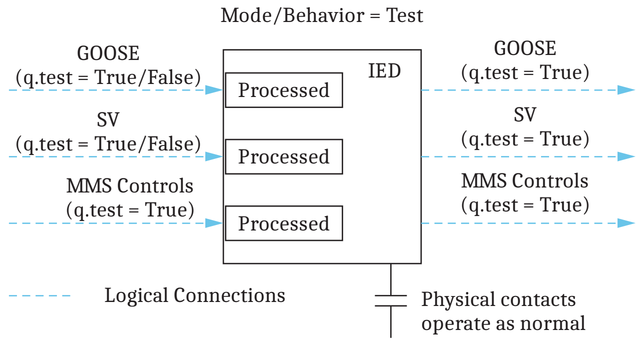

Figure 17.27 Relay Operations in Test Mode

Mode: Test/Blocked

In Test/Blocked mode (see *Section 10: Testing, Troubleshooting, and Maintenance* for more information), the relay processes valid incoming test signals or normal messages but blocks any physical contact outputs from operating. In this mode/behavior, outgoing MMS, GOOSE, and SV messages have the quality test bit set to True if the quality test bit is present. If the quality of the subscribed SV messages satisfies *Table 14.46* (regardless of whether the quality test bit is set to True or False), the relay processes the received SV messages as valid. If the quality of the subscribed GOOSE messages satisfies the user-defined quality type definition (regardless of whether the quality test bit is set to True or False—see *GOOSE Processing on page 17.28*), the relay processes the received GOOSE messages as valid.

NOTE: An IEC 61850 IED determines the processing of GOOSE messages based on the received quality of the GOOSE data and its current mode. If a GOOSE message does not contain quality information, the relay always processes it as valid. To use the IEC 61850 Mode/Behavior, SEL recommends including quality attributes in GOOSE messages.

Figure 17.28 illustrates the mode/behavior.

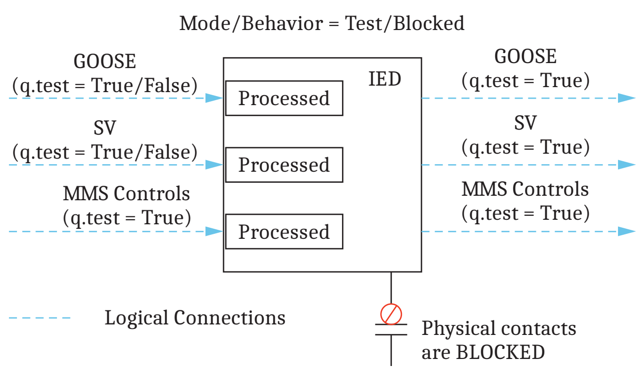

Figure 17.28 Relay Operations in Test/Blocked Mode

Mode: Off

In Off mode, the relay no longer processes incoming GOOSE and SV messages. The relay processes MMS control requests to change the IEC 61850 Mode/Behavior if the quality Test bit is set to False. The relay is in a disabled state, and it no longer trips any physical contact outputs.

In this mode, the relay is in a disabled state. Relay Word bit EN is set to False. The device processes MMS control requests to change the active mode of IEC 61850 Mode/Behavior if the quality Test bit of the control is set to False.

If EOFFMTX is set to True, the relay continues to transmit SV messages and GOOSE messages with the quality test bit set to False (0), the validity set to Invalid (01), and the quality failure bit set to True if the quality is present in the messages. If EOFFMTX is set to False, the relay does not transmit GOOSE or SV messages in this mode. The relay also does not process any incoming GOOSE and SV messages.

Table 17.24 IEC 61850 Incoming Message Handling in Off Mode

IEC 61850 Messages	Incoming Message With Quality Test Bit Set to False (0)	Incoming Message With Quality Test Bit Set to True (1)
MMS	Relay Only Processes Messages to Control the Mode	Not Processed
GOOSE	Not Processed	Not Processed
SV	Not Processed	Not Processed

Table 17.25 IEC 61850 Outgoing Message Handling in Off Mode

IEC 61850 Messages	Outgoing Message Quality Validity Bit
MMS	Invalid
GOOSE	Invalid
SV	Invalid

Figure 17.29 illustrates the IEC 61850 Mode/Behavior.

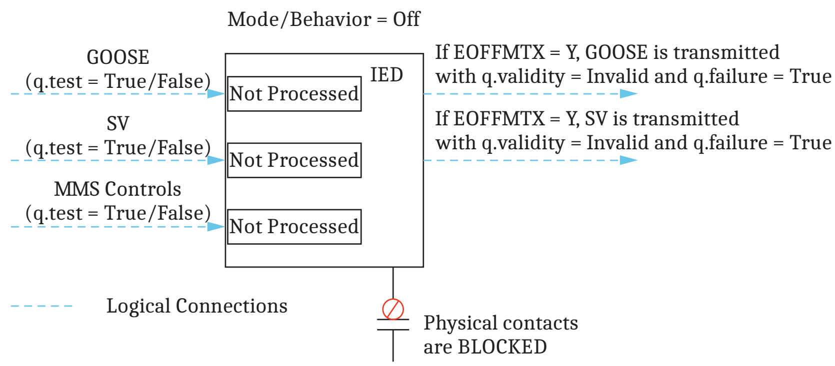

Figure 17.29 Relay Operations in Off Mode

Relay Output Contact Behavior Following a Power Cycle

The behavior of the relay output contacts vary based on the IEC 61850 mode in which the relay existed prior to the power cycle. The behavior for all contact outputs at relay loss of power is to de-energize the contact outputs (open for normally open and close for normally closed). Upon restoring power, the relay re-establishes the IEC 61850 mode prior to loss of power, and if the IEC 61850 mode was Blocked or Test/Blocked, the relay will not operate the output contacts based on the SELOGIC control equations, even if the outputs were energized prior to the power cycle. *Table 17.26* describes all scenarios.

Table 17.26 Output Contact Behavior for IEC 61850 Modes Following a Power Cycle

IEC 61850 Mode Prior to Power Cycle	Output Contact State Prior to Power Cycle	Output Contact State During Power Off	Output Contact State Following the Power Cycle
ON	0	0	0
BLOCKED	0	0	0
TEST	0	0	0
TEST/BLOCKED	0	0	0
OFF	0	0	0
ON	1	0	1
BLOCKED	1	0	0
TEST	1	0	1
TEST/BLOCKED	1	0	0
OFF	1	0	0

SEL TEST SV Mode

The SEL SV subscriber and the SEL SV publisher both support TEST SV mode. This mode is designed to validate SV communications during testing.

SEL SV Subscriber

When the **TEST SV** command is executed on an SEL SV subscriber, it sets the Relay Word bit SVSTST to TRUE. In this mode, the relay accepts either TEST SV data (test bit of the quality attribute is TRUE) or normal SV data (test bit of the quality attribute is FALSE). If the relay receives TEST SV data, the warning code `QUALITY(TEST)` is used to indicate the subscription status. While in TEST SV mode, the relay processes the SV stream and exercises all associated protection logic.

If the SEL SV subscriber is not in TEST SV mode, SVSTST is set to FALSE and the relay only accepts SV data with a valid quality. If TEST SV data are received, messages are discarded and error code `INVALID QUAL` is used to indicate the subscription status.

SEL SV Publisher

When the **TEST SV** command is executed on the SEL-401, SEL-421-7, or SEL-451-6 SV publishers, it sets the Relay Word bit SVPTST to TRUE. In this mode, the relay generates test signals on all configured SV streams. The test bit in the quality attribute is TRUE for all published SV messages. The published signals are scaled from secondary values (Magnitude in *Table 17.27*) to primary values in accordance with the CT and PT ratio setting as follows:

- CTRW is used for both IW and IX scaling.
- PTRY is used for both VY and VZ scaling.

Table 17.27 Secondary Quantities for the SEL SV Publishers

IEC	SEL	Magnitude (RMS)		Angle (Degrees)	
		5 A[a]	1 A[a]	ABC Rotation	ACB Rotation
I1	IA	5	1	0	0
I2	IB	5	1	–120	120
I3	IC	5	1	120	–120
I4	IN	0[b]	0[b]	0[b]	0[b]
V1	VA	67	67	0	0
V2	VB	67	67	–120	120
V3	VC	67	67	120	–120
V4	VN	0[b]	0[b]	0[b]	0[b]

[a] 1 A or 5 A nominal current.
[b] The neutral channel is the sum of the waveforms for A-, B-, and C-Phase

Refer to *Section 14: ASCII Command Reference* for more information about the **TEST SV** command.

IEC 61850 Configuration

Settings

Table 12.18 lists the IEC 61850 settings. *Table 12.19* lists the Mode/Behavior settings. These settings are only available if your device includes the optional IEC 61850 protocol.

Architect

NOTE: Not all SEL-400 series relays support SV.

NOTE: Other manufacturers' ICD and CID files must have IEC 61850 outgoing GOOSE messages with Application IDs (APPIDs) of exactly four characters and VLAN IDs of exactly three characters so that the relay can successfully subscribe to them. If you attempt to configure a relay to subscribe to a GOOSE message that does not meet this criteria, the relay will reject the CID file upon download. Edit other manufacturers' ICD and CID files prior to importing them into Architect by adding leading zeros to the APPID and VLAN ID of outgoing GOOSE messages, as necessary.

NOTE: Use unique VLAN tags when publishing 87L, GOOSE, and SV messages to avoid mixing process bus traffic with station bus traffic. However, the VLAN IDs of subscribed GOOSE messages can be the same as outgoing 87L or SV VLAN IDs.

The Architect software enables protection and integration engineers to design and commission IEC 61850 substations containing SEL IEDs.

Engineers can use Architect to perform the following configuration tasks:

- Organize and configure all SEL IEDs in a substation project.
- Configure incoming and outgoing GOOSE messages.
- Configure SV publication and subscription, if supported.
- Edit and create GOOSE and SV data sets.
- Read non-SEL IED Capability Description (ICD) and CID files and determine the available IEC 61850 messaging options.
- Use or edit preconfigured data sets for reports.
- Load device settings as part of IEC 61850 CID files into SEL IEDs.
- Generate ICD files that will provide SEL IED descriptions to other manufacturers' tools so they can use SEL GOOSE messages and reporting features.

Architect provides a GUI for engineers to select, edit, and create IEC 61850 GOOSE messages important for substation protection, coordination, and control schemes. Typically, the engineer first places icons representing IEDs in a substation container, then edits the outgoing GOOSE messages or creates new ones for each IED. The engineer may also select incoming GOOSE messages for each

IED to receive from any other IEDs in the domain. Architect has the capability to read other manufacturers' ICD and CID files, enabling the engineer to map the data seamlessly into SEL IED logic. See the Architect help for more information.

Architect also provides a GUI for engineers to configure SV publications and SV subscriptions when the IED supports SV. The process is similar to that described for GOOSE, except that SEL SV devices can either publish or subscribe to SV, but not both. The engineer edits or creates SV publication data sets to configure the SEL SV publisher(s). Architect then displays the available SV publications in the project, using any SV publications defined in the project, including those from imported CID files from other manufacturers' SV publishers. The engineer then configures subscriptions by mapping the published data to the available analog channels in the SEL SV subscriber.

The following example includes configurations via the Architect software. The software supports IEC 61850 MMS, GOOSE, and SV configurations. This example shows how to use the software to configure two SV publications on an SEL-401 and the SV subscriptions on an SEL-421-7.

Example 17.3 SV Application

Step 1. Open Architect.

Step 2. Insert the SEL-401 ICD and the SEL-421-7 SV Subscriber ICD in the project tree.

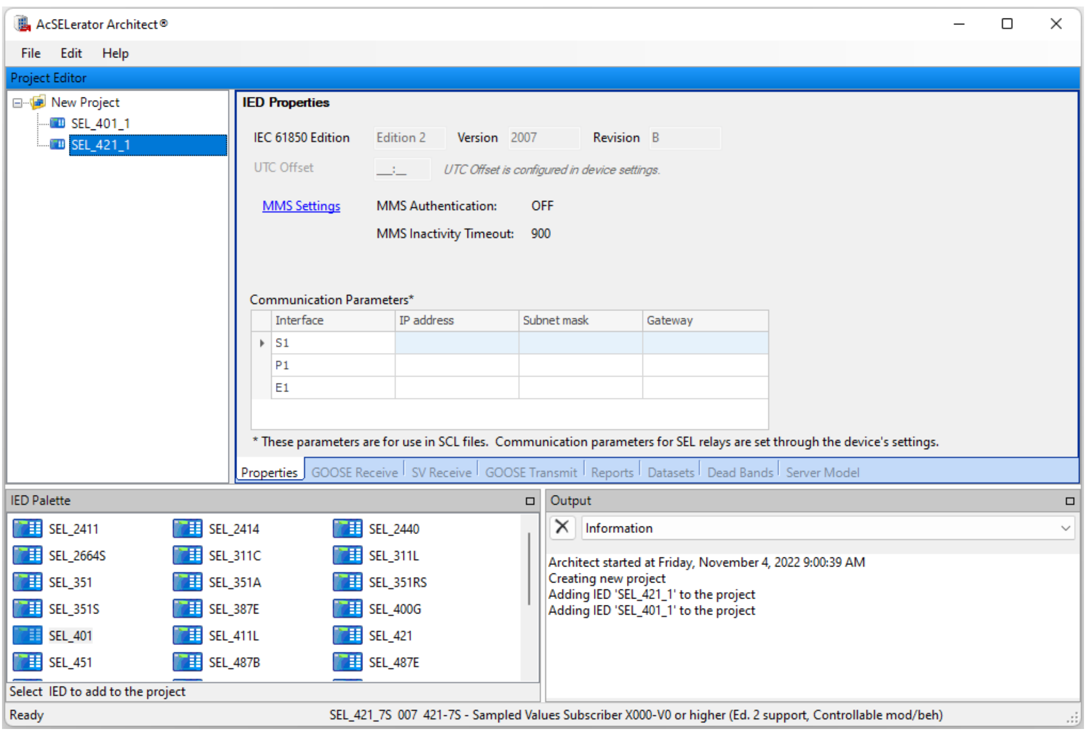

Figure 17.30 Add ICD to Project Tree

Example 17.3 SV Application (Continued)

Step 3. Create an SV Publication for the SEL-401. Configure SVID, MAC address, APP ID, and VLAN information as desired. Select an SV data set to associate it with the SV publication.

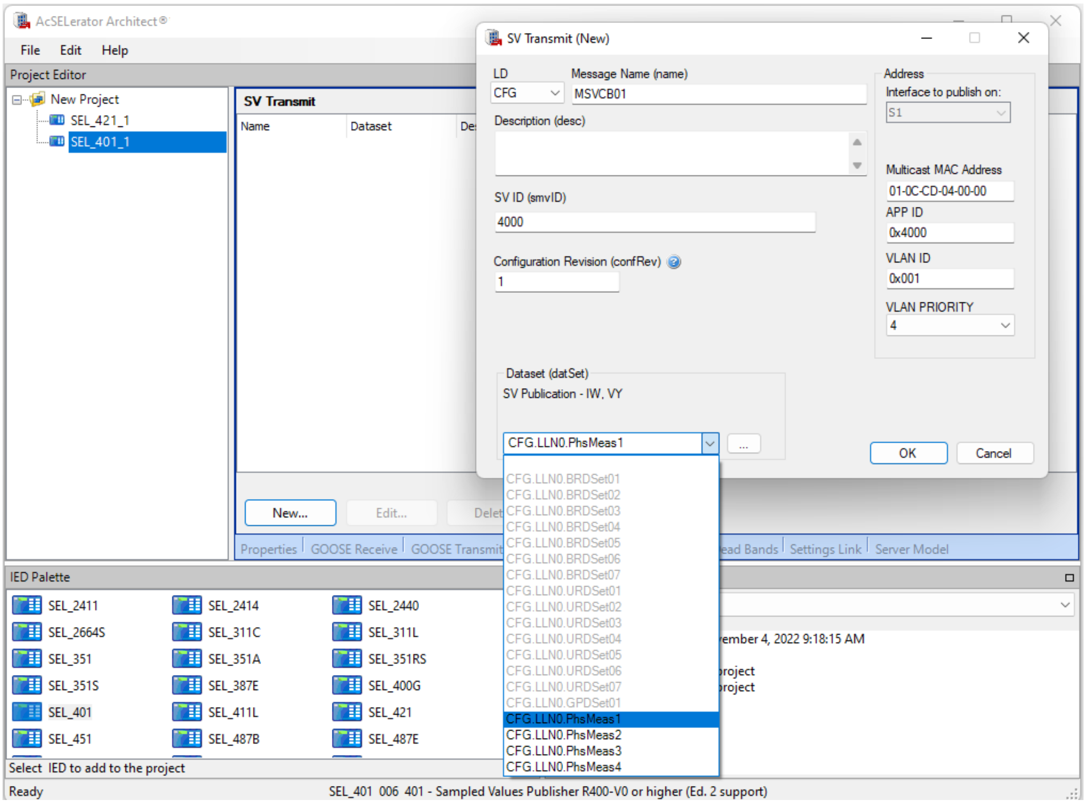

Figure 17.31 Configure an SV Publication

Example 17.3 SV Application (Continued)

Step 4. To view the content of the data set, select the **...** icon next to the data set.

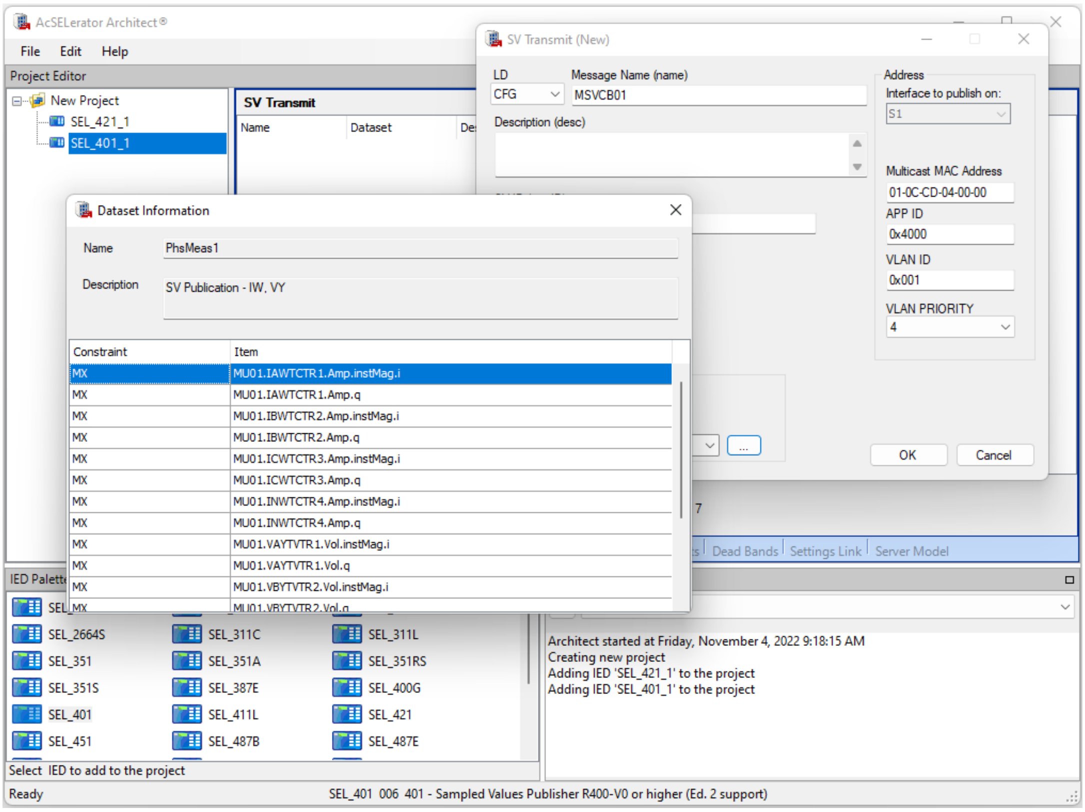

Figure 17.32 Example SV Publication Data Set

Example 17.3 SV Application (Continued)

Step 5. Select the SEL-421 and select the **SV Receive** tab to configure the SV subscriptions as shown in *Figure 17.33*.

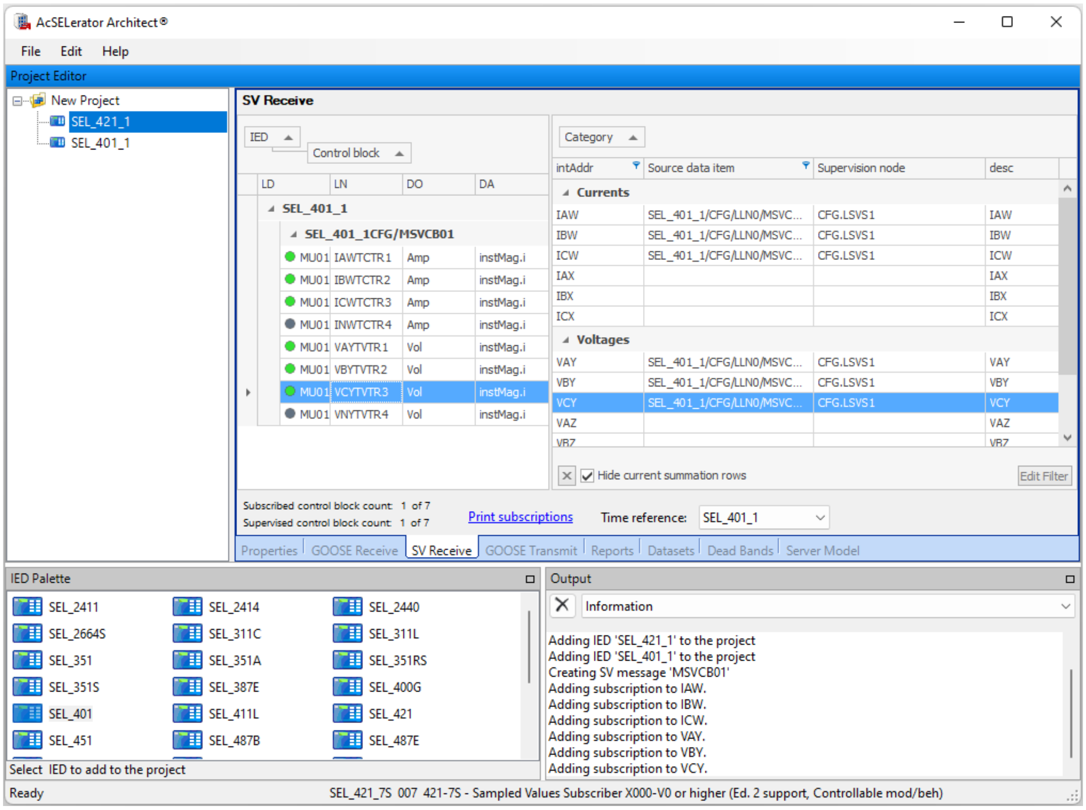

Figure 17.33 Configure SV Subscription

Step 6. Right-click the IED, and choose to send the CID file. Ensure that the FTP function is enabled on the IEDs before sending CID files.

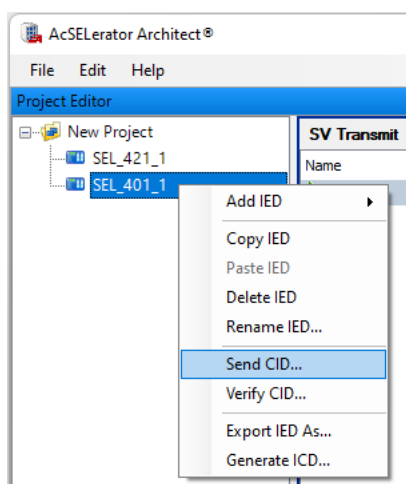

Figure 17.34 Send SEL-401 CID File

Example 17.3 SV Application (Continued)

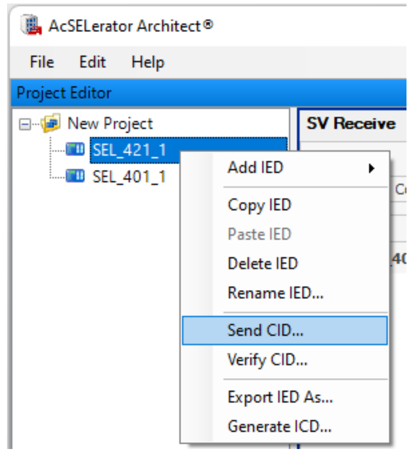

Figure 17.35 Send SEL-421-7 CID File

Step 7. Issue the **COM SV** command on the merging unit and the relay to verify successful publication and subscription.

```
=>>COM SV <Enter>

IEC 61850 Mode/Behavior: On

SEL TEST SV Mode: Off

SV Publication Information

 MultiCastAddr   Ptag:Vlan AppID  smpSynch
_________________________________________________________________________________
A0401_006_ICD_ExampleCFG/LLN0$MS$MSVCB01
 01-0C-CD-04-00-11  4:1    4001      0
 SV ID: 4001
 Data Set: A0401_006_ICD_ExampleCFG/LLN0$PhsMeas1
```

Figure 17.36 SEL-401 Publication Status

```
=>>COM SV <Enter>

IEC 61850 Mode/Behavior: On

SEL TEST SV Mode: Off

SIMULATED Mode: Off

SV Subscription Status

 MultiCastAddr   Ptag:Vlan AppID  smpSynch    Code          Network Delay (ms)
_________________________________________________________________________________
A0401_006_ICD_ExampleCFG/LLN0$MS$MSVCB01
 01-0C-CD-04-00-11  4:1    4001      1
 SV ID: 4001
 Data Set: A0401_006_ICD_ExampleCFG/LLN0$PhsMeas1
```

Figure 17.37 SEL-421-7 SV Subscription Status

SV Configuration

The SEL-400 series relays support SV configuration via Architect or **PORT 5** settings via ACSELERATOR QuickSet SEL-5030 Software, terminal window, or front-panel HMI. **PORT 5** SV settings take precedence over any SV configuration via CID files. If SVTXEN > 0 or SVRXEN > 0, **PORT 5** SV configuration is used.

SV Communication Status

SEL SV publishers support as many as seven SV publications. The SEL SV publishers indicate the publication status by using Relay Word bits SVP*nn*OK (*nn*= 01 to 07). If a publication is configured, the corresponding SVP*nn*OK Relay Word bit asserts. The **COM SV** command provides a detailed report on the configured SV publications.

SEL SV subscribers support as many as seven SV subscriptions. The SEL SV subscriber monitors each incoming SV stream and, when queried with the **COM SV** command, reports errors or warnings if detected. For example, if the relay has not received four or more consecutive SV messages, **COM SV** reports the error code `SV STREAM LOST`. If the received SV messages include more than one application service data unit (ASDU), the error code `ASDU ERROR` is reported to indicate that the SEL-400 only supports one ASDU. Warning codes include `CH DLY EXCEEDED`, `INTERPOLATED`, `SIMULATED`, etc. For example, if the measured network delay of any subscribed SV stream exceeded the CH_DLY when the relay is in coupled clock mode. If SV subscriptions experience an error, the corresponding subscription status, SVS*nn*OK (*nn* = 01–07), deasserts.

Refer to *Section 14: ASCII Command Reference* for more information about the **COM SV** command.

SEL ICD File Versions

Architect version 1.1.69.0 and higher supports multiple ICD file versions for each IED in a project. Because relays with different firmware may require different CID file versions, this allows users to manage the CID files of all IEDs within a single project.

Ensure that you work with the appropriate version of Architect relative to your current configuration, existing project files, and ultimate goals. If you desire the best available IEC 61850 functionality for your SEL relay, obtain the latest version of Architect and select the appropriate ICD version(s) for your needs. Architect generates CID files from ICD files so the ICD file version Architect uses also determines the CID file version generated.

Architect comes with several versions of relay ICD files. ICD file descriptions in Architect indicate the minimum firmware versions required to use that particular file. Unless otherwise indicated, ICD files will work with firmware higher than the firmware in the description. but not with lower firmware versions.

See *Appendix A: Firmware, ICD File, and Manual Versions* in the product-specific instruction manual for a list of ICD versions and corresponding firmware versions.

Logical Nodes

Each logical device (LD) has a set of common data objects at the top-level LN0. These represent the current state of the device, as well as some informational data. These data objects are: Mod (Mode), Beh (Behavior), Health, and NamPlt. See the following for brief descriptions of each object.

Mode

In the SEL-400 series relays, the top-level LN0 within each LD includes the following enumerations for **Mod stVal**:

Mod stVal Enumeration	Description
1	On
2	Blocked
3	Test
4	Test/Blocked
5	Off
0	IEC 61850 Mode/Behavior disabled

The top-level logical node of each LD also includes the following Mod attributes:

- **Mod.q** represents quality.
- **Mod.t** represents time stamps.
- **Mod.stVal** represents the current mode/behavior.

You can control IEC 61850 Mode/Behavior via LLN0COMod$Oper in your CFG logical device.

Behavior

SEL-400 series relay LNs include the following enumerations for **Beh stVal**:

Beh stVal Enumeration	Description
1	On
2	Blocked
3	Test
4	Test/Blocked
5	Off
0	IEC 61850 Mode/Behavior disabled

Logical nodes also include the following Beh attributes:

Beh q and **Beh t** per the Time Stamps and Quality section.

Health

The SEL-400 series relay includes at the top-level LN0 within each LD the following enumerations for **Health stVal**:

Health stVal Enumeration	Health stVal Value	Description
1	Ok	EN Relay Word bit = 1
3	Alarm	EN Relay Word bit = 0

The top-level logical node of each LD also includes the following Health attributes:

Health q and **Health t** per the Time Stamps and Quality section.

NamPlt

The top-level LN0 of each LD includes the following NamPlt attributes:

➤ NamPlt.vendor has a string value set to SEL.
➤ NamPlt.swRev contains the relay FID string value.
➤ NamPlt.d contains the LD description.

LPHD

The LPHD logical node in the CFG logical device contains information about the physical device, such as the physical device nameplate information. SEL extended this logical node to include an object that provides an identifier for the version of the IEC 61850 component firmware in the device. This object, LPHD.SelLibID, contains a checksum derived from the IEC 61850 library version and is the same value across different devices with the same underlying code. This value is also available in the LIB61850ID field of the ID command.

Common Logical Nodes

NOTE: With the introduction of the Flexible Server Model (FSM) in Architect for ICD files ClassFileVersion 010 or later, use FSM as the primary reference to view and edit the mapping between IEC 61850 data attributes and relay variables. The LN tables provided in this section serve as general guidelines.

Table 17.28–Table 17.31 list the logical nodes (LNs) supported in all SEL-400 series relays. See the respective product-specific instruction manuals to see which additional logical nodes are available in that relay.

Table 17.28 shows the LNs associated with the Logical Node CFG.

Table 17.28 Logical Device: CFG (Configuration) (Sheet 1 of 8)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = CO			
LLN0	LocSta.Oper.ctlVal	SC850LS	SELOGIC control for control authority at station level
LLN0	Mod.Oper.ctlVal	I60MOD[a]	IEC 61850 mode/behavior control
DevIDLPHD1	Sim.Oper.ctlVal	LPHDSIM	IEC 61850 logical node for physical device simulation
EALCCH1	RsStat.Oper.ctlVal	EARST[b, c]	Reset engineering access statistics
GOLCCH2	RsStat.Oper.ctlVal	GORST[b]	Reset statistics for GOOSE traffic
IPLCCH1	RsStat.Oper.ctlVal	IPRST[b]	Reset statistics for general IP traffic (excluding GOOSE, SV, and 87L traffic).
LGOS*n*[d]	RsStat.Oper.ctlVal	GRST*n*[e]	Reset GOOSE statistics for Message *n*
LSVS*n*[f]	RsStat.Oper.ctlVal	SRST*n*[e]	Reset SV statistics for SV Stream *n*
PBLCCH1	RsStat.Oper.ctlVal	PBRST[b, c]	Reset process bus statistics
SBLCCH1	RsStat.Oper.ctlVal	SBRST[b, c]	Reset station bus statistics
Functional Constraint = DC			
LLN0	NamPlt.swRev	VERFID	Relay FID string
DevIDLPHD1	PhyNam.hwRev	HWREV[g]	Hardware version of the relay main board
DevIDLPHD1	PhyNam.model	PARNUM	Relay part number string
DevIDLPHD1	PhyNam.serNum	SERNUM	Relay serial number string
DevIDLPHD1	SelLibId.val	–[b]	Checksum derived from the IEC 61850 library version
Functional Constraint = ST			
LLN0	Mod.stVal	I60MOD[a]	IEC 61850 mode/behavior status
LLN0	Health.stVal	EN?3:1[h]	Relay enabled

Table 17.28 Logical Device: CFG (Configuration) (Sheet 2 of 8)

Logical Node	Attribute	Data Source	Comment
LLN0	Loc.stVal	LOC	Control authority at local (bay) level
LLN0	LocSta.stVal	LOCSTA	Control authority at station level
LLN0	LocKey.stVal	NOOP	
DevIDLPHD1	Sim.stVal	LPHDSIM	IEC 61850 logical node for physical device simulation
DevIDLPHD1	PhyHealth.stVal	EN?3:1[h]	Relay enabled
EALCCH1	ChLiv.stVal	EACH[b, c]	Status of engineering access channel
EALCCH1	RxCnt.actVal	EARX[b, c]	Number of non-SV, non-GOOSE frames received on the engineering access channel
EALCCH1	TxCnt.actVal	EATX[b, c]	Number of frames transmitted on the engineering access channel
EALCCH1	RsStat.stVal	EARST[b, c]	Status of engineering access statistics reset
GOLCCH2	ChLiv.stVal	GOCH[b]	Status of primary GOOSE channel
GOLCCH2	RedChLiv.stVal	GORCH[b]	Status of redundant GOOSE channel
GOLCCH2	RxCnt.actVal	GORX[b]	Number of frames received over the primary GOOSE channel
GOLCCH2	RedRxCnt.actVal	GORRX[b]	Number of frames received over the redundant GOOSE channel
GOLCCH2	TxCnt.actVal	GOTX[b]	Number of frames transmitted on both primary and redundant GOOSE channels
GOLCCH2	FerCh.stValj	GOFER[b]	Frame error rate on the primary GOOSE channel
GOLCCH2	RedFerCh.stValj	GORFER[b]	Frame error rate on the redundant GOOSE channel
GOLCCH2	RsStat.stVal	GORST[b]	Status of statistics reset for GOOSE traffic
IPLCCH1	ChLiv.stVal	IPCH[b]	Status of primary IP channel
IPLCCH1	RedChLiv.stVal	IPRCH[b]	Status of redundant IP channel
IPLCCH1	RxCnt.actVal	IPRX[b]	Number of frames received over the primary IP channel
IPLCCH1	RedRxCnt.actVal	IPRRX[b]	Number of frames received over the redundant IP channel
IPLCCH1	TxCnt.actVal	IPTX[b]	Number of frames transmitted on both primary and redundant IP channels
IPLCCH1	FerCh.stVal	IPFER[b]	Frame error rate on the primary IP channel
IPLCCH1	RedFerCh.stValj	IPRFER[b]	Frame error rate on the redundant IP channel
IPLCCH1	RsStat.stVal	IPRST[b]	Status of statistics reset for general IP traffic (excludes GOOSE, SV, and 87L traffic)
LGOS*n*[d]	NdsCom.stVal	GNCM*n*[e]	Subscription needs commissioning for GOOSE Message *n*. True if ConfRevNum does not match RxConfRevNum
LGOS*n*[d]	St.stVal	GST*n*[e]	Status of the subscription (True = active, False = not active) for GOOSE Message *n*
LGOS*n*[d]	SimSt.stVal	GSIM*n*[e]	Status showing that simulation messages are received and accepted for GOOSE Message *n*
LGOS*n*[d]	LastStNum.stVal	GLST*n*[e]	Last state number received (StNum) for GOOSE Message *n*
LGOS*n*[d]	LastSqNum.stVal	GLSQ*n*[e]	Last sequence number received (SqNum) for GOOSE Message *n*
LGOS*n*[d]	LastTal.stVal	GTAL*n*[e]	Last time-allowed-to-live received (TTL) for GOOSE Message *n*
LGOS*n*[d]	ConfRevNum.stVal	–	Expected configuration revision number for GOOSE Message *n*
LGOS*n*[d]	RxConfRevNum.stVal	GCNF*n*[e]	Received configuration revision number for GOOSE Message *n*
LGOS*n*[d]	ErrSt.stVal	GERR*n*[e]	Error status of the subscription for GOOSE Message *n*
LGOS*n*[d]	OosCnt.stVal	GOOS*n*[e]	Number of out-of-sequence (OOS) errors for GOOSE Message *n*
LGOS*n*[d]	TalCnt.stVal	GTLC*n*[e]	Number of time-allowed-to-live violations for GOOSE Message *n*
LGOS*n*[d]	DecErrCnt.stVal	GDER*n*[e]	Number of messages that failed decoding for GOOSE Message *n*

Table 17.28 Logical Device: CFG (Configuration) (Sheet 3 of 8)

Logical Node	Attribute	Data Source	Comment
LGOS*n*[d]	BufOvflCnt.stVal	GBFO*n*[e]	Number of messages lost because of buffer overflow for GOOSE Message *n*
LGOS*n*[d]	MsgLosCnt.stVal	GMSL*n*[e]	Number of messages lost due to OOS errors (estimated) for GOOSE Message *n*
LGOS*n*[d]	MaxMsgLos.stVal	GMXM*n*[e]	Maximum number of sequential messages lost because of OOS error (estimated) for GOOSE Message *n*
LGOS*n*[d]	InvQualCnt.stVal	GIDQ*n*[e]	Number of mapped incoming GOOSE data with invalid quality for GOOSE Message *n*
LGOS*n*[d]	RsStat.stVal	GRST*n*[e]	Status of statistics reset for GOOSE messages
LSVS*n*[f]	NdsCom.stVal	SNCM*n*[e]	Subscription needs commissioning for SV Stream *n*. True if ConfRevNum does not match RxConfRevNum
LSVS*n*[f]	St.stVal	SST*n*[e]	Status of the subscription (True = active, False = not active) for SV Stream *n*
LSVS*n*[f]	SimSt.stVal	SSIM*n*[e]	Status showing that simulation messages are received and accepted for SV Stream *n*
LSVS*n*[f]	ConfRevNum.stVal	–[i]	Expected configuration revision number for SV Stream *n*
LSVS*n*[f]	RxConfRevNum.stVal	SCNF*n*[e]	Received configuration revision number for SV Stream *n*
LSVS*n*[f]	SmpSynch.stVal,	SSMP*n*[e]	Synchronization state for SV Stream *n*
LSVS*n*[f]	ErrSt.stVal	SERR*n*[e]	Error status of the subscription for SV Stream *n*
LSVS*n*[f]	OosCnt.stVal	SOOS*n*[e]	Number of OOS errors for SV Stream *n*
LSVS*n*[f]	DscdCnt.stVal	SDIS*n*[e]	Number of messages that were discarded for SV Stream *n*
LSVS*n*[f]	IntpCnt.stVal	SINT*n*[e]	Number of messages interpolated for SV Stream *n*
LSVS*n*[f]	RsStat.stVal	SRST*n*[e]	Status of statistics reset for SV Stream *n*
LTIM	TmDT.stVal	TMDT[b]	Indicates daylight-saving time is currently in effect at the IED location
LTMS	TmAcc.stVal	TSACC[b]	Number of significant bits in the FractionOfSecond (an attribute of TimeStamp) 20: 1 ms accuracy (2–20) 10: 1 ms accuracy (2–10) 7: 10 ms accuracy (2–7) 31: Unknown accuracy
LTMS	TmSrc.stVal	TSSRC[b]	Time-source identity If TmSrcTyp is PTP: For ICD files with ClassFileVersion 010 or later, TmSrc indicates the grandmaster clock identity according to IEC/IEEE 61855:2021 For ICD files with ClassFile version earlier than 010, TmSrc indicates the timeSource enumeration according to IEEE 1588-2008 If TmSrcTyp is SNTP, TmSrc indicates the IP address of the SNTP server For all other values of TmSrcTyp, TmSrc is set to “NA”
LTMS	TmSrcTyp.stVal	TSTYPE[b]	Type of the clock source as defined by Relay Word bits TSNTP, TPTP, and TIRIG 1: Unknown 2: SNTP 3: PTP 4: IRIG-B

Table 17.28 Logical Device: CFG (Configuration) (Sheet 4 of 8)

Logical Node	Attribute	Data Source	Comment
LTMS	TmSyn.stVal	TSSYN[b]	Traceability of the reference time to which the IED is synchronized 2: GlobalAreaClock—Time synchronized to a clock that is traceable to a global reference, or TmSrcTyp is SNTP 1: LocalAreaClock—Time synchronized to a local area clock that is not traceable to a global reference 0: InternalClock—Not synchronized to an external clock source
LTMS	TmSynLkd.stVal	TSSYNLK[b]	Status of clock synchronization: 1: Locked 2: Unlocked for 0–10 seconds 3: Unlocked for 10–100 seconds 4: Unlocked for 100–1000 seconds 5: Unlocked for more than 1000 seconds
PBLCCH1	ChLiv.stVal	PBCH[b, c]	Status of process bus primary channel
PBLCCH1	RedChLiv.stVal	PBRCH[b, c]	Status of process bus redundant channel
PBLCCH1	RxCnt.actVal	PBRX[b, c]	Number of non-SV, non-GOOSE frames received on the process bus primary channel
PBLCCH1	RedRxCnt.actVal	PBRRX[b, c]	Number of non-SV, non-GOOSE frames received on the process bus redundant channel
PBLCCH1	RxCntGo.actVal	PBRXGO[b, c]	Number of GOOSE frames received on the process bus primary channel
PBLCCH1	RedRxCntGo.actVal	PBRRXGO[b, c]	Number of GOOSE frames received on the process bus redundant channel
PBLCCH1	RxCntSv.actVal	PBRXSV[b, c]	Number of SV frames received on the process bus primary channel
PBLCCH1	RedRxCntSv.actVal	PBRRXSV[b, c]	Number of SV frames received on the process bus redundant channel
PBLCCH1	TxCnt.actVal	PBTX[b, c]	Number of frames transmitted on both process bus channels
PBLCCH1	FerCh.stVal	PBFER[b, c]	Number of non-SV, non-GOOSE PRP frames missed on the process bus primary channel over the last 1000 processed PRP frames
PBLCCH1	RedFerCh.stVal	PBRFER[b, c]	Number of non-SV, non-GOOSE PRP frames missed on the process bus redundant channel over the last 1000 processed PRP frames
PBLCCH1	FerChGo.stVal	PBFRGO[b, c]	Number of GOOSE PRP frames missed on the process bus primary channel over the last 1000 processed PRP frames
PBLCCH1	RedFerChGo.stVal	PBRFRGO[b, c]	Number of GOOSE PRP frames missed on the process bus redundant channel over the last 1000 processed PRP frames
PBLCCH1	FerChSv.stVal	PBFRSV[b, c]	Number of SV PRP frames missed on the process bus primary channel over the last second
PBLCCH1	RedFerChSv.stVal	PBRFRSV[b, c]	Number of SV PRP frames missed on the process bus redundant channel over the last second
PBLCCH1	RsStat.stVal	PBRST[b, c]	Status of process bus statistics reset
SBLCCH1	ChLiv.stVal	SBCH[b, c]	Status of station bus primary channel
SBLCCH1	RedChLiv.stVal	SBRCH[b, c]	Status of station bus redundant channel
SBLCCH1	RxCnt.actVal	SBRX[b, c]	Number of non-SV, non-GOOSE frames received on the station bus primary channel
SBLCCH1	RedRxCnt.actVal	SBRRX[b, c]	Number of non-SV, non-GOOSE frames received on the station bus redundant channel
SBLCCH1	RxCntGo.actVal	SBRXGO[b, c]	Number of GOOSE frames received on the station bus primary channel
SBLCCH1	RedRxCntGo.actVal	SBRRXGO[b, c]	Number of GOOSE frames received on the station bus redundant channel
SBLCCH1	TxCnt.actVal	SBTX[b, c]	Number of frames transmitted on both station bus channels
SBLCCH1	FerCh.stVal	SBFER[b, c]	Number of non-SV, non-GOOSE PRP frames missed on the station bus primary channel over the last 1000 processed PRP frames

Table 17.28 Logical Device: CFG (Configuration) (Sheet 5 of 8)

Logical Node	Attribute	Data Source	Comment
SBLCCH1	RedFerCh.stVal	SBRFER[b, c]	Number of non-SV, non-GOOSE PRP frames missed on the station bus redundant channel over the last 1000 processed PRP frames
SBLCCH1	FerChGo.stVal	SBFRGO[b, c]	Number of GOOSE PRP frames missed on the station bus primary channel over the last 1000 processed PRP frames
SBLCCH1	RedFerChGo.stVal	SBRFRGO[b, c]	Number of GOOSE PRP frames missed on the station bus redundant channel over the last 1000 processed PRP frames
SBLCCH1	RsStat.stVal	SBRST[b, c]	Status of station bus statistics reset
Functional Constraint = MX			
LGOS*n*[d]	TotDwnTm.instMag.f	GDWT*n*[e]	Total downtime in seconds for GOOSE Message *n*
LGOS*n*[d]	MaxDwnTm.instMag.f	GMXD*n*[e]	Maximum continuous downtime in seconds for GOOSE Message *n*
LSVS*n*[f]	NetwDly.instMag.f	SNET*n*[e]	Network delay in milliseconds for SV Stream *n*
LSVS*n*[f]	TotDwnTm.instMag.f	SDWT*n*[e]	Total downtime in seconds for SV Stream *n*
LSVS*n*[f]	MaxDwnTm.instMag.f	SMXD*n*[e]	Maximum continuous downtime in seconds for SV Stream *n*
LTMS	TmTosPer.instMag.f	TSPER[b]	Duration, in milliseconds, between two consecutive top-of-second points on the synchronized time; TmTosPer is set to 0 for time sources other than high-accuracy PTP or IRIG-B
Functional Constraint = SP			
LLN0	MltLev.setVal	MLTLEV	Multi-level mode of control authority
EALCCH1	ApNam.setVal	–[c, i]	Access point name for the engineering access channel
GOLCCH2	NetMod.setVal	NETMODE	PORT 5 network operating mode setting (1: Fixed, 2: Failover, 3: Switched, 4: PRP, 5: IsolatedIP)
IPLCCH1	NetMod.setVal	NETMODE	PORT 5 network operating mode setting (1: Fixed, 2: Failover, 3: Switched, 4: PRP, 5: IsolatedIP).
LGOS*n*[d]	GoCBRef.setSrcRef	–[i]	Configured GOOSE control block reference for GOOSE Message *n*
LGOS*n*[d]	DatSet.setSrcRef	–[i]	Configured data set reference for GOOSE Message *n*
LGOS*n*[d]	GoID.setVal	–[i]	Configured ID for GOOSE Message *n*
LGOS*n*[d]	Addr.setVal	–[i]	Configured multicast MAC address for GOOSE Message *n*
LGOS*n*[d]	VlanID.setVal	–[i]	Configured VLAN ID for GOOSE Message *n*
LGOS*n*[d]	VlanPri.setVal	–[i]	Configured VLAN priority for GOOSE Message *n*
LGOS*n*[d]	AppID.setVal	–[i]	Configured APPID for GOOSE Message *n*
LSVS*n*[f]	SvCBRef.setSrcRef	–[i]	Configured SV control block reference for SV Stream *n*
LSVS*n*[f]	DatSet.setSrcRef	–[i]	Configured data set reference for SV Stream *n*
LSVS*n*[f]	SvID.setVal	–[i]	Configured SV ID for SV Stream *n*
LSVS*n*[f]	Addr.setVal	–[i]	Configured multicast MAC address for SV Stream *n*
LSVS*n*[f]	VlanID.setVal	–[i]	Configured VLAN ID for SV Stream *n*
LSVS*n*[f]	VlanPri.setVal	–[i]	Configured VLAN priority for SV Stream *n*
LSVS*n*[f]	AppID.setVal	–[i]	Configured APPID for SV Stream *n*
LTIM	TmOfsTmm.setVal	TMOFFS[b]	Offset of local time from UTC in minutes
LTIM	TmUseDT.setVal	TMUSEDT[b]	Set to True if daylight-saving time is enabled
LTIM	TmChgDT.setTm	TMCHGDT[b]	Local time of next change to daylight-saving time
LTIM	TmChgST.setTm	TMCHGST[b]	Local time of next change to standard time
PBLCCH1	ApNam.setVal	–[c, i]	Access point name for the process bus
PBLCCH1	NetModP.setVal	NETMODP[c]	PORT 5 network operating mode setting for the process bus (1: Fixed, 2: Failover, 3: PRP)

Table 17.28 Logical Device: CFG (Configuration) (Sheet 6 of 8)

Logical Node	Attribute	Data Source	Comment
PBLCCH1	BusMode.setVal	BUSMODE[c]	PORT 5 bus operating mode setting (1: Independent, 2: Merged)
PBLCCH1	NetPorP.setVal	NETPORP[c]	PORT 5 primary network port setting for the process bus (1: A, 2: B)
SBLCCH1	ApNam.setVal	_[c, i]	Access point name for the station bus
SBLCCH1	NetMode.setVal	NETMODE[c]	PORT 5 network operating mode setting for the station bus (1: Fixed, 2: Failover, 3: PRP)
SBLCCH1	BusMode.setVal	BUSMODE[c]	PORT 5 bus operating mode setting (1: Independent, 2: Merged)
SBLCCH1	NetPort.setVal	NETPORT[c]	PORT 5 primary network port setting for the station bus (1: C, 2: D)
Functional Constraint = SR			
LTRK1	SpcTrk.objRef	_[j]	ACSI reference to the SPC object targeted in the request
LTRK1	SpcTrk.serviceType	_[j, k]	Type of service requested or executed
LTRK1	SpcTrk.errorCode	_[j, l]	ACSI service error status
LTRK1	SpcTrk.ctlVal	_[j]	Control value in the request
LTRK1	SpcTrk.ctlNum	_[j]	Control number in the request
LTRK1	SpcTrk.origin.orCat	_[j]	Originator category value in the request
LTRK1	SpcTrk.origin.orIdent	_[j]	Originator identity value in the request
LTRK1	SpcTrk.T	_[j]	Time-stamp value in the request
LTRK1	SpcTrk.Test	_[j]	Test value in the request
LTRK1	SpcTrk.Check	_[j]	Check condition value in the request
LTRK1	SpcTrk.respAddCause	_[j]	AddCause value returned in the response
LTRK1	DpcTrk.objRef	_[j]	ACSI reference of the DPC object targeted in the request
LTRK1	DpcTrk.serviceType	_[j, k]	Type of service requested or executed
LTRK1	DpcTrk.errorCode	_[j, l]	ACSI service error status
LTRK1	DpcTrk.ctlVal	_[j]	Control value in the request
LTRK1	DpcTrk.ctlNum	_[j]	Control number in the request
LTRK1	DpcTrk.origin.orCat	_[j]	Originator category value in the request
LTRK1	DpcTrk.origin.orIdent	_[j]	Originator identity value in the request
LTRK1	DpcTrk.T	_[j]	Time-stamp value in the request
LTRK1	DpcTrk.Test	_[j]	Test value in the request
LTRK1	DpcTrk.Check	_[j]	Check condition value in the request
LTRK1	DpcTrk.respAddCause	_[j]	AddCause value returned in the response
LTRK1	EncTrk.objRef	_[j]	ACSI reference of the ENC object targeted in the request
LTRK1	EncTrk.serviceType	_[j, k]	Type of service requested or executed
LTRK1	EncTrk.errorCode	_[j, l]	ACSI service error status
LTRK1	EncTrk.ctlVal	_[j]	Control value in the request
LTRK1	EncTrk.ctlNum	_[j]	Control number in the request
LTRK1	EncTrk.origin.orCat	_[j]	Originator category value in the request
LTRK1	EncTrk.origin.orIdent	_[j]	Originator identity value in the request
LTRK1	EncTrk.T	_[j]	Time-stamp value in the request
LTRK1	EncTrk.Test	_[j]	Test value in the request
LTRK1	EncTrk.Check	_[j]	Check condition value in the request
LTRK1	EncTrk.respAddCause	_[j]	AddCause value returned in the response

Table 17.28 Logical Device: CFG (Configuration) (Sheet 7 of 8)

Logical Node	Attribute	Data Source	Comment
LTRK1	BrcbTrk.objRef	_[j]	ACSI reference of the BRCB object targeted in the request
LTRK1	BrcbTrk.serviceType	_[j, k]	Type of service requested or executed
LTRK1	BrcbTrk.errorCode	_[j, l]	ACSI service error status
LTRK1	BrcbTrk.rptID	_[j]	RptID attribute value in the request or target BRCB object
LTRK1	BrcbTrk.rptEna	_[j]	RptEna attribute value in the request or target BRCB object
LTRK1	BrcbTrk.datSet	_[j]	DatSet attribute value in the target BRCB object
LTRK1	BrcbTrk.confRev	_[j]	ConfRev attribute value in the target BRCB object
LTRK1	BrcbTrk.optFlds	_[j]	OptFlds attribute value in the request or target BRCB object
LTRK1	BrcbTrk.bufTm	_[j]	BufTm attribute value in the request or target BRCB object
LTRK1	BrcbTrk.sqNum	_[j]	SqNum attribute value in the target BRCB object
LTRK1	BrcbTrk.trgOps	_[j]	TrgOps attribute value in the request or target BRCB object
LTRK1	BrcbTrk.intgPd	_[j]	IntgPd attribute value in the request or target BRCB object
LTRK1	BrcbTrk.gi	_[j]	GI attribute value in the request or target BRCB object
LTRK1	BrcbTrk.purgeBuf	_[j]	PurgeBuf attribute value in the request or target BRCB object
LTRK1	BrcbTrk.entryID	_[j]	EntryID attribute value in the request or target BRCB object
LTRK1	BrcbTrk.timeOfEntry	_[j]	TimeOfEntry attribute value in the target BRCB object
LTRK1	UrcbTrk.objRef	_[j]	ACSI reference of the URCB object targeted in the request
LTRK1	UrcbTrk.serviceType	_[j, k]	Type of service requested or executed
LTRK1	UrcbTrk.errorCode	_[j, l]	ACSI service error status
LTRK1	UrcbTrk.rptID	_[j]	RptID attribute value in the request or target URCB object
LTRK1	UrcbTrk.rptEna	_[j]	RptEna attribute value in the request or target URCB object
LTRK1	UrcbTrk.resv	_[j]	Resv attribute value in the request or target URCB object
LTRK1	UrcbTrk.datSet	_[j]	DatSet attribute value in the target URCB object
LTRK1	UrcbTrk.confRev	_[j]	ConfRev attribute value in the target URCB object
LTRK1	UrcbTrk.optFlds	_[j]	OptFlds attribute value in the request or target URCB object
LTRK1	UrcbTrk.bufTm	_[j]	BufTm attribute value in the request or target URCB object
LTRK1	UrcbTrk.sqNum	_[j]	SqNum attribute value in the target URCB object
LTRK1	UrcbTrk.trgOps	_[j]	TrgOps attribute value in the request or target URCB object
LTRK1	UrcbTrk.intgPd	_[j]	IntgPd attribute value in the request or target URCB object
LTRK1	UrcbTrk.gi	_[j]	GI attribute value in the request or target URCB object
LTRK1	SgcbTrk.objRef	_[j]	ACSI reference of the SGCB object targeted in the request
LTRK1	SgcbTrk.serviceType	_[j, k]	Type of service requested (SelectActiveSG)
LTRK1	SgcbTrk.errorCode	_[j, l]	ACSI service error status
LTRK1	SgcbTrk.numOfSG	_[j]	NumOfSG attribute value in the target SGCB object
LTRK1	SgcbTrk.actSG	_[j]	ActSG attribute value in the request
LTRK1	SgcbTrk.editSG	_[j]	EditSG attribute value in the target SGCB object (0)

Table 17.28 Logical Device: CFG (Configuration) (Sheet 8 of 8)

Logical Node	Attribute	Data Source	Comment
LTRK1	SgcbTrk.cnfEdit	_[j]	CnfEdit attribute value in the target SGCB object (FALSE)
LTRK1	SgcbTrk.lActTm	_[j]	LActTm attribute value in the target SGCB object after the activation of the settings group via MMS or non-MMS means

[a] I60MOD is an internal data source derived from the I850MOD analog quantity and is not available to the user.
[b] Internal data source and not available to the user.
[c] Only applicable when using the five-port Ethernet card.
[d] Where n = 1–64, corresponding to the first 64 GOOSE message subscriptions.
[e] Internal data source not available to the user. See COM SV on page 14.18 and GOOSE on page 14.38 for more information.
[f] Where n = 1–7, corresponding to each of the seven possible SV subscriptions.
[g] HWREV is an internal data source and is not available to the user.
[h] If enabled, value = 1. If disabled, value = 3.
[i] Data source defined in the IEC 61850 Configured IED Description (CID) file.
[j] The value depends on the ACSI service type requested, the target object, and the error status.
[k] Refer to Table 17.12 IEC 61850 service type enumeration.
[l] Refer to Table 17.13 IEC 61850 ACSI service error.

Table 17.29 shows the LNs associated with control elements, defined as Logical Device CON.

NOTE: For logical node PRBGGIO, writing TRUE to either operSet or operClear pulses the remote bit.

Table 17.29 Logical Device: CON (Remote Control) (Sheet 1 of 6)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = CO			
RB1GGIO1[a]	SPCSO01.Oper.ctlVal	RB01	Remote Bit 1
RB1GGIO1[a]	SPCSO02.Oper.ctlVal	RB02	Remote Bit 2
RB1GGIO1[a]	SPCSO03.Oper.ctlVal	RB03	Remote Bit 3
RB1GGIO1[a]	SPCSO04.Oper.ctlVal	RB04	Remote Bit 4
RB1GGIO1[a]	SPCSO05.Oper.ctlVal	RB05	Remote Bit 5
RB1GGIO1[a]	SPCSO06.Oper.ctlVal	RB06	Remote Bit 6
RB1GGIO1[a]	SPCSO07.Oper.ctlVal	RB07	Remote Bit 7
RB1GGIO1[a]	SPCSO08.Oper.ctlVal	RB08	Remote Bit 8
RB2GGIO1[a]	SPCSO09.Oper.ctlVal	RB09	Remote Bit 9
RB2GGIO1[a]	SPCSO10.Oper.ctlVal	RB10	Remote Bit 10
RB2GGIO1[a]	SPCSO11.Oper.ctlVal	RB11	Remote Bit 11
RB2GGIO1[a]	SPCSO12.Oper.ctlVal	RB12	Remote Bit 12
RB2GGIO1[a]	SPCSO13.Oper.ctlVal	RB13	Remote Bit 13
RB2GGIO1[a]	SPCSO14.Oper.ctlVal	RB14	Remote Bit 14
RB2GGIO1[a]	SPCSO15.Oper.ctlVal	RB15	Remote Bit 15
RB2GGIO1[a]	SPCSO16.Oper.ctlVal	RB16	Remote Bit 16
RB3GGIO1[a]	SPCSO17.Oper.ctlVal	RB17	Remote Bit 17
RB3GGIO1[a]	SPCSO18.Oper.ctlVal	RB18	Remote Bit 18
RB3GGIO1[a]	SPCSO19.Oper.ctlVal	RB19	Remote Bit 19
RB3GGIO1[a]	SPCSO20.Oper.ctlVal	RB20	Remote Bit 20
RB3GGIO1[a]	SPCSO21.Oper.ctlVal	RB21	Remote Bit 21
RB3GGIO1[a]	SPCSO22.Oper.ctlVal	RB22	Remote Bit 22
RB3GGIO1[a]	SPCSO23.Oper.ctlVal	RB23	Remote Bit 23
RB3GGIO1[a]	SPCSO24.Oper.ctlVal	RB24	Remote Bit 24

Table 17.29 Logical Device: CON (Remote Control) (Sheet 2 of 6)

Logical Node	Attribute	Data Source	Comment
RB4GGIO1[a]	SPCSO25.Oper.ctlVal	RB25	Remote Bit 25
RB4GGIO1[a]	SPCSO26.Oper.ctlVal	RB26	Remote Bit 26
RB4GGIO1[a]	SPCSO27.Oper.ctlVal	RB27	Remote Bit 27
RB4GGIO1[a]	SPCSO28.Oper.ctlVal	RB28	Remote Bit 28
RB4GGIO1[a]	SPCSO29.Oper.ctlVal	RB29	Remote Bit 29
RB4GGIO1[a]	SPCSO30.Oper.ctlVal	RB30	Remote Bit 30
RB4GGIO1[a]	SPCSO31.Oper.ctlVal	RB31	Remote Bit 31
RB4GGIO1[a]	SPCSO32.Oper.ctlVal	RB32	Remote Bit 32
RB5GGIO1	SPCSO33.Oper.ctlVal	RB33	Remote Bit 33
RB5GGIO1	SPCSO34.Oper.ctlVal	RB34	Remote Bit 34
RB5GGIO1	SPCSO35.Oper.ctlVal	RB35	Remote Bit 35
RB5GGIO1	SPCSO36.Oper.ctlVal	RB36	Remote Bit 36
RB5GGIO1	SPCSO37.Oper.ctlVal	RB37	Remote Bit 37
RB5GGIO1	SPCSO38.Oper.ctlVal	RB38	Remote Bit 38
RB5GGIO1	SPCSO39.Oper.ctlVal	RB39	Remote Bit 39
RB5GGIO1	SPCSO40.Oper.ctlVal	RB40	Remote Bit 40
RB6GGIO1	SPCSO41.Oper.ctlVal	RB41	Remote Bit 41
RB6GGIO1	SPCSO42.Oper.ctlVal	RB42	Remote Bit 42
RB6GGIO1	SPCSO43.Oper.ctlVal	RB43	Remote Bit 43
RB6GGIO1	SPCSO44.Oper.ctlVal	RB44	Remote Bit 44
RB6GGIO1	SPCSO45.Oper.ctlVal	RB45	Remote Bit 45
RB6GGIO1	SPCSO46.Oper.ctlVal	RB46	Remote Bit 46
RB6GGIO1	SPCSO47.Oper.ctlVal	RB47	Remote Bit 47
RB6GGIO1	SPCSO48.Oper.ctlVal	RB48	Remote Bit 48
RB7GGIO1	SPCSO49.Oper.ctlVal	RB49	Remote Bit 49
RB7GGIO1	SPCSO50.Oper.ctlVal	RB50	Remote Bit 50
RB7GGIO1	SPCSO51.Oper.ctlVal	RB51	Remote Bit 51
RB7GGIO1	SPCSO52.Oper.ctlVal	RB52	Remote Bit 52
RB7GGIO1	SPCSO53.Oper.ctlVal	RB53	Remote Bit 53
RB7GGIO1	SPCSO54.Oper.ctlVal	RB54	Remote Bit 54
RB7GGIO1	SPCSO55.Oper.ctlVal	RB55	Remote Bit 55
RB7GGIO1	SPCSO56.Oper.ctlVal	RB56	Remote Bit 56
RB8GGIO1	SPCSO57.Oper.ctlVal	RB57	Remote Bit 57
RB8GGIO1	SPCSO58.Oper.ctlVal	RB58	Remote Bit 58
RB8GGIO1	SPCSO59.Oper.ctlVal	RB59	Remote Bit 59
RB8GGIO1	SPCSO60.Oper.ctlVal	RB60	Remote Bit 60
RB8GGIO1	SPCSO61.Oper.ctlVal	RB61	Remote Bit 61
RB8GGIO1	SPCSO62.Oper.ctlVal	RB62	Remote Bit 62
RB8GGIO1	SPCSO63.Oper.ctlVal	RB63	Remote Bit 63
RB8GGIO1	SPCSO64.Oper.ctlVal	RB64	Remote Bit 64
RB9GGIO1[b]	SPCSO65.Oper.ctlVal	RB65	Remote Bit 65

Table 17.29 Logical Device: CON (Remote Control) (Sheet 3 of 6)

Logical Node	Attribute	Data Source	Comment
RB9GGIO1[b]	SPCSO66.Oper.ctlVal	RB66	Remote Bit 66
RB9GGIO1[b]	SPCSO67.Oper.ctlVal	RB67	Remote Bit 67
RB9GGIO1[b]	SPCSO68.Oper.ctlVal	RB68	Remote Bit 68
RB9GGIO1[b]	SPCSO69.Oper.ctlVal	RB69	Remote Bit 69
RB9GGIO1[b]	SPCSO70.Oper.ctlVal	RB70	Remote Bit 70
RB9GGIO1[b]	SPCSO71.Oper.ctlVal	RB71	Remote Bit 71
RB9GGIO1[b]	SPCSO72.Oper.ctlVal	RB72	Remote Bit 72
RB10GGIO1[b]	SPCSO73.Oper.ctlVal	RB73	Remote Bit 73
RB10GGIO1[b]	SPCSO74.Oper.ctlVal	RB74	Remote Bit 74
RB10GGIO1[b]	SPCSO75.Oper.ctlVal	RB75	Remote Bit 75
RB10GGIO1[b]	SPCSO76.Oper.ctlVal	RB76	Remote Bit 76
RB10GGIO1[b]	SPCSO77.Oper.ctlVal	RB77	Remote Bit 77
RB10GGIO1[b]	SPCSO78.Oper.ctlVal	RB78	Remote Bit 78
RB10GGIO1[b]	SPCSO79.Oper.ctlVal	RB79	Remote Bit 79
RB10GGIO1[b]	SPCSO80.Oper.ctlVal	RB80	Remote Bit 80
RB11GGIO1[b]	SPCSO81.Oper.ctlVal	RB81	Remote Bit 81
RB11GGIO1[b]	SPCSO82.Oper.ctlVal	RB82	Remote Bit 82
RB11GGIO1[b]	SPCSO83.Oper.ctlVal	RB83	Remote Bit 83
RB11GGIO1[b]	SPCSO84.Oper.ctlVal	RB84	Remote Bit 84
RB11GGIO1[b]	SPCSO85.Oper.ctlVal	RB85	Remote Bit 85
RB11GGIO1[b]	SPCSO86.Oper.ctlVal	RB86	Remote Bit 86
RB11GGIO1[b]	SPCSO87.Oper.ctlVal	RB87	Remote Bit 87
RB11GGIO1[b]	SPCSO88.Oper.ctlVal	RB88	Remote Bit 88
RB12GGIO1[b]	SPCSO89.Oper.ctlVal	RB89	Remote Bit 89
RB12GGIO1[b]	SPCSO90.Oper.ctlVal	RB90	Remote Bit 90
RB12GGIO1[b]	SPCSO91.Oper.ctlVal	RB91	Remote Bit 91
RB12GGIO1[b]	SPCSO92.Oper.ctlVal	RB92	Remote Bit 92
RB12GGIO1[b]	SPCSO93.Oper.ctlVal	RB93	Remote Bit 93
RB12GGIO1[b]	SPCSO94.Oper.ctlVal	RB94	Remote Bit 94
RB12GGIO1[b]	SPCSO95.Oper.ctlVal	RB95	Remote Bit 95
RB12GGIO1[b]	SPCSO96.Oper.ctlVal	RB96	Remote Bit 96
Functional Constraint = DC			
CTRLLPHD1	PhyNam.model	PARNUM	Relay part number string
CTRLLPHD1	PhyNam.hwRev	HWREV[c]	Hardware version of the relay main board
CTRLLPHD1	PhyNam.serNum	SERNUM	Relay serial number
LLN0	NamPlt.swRev	VERFID	Relay FID string
Functional Constraint = ST			
CTRLLPHD1	PhyHealth.stVal	EN?3:1[d]	Relay enabled
LLN0	Mod.stVal	I60MOD[e]	IEC 61850 mode/behavior status
LLN0	Loc.stVal	LOC	Control authority at local (bay) level

Table 17.29 Logical Device: CON (Remote Control) (Sheet 4 of 6)

Logical Node	Attribute	Data Source	Comment
LLN0	LocSta.stVal	LOCSTA	Control authority at station level
LLN0	LocKey.stVal	NOOP	
RB1GGIO1	SPCSO01.stVal	RB01	Remote Bit 1
RB1GGIO1	SPCSO02.stVal	RB02	Remote Bit 2
RB1GGIO1	SPCSO03.stVal	RB03	Remote Bit 3
RB1GGIO1	SPCSO04.stVal	RB04	Remote Bit 4
RB1GGIO1	SPCSO05.stVal	RB05	Remote Bit 5
RB1GGIO1	SPCSO06.stVal	RB06	Remote Bit 6
RB1GGIO1	SPCSO07.stVal	RB07	Remote Bit 7
RB1GGIO1	SPCSO08.stVal	RB08	Remote Bit 8
RB2GGIO1	SPCSO09.stVal	RB09	Remote Bit 9
RB2GGIO1	SPCSO10.stVal	RB10	Remote Bit 10
RB2GGIO1	SPCSO11.stVal	RB11	Remote Bit 11
RB2GGIO1	SPCSO12.stVal	RB12	Remote Bit 12
RB2GGIO1	SPCSO13.stVal	RB13	Remote Bit 13
RB2GGIO1	SPCSO14.stVal	RB14	Remote Bit 14
RB2GGIO1	SPCSO15.stVal	RB15	Remote Bit 15
RB2GGIO1	SPCSO16.stVal	RB16	Remote Bit 16
RB3GGIO1	SPCSO17.stVal	RB17	Remote Bit 17
RB3GGIO1	SPCSO18.stVal	RB18	Remote Bit 18
RB3GGIO1	SPCSO19.stVal	RB19	Remote Bit 19
RB3GGIO1	SPCSO20.stVal	RB20	Remote Bit 20
RB3GGIO1	SPCSO21.stVal	RB21	Remote Bit 21
RB3GGIO1	SPCSO22.stVal	RB22	Remote Bit 22
RB3GGIO1	SPCSO23.stVal	RB23	Remote Bit 23
RB3GGIO1	SPCSO24.stVal	RB24	Remote Bit 24
RB4GGIO1	SPCSO25.stVal	RB25	Remote Bit 25
RB4GGIO1	SPCSO26.stVal	RB26	Remote Bit 26
RB4GGIO1	SPCSO27.stVal	RB27	Remote Bit 27
RB4GGIO1	SPCSO28.stVal	RB28	Remote Bit 28
RB4GGIO1	SPCSO29.stVal	RB29	Remote Bit 29
RB4GGIO1	SPCSO30.stVal	RB30	Remote Bit 30
RB4GGIO1	SPCSO31.stVal	RB31	Remote Bit 31
RB4GGIO1	SPCSO32.stVal	RB32	Remote Bit 32
RB5GGIO1	SPCSO33.stVal	RB33	Remote Bit 33
RB5GGIO1	SPCSO34.stVal	RB34	Remote Bit 34
RB5GGIO1	SPCSO35.stVal	RB35	Remote Bit 35
RB5GGIO1	SPCSO36.stVal	RB36	Remote Bit 36
RB5GGIO1	SPCSO37.stVal	RB37	Remote Bit 37
RB5GGIO1	SPCSO38.stVal	RB38	Remote Bit 38
RB5GGIO1	SPCSO39.stVal	RB39	Remote Bit 39

Table 17.29 Logical Device: CON (Remote Control) (Sheet 5 of 6)

Logical Node	Attribute	Data Source	Comment
RB5GGIO1	SPCSO40.stVal	RB40	Remote Bit 40
RB6GGIO1	SPCSO41.stVal	RB41	Remote Bit 41
RB6GGIO1	SPCSO42.stVal	RB42	Remote Bit 42
RB6GGIO1	SPCSO43.stVal	RB43	Remote Bit 43
RB6GGIO1	SPCSO44.stVal	RB44	Remote Bit 44
RB6GGIO1	SPCSO45.stVal	RB45	Remote Bit 45
RB6GGIO1	SPCSO46.stVal	RB46	Remote Bit 46
RB6GGIO1	SPCSO47.stVal	RB47	Remote Bit 47
RB6GGIO1	SPCSO48.stVal	RB48	Remote Bit 48
RB7GGIO1	SPCSO49.stVal	RB49	Remote Bit 49
RB7GGIO1	SPCSO50.stVal	RB50	Remote Bit 50
RB7GGIO1	SPCSO51.stVal	RB51	Remote Bit 51
RB7GGIO1	SPCSO52.stVal	RB52	Remote Bit 52
RB7GGIO1	SPCSO53.stVal	RB53	Remote Bit 53
RB7GGIO1	SPCSO54.stVal	RB54	Remote Bit 54
RB7GGIO1	SPCSO55.stVal	RB55	Remote Bit 55
RB7GGIO1	SPCSO56.stVal	RB56	Remote Bit 56
RB8GGIO1	SPCSO57.stVal	RB57	Remote Bit 57
RB8GGIO1	SPCSO58.stVal	RB58	Remote Bit 58
RB8GGIO1	SPCSO59.stVal	RB59	Remote Bit 59
RB8GGIO1	SPCSO60.stVal	RB60	Remote Bit 60
RB8GGIO1	SPCSO61.stVal	RB61	Remote Bit 61
RB8GGIO1	SPCSO62.stVal	RB62	Remote Bit 62
RB8GGIO1	SPCSO63.stVal	RB63	Remote Bit 63
RB8GGIO1	SPCSO64.stVal	RB64	Remote Bit 64
RB9GGIO1[b]	SPCSO65.stVal	RB65	Remote Bit 65
RB9GGIO1[b]	SPCSO66.stVal	RB66	Remote Bit 66
RB9GGIO1[b]	SPCSO67.stVal	RB67	Remote Bit 67
RB9GGIO1[b]	SPCSO68.stVal	RB68	Remote Bit 68
RB9GGIO1[b]	SPCSO69.stVal	RB69	Remote Bit 69
RB9GGIO1[b]	SPCSO70.stVal	RB70	Remote Bit 70
RB9GGIO1[b]	SPCSO71.stVal	RB71	Remote Bit 71
RB9GGIO1[b]	SPCSO72.stVal	RB72	Remote Bit 72
RB10GGIO1[b]	SPCSO73.stVal	RB73	Remote Bit 73
RB10GGIO1[b]	SPCSO74.stVal	RB74	Remote Bit 74
RB10GGIO1[b]	SPCSO75.stVal	RB75	Remote Bit 75
RB10GGIO1[b]	SPCSO76.stVal	RB76	Remote Bit 76
RB10GGIO1[b]	SPCSO77.stVal	RB77	Remote Bit 77
RB10GGIO1[b]	SPCSO78.stVal	RB78	Remote Bit 78
RB10GGIO1[b]	SPCSO79.stVal	RB79	Remote Bit 79
RB10GGIO1[b]	SPCSO80.stVal	RB80	Remote Bit 80

Table 17.29 Logical Device: CON (Remote Control) (Sheet 6 of 6)

Logical Node	Attribute	Data Source	Comment
RB11GGIO1[b]	SPCSO81.stVal	RB81	Remote Bit 81
RB11GGIO1[b]	SPCSO82.stVal	RB82	Remote Bit 82
RB11GGIO1[b]	SPCSO83.stVal	RB83	Remote Bit 83
RB11GGIO1[b]	SPCSO84.stVal	RB84	Remote Bit 84
RB11GGIO1[b]	SPCSO85.stVal	RB85	Remote Bit 85
RB11GGIO1[b]	SPCSO86.stVal	RB86	Remote Bit 86
RB11GGIO1[b]	SPCSO87.stVal	RB87	Remote Bit 87
RB12GGIO1[b]	SPCSO88.stVal	RB88	Remote Bit 88
RB12GGIO1[b]	SPCSO89.stVal	RB89	Remote Bit 89
RB12GGIO1[b]	SPCSO90.stVal	RB90	Remote Bit 90
RB12GGIO1[b]	SPCSO91.stVal	RB91	Remote Bit 91
RB12GGIO1[b]	SPCSO92.stVal	RB92	Remote Bit 92
RB12GGIO1[b]	SPCSO93.stVal	RB93	Remote Bit 93
RB12GGIO1[b]	SPCSO94.stVal	RB94	Remote Bit 94
RB12GGIO1[b]	SPCSO95.stVal	RB95	Remote Bit 95
RB12GGIO1[b]	SPCSO96.stVal	RB96	Remote Bit 96
Functional Constraint = SP			
LLN0	GrRef.setSrcRef	@CFG	Functional name

[a] The SEL-487V supports only RBGGIO1–RBGGIO4 and PRBGGIO1–PRBGGIO4.
[b] Only the SEL-487B and SEL-487E support RBGGIO9–RBGGIO12 and PRBGGIO9–PRBGGIO12.
[c] HWREV is an internal data source and is not available to the user.
[d] If enabled, value = 1. If disabled, value = 3.
[e] I60MOD is an internal data source derived from the I850MOD analog quantity and is not available to the user.

Table 17.30 shows the LNs associated with the annunciation element, defined as Logical Device ANN.

Table 17.30 Logical Device: ANN (Annunciation) (Sheet 1 of 17)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = CO			
ETH1GGIO1	SPCSO01.Oper.ctlVal	ETHRST[a, b]	Reset Ethernet card statistics
Functional Constraint = DC			
STALPHD1	PhyNam.model	PARNUM	Relay part number string
STALPHD1	PhyNam.hwRev	HWREV[c]	Hardware version of the relay main board
STALPHD1	PhyNam.serNum	SERNUM	Relay serial number
LLN0	NamPlt.swRev	VERFID	Relay FID string
Functional Constraint = MX			
ACN1GGIO1	AnIn001.instMag.f	ACN01CV	Automation SELOGIC Counter 01 current value
ACN1GGIO1	AnIn002.instMag.f	ACN02CV	Automation SELOGIC Counter 02 current value
ACN1GGIO1	AnIn003.instMag.f	ACN03CV	Automation SELOGIC Counter 03 current value
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Table 17.30 Logical Device: ANN (Annunciation) (Sheet 2 of 17)

Logical Node	Attribute	Data Source	Comment
ACN1GGIO1	AnIn014.instMag.f	ACN14CV	Automation SELOGIC Counter 14 current value
ACN1GGIO1	AnIn015.instMag.f	ACN15CV	Automation SELOGIC Counter 15 current value
ACN1GGIO1	AnIn016.instMag.f	ACN16CV	Automation SELOGIC Counter 16 current value
AMV1GGIO1	AnIn001.instMag.f	AMV001	Automation SELOGIC Math Variable 001
AMV1GGIO1	AnIn002.instMag.f	AMV002	Automation SELOGIC Math Variable 002
AMV1GGIO1	AnIn003.instMag.f	AMV003	Automation SELOGIC Math Variable 003
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AMV1GGIO1	AnIn030.instMag.f	AMV030	Automation SELOGIC Math Variable 030
AMV1GGIO1	AnIn031.instMag.f	AMV031	Automation SELOGIC Math Variable 031
AMV1GGIO1	AnIn032.instMag.f	AMV032	Automation SELOGIC Math Variable 032
AMV2GGIO1	AnIn001.instMag.f	AMV033	Automation SELOGIC Math Variable 033
AMV2GGIO1	AnIn002.instMag.f	AMV034	Automation SELOGIC Math Variable 034
AMV2GGIO1	AnIn003.instMag.f	AMV035	Automation SELOGIC Math Variable 035
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AMV2GGIO1	AnIn030.instMag.f	AMV062	Automation SELOGIC Math Variable 062
AMV2GGIO1	AnIn031.instMag.f	AMV063	Automation SELOGIC Math Variable 063
AMV2GGIO1	AnIn032.instMag.f	AMV064	Automation SELOGIC Math Variable 064
AMV3GGIO1	AnIn001.instMag.f	AMV065	Automation SELOGIC Math Variable 065
AMV3GGIO1	AnIn002.instMag.f	AMV066	Automation SELOGIC Math Variable 066
AMV3GGIO1	AnIn003.instMag.f	AMV067	Automation SELOGIC Math Variable 067
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AMV3GGIO1	AnIn030.instMag.f	AMV094	Automation SELOGIC Math Variable 094
AMV3GGIO1	AnIn031.instMag.f	AMV095	Automation SELOGIC Math Variable 095
AMV3GGIO1	AnIn032.instMag.f	AMV096	Automation SELOGIC Math Variable 096
AMV4GGIO1	AnIn001.instMag.f	AMV097	Automation SELOGIC Math Variable 097
AMV4GGIO1	AnIn002.instMag.f	AMV098	Automation SELOGIC Math Variable 098
AMV4GGIO1	AnIn003.instMag.f	AMV099	Automation SELOGIC Math Variable 099
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AMV4GGIO1	AnIn030.instMag.f	AMV126	Automation SELOGIC Math Variable 126
AMV4GGIO1	AnIn031.instMag.f	AMV127	Automation SELOGIC Math Variable 127
AMV4GGIO1	AnIn032.instMag.f	AMV128	Automation SELOGIC Math Variable 128
ETH2GGIO1	AnIn01.instMag.f	P5ARXP[a, b]	SFP transceiver receive power info (dBm) on PORT 5A
ETH2GGIO1	AnIn02.instMag.f	P5BRXP[a, b]	SFP transceiver receive power info (dBm) on PORT 5B
ETH2GGIO1	AnIn03.instMag.f	P5CRXP[a, b]	SFP transceiver receive power info (dBm) on PORT 5C
ETH2GGIO1	AnIn04.instMag.f	P5DRXP[a, b]	SFP transceiver receive power info (dBm) on PORT 5D

Table 17.30 Logical Device: ANN (Annunciation) (Sheet 3 of 17)

Logical Node	Attribute	Data Source	Comment
ETH2GGIO1	AnIn05.instMag.f	P5ERXP[a, b]	SFP transceiver receive power info (dBm) on PORT 5E
ETH2GGIO1	AnIn06.instMag.f	P5ATXP[a, b]	SFP transceiver transmit power info (dBm) on PORT 5A
ETH2GGIO1	AnIn07.instMag.f	P5BTXP[a, b]	SFP transceiver transmit power info (dBm) on PORT 5B
ETH2GGIO1	AnIn08.instMag.f	P5CTXP[a, b]	SFP transceiver transmit power info (dBm) on PORT 5C
ETH2GGIO1	AnIn09.instMag.f	P5DTXP[a, b]	SFP transceiver transmit power info (dBm) on PORT 5D
ETH2GGIO1	AnIn10.instMag.f	P5ETXP[a, b]	SFP transceiver transmit power info (dBm) on PORT 5E
ETH2GGIO1	AnIn11.instMag.f	P5ATMP[a, b]	SFP transceiver temperature info (°C) on PORT 5A
ETH2GGIO1	AnIn12.instMag.f	P5BTMP[a, b]	SFP transceiver temperature info (°C) on PORT 5B
ETH2GGIO1	AnIn13.instMag.f	P5CTMP[a, b]	SFP transceiver temperature info (°C) on PORT 5C
ETH2GGIO1	AnIn14.instMag.f	P5DTMP[a, b]	SFP transceiver temperature info (°C) on PORT 5D
ETH2GGIO1	AnIn15.instMag.f	P5ETMP[a, b]	SFP transceiver temperature info (°C) on PORT 5E
PCNGGIO1	AnIn001.instMag.f	PCN01CV	Protection SELOGIC Counter 01 current value
PCN1GGIO1	AnIn002.instMag.f	PCN02CV	Protection SELOGIC Counter 02 current value
PCN1GGIO1	AnIn003.instMag.f	PCN03CV	Protection SELOGIC Counter 03 current value
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PCN1GGIO1	AnIn014.instMag.f	PCN14CV	Protection SELOGIC Counter 14 current value
PCN1GGIO1	AnIn015.instMag.f	PCN15CV	Protection SELOGIC Counter 15 current value
PCN1GGIO1	AnIn016.instMag.f	PCN16CV	Protection SELOGIC Counter 16 current value
PMV1GGIO1	AnIn01.instMag.f	PMV01	Protection SELOGIC Math Variable 01
PMV1GGIO1	AnIn02.instMag.f	PMV02	Protection SELOGIC Math Variable 02
PMV1GGIO1	AnIn03.instMag.f	PMV03	Protection SELOGIC Math Variable 03
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PMV1GGIO1	AnIn30.instMag.f	PMV30	Protection SELOGIC Math Variable 30
PMV1GGIO1	AnIn31.instMag.f	PMV31	Protection SELOGIC Math Variable 31
PMV1GGIO1	AnIn32.instMag.f	PMV32	Protection SELOGIC Math Variable 32
PMV2GGIO1	AnIn01.instMag.f	PMV33	Protection SELOGIC Math Variable 33
PMV2GGIO1	AnIn02.instMag.f	PMV34	Protection SELOGIC Math Variable 34
PMV2GGIO1	AnIn03.instMag.f	PMV35	Protection SELOGIC Math Variable 35
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PMV2GGIO1	AnIn30.instMag.f	PMV62	Protection SELOGIC Math Variable 62
PMV2GGIO1	AnIn31.instMag.f	PMV63	Protection SELOGIC Math Variable 63
PMV2GGIO1	AnIn32.instMag.f	PMV64	Protection SELOGIC Math Variable 64
RAI1GGIO1	AnIn01.instMag.f	RA001	Remote Analog Input 001
RAI1GGIO1	AnIn02.instMag.f	RA002	Remote Analog Input 002
RAI1GGIO1	AnIn03.instMag.f	RA003	Remote Analog Input 003

Table 17.30 Logical Device: ANN (Annunciation) (Sheet 4 of 17)

Logical Node	Attribute	Data Source	Comment
• • •			
RAI1GGIO1	AnIn30.instMag.f	RA030	Remote Analog Input 030
RAI1GGIO1	AnIn31.instMag.f	RA031	Remote Analog Input 031
RAI1GGIO1	AnIn32.instMag.f	RA032	Remote Analog Input 032
RAI2GGIO1	AnIn01.instMag.f	RA033	Remote Analog Input 033
RAI2GGIO1	AnIn02.instMag.f	RA034	Remote Analog Input 034
RAI2GGIO1	AnIn03.instMag.f	RA035	Remote Analog Input 035
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RAI2GGIO1	AnIn30.instMag.f	RA062	Remote Analog Input 062
RAI2GGIO1	AnIn31.instMag.f	RA063	Remote Analog Input 063
RAI2GGIO1	AnIn32.instMag.f	RA064	Remote Analog Input 064
RAI3GGIO1	AnIn01.instMag.f	RA065	Remote Analog Input 065
RAI3GGIO1	AnIn02.instMag.f	RA066	Remote Analog Input 066
RAI3GGIO1	AnIn03.instMag.f	RA067	Remote Analog Input 067
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RAI3GGIO1	AnIn30.instMag.f	RA094	Remote Analog Input 094
RAI3GGIO1	AnIn31.instMag.f	RA095	Remote Analog Input 095
RAI3GGIO1	AnIn32.instMag.f	RA096	Remote Analog Input 096
RAI4GGIO1	AnIn01.instMag.f	RA097	Remote Analog Input 097
RAI4GGIO1	AnIn02.instMag.f	RA098	Remote Analog Input 098
RAI4GGIO1	AnIn03.instMag.f	RA099	Remote Analog Input 099
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RAI4GGIO1	AnIn30.instMag.f	RA126	Remote Analog Input 126
RAI4GGIO1	AnIn31.instMag.f	RA127	Remote Analog Input 127
RAI4GGIO1	AnIn32.instMag.f	RA128	Remote Analog Input 128
RAI5GGIO1	AnIn01.instMag.f	RA129	Remote Analog Input 129
RAI5GGIO1	AnIn02.instMag.f	RA130	Remote Analog Input 130
RAI5GGIO1	AnIn03.instMag.f	RA131	Remote Analog Input 131
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RAI5GGIO1	AnIn30.instMag.f	RA158	Remote Analog Input 158
RAI5GGIO1	AnIn31.instMag.f	RA159	Remote Analog Input 159
RAI5GGIO1	AnIn32.instMag.f	RA160	Remote Analog Input 160
RAI6GGIO1	AnIn01.instMag.f	RA161	Remote Analog Input 161

Table 17.30 Logical Device: ANN (Annunciation) (Sheet 5 of 17)

Logical Node	Attribute	Data Source	Comment
RAI6GGIO1	AnIn02.instMag.f	RA162	Remote Analog Input 162
RAI6GGIO1	AnIn03.instMag.f	RA163	Remote Analog Input 163
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RAI6GGIO1	AnIn30.instMag.f	RA190	Remote Analog Input 190
RAI6GGIO1	AnIn31.instMag.f	RA191	Remote Analog Input 191
RAI6GGIO1	AnIn32.instMag.f	RA192	Remote Analog Input 192
RAI7GGIO1	AnIn01.instMag.f	RA193	Remote Analog Input 193
RAI7GGIO1	AnIn02.instMag.f	RA194	Remote Analog Input 194
RAI7GGIO1	AnIn03.instMag.f	RA195	Remote Analog Input 195
• • •			
RAI7GGIO1	AnIn30.instMag.f	RA222	Remote Analog Input 222
RAI7GGIO1	AnIn31.instMag.f	RA223	Remote Analog Input 223
RAI7GGIO1	AnIn32.instMag.f	RA224	Remote Analog Input 224
RAI8GGIO1	AnIn01.instMag.f	RA225	Remote Analog Input 225
RAI8GGIO1	AnIn02.instMag.f	RA226	Remote Analog Input 226
RAI8GGIO1	AnIn03.instMag.f	RA227	Remote Analog Input 227
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RAI8GGIO1	AnIn30.instMag.f	RA254	Remote Analog Input 254
RAI8GGIO1	AnIn31.instMag.f	RA255	Remote Analog Input 255
RAI8GGIO1	AnIn32.instMag.f	RA256	Remote Analog Input 256
RAO1GGIO1	AnIn01.instMag.f	RAO01	Remote Analog Output 01
RAO1GGIO1	AnIn02.instMag.f	RAO02	Remote Analog Output 02
RAO1GGIO1	AnIn03.instMag.f	RAO03	Remote Analog Output 03
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RAO1GGIO1	AnIn30.instMag.f	RAO30	Remote Analog Output 30
RAO1GGIO1	AnIn31.instMag.f	RAO31	Remote Analog Output 31
RAO1GGIO1	AnIn32.instMag.f	RAO32	Remote Analog Output 32
RAO2GGIO1	AnIn01.instMag.f	RAO33	Remote Analog Output 33
RAO2GGIO1	AnIn02.instMag.f	RAO34	Remote Analog Output 34
RAO2GGIO1	AnIn03.instMag.f	RAO35	Remote Analog Output 35
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RAO2GGIO1	AnIn30.instMag.f	RAO62	Remote Analog Output 62

Table 17.30 Logical Device: ANN (Annunciation) (Sheet 6 of 17)

Logical Node	Attribute	Data Source	Comment
RAO2GGIO1	AnIn31.instMag.f	RAO63	Remote Analog Output 63
RAO2GGIO1	AnIn32.instMag.f	RAO64	Remote Analog Output 64
Functional Constraint = ST			
STALPHD1	PhyHealth.stVal	EN?3:1[d]	Relay enabled
LLN0	Mod.stVal	I60MOD[e]	IEC 61850 mode/behavior status
LLN0	Loc.stVal	LOC	Control authority at local (bay) level
LLN0	LocSta.stVal	LOCSTA	Control authority at station level
LLN0	LocKey.stVal	NOOP	
ALMGGIO1	Ind01.stVal	SALARM	Software alarm
ALMGGIO1	Ind02.stVal	HALARM	Hardware alarm
ALMGGIO1	Ind03.stVal	BADPASS	Invalid password attempt alarm
ALMGGIO1	Ind04.stVal	SETCHG	Pulsed alarm for settings changes
ALMGGIO1	Ind05.stVal	GRPSW	Pulsed alarm for group switches
ALMGGIO1	Ind06.stVal	ACCESS	A user is logged in at Access Level B or higher
ALMGGIO1	Ind07.stVal	PASSDIS	Asserts to indicate password disable jumper is installed
ALMGGIO1	Ind08.stVal	BRKENAB	Asserts to indicate breaker control enable jumper is installed
ALT1GGIO1	Ind01.stVal	ALT01	Automation Latch 1
ALT1GGIO1	Ind02.stVal	ALT02	Automation Latch 2
ALT1GGIO1	Ind03.stVal	ALT03	Automation Latch 3
• • •			
ALT1GGIO1	Ind30.stVal	ALT30	Automation Latch 30
ALT1GGIO1	Ind31.stVal	ALT31	Automation Latch 31
ALT1GGIO1	Ind32.stVal	ALT32	Automation Latch 32
ASV1GGIO1	Ind01.stVal	ASV001	Automation SELOGIC Variable 1
ASV1GGIO1	Ind02.stVal	ASV002	Automation SELOGIC Variable 2
ASV1GGIO1	Ind03.stVal	ASV003	Automation SELOGIC Variable 3
• • •			
ASV1GGIO1	Ind30.stVal	ASV030	Automation SELOGIC Variable 30
ASV1GGIO1	Ind31.stVal	ASV031	Automation SELOGIC Variable 31
ASV1GGIO1	Ind32.stVal	ASV032	Automation SELOGIC Variable 32
ASV2GGIO1	Ind01.stVal	ASV033	Automation SELOGIC Variable 33
ASV2GGIO1	Ind02.stVal	ASV034	Automation SELOGIC Variable 34
ASV2GGIO1	Ind03.stVal	ASV035	Automation SELOGIC Variable 35
• • •			
ASV2GGIO1	Ind30.stVal	ASV062	Automation SELOGIC Variable 62
ASV2GGIO1	Ind31.stVal	ASV063	Automation SELOGIC Variable 63

Table 17.30 Logical Device: ANN (Annunciation) (Sheet 7 of 17)

Logical Node	Attribute	Data Source	Comment
ASV2GGIO1	Ind32.stVal	ASV064	Automation SELOGIC Variable 64
ASV3GGIO1	Ind01.stVal	ASV065	Automation SELOGIC Variable 65
ASV3GGIO1	Ind02.stVal	ASV066	Automation SELOGIC Variable 66
ASV3GGIO1	Ind03.stVal	ASV067	Automation SELOGIC Variable 67
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ASV3GGIO1	Ind30.stVal	ASV094	Automation SELOGIC Variable 94
ASV3GGIO1	Ind31.stVal	ASV095	Automation SELOGIC Variable 95
ASV3GGIO1	Ind32.stVal	ASV096	Automation SELOGIC Variable 96
ASV4GGIO1	Ind01.stVal	ASV097	Automation SELOGIC Variable 97
ASV4GGIO1	Ind02.stVal	ASV098	Automation SELOGIC Variable 98
ASV4GGIO1	Ind03.stVal	ASV099	Automation SELOGIC Variable 99
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ASV4GGIO1	Ind30.stVal	ASV126	Automation SELOGIC Variable 126
ASV4GGIO1	Ind31.stVal	ASV127	Automation SELOGIC Variable 127
ASV4GGIO1	Ind32.stVal	ASV128	Automation SELOGIC Variable 128
ETH1GGIO1	Ind01.stVal	P5ASEL	PORT 5A active/inactive
ETH1GGIO1	Ind02.stVal	LINK5A	Link status of PORT 5A connection
ETH1GGIO1	Ind03.stVal	P5BSEL	PORT 5B active/inactive
ETH1GGIO1	Ind04.stVal	LINK5B	Link status of PORT 5B connection
ETH1GGIO1	Ind05.stVal	P5CSEL	PORT 5C active/inactive
ETH1GGIO1	Ind06.stVal	LINK5C	Link status of PORT 5C connection
ETH1GGIO1	Ind07.stVal	P5DSEL	PORT 5D active/inactive
ETH1GGIO1	Ind08.stVal	LINK5D	Link status of PORT 5D connection
ETH1GGIO1	Ind09.stVal	LNKFAIL	Link status of the active station bus port
ETH1GGIO1	Ind10.stVal	LNKFL2[f]	Link status of the active process bus port
ETH1GGIO1	Ind11.stVal	P5ESEL[b]	PORT 5E active/inactive
ETH1GGIO1	Ind12.stVal	LINK5E[b]	Link status of the PORT 5E connection
ETH2GGIO1	CntVal01.actVal	P5ATPTX[a, b]	Total number of packets transmitted on PORT 5A
ETH2GGIO1	CntVal02.actVal	P5BTPTX[a, b]	Total number of packets transmitted on PORT 5B
ETH2GGIO1	CntVal03.actVal	P5CTPTX[a, b]	Total number of packets transmitted on PORT 5C
ETH2GGIO1	CntVal04.actVal	P5DTPTX[a, b]	Total number of packets transmitted on PORT 5D
ETH2GGIO1	CntVal05.actVal	P5ETPTX[a, b]	Total number of packets transmitted on PORT 5E
ETH2GGIO1	CntVal06.actVal	P5ATPRX[a, b]	Total number of packets received on PORT 5A
ETH2GGIO1	CntVal07.actVal	P5BTPRX[a, b]	Total number of packets received on PORT 5B
ETH2GGIO1	CntVal08.actVal	P5CTPRX[a, b]	Total number of packets received on PORT 5C
ETH2GGIO1	CntVal09.actVal	P5DTPRX[a, b]	Total number of packets received on PORT 5D
ETH2GGIO1	CntVal10.actVal	P5ETPRX[a, b]	Total number of packets received on PORT 5E
ETH2GGIO1	CntVal11.actVal	P5ATPDI[a, b]	Total number of packets discarded on PORT 5A

Table 17.30 Logical Device: ANN (Annunciation) (Sheet 8 of 17)

Logical Node	Attribute	Data Source	Comment
ETH2GGIO1	CntVal12.actVal	P5BTPDI[a, b]	Total number of packets discarded on PORT 5B
ETH2GGIO1	CntVal13.actVal	P5CTPDI[a, b]	Total number of packets discarded on PORT 5C
ETH2GGIO1	CntVal14.actVal	P5DTPDI[a, b]	Total number of packets discarded on PORT 5D
ETH2GGIO1	CntVal15.actVal	P5ETPDI[a, b]	Total number of packets discarded on PORT 5E
ETH2GGIO1	CntVal16.actVal	P5ATEPR[a, b]	Total number of erroneous packets received on PORT 5A
ETH2GGIO1	CntVal17.actVal	P5BTEPR[a, b]	Total number of erroneous packets received on PORT 5B
ETH2GGIO1	CntVal18.actVal	P5CTEPR[a, b]	Total number of erroneous packets received on PORT 5C
ETH2GGIO1	CntVal19.actVal	P5DTEPR[a, b]	Total number of erroneous packets received on PORT 5D
ETH2GGIO1	CntVal20.actVal	P5ETEPR[a, b]	Total number of erroneous packets received on PORT 5E
ETH2GGIO1	SPCSO01.stVal	ETHRST[a, b]	Status of Ethernet card statistics reset
HSRGGIO1	Ind01.stVal	HSRAOK[b]	HSR Port 5A status
HSRGGIO1	Ind02.stVal	HSRBOK[b]	HSR Port 5B status
HSRGGIO1	Ind03.stVal	HSRCOK[b]	HSR Port 5C status
HSRGGIO1	Ind04.stVal	HSRDOK[b]	HSR Port 5D status
HSRGGIO1	AnIn01.instMag.f	HSRSRTP[b]	Round-trip time for HSR supervision frames on process bus
HSRGGIO1	AnIn02.instMag.f	HSRSRTS[b]	Round-trip time for HSR supervision frames on station bus
IN1XGGIO1	Ind01.stVal	IN101	Main Board Input 1
IN1XGGIO1	Ind02.stVal	IN102	Main Board Input 2
IN1XGGIO1	Ind03.stVal	IN103	Main Board Input 3
IN1XGGIO1	Ind04.stVal	IN104	Main Board Input 4
IN1XGGIO1	Ind05.stVal	IN105	Main Board Input 5
IN1XGGIO1	Ind06.stVal	IN106	Main Board Input 6
IN1XGGIO1	Ind07.stVal	IN107	Main Board Input 7
IN2XGGIO1	Ind01.stVal	IN201	First Optional I/O Board Input 1 (if installed)
IN2XGGIO1	Ind02.stVal	IN202	First Optional I/O Board Input 2 (if installed)
IN2XGGIO1	Ind03.stVal	IN203	First Optional I/O Board Input 3 (if installed)
• • •			
IN2XGGIO1	Ind22.stVal	IN222	First Optional I/O Board Input 22 (if installed)
IN2XGGIO1	Ind23.stVal	IN223	First Optional I/O Board Input 23 (if installed)
IN2XGGIO1	Ind24.stVal	IN224	First Optional I/O Board Input 24 (if installed)
IN3XGGIO1	Ind01.stVal	IN301	Second Optional I/O Board Input 1 (if installed)
IN3XGGIO1	Ind02.stVal	IN302	Second Optional I/O Board Input 2 (if installed)
IN3XGGIO1	Ind03.stVal	IN303	Second Optional I/O Board Input 3 (if installed)
• • •			
IN3XGGIO1	Ind22.stVal	IN322	Second Optional I/O Board Input 22 (if installed)
IN3XGGIO1	Ind23.stVal	IN323	Second Optional I/O Board Input 23 (if installed)
IN3XGGIO1	Ind24.stVal	IN324	Second Optional I/O Board Input 24 (if installed)
IN4XGGIO1[g]	Ind01.stVal	IN401	Third Optional I/O Board Input 1 (if installed)

Table 17.30 Logical Device: ANN (Annunciation) (Sheet 9 of 17)

Logical Node	Attribute	Data Source	Comment
IN4XGGIO1[g]	Ind02.stVal	IN402	Third Optional I/O Board Input 2 (if installed)
IN4XGGIO1[g]	Ind03.stVal	IN403	Third Optional I/O Board Input 3 (if installed)
• • •			
IN4XGGIO1[g]	Ind22.stVal	IN422	Third Optional I/O Board Input 22 (if installed)
IN4XGGIO1[g]	Ind23.stVal	IN423	Third Optional I/O Board Input 23 (if installed)
IN4XGGIO1[g]	Ind24.stVal	IN424	Third Optional I/O Board Input 24 (if installed)
IN5XGGIO1[h]	Ind01.stVal	IN501	Fourth Optional I/O Board Input 01 (if installed)
IN5XGGIO1[h]	Ind02.stVal	IN502	Fourth Optional I/O Board Input 02 (if installed)
IN5XGGIO1[h]	Ind03.stVal	IN503	Fourth Optional I/O Board Input 03 (if installed)
• • •			
IN5XGGIO1[h]	Ind22.stVal	IN522	Fourth Optional I/O Board Input 22 (if installed)
IN5XGGIO1[h]	Ind23.stVal	IN523	Fourth Optional I/O Board Input 23 (if installed)
IN5XGGIO1[h]	Ind24.stVal	IN524	Fourth Optional I/O Board Input 24 (if installed)
LB1XGGIO1[i]	Ind01.stVal	LB01	Local Bit 1
LB1XGGIO1[i]	Ind02.stVal	LB02	Local Bit 2
LB1XGGIO1[i]	Ind03.stVal	LB03	Local Bit 3
• • •			
LB1XGGIO1[i]	Ind30.stVal	LB30	Local Bit 30
LB1XGGIO1[i]	Ind31.stVal	LB31	Local Bit 31
LB1XGGIO1[i]	Ind32.stVal	LB32	Local Bit 32
LB2XGGIO1[i]	Ind01.stVal	LB33	Local Bit 33
LB2XGGIO1[i]	Ind02.stVal	LB34	Local Bit 34
LB2XGGIO1[i]	Ind03.stVal	LB35	Local Bit 35
• • •			
LB2XGGIO1[i]	Ind30.stVal	LB62	Local Bit 62
LB2XGGIO1[i]	Ind31.stVal	LB63	Local Bit 63
LB2XGGIO1[i]	Ind32.stVal	LB64	Local Bit 64
LB3XGGIO1[i]	Ind01.stVal	LB65	Local Bit 65
LB3XGGIO1[i]	Ind02.stVal	LB66	Local Bit 66
LB3XGGIO1[i]	Ind03.stVal	LB67	Local Bit 67
• • •			
LB3XGGIO1[i]	Ind30.stVal	LB94	Local Bit 94
LB3XGGIO1[i]	Ind31.stVal	LB95	Local Bit 95

Table 17.30 Logical Device: ANN (Annunciation) (Sheet 10 of 17)

Logical Node	Attribute	Data Source	Comment
LB3XGGIO1[i]	Ind32.stVal	LB96	Local Bit 96
MBOKGGIO1	Ind01.stVal	ROKA	Normal MIRRORED BITS communications Channel A status while not in loop-back mode
MBOKGGIO1	Ind02.stVal	RBADA	Outage too long on MIRRORED BITS communications Channel A
MBOKGGIO1	Ind03.stVal	CBADA	Unavailability threshold exceeded for MIRRORED BITS communications Channel A
MBOKGGIO1	Ind04.stVal	LBOKA	Normal MIRRORED BITS communications Channel A status while in loopback mode
MBOKGGIO1	Ind05.stVal	ANOKA	Analog transfer OK on MIRRORED BITS communications Channel A
MBOKGGIO1	Ind06.stVal	DOKA	Normal MIRRORED BITS communications Channel A status
MBOKGGIO1	Ind07.stVal	ROKB	Normal MIRRORED BITS communications Channel B status while not in loop-back mode
MBOKGGIO1	Ind08.stVal	RBADB	Outage too long on MIRRORED BITS communications Channel B
MBOKGGIO1	Ind09.stVal	CBADB	Unavailability threshold exceeded for MIRRORED BITS communications Channel B
MBOKGGIO1	Ind10.stVal	LBOKB	Normal MIRRORED BITS communications Channel B status while in loopback mode
MBOKGGIO1	Ind11.stVal	ANOKB	Analog transfer OK on MIRRORED BITS communications Channel B
MBOKGGIO1	Ind12.stVal	DOKB	Normal MIRRORED BITS communications Channel B status
OUT1GGIO1[j]	Ind01.stVal	OUT101	Main Board Output 1
OUT1GGIO1[j]	Ind02.stVal	OUT102	Main Board Output 2
OUT1GGIO1[j]	Ind03.stVal	OUT103	Main Board Output 3
OUT1GGIO1[j]	Ind04.stVal	OUT104	Main Board Output 4
OUT1GGIO1[j]	Ind05.stVal	OUT105	Main Board Output 5
OUT1GGIO1[j]	Ind06.stVal	OUT106	Main Board Output 6
OUT1GGIO1[j]	Ind07.stVal	OUT107	Main Board Output 7
OUT1GGIO1[j]	Ind08.stVal	OUT108	Main Board Output 8
OUT2GGIO1	Ind01.stVal	OUT201	First Optional I/O Board Output 1
OUT2GGIO1	Ind02.stVal	OUT202	First Optional I/O Board Output 2
OUT2GGIO1	Ind03.stVal	OUT203	First Optional I/O Board Output 3
• • •			
OUT2GGIO1	Ind14.stVal	OUT214	First Optional I/O Board Output 14
OUT2GGIO1	Ind15.stVal	OUT215	First Optional I/O Board Output 15
OUT2GGIO1	Ind16.stVal	OUT216	First Optional I/O Board Output 16
OUT3GGIO1	Ind01.stVal	OUT301	Second Optional I/O Board Output 1
OUT3GGIO1	Ind02.stVal	OUT302	Second Optional I/O Board Output 2
OUT3GGIO1	Ind03.stVal	OUT303	Second Optional I/O Board Output 3
• • •			
OUT3GGIO1	Ind14.stVal	OUT314	Second Optional I/O Board Output 14
OUT3GGIO1	Ind15.stVal	OUT315	Second Optional I/O Board Output 15

Table 17.30 Logical Device: ANN (Annunciation) (Sheet 11 of 17)

Logical Node	Attribute	Data Source	Comment
OUT3GGIO1	Ind16.stVal	OUT316	Second Optional I/O Board Output 16
OUT4GGIO1[i]	Ind01.stVal	OUT401	Third Optional I/O Board Output 1
OUT4GGIO1[i]	Ind02.stVal	OUT402	Third Optional I/O Board Output 2
OUT4GGIO1[i]	Ind03.stVal	OUT403	Third Optional I/O Board Output 3
• • •			
OUT4GGIO1[i]	Ind14.stVal	OUT414	Third Optional I/O Board Output 14
OUT4GGIO1[i]	Ind15.stVal	OUT415	Third Optional I/O Board Output 15
OUT4GGIO1[i]	Ind16.stVal	OUT416	Third Optional I/O Board Output 16
OUT5GGIO1[h]	Ind01.stVal	OUT501	Fourth Optional I/O Board Output 1
OUT5GGIO1[h]	Ind02.stVal	OUT502	Fourth Optional I/O Board Output 2
OUT5GGIO1[h]	Ind03.stVal	OUT503	Fourth Optional I/O Board Output 3
• • •			
OUT5GGIO1[h]	Ind14.stVal	OUT514	Fourth Optional I/O Board Output 14
OUT5GGIO1[h]	Ind15.stVal	OUT515	Fourth Optional I/O Board Output 15
OUT5GGIO1[h]	Ind16.stVal	OUT516	Fourth Optional I/O Board Output 16
OUT3SGGIO1	Ind01.stVal	OUT301S	TiDL mapped OUT301 contact status
OUT3SGGIO1	Ind02.stVal	OUT302S	TiDL mapped OUT302 contact status
OUT3SGGIO1	Ind03.stVal	OUT303S	TiDL mapped OUT303 contact status
• • •			
OUT3SGGIO1	Ind14.stVal	OUT314S	TiDL mapped OUT314 contact status
OUT3SGGIO1	Ind15.stVal	OUT315S	TiDL mapped OUT315 contact status
OUT3SGGIO1	Ind16stVal	OUT316S	TiDL mapped OUT316 contact status
OUT4SGGIO1	Ind01stVal	OUT401S	TiDL mapped OUT401 contact status
OUT4SGGIO1	Ind02.stVal	OUT402S	TiDL mapped OUT402 contact status
OUT4SGGIO1	Ind03.stVal	OUT403S	TiDL mapped OUT403 contact status
• • •			
OUT4SGGIO1	Ind14.stVal	OUT414S	TiDL mapped OUT414 contact status
OUT4SGGIO1	Ind15.stVal	OUT415S	TiDL mapped OUT415 contact status
OUT4SGGIO1	Ind16stVal	OUT416S	TiDL mapped OUT416 contact status
OUT5SGGIO1	Ind01stVal	OUT501S	TiDL mapped OUT501 contact status
OUT5SGGIO1	Ind02.stVal	OUT502S	TiDL mapped OUT502 contact status
OUT5SGGIO1	Ind03.stVal	OUT503S	TiDL mapped OUT503 contact status
• • •			

Table 17.30 Logical Device: ANN (Annunciation) (Sheet 12 of 17)

Logical Node	Attribute	Data Source	Comment
OUT5SGGIO1	Ind14.stVal	OUT514S	TiDL mapped OUT514 contact status
OUT5SGGIO1	Ind15.stVal	OUT515S	TiDL mapped OUT515 contact status
OUT5SGGIO1	Ind16stVal	OUT516S	TiDL mapped OUT516 contact status
PBLEDGGIO1	Ind01.stVal	PB1_LED	Pushbutton 1 LED
PBLEDGGIO1	Ind02.stVal	PB2_LED	Pushbutton 2 LED
PBLEDGGIO1	Ind03.stVal	PB3_LED	Pushbutton 3 LED
PBLEDGGIO1	Ind04.stVal	PB4_LED	Pushbutton 4 LED
PBLEDGGIO1	Ind05.stVal	PB5_LED	Pushbutton 5 LED
PBLEDGGIO1	Ind06.stVal	PB6_LED	Pushbutton 6 LED
PBLEDGGIO1	Ind07.stVal	PB7_LED	Pushbutton 7 LED
PBLEDGGIO1	Ind08.stVal	PB8_LED	Pushbutton 8 LED
PBLEDGGIO1	Ind09.stVal	PB9_LED	Pushbutton 9 LED
PBLEDGGIO1	Ind10.stVal	PB10LED	Pushbutton 10 LED
PBLEDGGIO1	Ind11.stVal	PB11LED	Pushbutton 11 LED
PBLEDGGIO1	Ind12.stVal	PB12LED	Pushbutton 12 LED
PLT1GGIO1	Ind01.stVal	PLT01	Protection Latch 1
PLT1GGIO1	Ind02.stVal	PLT02	Protection Latch 2
PLT1GGIO1	Ind03.stVal	PLT03	Protection Latch 3
• • •			
PLT1GGIO1	Ind30.stVal	PLT30	Protection Latch 30
PLT1GGIO1	Ind31.stVal	PLT31	Protection Latch 31
PLT1GGIO1	Ind32.stVal	PLT32	Protection Latch 32
PRPGGIO1	Ind01.stVal	PRPAGOK[b]	PRP PORT 5A GOOSE status
PRPGGIO1	Ind02.stVal	PRPBGOK[b]	PRP PORT 5B GOOSE status
PRPGGIO1	Ind03.stVal	PRPCGOK[b]	PRP PORT 5C GOOSE status
PRPGGIO1	Ind04.stVal	PRPDGOK[b]	PRP PORT 5D GOOSE status
PRPGGIO1	Ind05.stVal	PRPASOK[b]	PRP PORT 5A SV status
PRPGGIO1	Ind06.stVal	PRPBSOK[b]	PRP PORT 5B SV status
PSV1GGIO1	Ind01.stVal	PSV01	Protection SELOGIC Variable 1
PSV1GGIO1	Ind02.stVal	PSV02	Protection SELOGIC Variable 2
PSV1GGIO1	Ind03.stVal	PSV03	Protection SELOGIC Variable 3
• • •			
PSV1GGIO1	Ind30.stVal	PSV30	Protection SELOGIC Variable 30
PSV1GGIO1	Ind31.stVal	PSV31	Protection SELOGIC Variable 31
PSV1GGIO1	Ind32.stVal	PSV32	Protection SELOGIC Variable 32
PSV2GGIO1	Ind01.stVal	PSV33	Protection SELOGIC Variable 33
PSV2GGIO1	Ind02.stVal	PSV34	Protection SELOGIC Variable 34
PSV2GGIO1	Ind03.stVal	PSV35	Protection SELOGIC Variable 35

Table 17.30 Logical Device: ANN (Annunciation) (Sheet 13 of 17)

Logical Node	Attribute	Data Source	Comment
• • •			
PSV2GGIO1	Ind30.stVal	PSV62	Protection SELOGIC Variable 62
PSV2GGIO1	Ind31.stVal	PSV63	Protection SELOGIC Variable 63
PSV2GGIO1	Ind32.stVal	PSV64	Protection SELOGIC Variable 64
RMBAGGIO1	Ind01.stVal	RMB1A	Channel A Receive Mirrored Bit 1
RMBAGGIO1	Ind02.stVal	RMB2A	Channel A Receive Mirrored Bit 2
RMBAGGIO1	Ind03.stVal	RMB3A	Channel A Receive Mirrored Bit 3
RMBAGGIO1	Ind04.stVal	RMB4A	Channel A Receive Mirrored Bit 4
RMBAGGIO1	Ind05.stVal	RMB5A	Channel A Receive Mirrored Bit 5
RMBAGGIO1	Ind06.stVal	RMB6A	Channel A Receive Mirrored Bit 6
RMBAGGIO1	Ind07.stVal	RMB7A	Channel A Receive Mirrored Bit 7
RMBAGGIO1	Ind08.stVal	RMB8A	Channel A Receive Mirrored Bit 8
RMBBGGIO1	Ind01.stVal	RMB1B	Channel B Receive Mirrored Bit 1
RMBBGGIO1	Ind02.stVal	RMB2B	Channel B Receive Mirrored Bit 2
RMBBGGIO1	Ind03.stVal	RMB3B	Channel B Receive Mirrored Bit 3
RMBBGGIO1	Ind04.stVal	RMB4B	Channel B Receive Mirrored Bit 4
RMBBGGIO1	Ind05.stVal	RMB5B	Channel B Receive Mirrored Bit 5
RMBBGGIO1	Ind06.stVal	RMB6B	Channel B Receive Mirrored Bit 6
RMBBGGIO1	Ind07.stVal	RMB7B	Channel B Receive Mirrored Bit 7
RMBBGGIO1	Ind08.stVal	RMB8B	Channel B Receive Mirrored Bit 8
RTCAGGIO1	Ind01.stVal	RTCAD01	RTC Remote Data Bits, Channel A, Bit 1
RTCAGGIO1	Ind02.stVal	RTCAD02	RTC Remote Data Bits, Channel A, Bit 2
RTCAGGIO1	Ind03.stVal	RTCAD03	RTC Remote Data Bits, Channel A, Bit 3
• • •			
RTCAGGIO1	Ind14.stVal	RTCAD14	RTC Remote Data Bits, Channel A, Bit 14
RTCAGGIO1	Ind15.stVal	RTCAD15	RTC Remote Data Bits, Channel A, Bit 15
RTCAGGIO1	Ind16.stVal	RTCAD16	RTC Remote Data Bits, Channel A, Bit 16
RTCBGGIO1	Ind01.stVal	RTCBD01	RTC Remote Data Bits, Channel B, Bit 1
RTCBGGIO1	Ind02.stVal	RTCBD02	RTC Remote Data Bits, Channel B, Bit 2
RTCBGGIO1	Ind03.stVal	RTCBD03	RTC Remote Data Bits, Channel B, Bit 3
• • •			
RTCBGGIO1	Ind14.stVal	RTCBD14	RTC Remote Data Bits, Channel B, Bit 14
RTCBGGIO1	Ind15.stVal	RTCBD15	RTC Remote Data Bits, Channel B, Bit 15
RTCBGGIO1	Ind16.stVal	RTCBD16	RTC Remote Data Bits, Channel B, Bit 16
RTDHGGIO1	Ind01.stVal	RTD01ST	RTD Status for Channel 1
RTDHGGIO1	Ind02.stVal	RTD02ST	RTD Status for Channel 2

Table 17.30 Logical Device: ANN (Annunciation) (Sheet 14 of 17)

Logical Node	Attribute	Data Source	Comment
RTDHGGIO1	Ind03.stVal	RTD03ST	RTD Status for Channel 3
RTDHGGIO1	Ind04.stVal	RTD04ST	RTD Status for Channel 4
RTDHGGIO1	Ind05.stVal	RTD05ST	RTD Status for Channel 5
RTDHGGIO1	Ind06.stVal	RTD06ST	RTD Status for Channel 6
RTDHGGIO1	Ind07.stVal	RTD07ST	RTD Status for Channel 7
RTDHGGIO1	Ind08.stVal	RTD08ST	RTD Status for Channel 8
RTDHGGIO1	Ind09.stVal	RTD09ST	RTD Status for Channel 9
RTDHGGIO1	Ind10.stVal	RTD10ST	RTD Status for Channel 10
RTDHGGIO1	Ind11.stVal	RTD11ST	RTD Status for Channel 11
RTDHGGIO1	Ind12.stVal	RTD12ST	RTD Status for Channel 12
SG1XGGIO1	Ind01.stVal	SG1	Settings Group 1 active
SG1XGGIO1	Ind02.stVal	SG2	Settings Group 2 active
SG1XGGIO1	Ind03.stVal	SG3	Settings Group 3 active
SG1XGGIO1	Ind04.stVal	SG4	Settings Group 4 active
SG1XGGIO1	Ind05.stVal	SG5	Settings Group 5 active
SG1XGGIO1	Ind06.stVal	SG6	Settings Group 6 active
SG1XGGIO1	Ind07.stVal	CHSG	Settings group change
SG1XGGIO1	Ind08.stVal	GRPSW	Pulsed alarm for group switches
TLEDGGIO1	Ind01.stVal	EN	Relay enabled
TLEDGGIO1	Ind02.stVal	TRIPLED	Trip LED
TLEDGGIO1	Ind03.stVal	TLED_1	Target LED 1
TLEDGGIO1	Ind04.stVal	TLED_2	Target LED 2
TLEDGGIO1	Ind05.stVal	TLED_3	Target LED 3
TLEDGGIO1	Ind06.stVal	TLED_4	Target LED 4
TLEDGGIO1	Ind07.stVal	TLED_5	Target LED 5
TLEDGGIO1	Ind08.stVal	TLED_6	Target LED 6
TLEDGGIO1	Ind09.stVal	TLED_7	Target LED 7
TLEDGGIO1	Ind10.stVal	TLED_8	Target LED 8
TLEDGGIO1	Ind11.stVal	TLED_9	Target LED 9
TLEDGGIO1	Ind12.stVal	TLED_10	Target LED 10
TLEDGGIO1	Ind13.stVal	TLED_11	Target LED 11
TLEDGGIO1	Ind14.stVal	TLED_12	Target LED 12
TLEDGGIO1	Ind15.stVal	TLED_13	Target LED 13
TLEDGGIO1	Ind16.stVal	TLED_14	Target LED 14
TLEDGGIO1	Ind17.stVal	TLED_15	Target LED 15
TLEDGGIO1	Ind18.stVal	TLED_16	Target LED 16
TLEDGGIO1	Ind19.stVal	TLED_17	Target LED 17
TLEDGGIO1	Ind20.stVal	TLED_18	Target LED 18
TLEDGGIO1	Ind21.stVal	TLED_19	Target LED 19
TLEDGGIO1	Ind22.stVal	TLED_20	Target LED 20
TLEDGGIO1	Ind23.stVal	TLED_21	Target LED 21

Table 17.30 Logical Device: ANN (Annunciation) (Sheet 15 of 17)

Logical Node	Attribute	Data Source	Comment
TLEDGGIO1	Ind24.stVal	TLED_22	Target LED 22
TLEDGGIO1	Ind25.stVal	TLED_23	Target LED 23
TLEDGGIO1	Ind26.stVal	TLED_24	Target LED 24
TMBAGGIO1	Ind01.stVal	TMB1A	Channel A Transmit Mirrored Bit 1
TMBAGGIO1	Ind02.stVal	TMB2A	Channel A Transmit Mirrored Bit 2
TMBAGGIO1	Ind03.stVal	TMB3A	Channel A Transmit Mirrored Bit 3
TMBAGGIO1	Ind04.stVal	TMB4A	Channel A Transmit Mirrored Bit 4
TMBAGGIO1	Ind05.stVal	TMB5A	Channel A Transmit Mirrored Bit 5
TMBAGGIO1	Ind06.stVal	TMB6A	Channel A Transmit Mirrored Bit 6
TMBAGGIO1	Ind07.stVal	TMB7A	Channel A Transmit Mirrored Bit 7
TMBAGGIO1	Ind08.stVal	TMB8A	Channel A Transmit Mirrored Bit 8
TMBBGGIO1	Ind01.stVal	TMB1B	Channel B Transmit Mirrored Bit 1
TMBBGGIO1	Ind02.stVal	TMB2B	Channel B Transmit Mirrored Bit 2
TMBBGGIO1	Ind03.stVal	TMB3B	Channel B Transmit Mirrored Bit 3
TMBBGGIO1	Ind04.stVal	TMB4B	Channel B Transmit Mirrored Bit 4
TMBBGGIO1	Ind05.stVal	TMB5B	Channel B Transmit Mirrored Bit 5
TMBBGGIO1	Ind06.stVal	TMB6B	Channel B Transmit Mirrored Bit 6
TMBBGGIO1	Ind07.stVal	TMB7B	Channel B Transmit Mirrored Bit 7
TMBBGGIO1	Ind08.stVal	TMB8B	Channel B Transmit Mirrored Bit 8
TPORTGGIO1	Ind01.stVal	TDLCMSD	TiDL active topology commissioned
TPORTGGIO1	Ind02.stVal	TIDLALM	TiDL alarm
TPORTGGIO1	Ind03.stVal	P6AMAP	PORT 6A mapped
TPORTGGIO1	Ind04.stVal	P6AOK	PORT 6A OK
TPORTGGIO1	Ind05.stVal	P6BMAP	PORT 6B mapped
TPORTGGIO1	Ind06.stVal	P6BOK	PORT 6BOK
TPORTGGIO1	Ind07.stVal	P6CMAP	PORT 6C mapped
TPORTGGIO1	Ind08.stVal	P6COK	PORT 6C OK
TPORTGGIO1	Ind09.stVal	P6DMAP	PORT 6D mapped
TPORTGGIO1	Ind10.stVal	P6DOK	PORT 6D OK
TPORTGGIO1	Ind11.stVal	P6EMAP	PORT 6E mapped
TPORTGGIO1	Ind12.stVal	P6EOK	PORT 6E OK
TPORTGGIO1	Ind13.stVal	P6FMAP	PORT 6F mapped
TPORTGGIO1	Ind14.stVal	P6FOK	PORT 6F OK
VB1XGGIO1	Ind01.stVal	VB001	Virtual Bit 001
VB1XGGIO1	Ind02.stVal	VB002	Virtual Bit 002
VB1XGGIO1	Ind03.stVal	VB003	Virtual Bit 003
• • •			
VB1XGGIO1	Ind30.stVal	VB030	Virtual Bit 030
VB1XGGIO1	Ind31.stVal	VB031	Virtual Bit 031

Table 17.30 Logical Device: ANN (Annunciation) (Sheet 16 of 17)

Logical Node	Attribute	Data Source	Comment
VB1XGGIO1	Ind32.stVal	VB032	Virtual Bit 032
VB2XGGIO1	Ind01.stVal	VB033	Virtual Bit 033
VB2XGGIO1	Ind02.stVal	VB034	Virtual Bit 034
VB2XGGIO1	Ind03.stVal	VB035	Virtual Bit 035
• • •			
VB2XGGIO1	Ind30.stVal	VB062	Virtual Bit 062
VB2XGGIO1	Ind31.stVal	VB063	Virtual Bit 063
VB2XGGIO1	Ind32.stVal	VB064	Virtual Bit 064
VB3XGGIO1	Ind01.stVal	VB065	Virtual Bit 065
VB3XGGIO1	Ind02.stVal	VB066	Virtual Bit 066
VB3XGGIO1	Ind03.stVal	VB067	Virtual Bit 067
• • •			
VB3XGGIO1	Ind30.stVal	VB094	Virtual Bit 094
VB3XGGIO1	Ind31.stVal	VB095	Virtual Bit 095
VB3XGGIO1	Ind32.stVal	VB096	Virtual Bit 096
VB4XGGIO1	Ind01.stVal	VB097	Virtual Bit 097
VB4XGGIO1	Ind02.stVal	VB098	Virtual Bit 098
VB4XGGIO1	Ind03.stVal	VB099	Virtual Bit 099
• • •			
VB4XGGIO1	Ind30.stVal	VB126	Virtual Bit 126
VB4XGGIO1	Ind31.stVal	VB127	Virtual Bit 127
VB4XGGIO1	Ind32.stVal	VB128	Virtual Bit 128
VB5XGGIO1	Ind01.stVal	VB129	Virtual Bit 129
VB5XGGIO1	Ind02.stVal	VB130	Virtual Bit 130
VB5XGGIO1	Ind03.stVal	VB131	Virtual Bit 131
• • •			
VB5XGGIO1	Ind30.stVal	VB158	Virtual Bit 158
VB5XGGIO1	Ind31.stVal	VB159	Virtual Bit 159
VB5XGGIO1	Ind32.stVal	VB160	Virtual Bit 160
VB6XGGIO1	Ind01.stVal	VB161	Virtual Bit 161
VB6XGGIO1	Ind02.stVal	VB162	Virtual Bit 162
VB6XGGIO1	Ind03.stVal	VB163	Virtual Bit 163
• • •			

Table 17.30 Logical Device: ANN (Annunciation) (Sheet 17 of 17)

Logical Node	Attribute	Data Source	Comment
VB6XGGIO1	Ind31.stVal	VB191	Virtual Bit 191
VB6XGGIO1	Ind32.stVal	VB192	Virtual Bit 192
VB7XGGIO1	Ind01.stVal	VB193	Virtual Bit 193
VB7XGGIO1	Ind02.stVal	VB194	Virtual Bit 194
VB7XGGIO1	Ind03.stVal	VB195	Virtual Bit 195
• • •			
VB7XGGIO1	Ind30.stVal	VB222	Virtual Bit 222
VB7XGGIO1	Ind31.stVal	VB223	Virtual Bit 223
VB7XGGIO1	Ind32.stVal	VB224	Virtual Bit 224
VB8XGGIO1	Ind01.stVal	VB225	Virtual Bit 225
VB8XGGIO1	Ind02.stVal	VB226	Virtual Bit 226
VB8XGGIO1	Ind03.stVal	VB227	Virtual Bit 227
• • •			
VB8XGGIO1	Ind30.stVal	VB254	Virtual Bit 254
VB8XGGIO1	Ind31.stVal	VB255	Virtual Bit 255
VB8XGGIO1	Ind32.stVal	VB256	Virtual Bit 256

[a] Internal data source and not available to the user.
[b] Only applicable when using the five-port Ethernet card.
[c] HWREV is an internal data source and is not available to the user.
[d] If enabled, value = 1. If disabled, value = 3.
[e] I60MOD is an internal data source derived from the I850MOD analog quantity and is not available to the user.
[f] Only applicable to SEL-400 series relays with SV support and the SEL-411L with 87L over Ethernet.
[g] Not all SEL-400 series relays support a third interface board.
[h] Not all SEL-400 series relays support four interface boards.
[i] Not supported in the SEL-487V.
[j] Not all SEL-400 series relays support main board outputs.

SEL Nameplate Data

The CID file contains information that describes the physical device attributes according to IEC 61850 standards. The LN0 logical node of each logical device contains the Nameplate DOI (instantiated data object) with the following data.

Table 17.31 SEL Nameplate Data

Data Attribute	Value
vendor	“SEL”
swRev	Contents of FID string from **ID** command
d	Description of LD
configRev	Always 0
1dNs	IEC 61850-7-4:2007A

Protocol Implementation Conformance Statement

Table 17.32 and *Table 17.33* are as shown in the IEC 61850 standard, Part 8-1, Section 24. Because the standard explicitly dictates which services and functions must be implemented to achieve conformance, only the optional services and functions are listed.

Table 17.32 PICS for A-Profile Support

Profile		Client	Server	Value/Comment
A1	Client/Server		Y	
A2	GOOSE/GSE management	Y	Y	Only GOOSE, not GSSE management
A3	GSSE			
A4	Time Sync	Y		

Table 17.33 PICS for T-Profile Support

Profile		Client	Server	Value/Comment
T1	TCP/IP		Y	
T2	OSI			
T3	GOOSE/GSE	Y	Y	Only GOOSE, not GSSE
T4	GSSE			
T5	Time Sync	Y		

Refer to the *ACSI Conformance Statements on page 17.89* for information on the supported services.

MMS Conformance

The MMS stack provides the basis for many IEC 61850 protocol services. *Table 17.34* defines the service support requirement and restrictions of the MMS services that support Conformance Building Block (CBB) in the SEL-400 series devices. Generally, only those services whose implementation is not mandatory are shown in Server-CR (Conformance Requirement). Refer to the IEC 61850 standard Part 8-1 for more information.

Table 17.34 MMS Service Supported Conformance (Sheet 1 of 3)

MMS Service Supported CBB	Client-CR Supported	Server-CR Supported
status		Y
getNameList		Y
identify		Y
rename		
read		Y
write		Y
getVariableAccessAttributes		Y
defineNamedVariable		
defineScatteredAccess		
getScatteredAccessAttributes		

Table 17.34 MMS Service Supported Conformance (Sheet 2 of 3)

MMS Service Supported CBB	Client-CR Supported	Server-CR Supported
deleteVariableAccess		
defineNamedVariableList		
getNamedVariableListAttributes		Y
deleteNamedVariableList		
defineNamedType		
getNamedTypeAttributes		
deleteNamedType		
input		
output		
takeControl		
relinquishControl		
defineSemaphore		
deleteSemaphore		
reportPoolSemaphoreStatus		
reportSemaphoreStatus		
initiateDownloadSequence		
downloadSegment		
terminateDownloadSequence		
initiateUploadSequence		
uploadSegment		
terminateUploadSequence		
requestDomainDownload		
requestDomainUpload		
loadDomainContent		
storeDomainContent		
deleteDomain		
getDomainAttributes		Y
createProgramInvocation		
deleteProgramInvocation		
start		
stop		
resume		
reset		
kill		
getProgramInvocationAttributes		
obtainFile		Y
defineEventCondition		
deleteEventCondition		
getEventConditionAttributes		
reportEventConditionStatus		

Table 17.34 MMS Service Supported Conformance (Sheet 3 of 3)

MMS Service Supported CBB	Client-CR Supported	Server-CR Supported
alterEventConditionMonitoring		
triggerEvent		
defineEventAction		
deleteEventAction		
alterEventEnrollment		
reportEventEnrollmentStatus		
getEventEnrollmentAttributes		
acknowledgeEventNotification		
getAlarmSummary		
getAlarmEnrollmentSummary		
readJournal		
writeJournal		
initializeJournal		
reportJournalStatus		
createJournal		
deleteJournal		
fileOpen		Y
fileRead		Y
fileClose		Y
fileRename		
fileDelete		Y
fileDirectory		Y
unsolicitedStatus		
informationReport		Y
eventNotification		
attachToEventCondition		
attachToSemaphore		
conclude		Y
cancel		Y
getDataExchangeAttributes		
exchangeData		
defineAccessControlList		
getAccessControlListAttributes		
reportAccessControlledObjects		
deleteAccessControlList		
alterAccessControl		
reconfigureProgramInvocation		

Table 17.35 lists specific settings for the MMS parameter conformance building block (CBB).

Table 17.35 MMS Parameter CBB

MMS Parameter CBB	Client-CR Supported	Server-CR Supported
STR1		Y
STR2		Y
VNAM		Y
VADR		Y
VALT		Y
TPY		Y
VLIS		Y
CEI		

The following variable access conformance statements are listed in the order specified in the IEC 61850 standard, Part 8-1. Generally, only those services whose implementation is not mandatory are shown. Refer to the IEC 61850 standard Part 8-1 for more information.

Table 17.36 AlternateAccessSelection Conformance Statement

AlternateAccessSelection	Client-CR Supported	Server-CR Supported
accessSelection		Y
component		Y
index		
indexRange		
allElements		
alternateAccess		Y
selectAccess		Y
component		Y
index		
indexRange		
allElements		

Table 17.37 VariableAccessSpecification Conformance Statement

VariableAccessSpecification	Client-CR Supported	Server-CR Supported
listOfVariable		Y
variableSpecification		Y
alternateAccess		Y
variableListName		Y

Table 17.38 VariableSpecification Conformance Statement

VariableSpecification	Client-CR Supported	Server-CR Supported
name		Y
address		
variableDescription		
scatteredAccessDescription		
invalidated		

Table 17.39 Read Conformance Statement

Read	Client-CR Supported	Server-CR Supported
Request		
specificationWithResult		
variableAccessSpecification		
Response		
variableAccessSpecification		Y
listOfAccessResult		Y

Table 17.40 GetVariableAccessAttributes Conformance Statement

GetVariableAccessAttributes	Client-CR Supported	Server-CR Supported
Request		
name		
address		
Response		
mmsDeletable		
address		
typeSpecification		

Table 17.41 DefineNamedVariableList Conformance Statement

DefineVariableAccessAttributes	Client-CR Supported	Server-CR Supported
Request		
variableListName		
listOfVariable		
variableSpecification		
alternateAccess		
Response		

Table 17.42 GetNamedVariableListAttributes Conformance Statement (Sheet 1 of 2)

GetNamedVariableListAttributes	Client-CR Supported	Server-CR Supported
Request		
ObjectName		

Table 17.42 GetNamedVariableListAttributes Conformance Statement (Sheet 2 of 2)

GetNamedVariableListAttributes	Client-CR Supported	Server-CR Supported
Response		
mmsDeletable		Y
listOfVariable		Y
variableSpecification		Y
alternateAccess		Y

Table 17.43 DeleteNamedVariableList Conformance Statement

DeleteNamedVariableList	Client-CR Supported	Server-CR Supported
Request		
Scope		
listOfVariableListName		
domainName		
Response		
numberMatched		
numberDeleted		
DeleteNamedVariableList-Error		

GOOSE Services Conformance Statement

Table 17.44 GOOSE Conformance

	Subscriber	Publisher	Value/Comment
GOOSE Services	Y	Y	
SendGOOSEMessage		Y	
GetGoReference			
GetGOOSEElementNumber			
GetGoCBValues		Y	
SetGoCBValues			
GSENotSupported			
GOOSE Control Block (GoCB)		Y	

ACSI Conformance Statements

Table 17.45 Basic Conformance Statement (Sheet 1 of 2)

Services		Client/ Subscriber[a]	Server/ Publisher[a]	Value/ Comments[a]
Client-Server Roles				
B11	Server side (of TWO-PARTY-APPLICATION-ASSOCIATION)		Y	
B12	Client side (of TWO-PARTY-APPLICATION-ASSOCIATION)			

Table 17.45 Basic Conformance Statement (Sheet 2 of 2)

Services		Client/ Subscriber[a]	Server/ Publisher[a]	Value/ Comments[a]
SCSMs Supported				
B21	SCSM: IEC 6185-8-1 used		Y	
B22	SCSM: IEC 6185-9-1 used			Deprecated in Ed2
B23	SCSM: IEC 6185-9-2 used	Y[b]	Y[c]	
B24	SCSM: other			
Generic Substation Event (GSE) Model				
B31	Publisher side		Y	
B32	Subscriber side	Y		
Transmission of Sampled Value Model (SVC)				
B41	Publisher side		Y[c]	
B42	Subscriber side	Y[b]		

[a] Y = supported
N or blank = not supported
[b] Only applicable for SV Subscriber devices
[c] Only applicable for SV Publisher devices

Table 17.46 ACSI Models Conformance Statement (Sheet 1 of 2)

		Client/Subscriber[a]	Server/Publisher[a]	Value/Comments
If Server Side (B11) and/or Client Side (B12) Supported				
M1	Logical device		Y	
M2	Logical node		Y	
M3	Data		Y	
M4	Data set		Y	
M5	Substitution			
M6	Setting group control		Y	
Reporting				
M7	Buffered report control		Y	
M7–1	sequence-number		Y	
M7–2	report-time-stamp		Y	
M7–3	reason-for-inclusion		Y	
M7–4	data-set-name		Y	
M7–5	data-reference		Y	
M7–6	buffer-overflow		Y	
M7–7	entryID		Y	
M7–8	BufTim		Y	
M7–9	IntgPd		Y	
M7–10	GI		Y	
M7–11	conf-revision		Y	
M8	Unbuffered report control		Y	
M8–1	sequence-number		Y	
M8–2	report-time-stamp		Y	

Table 17.46 ACSI Models Conformance Statement (Sheet 2 of 2)

		Client/Subscriber[a]	Server/Publisher[a]	Value/Comments
M8–3	reason-for-inclusion		Y	
M8–4	data-set-name		Y	
M8–5	data-reference		Y	
M8–6	BufTim		Y	
M8–7	IntgPd		Y	
M8–8	GI		Y	
M8–9	conf-revision		Y	
	Logging			
M9	Log control			
M9–1	IntgPd			
M10	Log			
M11	Control		Y	
M17	File transfer		Y	
M18	Application association		Y	
M19	GOOSE control block		Y	
M20	Sampled Value control block		Y[b]	
If GSE (B31/32) Is Supported				
M12	GOOSE		Y	
M13	GSSE			Deprecated in Ed2
If SVC (B41/42) Is Supported				
M14	Multicast SVC		Y[b]	
M15	Unicast SVC			
For All IEDs				
M16	Time		Y	Time source with required accuracy shall be available. Only the time master is an SNTP (Mode 4 response) time server. All other client/server devices require SNTP (Mode 3 request) clients.

[a] Y = supported
N or blank = not supported
[b] SV publisher only

Table 17.47 ACSI Service Conformance Statement (Sheet 1 of 4)

Services			AA: TP/MC	Client (C)	Server (S)	Comments
Server						
S1	1, 2	GetServerDirectory (LOGICAL-DEVICE)	TP		Y	
Application Association						
S2	1, 2	Associate			Y	
S3	1, 2	Abort			Y	
S4	1, 2	Release			Y	
Logical Device						
S5	1, 2	GetLogicalDeviceDirectory	TP		Y	

Table 17.47 ACSI Service Conformance Statement (Sheet 2 of 4)

Services			AA: TP/MC	Client (C)	Server (S)	Comments
Logical Node						
S6	1, 2	GetLogicalNodeDirectory	TP		Y	
S7	1, 2	GetAllDataValues	TP		Y	
Data						
S8	1, 2	GetDataValues	TP		Y	
S9	1, 2	SetDataValues	TP			
S10	1, 2	GetDataDirectory	TP		Y	
S11	1, 2	GetDataDefinition	TP		Y	
Data Set						
S12	1, 2	GetDataSetValues	TP		Y	
S13	1, 2	SetDataSetValues	TP			
S14	1, 2	CreateDataSet	TP			
S15	1, 2	DeleteDataSet	TP			
S16	1, 2	GetDataSetDirectory	TP		Y	
Substitution						
S17	1	SetDataValues	TP			
Setting Group Control						
S18	1, 2	SelectActiveSG	TP		Y	
S19	1, 2	SelectEditSG	TP			
S20	1, 2	SetEditSGValues	TP			
S21	1, 2	ConfirmEditSGValues	TP			
S22	1, 2	GetEditSGValues	TP			
S23	1, 2	GetSGCBValues	TP		Y	
Reporting						
Buffered Report Control Block (BRCB)						
S24	1, 2	Report	TP		Y	
S24–1	1, 2	data-change (dchg)			Y	
S24–2	1, 2	quality-change (qchg)			Y	
S24–3	1, 2	data-update (dupd)			Y	
S25	1, 2	GetBRCBValues	TP		Y	
S26	1, 2	SetBRCBValues	TP		Y	
Unbuffered Report Control Block (URCB)						
S27	1, 2	Report	TP		Y	
S27–1	1, 2	data-change (dchg)			Y	
S27–2	1, 2	quality-change (qchg)			Y	
S27–3	1, 2	data-update (dup)			Y	
S28	1, 2	GetURCBValues	TP		Y	
S29	1, 2	SetURCBValues	TP		Y	

Table 17.47 ACSI Service Conformance Statement (Sheet 3 of 4)

Services			AA: TP/MC	Client (C)	Server (S)	Comments
Logging						
Log Control Block						
S30	1, 2	GetLCBValues	TP			
S31	1, 2	SetLCBValues	TP			
Log						
S32	1, 2	QueryLogByTime	TP			
S33	1, 2	QueryLogAfter	TP			
S34	1, 2	GetLogStatusValues	TP			
Generic Substation Event Model (GSE)						
GOOSE						
S35	1, 2	SendGOOSEMessage	MC		Y	
GOOSE-CONTROL-BLOCK						
S36	1, 2	GetGoReference	TP			
S37	1, 2	GetGOOSEElementNumber	TP			
S38	1, 2	GetGoCBValues	TP		Y	
S39	1, 2	SetGoCBValues	TP			
GSSE						
S40	1	SendGSSEMessage	MC			Deprecated in Ed2
GSSE-CONTROL-BLOCK						
S41	1	GetReference	TP			Deprecated in Ed2
S42	1	GetGSSEElementNumber	TP			Deprecated in Ed2
S43	1	GetGsCBValues	TP			Deprecated in Ed2
S44	1	SetGsCBValues	TP			Deprecated in Ed2
Transmission of Sampled Value Model (SVC)						
Multicast SV						
S45	1, 2	SendMSVMessage	MC		Y[a]	
Multicast Sampled Value Control Block						
S46	1, 2	GetMSVCBValues	TP		Y[a]	
S47	1, 2	SetMSVCBValues	TP			
Unicast SV						
S48	1, 2	SendUSVMessage	TP			
Unicast Sampled Value Control Block						
S49	1, 2	GetUSVCBValues	TP			
S50	1, 2	SetUSVCBValues	TP			
Control						
S51	1, 2	Select				
S52	1, 2	SelectWithValue	TP		Y	
S53	1, 2	Cancel	TP		Y	
S54	1, 2	Operate	TP		Y	
S55	1, 2	CommandTermination	TP		Y	
S56	1, 2	TimeActivatedOperate	TP			

Table 17.47 ACSI Service Conformance Statement (Sheet 4 of 4)

Services			AA: TP/MC	Client (C)	Server (S)	Comments
File Transfer						
S57	1, 2	GetFile	TP		Y	
S58	1, 2	SetFile	TP		Y	
S59	1, 2	DeleteFile	TP			
S60	1, 2	GetFileAttributeValues	TP		Y	
S61	1, 2	GetServerDirectory (FILE SYSTEM)	TP		Y	
Time						
T1	1, 2	Time resolution of internal clock			20	Nearest negative power of 2^{-n} in seconds (number 0 . . . 24)
T2	1, 2	Time accuracy of internal clock			IRIG-B T5 PTP T5 SNTP T1	TL (ms) (low-accuracy), T3 < 7) (only Ed. 2) T0 (ms) (≤ 10 ms), 7 ≤ T3 < 10 T1 (μs) (≤ 1 ms), 10 ≤ T3 < 13 T2 (μs) (≤ 100 μS), 13 ≤ T3 < 15 T3 (μs) (≤ 25 μS), 15 ≤ T3 < 18 T4 (μs) (≤ 25 μS), 15 ≤ T3 < 18 T5 (μs) (≤ 1 μS), T3 ≥ 20
T3	1, 2	Supported TimeStamp resolution			IRIGB 18 PTP 18 SNTP 7	Nearest negative power of 2^{-n} in seconds (number 0 . . . 24)

[a] SV publisher only

Potential Client and Automation Application Issues With Ed2 and Ed2.1 Upgrades

The following are issues that IEC 61850 Ed1-based client or automation applications may experience with IEC 61850 Ed2 and Ed2.1 ICD and firmware changes. However, such issues may be resolved by reconfiguring the client or automation application or worked around by restoring the Ed1 (CID) configuration. None of these should prevent a client application from dynamically discovering the data in the IED as long as the application adheres to the specification of the standard. Note that upgrading to Ed2 or Ed2.1 firmware will not break existing Ed1 configurations (CID files) in the field, nor require loading a new version of the CID file.

Unexpected Error Messages

Some MMS and control errors have been changed in Ed2. Hence, the firmware now issues only the Ed2-compliant errors. Clients or automation applications that rely on the Ed1-compliant errors will not function correctly. You can resolve this by reconfiguring the client or automation application to accept Ed2-compliant errors.

Missing or Unknown Data Objects and Attributes

Ed2 has changed some data object and attribute names, as well as the data types of some attributes. Ed2 also prohibits the use of proprietary CDCs. See *Common Logical Nodes on page 17.55* and the logical nodes tables in each product-specific manual to determine the Ed2 names. This may cause the failure of clients or automation applications that rely on the Ed1 names. A workaround is to use the Ed1 version of the CID file, if available, to configure the IED. You can also resolve this by reconfiguring the client or automation application to accept the Ed2 names.

Unable to Find Operate Time-Out

A proprietary method was used to specify the operate time-out of control objects in the CID files. A client or automation application that relies on this proprietary method will fail to find the operate time-out in the CID file. A workaround is to use the Ed1 CID file to configure the IED. You can also resolve this by reconfiguring the client or automation application to accept the Ed2 control object operate time-outs.

Unexpected Control Block Data Attribute Type

The string type data attributes in control blocks (RptID, DatSet, etc.) have been changed from a maximum length of 65 to 129 characters, i.e., VisString65 to VisString129. Some clients and automation applications might see this as an error when the type is reported in the MMS GetVariableAccessAttributes response. You can resolve this by reconfiguring the client or automation application or enabling the Ed1 server compatibility mode in the relay (see *Backward Compatibility With Ed1 Devices on page 17.97*).

Unexpected Reports

Ed2 requires report buffering to start when the device is turned on, unlike in the Ed1 implementation where report buffering started after the first report enable. If a client or automation application relies on the Ed1 behavior, it might fail or indicate an error if the IED sends buffered reports immediately after the first enable. You can resolve this by reconfiguring the client or automation application.

Failure to Reselect a Control Object Before the Time-Out

In Ed1, if a client reselected a control object before the select-before-operate time-out expired, the reselection would succeed and cause the selected time-out to restart. According to Ed2, this reselection is supposed to fail. Ed1-based clients or automation applications that rely on successful reselection might operate incorrectly. You can resolve this by reconfiguring the client or automation application.

Test Control Commands Fail Immediately

In Ed1, if the test attribute was set in a control command structure, the relay would accept the command but perform no action on the target control object. With enhanced control models, the IED would eventually report an operate time-out error after the operate time-out expired. However, in Ed2, any such test commands will fail immediately with an error indicating that the command is blocked because the IED is not in the appropriate mode. Clients or automation applications that depend on the Ed1 behavior might fail. You can resolve this by reconfiguring the client or automation application.

No Reports

Ed2 specifies that no reports are to be generated for a deadbanded attribute if the deadband is set to 0. Previously in Ed1, a deadband of 0 would cause the relay to generate reports for any change in the instantaneous value. Ed1-based clients or automation applications might not operate correctly because of the lack of reports. You can resolve this by reconfiguring the client or automation application.

Known Interoperability Issues Between Ed2.1 and Ed2

For unbuffered and buffered reporting, the client reserves the RCB first before changing the configuration and enabling it. Otherwise, if not reserved, the server refuses the configuration and enable request. SEL recommends that you update each client system to Ed2.1 when an Ed2.1 server device is used.

Changes to Data Modeling in Ed2.1

Some logical nodes and data objects have been extended and updated in Ed2.1. The logical nodes and objects present in the default ICD files for SEL devices may have changed for Ed2.1. A table of objects included in the default ICD files is included in the product-specific instruction manual. Optional objects and attributes not included in the default ICD files may not be listed.

The name space for data modeling in Ed2.1 has been changed from IEC 61850-7-4:2007A to IEC 61850-7-4:2007B.

Changes Related to Communication Services in Ed2.1

The changes for communication services in Ed2.1 include:

- Setting Group
  - SGCB.LActTm updates when the active setting group has changed via non-IEC 61850 means or if a setting has changed in the active setting group.
- Unbuffered Reporting
  - Clients must always set Resv = TRUE, even when the URCB is preassigned, before the report can be enabled.
  - When a URCB instance is preassigned to a specific client, Resv = TRUE.
- Buffered Reporting
  - Clients must always set ResvTms to a value greater than 0, even when the BRCB is preassigned, before the report can be enabled.
  - Servers will refuse configuration and RptEna = T if the client did not reserve a report.
- LTMS.TmSrc Data Object
  - When the type of clock source is PTP, the LTMS.TmSrc data object outputs the grandmaster PTP clock identity according to IEC/IEEE 61588:2021.

Backward Compatibility With Ed1 Devices

In some cases, updating Ed1 client applications or server devices in an existing IEC 61850 system may not be feasible. While Ed2 or Ed2.1 devices are generally backward compatible, it might be preferable to use an Ed1 ICD file in a device that supports Ed2 or Ed2.1. Architect provides a selection option to allow an Ed2.1 device to communicate with an Ed1 client.

Ed1 subscriber devices cannot interpret the simulation bit or Mode/Behavior in a GOOSE or Sampled Values data message, which could lead to a misoperation. Therefore, caution and thorough testing are essential in mixed edition systems.

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SECTION 18

Synchrophasors

Most SEL-400 series relays can be configured to function as a phasor measurement unit (PMU).

This section covers:

Introduction

The word synchrophasor is derived from two words: synchronized phasor. Synchrophasor measurement refers to the concept of providing measurements taken on a synchronized schedule in multiple locations. A high-accuracy clock, commonly a Global Positioning System (GPS) receiver such as the SEL-2488 Satellite-Synchronized Network Clock, makes synchrophasor measurement possible.

The availability of an accurate time reference over a large geographic area allows multiple devices, such as a number of relays, to synchronize the gathering of power system data. The accurate clock allows precise event report triggering and other offline analysis functions.

The Global settings class contains the synchrophasor settings, including the choice of Synchrophasor Protocol and the synchrophasor data set the relay will transmit. The Port settings class selects which port(s) are configured for Synchrophasor Protocol use.

The high-accuracy timekeeping function generates status Relay Word bits and time-quality information that is important for synchrophasor measurement.

When synchrophasor measurement is enabled, the relay creates the synchrophasor data set at a rate of either 50 or 60 times per second, depending on the nominal system frequency (Global setting NFREQ). This data set, including time-of-sample, is available in analog quantities in the relay (see Synchrophasor Analog Quantities). You can view synchrophasor data over the relay ASCII terminal interface (see *View Synchrophasors by Using the MET PM Command on page 18.21*).

The value of synchrophasor data increases greatly when the data can be shared over a communications network in real time. Two Synchrophasor Protocols are available in the relay that allow for a centralized device to collect data efficiently from several PMUs. Some possible uses of a system-wide synchrophasor system include the following:

- Power system state measurement
- Wide-area network protection and control schemes
- Small-signal analysis
- Power system disturbance analysis

NOTE: The SEL-3555 RTAC with the SVP library has replaced the SEL-3378, which is no longer in production, but you can still use the SEL-3378 in the examples in this section.

The SEL-3555 Real-Time Automation Controller (RTAC) is a real-time synchrophasor programmable logic controller. Use the SEL-3555 to collect synchrophasor messages from relays and PMUs. The SEL-3555 time-aligns incoming messages and processes these messages with an internal logic engine. Additionally, the SEL-3555 can send calculated or derived data to devices such as other synchrophasor vector processors (SVPs), phasor data concentrators (PDCs), and monitoring systems.

In any installation, the relay can use only one of the synchrophasor message formats, SEL Fast Message Synchrophasor, or IEEE C37.118, as selected by Global setting MFRMT. The chosen format is available on multiple serial ports when port setting(s) PROTO := PMU. IEEE C37.118 is available over Ethernet when the **PORT 5** setting EPMIP is enabled.

NOTE: Relays that support IEEE C37.118.1-2011 do not support SEL Fast Message Synchophasor protocol.

With either the SEL Fast Message or IEEE C37.118 synchrophasor format, the relay can receive control operation commands over the same channel used for synchrophasor data transmission. These commands are SEL Fast Operate messages, which are described in *SEL Fast Meter, Fast Operate, Fast SER Messages, and Fast Message Data Access on page 15.34*.

After enabling the data recording function with the Global EPMDR settings, record synchrophasor data using the PMTRIG setting. When PMTRIG asserts, the relay records IEEE synchrophasor data in binary format for the duration specified with the PMLER setting. The relay stores these files in the synchrophasor subdirectory in the relay.

You can configure the relay to receive IEEE C37.118 protocol synchrophasor data. The relay receives the data over a serial connection and stores these data in Analog Quantities. Time-alignment is automatic. Use the local phasor data and as many as two remote sets of phasor data in SELOGIC equations.

Functionality in IEEE C37.118.1-2011-Compliant Synchrophasors

When compared to IEEE C37.118-2005, IEEE C37.118.1 has several differences, some of which are described below.

NOTE: All references to IEEE C37.118.1 in this document are references to IEEE C37.118.1-2011, as amended by IEEE C37.118.1a-2014.

Performance Classes. IEEE C37.118.1 introduced two performance classes: P class and M class. P class (protection) is for applications that require a faster response and less filtering. M class (measurement) is for applications that require more accuracy and do not require minimal reporting delay.

Specified Latency. IEEE C37.118.1 introduced message latency requirements. In this context, message latency is defined as the time interval between when an event occurs on the power system to the time that it is reported in data.

Dynamic Performance. IEEE C37.118.1 introduced dynamic performance requirements, whereas the 2005 standard only specified performance when the power system was in steady state.

Rate-of-Change of Frequency (ROCOF). IEEE C37.118.1 introduced requirements on the responsiveness of ROCOF beyond that of the 2005 standard. One effect of these changes is to make ROCOF more sensitive to noise, so care should be taken before applying the ROCOF value to a control scheme.

Synchrophasor Measurement

The PMU uses the signal processing shown in *Figure 18.1* to measure the synchrophasors. The input signal passes through a traditional anti-aliasing low-pass filter (LPF). This filter has a cutoff frequency of 250 Hz. The PMU decimates this 8 kHz filtered data by eight and then processes the resulting data at 1 kHz.

NOTE: This section describes IEEE C37.118-2005-compliant devices.

The PMU then modulates the 1 kHz data with two sinusoids, each 90 degrees apart to produce real and imaginary components of the synchrophasor. The modulating sinusoids are synchronized to absolute time to provide an absolute time reference for the synchrophasor. Also an angular compensation factor compensates for the phase shift introduced by the PMU hardware and software.

The modulated data are filtered using low-pass filters. The filter coefficients are based on NFREQ, PMAPP, and MRATE. The filtered data provides good attenuation for harmonics and interharmonics. For PMAPP = F and N the attenuation is 20 dB. For PMAPP = 1 the attenuation is 40 dB.

Relays with DSS technology adjust synchrophasors automatically by the channel delay associated with the DSS technology used. This allows for comparing synchrophasor measurements gathered from traditional, non-DSS relays.

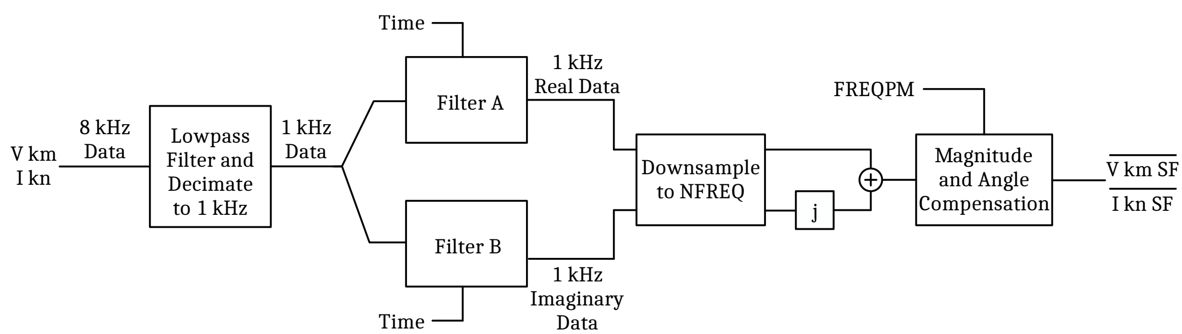


Figure 18.1 Synchrophasor Processing Block Diagram

Figure 18.2 shows the magnitude frequency response of the synchronized phasor measurement for PMAPP = F, N, and 1 for MRATE = 60.

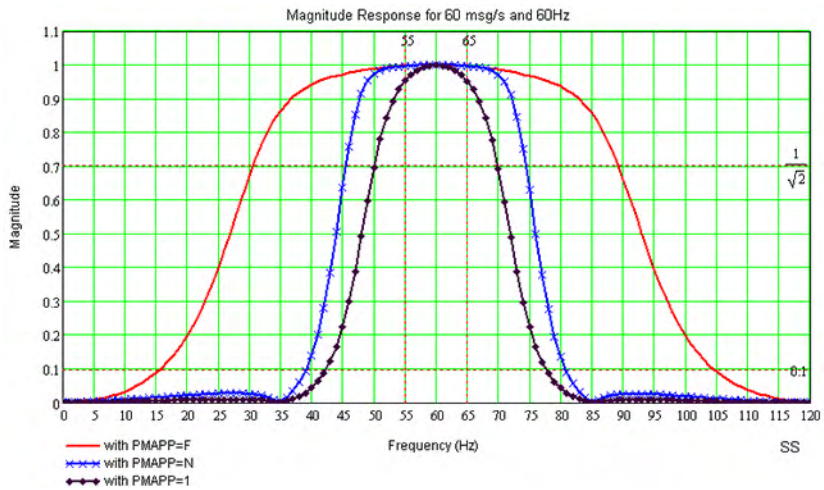


Figure 18.2 Magnitude Frequency Response

After low-pass filtering, the data are decimated to the nominal power system frequency (NFREQ).

If frequency-based phasor compensation is enabled (PHCOMP = Y), the relay calculates a compensation factor based on the measured synchrophasor frequency (FREQPM) and filter configuration (based on NFREQ, MRATE, and PMAPP). The PMU then corrects the measured synchrophasors by this factor.

Using the V*m*COMP and I*n*COMP settings, the PMU compensates the voltage and current synchrophasors for any externally introduced phase angle errors. The PMU adds the user-entered phase angle to the phase angle of the measured synchrophasor.

The PMU converts the synchrophasor data to primary units by multiplying them with the respective PT or CT ratios. Note that the resulting data Vk*m*SF and Ik*n*SF is in complex form (A + jB). The PMU calculates the positive-sequence synchrophasor with the three-phase synchrophasors.

The PMU then converts all synchrophasor data to polar and rectangular quantities. The data are available as analog quantities as well as for the synchrophasor data frames. The synchrophasor data are updated at the nominal power system frequency.

Accuracy

For devices that comply to IEEE C37.118.1, refer to the IEEE standard.

For synchrophasors that comply to the 2005 standard, the following phasor measurement accuracy is valid when frequency-based phasor compensation is enabled (Global setting PHCOMP := Y), and when the phasor measurement application setting is in the narrow bandwidth mode (Global setting PMAPP := N).

NOTE: When the PMU is in the fast response mode (Global setting PMAPP := F), the TVE is within specified limits only when the out of band interfering signals influence quantity is not included.

TVE (total vector error) ≤1% for one or more of the following influence quantities.

- For PMAPP = N Signal Frequency Range: ±5 Hz of nominal (50 or 60 Hz)
- For PMAPP = 1 Signal Frequency Range: ±2 Hz of 60 Hz
- Voltage Magnitude Range: 30 V–150 V
- Current Magnitude Range: (0.1–2) • I_{NOM}, (I_{NOM} = 1 A or 5 A)
- Phase Angle Range: –179.99° to 180°
- Harmonic distortion ≤10 percent (any harmonic)
- Out of band interfering signals ≤10 percent

The out-of-band interfering signal frequency (f_i) must satisfy:

$| f_i – NFREQ | > MRATE/2$,

where NFREQ is nominal system frequency and MRATE is the message rate, as defined in IEEE C37.118.

It is important to note that the synchrophasors can only be correlated when the PMU is in HIRIG or HPTP timekeeping mode, which can be verified by monitoring the TSOK Relay Word bit. When TSOK = logical 1, the PMU timekeeping is synchronized to the high-accuracy IRIG-B signal or Precision Time Protocol (PTP) time source, and the synchrophasor data are precisely time-stamped. See *Section 11: Time and Date Management* for details.

PMU Data Block Status

In a PMU data frame, each data block is headed by a two-byte STAT field. This field indicates the status of the PMU data block. Bit 15 of the STAT field indicates the validity of data. SEL-400 series relays assert bit 15 of the STAT when synchrophasor test mode indicator PMTEST asserts or SVBK_EX asserts in SEL-400 series Sampled Values (SV) subscribers.

For SV-subscribing relays, configure Global setting SVBLK to assert on errors encountered in SV data acquisition. For example, set SVBLK := IAWBK OR IBWBK OR ICWBK. In this example, if SV data for any Terminal W current is lost, SVBK_EX asserts, which then asserts bit 15 in the STAT field, indicating current data have errors and, therefore, synchrophasor data are invalid.

For an explanation of other bits in the STAT field, refer to the IEEE C37.118 standard.

Synchrophasor Frequency

The PMU calculates frequency deviation and rate-of-change of frequency from the synchrophasor positive-sequence voltage angle (V1*n*PMA, where *n* = PMFRQST) as follows.

NOTE: Applies to IEEE C37.118-2005-compliant devices.

First, the PMU calculates the frequency deviation from nominal using the following formula.

$$f_k = \frac{(\theta_k - \theta_{k-1})}{\Delta t \bullet 360}$$

Equation 18.1

Where θ_k is the V1*n*PMA and θ_{k-1} is V1*n*PMA calculated 1 cycle previously. Δt is the time difference between the angle calculations (*k* increments once a nominal power system cycle).

Next, the PMU averages the frequency deviation as shown in *Equation 18.2* and *Equation 18.3*.

If the frequency application is smooth (PMFRQA = S)

$$favg_k = \frac{\left(\sum_{n=0}^{9} f_k - n\right) - f_{max1} - f_{max2} - f_{min1} - f_{min2}}{6}$$

Equation 18.2

If the frequency application is fast (PMFRQA = F)

$$favg_k = \frac{\left(\sum_{n=0}^{3} f_k - n\right) - f_{max} - f_{min}}{2}$$

Equation 18.3

The PMU then calculates rate-of-change of frequency, df/dt from the averaged frequencies deviations (*Equation 18.4*).

$$df/dt_k = \frac{(favg_k - favg_{k-1})}{\Delta t}$$

Equation 18.4

If the frequency value is equal to or within ±20 Hz and V1*n*MPM/PTR*n* (secondary) is larger than 0.1 • VNOM*n* then:

$FREQPM_k = favg_k + NFREQ$ <analog>
$DFDTPM_k = df/dt_k$ <analog>
After six consecutive cycles
$FROKPM_k = 1$ <digital>

If the frequency value exceeds ±20 Hz or the V1*n*MPM/PTR*n* (secondary) is below 0.1 • VNOM*n* then:

$FREQPM_k = FREQPM_{k-1}$ <analog>
$DFDTPM_k = 0$ <analog>
$FROKPM_k = 0$ <digital>

The frequency and rate-of-change of frequency are available as analog quantities as well as for the synchrophasor data frames. The data are updated at the nominal power system frequency.

Table 18.1 Synchrophasor Analog Quantities Frequency

Name	Description	Units
FREQPM	Measured system frequency	Hz
DFDTPM	Rate-of-change of frequency	Hz/s

Settings for Synchrophasors

Each SEL-400 series relay supports a variety of current and voltage terminals. See the product-specific instruction manuals for specific settings based on the synchrophasor standard supported and to see which terminals are available to synchrophasors. Synchrophasors are primarily configured through the Global settings. There are also a few port settings necessary to enable synchrophasor communications.

Global Settings

The Global enable setting EPMU must be set to Y before the remaining synchrophasor settings are available. The PMU is disabled when EPMU := N.

Table 18.2 Global Settings for Configuring the PMU

Setting	Setting Prompt
EPMU	Synchronized Phasor Measurement (Y, N)
MFRMT[a]	Message Format (C37.118, FM)
MRATE[a]	Messages per Second (1, 2, 4, 5, 10, 12, 15, 20, 30, 60)[b]
PMAPP[a]	PMU Application (F, N, 1)
MRATE*n*[c]	Messages per Second (1, 2, 4, 5, 10, 12, 15, 20, 30, 60)[b]
PMAPP*n*[c]	PMU Application (P, M)
PMLEGCY[a]	Synchrophasor Legacy Settings (Y, N, N1[d])
NUMPHDC	Number of Data Configurations (1–5)
PMSTN*q*[e]	Station Name (16 characters)
PMID*q*[e]	PMU Hardware ID (1–65534)
PHDV*q*[e]	Phasor Data Set, Voltages (V1, PH, ALL)
PHDI*q*[e]	Phasor Data Set, Currents (I1, PH, ALL)
PHNR*q*[e]	Phasor Num. Representation (I = Integer, F = Float)
PHFMT*q*[e]	Phasor Format (R = Rectangular, P = Polar)
FNR*q*[e]	Freq. Num. Representation (I = Integer, F = Float)
TREA[1–4]	Trigger Reason Bit [1–4] (SELOGIC Equation)
PMTRIG	Trigger (SELOGIC Equation)
PMTEST	PMU in Test Mode (SELOGIC Equation)
V*k*COMP[f]	Comp. Angle Terminal *k* (–179.99° to 180°)
I*n*COMP[g]	Comp. Angle Terminal *n* (–179.99° to 180°)
PMFRQST	PMU Primary Frequency Source Terminal
PMFRQA[a]	PMU Frequency Application (F, S)
PHCOMP[a]	Freq. Based Phasor Compensation (Y, N)

[a] Not used in IEEE C37.118-2011-compliant devices.
[b] If NFREQ = 50 then the range is 1, 2, 5, 10, 25, 50.
[c] Only used in IEEE C37.118-2011-compliant devices.
[d] PMLEGCY option of N1 only applies to the SEL-487E.
[e] q = 1–NUMPHDC.
[f] k = voltage terminal.
[g] n = current terminal.

Descriptions for some of the settings in *Table 18.2* are as follows.

MFRMT

Selects the message format for synchrophasor data.

SEL recommends the use of MFRMT := C37.118 for any new PMU applications because of increased setting flexibility and the expected availability of software for synchrophasor processors. The PMU still includes the MFRMT := FM setting choice to maintain compatibility in any systems presently using SEL Fast Message synchrophasors.

MRATE

Selects the message rate in messages per second for synchrophasor data.

Choose the MRATE setting that suits the needs of your PMU application. The PMU supports as many as 60 messages per second if NFREQ = 60 and as many as 50 messages per second if NFREQ = 50.

MRATEn

Selects the message rate in messages per second for synchrophasor data per data configuration 1–5. MRATE*n* must be set to the same value across all data configurations that share the same filter type. The filter type is determined by the PMAPP*n* setting.

PMAPP

Selects the type of digital filters used in the synchrophasor measurement.

- The Narrow Bandwidth setting (N) represents filters with a cutoff frequency approximately 1/4 of MRATE. The response in the frequency domain is narrower, and response in the time domain is slower. This method results in synchrophasor data that are free of aliasing signals and well suited for post-disturbance analysis.
- The Fast Response setting (F) represents filters with a higher cutoff frequency. The response in the frequency domain is wider and the response in the time domain is faster. This method results in synchrophasor data that can be used in synchrophasor applications requiring more speed in tracing system parameters.
- The Filter One setting (1) represents filters that have a response much narrower than the narrow bandwidth filters. This method has a better step response with overshoot within 7.5 percent. This filter is available only for MRATE = 60.

PMAPPn

Selects the type of digital filters used in the synchrophasor measurement per data configuration 1–5. The filter that you select is applied to all configured data streams.

IEEE C37.118.1-2011 defines two performance classes: P (protection) and M (meter). P class measurements has faster response times and lower message latency. M class measurements are more accurate but have a slower response time and higher message latency.

For more information on the filtering classes, refer to the IEEE C37.118 standard.

PMLEGCY

This setting is provided for supporting legacy synchrophasor settings. Set this to N to access the latest features. See *Legacy Settings on page 18.15* to see a description of the legacy settings. The remainder of this section describes the non-legacy settings. Relays that support IEEE C37.118.1-2011 do not contain this setting.

NUMPHDC

Enables as many as five unique synchrophasor data configurations.

The four serial ports (**PORT 1**, **PORT 2**, **PORT 3**, and **PORT F**) and two Ethernet sessions (TCP/UDP Sessions 1 and 2) can be mapped to any of these five data configurations. In other words each port can be configured to send unique synchrophasor data streams.

PMSTNq and PMIDq

Defines the station name and number of the PMU for data configuration *q*.

The PMSTN*q* setting is an ASCII string with as many as 16 characters. The PMID*q* setting is a numeric value. Use your utility or synchrophasor data concentrator naming convention to determine these settings. PMSTN*q* allows all printable characters.

Phasors Included in the Data q

Terminal Name, Relay Word Bit, Alternative Terminal Name

Specify the terminal for Synchrophasor measurement and transmission in the synchrophasor data stream *q*.

This is a freeform setting category for enabling the terminals for synchrophasor measurement and transmission. This freeform setting has three arguments. Specify the terminal name (any one of the valid terminals for the relay) for the first argument. Specify any Relay Word bit for the second argument. Specify the alternative terminal name (any one of the valid terminals for the relay) for the third argument.

The second and third arguments are optional unless switching between terminals is required. Whenever the Relay Word bit in the second argument is asserted the terminal synchrophasor data are replaced by the alternative terminal data.

PHDVq

Selects the type of voltages to be included in the synchrophasor data stream *q*.

This setting affects the synchrophasor data packet size.

- PHDV*q* := V1, sends only positive-sequence voltage synchrophasors of selected terminals.
- PHDV*q* := PH, sends only phase voltage synchrophasors of selected terminals.
- PHDV*q* := ALL, sends phase and positive-sequence voltage synchrophasors of selected terminals.

PHDIq

Selects the type of currents to be included in the synchrophasor data stream q.

This setting affects the synchrophasor data packet size.

- PHDI*q* := I1, sends only positive-sequence current synchrophasors of selected terminals.
- PHDI*q* := PH, sends only phase current synchrophasors of selected terminals.
- PHDI*q* := ALL, sends phase and positive-sequence current synchrophasors of selected terminals.

PHNRq

Selects the numeric representation, integer (I) or floating-point (F), of voltage and current phasor data in the synchrophasor data stream *q*. This setting affects the synchrophasor data packet size.

- PHNR*q* := I sends each voltage and/or current synchrophasor as 2 two-byte integer values. The PMU uses ((7 • I_{NOM} • CT Ratio) / 32768) • 100000)) for the current phasor scaling factor and uses ((150 • PTR) / 32768) • 100000)) for the voltage phasor scaling factor. I_{NOM} is 1 A or 5 A.
- PHNR*q* := F sends each voltage and/or current synchrophasor as 2 four-byte floating-point values.

PHFMTq

Selects the phasor representation of voltage and current phasor data in the synchrophasor data stream q.

- PHFMT*q* := R (rectangular) sends each voltage and/or current synchrophasor as a pair of signed real and imaginary values.
- PHFMT*q* := P (polar) sends each voltage and/or current synchrophasor as a magnitude and angle pair. The angle is in radians when PHNR*q* := F, and in radians • 10^4 when PHNR*q* := I. The range is $-\pi < \text{angle} \le \pi$.

In both the rectangular and polar representations, the values are scaled in root mean square (rms) units. For example, a synchrophasor with a magnitude of 1.0 at an angle of –30 degrees will have a real component of 0.866, and an imaginary component of –0.500.

FNRq

Selects the numeric representation, integer (I) or floating-point (F), of the two frequency values in the synchrophasor data stream *q*.

This setting affects the synchrophasor data packet size.

- FNR*q* := I sends the frequency data as a difference from nominal frequency, NFREQ, with the following formula.

  (FREQPM – NFREQ) • 1000,

  represented as a signed, two-byte value. See *Synchrophasor Frequency on page 18.5* for details.
- FNR*q* := I also sends the rate-of-change-of-frequency data with scaling.

  DFDTPM • 100,

  represented as a signed, two-byte value. See *Synchrophasor Frequency on page 18.5* for details.
- FNR*q* := F sends the measured frequency data and rate-of-change of frequency as two four-byte, floating-point values.

Phasor Aliases in Data Configuration q

Phasor Name, Alias Name

This is a freeform setting category with two arguments. Specify the phasor name and a 16 character descriptive name to be included in the synchrophasor data stream *q*. If a phasor is not assigned a descriptive name, it will be described using the phasor name.

Analog Quantities in Data Configuration q

Analog Quantity Name, Alias Name

This is a freeform setting category with two arguments. Specify the analog quantity name and an optional 16 character descriptive name to be included in the synchrophasor data stream *q*. See *Section 12: Analog Quantities* in the product-specific instruction manual for a list of analog quantities that the PMU supports. The PMU can be configured for as many as 16 unique analog quantities for each data configuration *q*. The analog quantities are floating-point values, so each analog quantity the PMU includes will take four bytes.

Digitals in Data Configuration q

Relay Word Bit Name, Alias Name

This is a freeform setting category with two arguments. Specify the Relay Word bit name and an optional 16 character descriptive name that you need to include in the synchrophasor data stream *q*. See the Relay Word Bits section of the relay-specific instruction manual for a list of Relay Word bits that the PMU supports. You can configure the PMU for as many as 64 unique digitals for each data configuration.

TREA1, TREA2, TREA3, TREA4, and PMTRIG

Defines the programmable trigger bits as allowed by IEEE C37.118.

Each of the four Trigger Reason settings, TREA1–TREA4, and the PMU Trigger setting, PMTRIG, are SELOGIC control equations. The PMU evaluates these equations and places the results in Relay Word bits with the same names: TREA1–TREA4 and PMTRIG.

NOTE: Select PMTRIG trigger conditions to assert PMTRIG no more frequently than once every four hours if EPMDR = Y (i.e., synchrophasor recording is enabled).

The Trigger Reason equations represent the Trigger Reason bits in the STAT field of the data packet. After the Trigger Reason bits are set to convey a message, the PMTRIG Equation should be asserted long enough to allow the synchrophasor processor to read the TREA1–TREA4 fields. To calculate how long PMTRIG should remain asserted (in seconds), divide 1 by the MRATE Global settings value. For example, if MRATE = 60, PMTRIG should be asserted at least 17 ms. If MRATE = 1, PMTRIG should be asserted at least 1 second.

The IEEE C37.118 standard defines the first 8 of 16 binary combinations of these trigger reason bits (Bits 0–3).

The remaining eight binary combinations are available for user definition.

The PMU does not automatically set the TREA1–TREA4 or PMTRIG Relay Word bits—these bits must be programmed.

These bits may be used to send various messages at a low bandwidth via the synchrophasor message stream. Digital Status Words may also be used to send binary information directly, without the need to manage the coding of the trigger reason messages in SELOGIC.

Use these Trigger Reason bits if your synchrophasor system design requires these bits. The PMU synchrophasor processing and protocol transmission are not affected by the status of these bits.

PMTEST

Program this SELOGIC setting to force the PMU to test mode. The SELOGIC evaluation of this setting, PMTEST is mapped to the data valid bit (i.e., bit 15) in the STAT field.

VkCOMP

The V*k*COMP (*k* = voltage terminals) setting allows correction for any steady-state voltage phase errors (from the PTs or wiring characteristics). See *Synchrophasor Measurement on page 18.3* for details on this setting.

InCOMP

The I*n*COMP (*n* = current terminals) settings allow correction for any steady-state phase errors (from the CTs or wiring characteristics). See *Synchrophasor Measurement on page 18.3* for details on these settings.

PMFRQST

Selects the voltage terminal that will be the primary source of the system frequency for the PMU calculations. For example, if PMFRQST = Z, then the Z PT terminal is the source for frequency estimation.

PMFRQA

Selects the PMU frequency application. A setting of S sets a smooth frequency application. A setting of F selects a fast frequency application.

NOTE: Does not apply to newer synchrophasors.

The frequency application is used in the calculation of the rate-of-change of frequency for a given analog signal. A smooth frequency application setting (PMFRQA = S) uses 9 cycles of data for the rate-of-change calculation. A fast frequency application setting (PMFRQA = F) uses 3 cycles of data for the rate-of-change calculation.

The fast frequency application will detect rapid changes in frequency faster, but will also contain more low-level oscillations. The slow frequency application will provide a rate-of-change profile that is smoother, but slower to respond to rapid frequency fluctuations.

PHCOMP

Enables or disables frequency-based compensation for synchrophasors.

NOTE: Does not apply to newer synchrophasors.

For most applications, set PHCOMP := Y to activate the algorithm that compensates for the magnitude and angle errors of synchrophasors for frequencies that are off nominal.

For PMAPP = F or N, the PMU only compensates if the estimated frequency is ±5 Hz of nominal frequency. For PMAPP = 1 the PMU compensates if the frequency is ±2 Hz of nominal frequency.

Serial Port Settings

The port settings found in *Table 18.3* are used for configuring synchrophasor data transmission over a serial port.

Table 18.3 Serial PORT 1, PORT 2, PORT 3, PORT F Settings for Synchrophasors

Setting	Description
PROTO	Protocol (SEL, DNP, MBA, MBB, PMU[a])
SPEED	Data Speed (300–57600)
STOPBIT	Stop Bits (1, 2)
RTSCTS	Enable Hardware Handshaking (Y, N)
FASTOP	Enable Fast Operate Messages (Y, N)
PMUMODE	PMU Mode (CLIENTA, CLIENTB, SERVER)
PMODC	PMU Output Data Configuration (1–5)

[a] The specific protocol choices available depends on the relay.

Descriptions for some of the settings in *Table 18.3* are as follows.

PROTO

Setting this to PMU enables synchrophasor data transmission on the specific serial port. Once set to PMU that specific serial port cannot be used for accessing settings or issuing any ASCII commands.

If PROTO := PMU and MFRMT := C37.118, then the serial port will only respond to IEEE C37.118 commands.

- Stop synchrophasor data
- Start synchrophasor data
- Send header data
- Send Configuration 1 data
- Send Configuration 2 data
- Process extended frame data

NOTE: Relays that support IEEE C37.118.1-2011 do not support SEL Fast Message Synchrophasor protocol.

If PROTO := PMU or SEL and MFRMT := FM, then the serial port will only respond to SEL Fast Message synchrophasor commands.

SPEED

Select the data rate (300–57600) for synchrophasor data transmission on the specific serial port. This setting affects the synchrophasor data packet size. See *Communications Bandwidth on page 18.24* for detailed information.

PMUMODE

Set PMUMODE := SERVER if the serial port is intended to send synchrophasor data. Client applications are described in *Real-Time Control on page 18.36*.

PMODC

NOTE: If PMODC is set to a number that exceeds the setting for NUMPHDC, the port sends the data for the first PMU configuration.

Select the data configuration (1-NUMPHDC) for synchrophasor data transmission on the specific serial port. This setting affects the synchrophasor data packet size. See *Communications Bandwidth on page 18.24* for detailed information. Through the use of this setting each serial port can be configured to stream unique synchrophasor data.

EPMU := N Supersedes Synchrophasor Port Settings

The PROTO := PMU settings choice can be made even when Global setting EPMU := N. However, in this situation, the serial port will not respond to any commands or requests. Either enable synchrophasors by setting EPMU to Y, or change the port PROTO setting to SEL.

If you use a computer terminal session or ACSELERATOR QuickSet SEL-5030 Software connected to a serial port, and then set that same serial port PROTO setting to PMU, you will lose the ability to communicate with the relay through ASCII commands or virtual file interface commands. If this happens, either connect via another serial port (that has PROTO := SEL) or use the front-panel HMI SET/SHOW screen to change the disabled port PROTO setting back to SEL.

Ethernet Port Settings

The settings found in *Table 12.24* and *Table 12.32* are used for configuring synchrophasor data transmission over an Ethernet port. Descriptions for some of the settings are as follows.

EPMIP

This setting enables synchrophasor data transmission over Ethernet. Enabling EPMIP when Global setting EPMU := N results in the relay ignoring any incoming synchrophasor requests regardless of whether the Ethernet port settings are correct or not.

PMOTS[2]

Selects the PMU Output transport scheme for session 1 and 2, respectively.

- PMOTS[2] := TCP establishes a single, persistent TCP socket for transmitting and receiving synchrophasor messages (both commands and data), as illustrated in *Figure 18.3*.

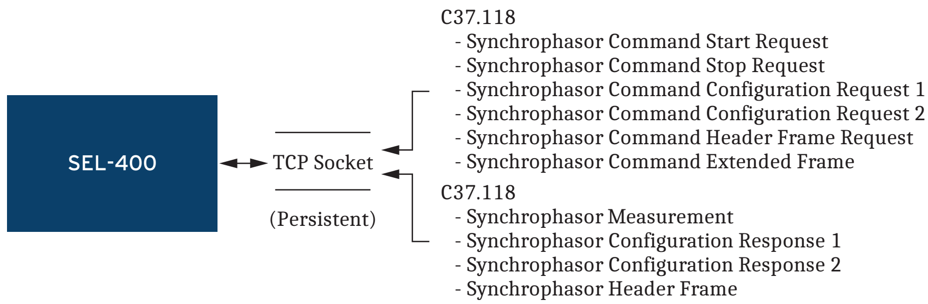


Figure 18.3 TCP Connection

- PMOTS[2] := UDP_T establishes two socket connections. A nonpersistent TCP connection is used for receiving synchrophasor command messages as well as synchrophasor configuration and header response messages. A persistent UDP connection is used to transmit synchrophasor data messages. *Figure 18.4* depicts the UDP_T connection.
- PMOTS[2] := UDP_U uses the same connection scheme as the UDP_T except the synchrophasor configuration and header response messages are sent over the UDP connection, as shown in *Figure 18.4*.

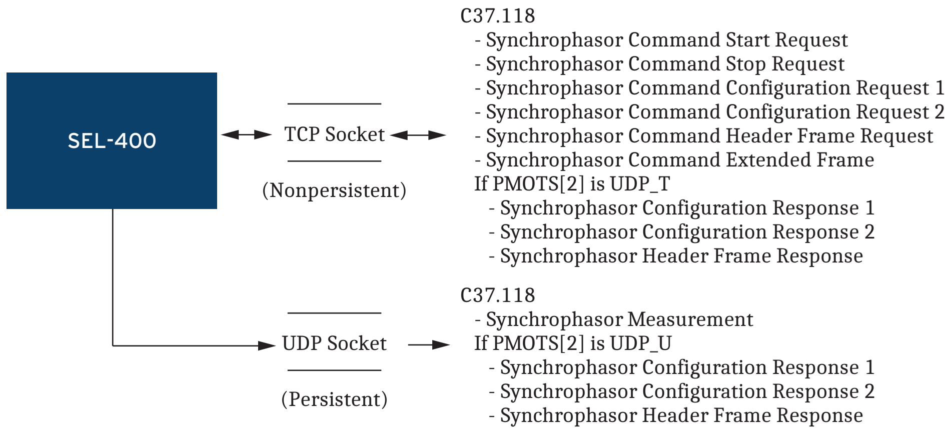


Figure 18.4 UDP_T and UDP_U Connections

➤ PMOTS[2] := UDP_S establishes a single persistent UDP socket to transmit synchrophasor messages. Synchrophasor data are transmitted whenever new data are read. With this communications scheme, the relay sends a “Synchrophasor Configuration Response 2” once every minute, as shown in *Figure 18.5*.

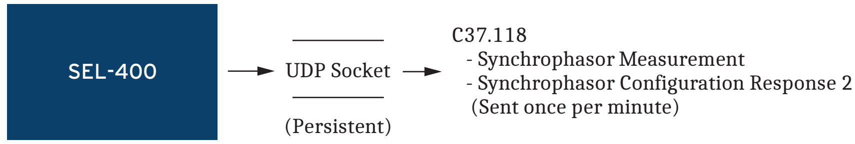


Figure 18.5 UDP_S Connection

PMODC[2]

NOTE: If PMODC is set to a number that exceeds the setting for NUMPHDC, the port sends the data for the first PMU configuration.

Select the data configuration (1-NUMPHDC) for synchrophasor data transmission on the specific session 1 and 2. Using this setting, each Ethernet session can be configured to stream unique synchrophasor data.

PMOIPA[2]

Defines the PMU Output Client IP address for session 1 and 2, respectively.

PMOTCP[2]

Defines the TCP/IP (Local) port number for session 1 and 2, respectively. These port numbers must all be unique.

PMOUDP[2]

Defines the UDP/IP (Remote) port number for session 1 and 2, respectively.

Legacy Settings

The PMU provides the following legacy synchrophasor settings that can be enabled by setting PMLEGCY = Y.

PMSTN and PMID

Defines the name and number of the PMU. The PMSTN setting is an ASCII string with as many as 16 characters. The PMID setting is a numeric value (1–65534). Use your utility or synchrophasor data concentrator naming convention to determine these settings.

PHVOLT and PHDATAV

PHDATAV and PHVOLT select which voltage synchrophasors to include in the data packet. If MFRMT = FM, the only options available are V1 and ALL.

- PHDATAV := V1 will transmit only positive-sequence voltage,V1
- PHDATAV = PH will transmit phase voltages only (VA, VB, VC)
- PHDATAV := ALL will transmit V1, VA, VB, and VC
- PHDATAV := NA will not transmit any voltages

PHVOLT selects the voltage sources for the synchrophasor data selected by PHDATAV.

Use the PHVOLT setting to select any combination of available voltage terminals.

PHCURR and PHDATAI

PHDATAI and PHCURR select which current synchrophasors to include in the data packet.

- PHDATAI := I1 will transmit only positive-sequence current, I1
- PHDATAI := PH transmits phase currents (IA, IB, IC)
- PHDATAI := ALL will transmit I1, IA, IB, and IC
- PHDATAI := NA will not transmit any currents

PHCURR selects the source current(s) for the synchrophasor data selected by PHDATAI.

Use the PHCURR setting to select any combination of available current terminals. If MFRMT = FM, only a single terminal can be selected.

PHNR

Selects the numerical representation of voltage and current phasor data in the synchrophasor data stream. If MFRMT = FM, this setting is forced to F, a floating-point value.

PHFMT

Selects the phasor representation of voltage and current phasor data in the synchrophasor data stream. If MFRMT = FM, this setting is forced to P, for polar phasor format. This setting is hidden if PHDATAV and PHDATAI = NA.

FNR

Selects the numeric representation of the two frequency values in the synchrophasor data stream. If MFRMT = FM, this setting is forced to F, a floating-point value.

NUMANA

Selects the number of user-definable analog values to be included in the synchrophasor data stream.

- Setting NUMANA := 0 sends no user-definable analog values.
- Setting NUMANA := 1–16 sends the user-definable analog values, as listed in *Table 18.4*.

The format of the user-defined analog data is always floating point, and each value occupies four bytes. If MFRMT = FM, this setting is forced to 0 and the relay does not send any user-definable analog values.

Table 18.4 User-Defined Analog Values Selected by NUMANA Setting

NUMANA Setting	Analog Quantities Sent	Total Number of Bytes Used for Analog Values
0	None	0
1	PMV64	4
2	Above, plus PMV63	8
3	Above, plus PMV62	12
4	Above, plus PMV61	16
5	Above, plus PMV60	20
6	Above, plus PMV59	24
7	Above, plus PMV58	28
8	Above, plus PMV57	32
9	Above, plus PMV56	36
10	Above, plus PMV55	40
11	Above, plus PMV54	44
12	Above, plus PMV53	48
13	Above, plus PMV52	52
14	Above, plus PMV51	56
15	Above, plus PMV50	60
16	Above, plus PMV49	64

NUMDSW

Selects the number of user-definable digital status words to be included in the synchrophasor data stream.

Setting NUMDSW := 0 sends no user-definable binary status words.

Setting NUMDSW := 1, 2, 3, or 4 sends the user-definable binary status words, as listed in *Table 18.5*. If MFRMT = FM, this is forced to 1.

Table 18.5 User-Defined Digital Status Words Selected by the NUMDSW Setting (Sheet 1 of 2)

NUMDSW Setting	Digital Status Words Sent	Total Number of Bytes Used for Digital Values
0	None	0
1	[PSV64, PSV63 … PSV49]	2

Table 18.5 User-Defined Digital Status Words Selected by the NUMDSW Setting (Sheet 2 of 2)

NUMDSW Setting	Digital Status Words Sent	Total Number of Bytes Used for Digital Values
2	[PSV64, PSV63 … PSV49] [PSV48, PSV47 … PSV33]	4
3	[PSV64,PSV63 … PSV49] [PSV48,PSV47 … PSV33] [PSV32,PSV31 … PSV17]	6
4	[PSV64,PSV63 … PSV49] [PSV48,PSV47 … PSV33] [PSV32,PSV31 … PSV17] [PSV16,PSV15 … PSV01]	8

Synchrophasor Quantities

Relay Word Bits

This section describes the Relay Word bits that are related to synchrophasor measurement.

The Synchrophasor Trigger Relay Word bits in *Table 18.6* follow the state of the SELOGIC control equations of the same name. These Relay Word bits are included in the IEEE C37.118 synchrophasor data frame STAT field. See *Table 18.6* for standard definitions for these settings.

Table 18.6 Synchrophasor Trigger Relay Word Bits

Name	Description
PMTRIG	Trigger (SELOGIC control equation)
TREA4	Trigger Reason Bit 4 (SELOGIC control equation)
TREA3	Trigger Reason Bit 3 (SELOGIC control equation)
TREA2	Trigger Reason Bit 2 (SELOGIC control equation)
TREA1	Trigger Reason Bit 1 (SELOGIC control equation)

The Time-Synchronization Relay Word bits in *Table 18.7* indicate the present status of the high-accuracy timekeeping function of the relay.

Table 18.7 Time-Synchronization Relay Word Bits

Name	Description
TIRIG	Asserts while relay time is based on IRIG-B time source.
PTP	Synchronized to a PTP source.
TPTP	The active relay time source is PTP.
TSOK	Time synchronization OK. Asserts while time is based on high-accuracy IRIG-B or PTP time source (HIRIG or HPTP mode) of sufficient accuracy for synchrophasor measurement.
PTPSYNC	Asserts while the relay is synchronized to a high-quality PTP time source.
PMDOK	Phasor measurement data OK. Asserts when the relay is enabled and synchrophasors are enabled (Global setting EPMU := Y).

When using the relay as a synchrophasor client, the Relay Word bits in *Table 18.8* indicate the state of the synchronization.

Table 18.8 Synchrophasor Client Status Bits for Real-Time Control

Name	Description
RTCENA	Asserts for one processing interval when a valid message is received on Channel A.
RTCENB	Asserts for one processing interval when a valid message is received on Channel B.
RTCROKA	Asserts for one processing interval when data are aligned for Channel A. Use this bit to condition usage of the Channel A data.
RTCROKB	Asserts for one processing interval when data are aligned for Channel B. Use this bit to condition usage of the Channel B data.
RTCROK	Asserts for one processing interval when data for all enabled channels are aligned. Use this bit to condition general usage of the aligned synchrophasor data.
RTCDLYA	This bit is asserted when the last received valid message on Channel A is older than MRTCDLY.
RTCDLYB	This bit is asserted when the last received valid message on Channel B is older than MRTCDLY.
RTCSEQA	This bit is asserted when the processed received message on Channel A is the expected next-in-sequence. It is deasserted if it is not. The deassertion implies that one or more packets of information were lost. Use this bit to condition usage of channel A data in applications where sequential data are required.
RTCSEQB	This bit is asserted when the processed received message on Channel B is the expected next-in-sequence. It is deasserted if it is not. The deassertion implies that one or more packets of information were lost. Use this bit to condition usage of channel B data in applications where sequential data are required.
RTCCFGA	Indicates Channel A is successfully configured.
RTCCFGB	Indicates Channel B is successfully configured.

When received, synchrophasor messages contain digital data. These data are stored in the Remote Synchrophasor Relay Word bits in *Table 18.9*.

Table 18.9 Remote Synchrophasor Data Bits for Real-Time Control

Name	Description
RTCAD01–RTCAD16	First 16 digitals received in synchrophasor message on Channel A. Only valid when RTCROKA is asserted.
RTCBD01–RTCBD16	First 16 digitals received in synchrophasor message on Channel B. Only valid when RTCROKB is asserted.

Analog Quantities

The synchrophasor measurements in *Table 18.10* are available whenever Global setting EPMU := Y. When EPMU := N, these analog quantities are set to 0.0000.

NOTE: Sampled Values-subscribing relays experience a communication delay in their analog data. Time-stamping of synchrophasor data is adjusted by the **PORT 5** channel delay setting CH_DLY.

It is important to note that the synchrophasors are only valid when the relay is in HIRIG or HPTP timekeeping mode, which can be verified by monitoring the TSOK Relay Word bit. When TSOK = logical 1, the relay timekeeping is synchronized to the high-accuracy IRIG-B signal or PTP time source, and the synchrophasor data are precisely time-stamped.

Table 18.10 Synchrophasor Analog Quantities

Name	Description	Units
Frequency		
FREQPM	Measured system frequency[a]	Hz
DFDTPM	Rate-of-change of frequency, df/dt[a]	Hz/s
Synchrophasor Measurements		
Vk*m*PMM, Vk*m*PMA, Vk*m*PMR, Vk*m*PMI[b, c]	Phase k synchrophasor voltage (M-magnitude, A-Angle, R-Real, I-Imaginary) Terminal *m*	kV Primary, degrees, kV Primary, kV Primary
V1*m*PMM, V1*m*PMA, V1*m*PMR, V1*m*PMI	Positive-sequence synchrophasor voltage (M-magnitude, A-Angle, R-Real, I-Imaginary) Terminal *m*	kV Primary, degrees, kV Primary, kV Primary
Ik*n*PMM, Ik*n*PMA, Ik*n*PMR, Ik*n*PMI[d]	Phase k synchrophasor current (M-magnitude, A-Angle, R-Real, I-Imaginary) Terminal *n*	A Primary, degrees, A Primary, A Primary
I1*n*PMM, I1*n*PMA, I1*n*PMR, I1*n*PMI	Positive-sequence synchrophasor current (M-magnitude, A-Angle, R-Real, I-Imaginary) Terminal *n*	A Primary, degrees, A Primary, A Primary
SODPM	Second of the day of the PM data	s
FOSPM	Fraction of the second of the PM data	s

[a] Measured value if the voltages are valid and EMPU = Y, otherwise FREQPM = nominal frequency setting NFREQ, and DFDT is zero.
[b] k = A, B, or C.
[c] m = voltage terminal.
[d] n = current terminal.

When using the relay for synchrophasor acquisition, the delayed and aligned analog quantities listed in *Table 18.11* are available. Be aware that these quantities are only valid when RTCROK is asserted and only for the enabled channels. The specific channel quantities are also valid whenever their respective RTCROK*c* Relay Word bit is set.

Table 18.11 Synchrophasor Aligned Analog Quantities for Real-Time Control (Sheet 1 of 2)

Name	Description	Units
RTCAP01–RTCAP32	Remote phasor pairs for Channel A. Only those channels provided by the remote are valid to use. Use the **RTC** command to confirm interpretation of these quantities.	
RTCBP01–RTCBP32	Remote phasor pairs for Channel B. Only those channels provided by the remote are valid to use. Use the **RTC** command to confirm interpretation of these quantities.	
RTCAA01–RTCAA08	Remote analogs for Channel A. Only those channels provided by the remote are valid to use. Use the **RTC** command to confirm interpretation of these quantities.	
RTCBA01–RTCBA08	Remote analogs for Channel B. Only those channels provided by the remote are valid to use. Use the **RTC** command to confirm interpretation of these quantities.	
RTCFA	Remote frequency for Channel A.	Hz
RTCFB	Remote frequency for Channel B.	Hz
RTCDFA	Remote frequency rate-of-change for Channel A.	Hz/s
RTCDFB	Remote frequency rate-of-change for Channel B.	Hz/s
Vk*m*PMMD, Vk*m*PMAD, Vk*m*PMRD, Vk*m*PMID[a, b]	Aligned phase k synchrophasor voltage (M-magnitude, A-Angle, R-Real, I-Imaginary) Terminal *m*.	kV Primary, degrees, kV Primary, kV Primary

Table 18.11 Synchrophasor Aligned Analog Quantities for Real-Time Control (Sheet 2 of 2)

Name	Description	Units
V1*m*PMMD, V1*m*PMAD, V1*m*PMRD, V1*m*PMID[b]	Aligned positive-sequence synchrophasor voltage (M-magnitude, A-Angle, R-Real, I-Imaginary) Terminal *m*.	kV Primary, degrees, kV Primary, kV Primary
Ik*n*PMMD, Ik*n*PMAD, Ik*n*PMRD, Ik*n*PMID[a, c]	Aligned phase *k* synchrophasor current (M-magnitude, A-Angle, R-Real, I-Imaginary) Terminal *n*.	A Primary, degrees, A Primary, A Primary
I1*n*PMMD, I1*n*PMAD, I1*n*PMRD, I1*n*PMID[c]	Aligned positive-sequence synchrophasor current (M-magnitude, A-Angle, R-Real, I-Imaginary) Terminal *n*.	A Primary, degrees, A Primary, A Primary
SODPMD	Second-of-day for all aligned data.	Seconds
FOSPMD	Fraction-of-second for all aligned data.	Seconds
FREQPMD	Aligned local system frequency.	Hz
DFDTPMD	Aligned local rate-of-change of frequency.	Hz/s

[a] k = A, B, or C.
[b] m = voltage terminal.
[c] n = current terminal.

View Synchrophasors by Using the MET PM Command

The **MET PM** serial port ASCII command may be used to view the PMU synchrophasor measurements. See *METER on page 14.47* for general information on the **MET** command.

The **MET PM** command can be used as follows:

- As a test tool, to verify connections, phase rotation, and scaling.
- As an analytical tool, to capture synchrophasor data at an exact time, to compare it with similar data captured in other phasor measurement unit(s) at the same time.
- As a method of periodically gathering synchrophasor data through a communications processor.

Figure 18.6 shows a sample **MET PM** command response. The synchrophasor data are also available via the **HMI > Synchrophasor Metering** menu in QuickSet, and has a similar format to *Figure 18.6*.

The **MET PM** command can work even when no serial or Ethernet ports are configured for sending synchrophasor data.

The **MET PM** command will only operate when the relay is in the HIRIG timekeeping mode, as indicated by Relay Word bit TSOK = logical 1.

The **MET PM** command shows if there is a serial port configuration error. If any of the SPCER*p* bits assert, then the command displays `Y`. Otherwise, it displays `N`.

The **MET PM** command checks for assertion of the PMTEST bit to show whether the PMU is in a test mode. If the bit is asserted then the command displays `Y`. Otherwise, it displays `N`.

The **MET PM** time command can be used to direct the PMU to display the synchrophasor for an exact specified time, in 24-hour format. For example, entering the command **MET PM 14:14:12** will result in a response similar to *Figure 18.6* occurring just after 14:14:12, with the time stamp 14:14:12.000000.

If you are not connected to the PMU when the **MET PM** time command issues its timed response, you can use the **MET PM HIS** command to view this response. This permits you to issue MET PM time to multiple PMUs at a certain point in time and then go back later to see the results from all the PMUs at that point in time.

See *MET PM on page 14.49* for complete command options, and error messages.

```
=>>MET PM <Enter>
Relay 1                                    Date: 04/20/2015 Time: 22:02:12.000
Station A                                  Serial Number: 1152490016

Time Quality   Maximum time synchronization error:  0.000 (ms)  TSOK = 1
Serial Port Configuration Error: N                     PMU in TEST MODE = N

Synchrophasors
                     VV Phase Voltages            Pos. Sequence Voltage
                 VA        VB        VC                V1
MAG (kV)        127.266   126.972   127.148           127.128
ANG (DEG)        73.542   -46.400  -166.103            73.677

                     VZ Phase Voltages            Pos. Sequence Voltage
                 VA        VB        VC                V1
MAG (kV)         76.383    76.103    76.277            76.254
ANG (DEG)        73.623   -46.319  -166.175            73.707

                     IS Phase Currents         IS Pos. Sequence Current
                 IA        IB        IC                 I1S
MAG (A)         221.707   221.851   221.661           221.740
ANG (DEG)        57.667   -62.223   177.875            57.767

                     T Phase Currents         IT Pos. Sequence Current
                 IA        IB        IC                 I1T
MAG (A)         440.487   441.507   440.698           440.897
ANG (DEG)      -122.055   118.057    -1.933          -121.983

                     I IU Phase Currents         IU Pos. Sequence Current
                 IA        IB        IC                 I1U
 I1U
MAG (A)           0.000     0.000     0.000             0.000
ANG (DEG)         0.000     0.000     0.000             0.000

                     IW Phase Currents         IW Pos. Sequence Current
                 IA        IB        IC                 I1W
MAG (A)           0.000     0.000     0.000             0.000
ANG (DEG)         0.000     0.000     0.000             0.000

                     IX Phase Currents         IX Pos. Sequence Current
                 IA        IB        IC                 I1X
MAG (A)           0.000     0.000     0.000             0.000
ANG (DEG)         0.000     0.000     0.000             0.000

                     IY Phase Currents         IY Pos. Sequence Current
                 IA        IB        IC                 I1Y
MAG (A)           0.000     0.000     0.000             0.000
ANG (DEG)         0.000     0.000     0.000             0.000
```

Figure 18.6 Sample SEL-487E MET PM Command Response

```
FREQ (Hz) 59.990          Frequency Tracking = Y
Rate-of-change of FREQ (Hz/s)    0.00


Digitals
PSV08  PSV07  PSV06  PSV05  PSV04  PSV03  PSV02  PSV01
  0      0      0      0      0      0      0      0
PSV16  PSV15  PSV14  PSV13  PSV12  PSV11  PSV10  PSV09
  0      0      0      0      0      0      0      0
PSV24  PSV23  PSV22  PSV21  PSV20  PSV19  PSV18  PSV17
  0      0      0      0      0      0      0      0
PSV32  PSV31  PSV30  PSV29  PSV28  PSV27  PSV26  PSV25
  0      0      0      0      0      0      0      0
PSV40  PSV39  PSV38  PSV37  PSV36  PSV35  PSV34  PSV33
  0      0      0      0      0      0      0      0
PSV48  PSV47  PSV46  PSV45  PSV44  PSV43  PSV42  PSV41
  0      0      0      0      0      0      0      0
PSV56  PSV55  PSV54  PSV53  PSV52  PSV51  PSV50  PSV49
  0      0      0      0      0      0      0      0
PSV64  PSV63  PSV62  PSV61  PSV60  PSV59  PSV58  PSV57
  0      0      0      0      0      0      0      0


Analogs
PMV49      0.000  PMV50      0.000  PMV51      0.000  PMV52      0.000
PMV53      0.000  PMV54      0.000  PMV55      0.000  PMV56      0.000
PMV57      0.000  PMV58      0.000  PMV59      0.000  PMV60      0.000
PMV61      0.000  PMV62      0.000  PMV63      0.000  PMV64      0.000
=>>
```

Figure 18.6 Sample SEL-487E MET PM Command Response (Continued)

IEEE C37.118 Synchrophasor Protocol

The relay complies with IEEE C37.118, Standard for Synchrophasor Measurements for Power Systems, when Global setting MFRMT := C37.118. The protocol is available on Serial Ports 1, 2, 3, and F by setting the corresponding Port setting PROTO := PMU. The protocol is available over Ethernet when EPMIP is enabled.

This section does not cover the details of the protocol, but highlights some of the important features and options that are available.

Settings Affect Message Contents

The relay allows several options for transmitting synchrophasor data. These are controlled by Global settings described in Settings for Synchrophasors. You can select how often to transmit the synchrophasor messages (MRATE), which synchrophasors to transmit, which numeric representation to use, and which coordinate system to use.

The relay automatically includes the frequency and rate-of-change of frequency in the synchrophasor messages. Global setting FNR*q* selects the numeric format to use for these two quantities.

The relay can include as many as sixteen user-programmable analog values in the synchrophasor message and 0, 16, 32, 48, or 64 digital status values.

The relay always includes the results of four synchrophasor trigger reason SELOGIC equations TREA1, TREA2, TREA3, and TREA4, and the trigger SELOGIC control equation result PMTRIG, in the synchrophasor message.

Communications Bandwidth

A PMU that is configured to transmit a single synchrophasor (positive-sequence voltage, for example) at a message rate of once per second places little burden on the communications channel. As more synchrophasors, analog values, or digital status words are added, or if the message rate is increased, some communications channel restrictions come into play.

If the SPEED setting on any serial port set with PROTO := PMU is insufficient for the PMU Global settings, the relay or QuickSet will display an error message and fail to save settings until the error is corrected.

The IEEE C37.118 synchrophasor message format always includes 16 bytes for the message header and terminal ID, time information, and status bits. The selection of synchrophasor data, numeric format, programmable analog, and programmable digital data will add to the byte requirements. *Table 18.12* can be used to calculate the number of bytes in a synchrophasor message.

Table 18.12 Size of a IEEE C37.118 Synchrophasor Message

Item	Possible number of quantities	Bytes per quantity	Minimum number of bytes	Maximum number of bytes
Fixed			18	18
Synchrophasors[a]	0, 1, 2…32	4 (PHNR := I) 8 (PHNR := F)	0	256
Frequency	2 (fixed)	2 (FNR := I) 4 (FNR := F)	4	8
Analog Values	0 – 16	4	0	64
Digital Status Words	0 – 4	2	0	8
Total (Minimum and Maximum)			22	354

[a] Some SEL relays have a smaller number of possible synchrophasors.

Table 18.13 lists the bps settings available on any relay serial port (setting SPEED), and the maximum message size that can fit within the port bandwidth. Blank entries indicate bandwidths of less than 20 bytes.

Table 18.13 Serial Port Bandwidth for Synchrophasors (in Bytes) (Sheet 1 of 2)

Global Setting MRATE	Maximum Message Size								
	300	600	1200	2400	4800	9600	19200	38400	57600
1	21	42	85	170	340	680	1360	2720	4080
2		21	42	85	170	340	680	1360	2040
4 (60 Hz only)			21	42	85	170	340	680	1020
5				34	68	136	272	544	816
10					34	68	136	272	408
12 (60 Hz only)					28	56	113	226	340
15 (60 Hz only)					21	45	90	181	272
20 (60 Hz only)						34	68	136	204
25 (50 Hz only)						27	54	108	163

Table 18.13 Serial Port Bandwidth for Synchrophasors (in Bytes) (Sheet 2 of 2)

Global Setting MRATE	Maximum Message Size								
30 (60 Hz only)						22	45	90	136
50 (50 Hz only)							27	54	81
60 (60 Hz only)							22	45	68

Referring to *Table 18.12* and *Table 18.13*, it is clear that the lower SPEED settings are very restrictive.

The smallest practical synchrophasor message would be comprised of one synchrophasor and one digital status word, and this message would consume between 26 and 34 bytes, depending on the numeric format settings. This type of message could be sent at any message rate (MRATE) when SPEED := 38400 or 57600, as fast as MRATE := 50 or 30 when SPEED := 19200, and as fast as MRATE := 25 or 20 when SPEED := 9600.

Another example application has messages comprised of eight synchrophasors, one digital status word, and two analog values. This type of message would consume between 62 and 98 bytes, depending on the numeric format settings. The 62-byte version, using integer numeric representation, could be sent at any message rate (MRATE) when SPEED := 57600. The 98-byte version, using floating-point numeric representation, could be sent at as fast as MRATE := 30 when SPEED := 57600, as fast as MRATE := 25 when SPEED := 38400, and as fast as MRATE := 12 when SPEED := 19200.

Protocol Operation

The relay will only transmit synchrophasor messages over serial ports that have setting PROTO := PMU. The connected device will typically be a synchrophasor processor. The synchrophasor processor controls the PMU functions of the relay, with IEEE C37.118 commands, including commands to start and stop synchrophasor data transmission, and commands to request a configuration block from the relay, so the synchrophasor processor can automatically build a database structure.

Transmit Mode Control

The relay will not begin transmitting synchrophasors until an enable message is received from the synchrophasor processor. The relay will stop synchrophasor transmission when the appropriate command is received from the synchrophasor processor. The relay can also indicate when a configuration change occurs, so the synchrophasor processor can request a new configuration block and keep its database up-to-date.

The relay will only respond to configuration block request messages when it is in the nontransmitting mode.

Independent Ports

Each serial port with the PROTO := PMU setting is independently configured and enabled for synchrophasor and Fast Operate commands. For example, if there are two serial ports set to PROTO := PMU, the status of one port has no effect on the other port. One port might be commanded to start transmitting synchrophasor messages, while the other port is idle, responding to a configuration block or Fast Operate request, or transmitting synchrophasors. The ports are not required to have the same SPEED setting, although the slowest SPEED setting on a PROTO := PMU port will affect the maximum Global MRATE setting that can be used.

Ethernet Operation

IEEE C37.118 Synchrophasors may be used over Ethernet if an Ethernet card is installed in the relay. Four transport methods are supported: UDP_U, UDP_S, UDP_T, and TCP.

UDP_U, UDP_S, UDP_T

UDP stands for User Datagram Protocol and is a network protocol used for the Internet. UDP uses a simple transmission model without implicit handshaking interchanges for guaranteeing reliability, ordering, or data integrity. As such, UDP minimizes additional overhead needed to send messages. Time-sensitive applications often use UDP because dropping packets is preferable to waiting for delayed packets, which may not be an option in a real-time system. UDP_S is a version of UDP that only sends data; no reverse messaging is used, thus providing streaming data in one direction only. UDP_T uses a TCP socket to command and configure PMU measurements, and then uses a UDP socket for sending data out. UDP_U is the same as UDP_T except that the synchrophasor configuration and header response messages are sent over UDP instead of TCP. A user may choose to use UDP to minimize the additional overhead bits added and thus minimize the communications bandwidth needed to send PMU information out of a substation. UDP_S uses the least amount of overhead (and provides some additional security as the PMU or PDC using this method is only sending data and ignores any messages coming in).

TCP

TCP stands for Transmission Control Protocol and is a connection-oriented protocol, which means that it requires handshaking to set up end-to-end communications. Once a connection is set up, user data may be sent bi-directionally over the connection. TCP manages message acknowledgment, retransmission, and timeouts. With TCP, there are no lost data; the server will request the lost portion to be resent. Additionally, TCP ensures that the messages are received in the order sent. TCP provides the most robust connection, but it also adds additional overhead bits to any message data.

PMU Setting Example

A power utility is upgrading the line protection on its 230 kV system to use the SEL-421 relay as main protection. The grid operator also wants the utility to install PMUs in each 230 kV substation to collect data for a new remedial action scheme, and to eventually replace their present state estimation system.

The PMU data collection requirements call for the following data, collected at 10 messages per second:

- Frequency
- Positive-sequence voltage from the bus in each substation
- Three-phase and positive-sequence current for each line terminal
- Indication when the line breaker is open
- Indication when the voltage or frequency information is unusable

- Ambient temperature (one reading per station)
- Station battery voltage
- No relay control from the PMU communications port, for the initial stage of the project

The utility is able to meet the grid operator requirements with the relay, an SEL-2600A RTD Module, an SEL-2407 Satellite-Synchronized Clock, and an SEL-3555 in each substation.

This example will cover the PMU settings in one of the relays.

Some system details:

- The nominal frequency is 60 Hz.
- The line is protected by a breaker-and-a-half scheme.
- The station ambient temperature is collected by an SEL-2600A, Channel RTD01.
- The line PTs and wiring have a phase error of 4.20 degrees (lagging) at 60 Hz.
- The Breaker 1 CTs and wiring have a phase error of 3.50 degrees (lagging) at 60 Hz.
- The Breaker 2 CTs and wiring have a phase error of 5.50 degrees (lagging) at 60 Hz.
- The synchrophasor data will be using **PORT 3**, and the maximum bps allowed is 19200.
- The system designer specified floating-point numeric representation for the synchrophasor data, and rectangular coordinates.
- The system designer specified integer numeric representation for the frequency data.
- The system designer specified fast synchrophasor response, because the data are being used for system monitoring.

The protection settings and resistance temperature detector (RTD) serial port settings will not be shown.

Determining Settings

The protection engineer performs a bandwidth check, using *Table 18.12*, and determines the required message size. The system requirements, in order of appearance in *Table 18.12*, are as follows.

- 5 Synchrophasors, in floating-point representation
- Integer representation for the frequency data
- 2 analog values
- 3 digital status bits, which require one status word

The message size is 16 + 5 • 8 + 2 • 2 + 2 • 4 + 1 • 2 = 70 bytes. Using *Table 18.13*, the engineer verifies that the port bps of 19200 is adequate for the message, at 10 messages per second.

Protection Math Variables PMV64 and PMV63 will be used to transmit the RTD01 ambient temperature data and the station battery voltage DC1, respectively.

The Protection SELOGIC Variables PSV64, PSV63, and PSV62 will be used to transmit the breaker status, loss-of-potential alarm, and frequency measurement status, respectively.

The **PORT 3** FASTOP setting will be set to N, to disable any control attempts from the PMU port.

Make the Global settings as shown in *Table 18.14*.

Table 18.14 Example Synchrophasor Global Settings (Sheet 1 of 2)

Setting	Description	Value
NFREQ	Nominal System Frequency (50, 60 Hz)	60
NUMBK	Number of Breakers in Scheme (1, 2)	2
EPMU	Enable Synchronized Phasor Measurement (Y, N)	Y
MFRMT	Message Format (IEEE C37.118, FM)	C37.118
MRATE	Messages per Second (1, 2, 4, 5, 10, 12, 15, 20, 30, 60)	10
PMAPP	PMU Application (F = Fast Response, N = Narrow Bandwidth, 1 = Extra Narrow[a])	F
PMLEGCY	Synchrophasor Legacy Settings	N
NUMPHDC	Number of Phasor Data Configurations	1
PMFRQA	PMU Frequency Application (F = Fast, S = Slow)	S
PHCOMP	Frequency-Based Phasor Compensation (Y, N)	Y
PMSTN	Station Name (16 characters)	SAMPLE1
PMID	PMU Hardware ID (1–65534)	14
PHVI111	Phasor 1 (S, W, X, Y, Z)	Y
PHVT112	Phasor 2 (S, W, X, Y, Z)	W
PHVI113	Phasor 3 (S, W, X, Y, Z)	X
PHDV1	Phasor Data Set, Voltages (I1, PH, ALL)	V1
VYCOMP	Voltage Angle Compensation Factor (–179.99 to 180 degrees)	4.20
PHDI1	Phasor Data Set, Currents (I1, PH, ALL)	ALL
IWCOMP	IW Angle Compensation Factor (–179.99 to 180 degrees)	3.50
IXCOMP	IX Angle Compensation Factor (–179.99 to 180 degrees)	5.50
PHNR1	Phasor Numeric Representation (I = Integer, F = Floating point)	F
PHFMT1	Phasor Format (R = Rectangular coordinates, P = Polar coordinates)	R
FNR1	Frequency Numeric Representation (I = Integer, F = Float)	I
PMAQ11	Any Analog Quantity or alias	RTD01
PMAA11	Alias Name for the analog quantity	AmbientTemp
PMAQ12	Any Analog Quantity or alias	DC1
PMAA12	Alias Name for the analog quantity	StationBattery
PMDG11	Any Relay Word bit or alias	PSV64
PMDA11	Alias Name of Relay Word bit	LineBKStatus
PMDG12	Any Relay Word bit or alias	LOP
TREA1	Trigger Reason Bit 1 (SELOGIC Equation)	NA
TREA2	Trigger Reason Bit 2 (SELOGIC Equation)	NA
TREA3	Trigger Reason Bit 3 (SELOGIC Equation)	NA
TREA4	Trigger Reason Bit 4 (SELOGIC Equation)	NA

Table 18.14 Example Synchrophasor Global Settings (Sheet 2 of 2)

Setting	Description	Value
PMTRIG	Trigger (SELOGIC Equation)	NA
EPMDR	Enable PMU Data Recording	N
PMTEST	PMU Test Mode Equation (SELOGIC Equation)	NA

[a] Option 1 is available only if MRATE = 60.

The line breaker status must be created with protection SELOGIC variables. Make the Protection Freeform logic settings in *Table 18.15* in all six settings groups.

Table 18.15 Example Synchrophasor Protection Freeform Logic Settings

Setting	Value
PSV64	NOT (3PO OR SPO) # Line breaker status

Make the *Table 18.16* settings for serial PORT 3, using the **SET P 3** command.

Table 18.16 Example Synchrophasor Port Settings

Setting	Description	Value
PROTO	Protocol (SEL, DNP, MBA, MBB, MBGA, MBGB, RTD, PMU)	PMU
SPEED	Data Speed (300 to 57600)	19200
STOPBIT	Stop Bits (1, 2 bits)	1
RTSCTS	Enable Hardware Handshaking (Y, N)	N
FASTOP	Enable Fast Operate Messages (Y, N)	N
PMU MODE	PMU Mode (CLIENTA, CLIENTB, SERVER)	SERVER
PMODC	PMU Output Data Configuration	1

SEL Fast Message Synchrophasor Protocol

NOTE: Relays that support IEEE C37.118.1-2011 do not support SEL Fast Message Synchrophasor protocol.

SEL Fast Message Unsolicited Write (synchrophasor) messages are general Fast Messages (A546h) that transport measured synchrophasor information. The relay can send unsolicited write messages as fast as every 50 ms on a 60 Hz system, and 100 ms on a 50 Hz system. When MFRMT = FM, set PMLEGCY = Y to use Global settings PHDATAV, PHDATAI, PHVOLT, and PHCURR to select the voltage and current data to include in the Fast Message. Not all messages are supported at all data speeds. If the selected data rate is not sufficient for the given message length, the relay responds with an error message.

Table 18.17 lists the Synchrophasor Fast Message Write function codes and the actions the relay takes in response to each command.

Table 18.17 Fast Message Command Function Codes for Synchrophasor Fast Write

Function Code (Hex)	Function	Relay Action
00h	Fast Message definition block request	Relay transmits Fast Message definition request acknowledge (Function Code 80)
01h	Enable unsolicited transfer	Relay transmits Fast Message command acknowledged message (Function Code 81). Relay transmits Synchrophasor Measured Quantities (function to enable: Unsolicited Write broadcast, Function Code 20)
02h	Disable unsolicited transfer	Relay sends Fast Message command acknowledge message (Function Code 82) and discontinues transferring unsolicited synchrophasor messages (function to disable: Unsolicited Write broadcast, Function Code 20)
05h	Ping: determine if channel is operable	Relay aborts unsolicited message in progress and transmits ping acknowledge message (Function Code 85)

See the SEL application guide “Using SEL-421 Relay Synchrophasors in Basic Applications” (AG2002-08) for more information on the SEL Fast Message Synchrophasor Protocol.

Fast Message Synchrophasor Settings

The settings for SEL Fast Message synchrophasors are listed in *Table 18.18*. Many of these settings are identical to the settings for the IEEE C37.118 format (see *Settings for Synchrophasors on page 18.6*).

Table 18.18 PMU Settings in the Relay for SEL Fast Message Protocol (in Global Settings)

Setting	Description
EPMU	Enable Synchronized Phasor Measurement (Y, N)
MFRMT	Message Format (C37.118, FM)[a]
PMAPP	PMU Application (F = Fast Response, N = Narrow Bandwidth, 1 = Extra Narrow[b])
PMLEGCY[c]	Synchrophasor Legacy Settings (Y, N)
PHCOMP	Frequency-Based Phasor Compensation (Y, N)
PMID	PMU Hardware ID (0–4294967295)
PHVOLT	Include Voltage Terminal
PHDATAV	Phasor Data Set, Voltages (V1, ALL)
V*k*COMP[d]	V*k* Voltage Angle Compensation Factor (–179.99 to +180 degrees)
PHCURR[e]	Current Source
PHDATAI[f]	Phasor Data Set, Currents (ALL, NA)
I*n*COMP[g]	In Angle Compensation Factor (–179.99 to +180 degrees)

a C37.118 = IEEE Std C37.118. FM := SEL Fast Message. Set MFRMT := FM to enter the Fast Message settings.
b Option 1 is not available when MFRMT = FM.
c PMLEGCY must be set to Y to access the data configuration settings shown in this table.
d k = voltage terminal.
e Setting hidden when PHDATAI := NA.
f When PHDATAV:= V1, this setting is forced to NA and cannot be changed.
g n = current terminal.

Certain settings in *Table 18.18* are hidden, depending on the status of other settings. For example, if PHDATAI := NA, the PHCURR setting is hidden to limit the number of settings for your synchrophasor application.

The SEL Fast Message Synchrophasor Protocol always includes the frequency information in floating-point representation, and 14 user-programmable SELOGIC variables PSV49–PSV64. There are no user-programmable analog quantities in the SEL Fast Message Synchrophasor Protocol.

Communications Bandwidth

A PMU that is configured to transmit a single synchrophasor (positive-sequence voltage, for example) at a message period of one second places little burden on the communications channel. As more synchrophasors are added, or if the message rate is increased, some communications channel restrictions come into play.

In the SEL Fast Message Synchrophasor Protocol, the master device determines the message period (the time among successive synchrophasor message timestamps) in the enable request. If the relay can support the requested message period on that serial port, the relay acknowledges the request (if an acknowledge was requested) and commences synchrophasor data transmission. If the relay cannot support the requested message period, the relay responds with a response code indicating bad data (if an acknowledge was requested).

The SPEED setting on any serial port set with PROTO := PMU should be set as high as possible, to allow for the largest number of possible message period requests to be successful.

The relay Fast Message synchrophasor format always includes 32 bytes for the message header and terminal ID, time information, frequency, and status bits. The selection of synchrophasor data will add to the byte requirements. *Table 18.19* can be used to calculate the number of bytes in a synchrophasor message.

Table 18.19 Size of an SEL Fast Message Synchrophasor Message

Item	Possible Number of Quantities	Bytes per Quantity	Minimum Number of Bytes	Median Number of Bytes	Maximum Number of Bytes
Fixed			32	32	32
Synchrophasors	1, 4, or 8	8	8	32	64
Total (Minimum, Median, and Maximum)			40	64	96

Table 18.20 lists the bps settings available on any relay serial port (setting SPEED), and the maximum message size that can fit within the port bandwidth. Blank entries indicate bandwidths of less than 40 bytes.

Table 18.20 Serial Port Bandwidth for Synchrophasors (in Bytes)

Requested Message Period (ms)	Equivalent Message Rate (messages per second)	Port Setting SPEED								
		300	600	1200	2400	4800	9600	19200	38400	57600
1000	1		41	83	166	333	666	1332	2665	3998
500	2			41	83	166	333	666	1332	1999
250 (60 Hz only)	4				41	83	166	333	666	999
200	5					66	133	266	533	799
100	10						66	133	266	399
50 (60 Hz only)	20							66	133	199

Referring to *Table 18.19* and *Table 18.20*, it is clear that the lower SPEED settings are very restrictive.

Some observations from *Table 18.20* follow.

- ➤ A serial port set with SPEED := 38400 or 57600 can handle any size message at any data rate.
- ➤ A serial port set with SPEED := 19200 can handle a single-synchrophasor or four-synchrophasor message at any data rate, and any size message as fast as 10 messages per second.
- ➤ A serial port set with SPEED := 9600 can handle a single-synchrophasor message at any data rate, a four-synchrophasor message at as fast as 10 messages per second, and any size message at as fast as 5 messages per second.
- ➤ A serial port set with SPEED := 300 cannot be used for Fast Message synchrophasors.

Protocol Operation

The relay will only transmit synchrophasor messages over serial ports that have setting PROTO := PMU. The connected device will typically be a synchrophasor processor. The synchrophasor processor controls the PMU functions of the relay, with SEL Fast Message commands, including commands to start and stop synchrophasor data transmission, and commands to request a configuration block from the relay, so the synchrophasor processor determine the correct configuration for storing the synchrophasor data.

Transmit Mode Control

The relay will not begin transmitting synchrophasors until an enable message is received from the synchrophasor processor. The relay will stop synchrophasor transmission on a particular serial port when the disable command is received from the synchrophasor processor, or when the relay settings for that port are changed. The relay will stop synchrophasor transmission on all serial ports when any Global or Group settings change is made.

The relay will respond to configuration block request messages regardless of the present transmit status, waiting only as long as it takes for any partially sent messages to be completely transmitted.

The relay will respond to a ping request immediately upon receipt, terminating any partially sent messages.

Independent Ports

Each serial port with the PROTO := PMU setting is independently configured and enabled for synchrophasor and Fast Operate commands. For example, if there are two serial ports set to PROTO := PMU, the status of one port has no effect on the other port. One port might be commanded to start transmitting synchrophasor messages, while the other port is idle, responding to a configuration block or Fast Operate request, or transmitting synchrophasors. The ports are not required to have the same SPEED setting, although the SPEED setting on each PROTO := PMU port will affect the minimum synchrophasor message data period that can be used on that port.

Control Capabilities

Serial Port Fast Operate Operation

The PMU can be configured to process SEL Fast Operate commands received on serial ports that have the Port setting PROTO := PMU, when the Port setting FASTOP := Y, and Global Settings EPMU := Y and PMAPP := F.

This functionality can allow a remote device (client) to initiate control actions in a serially connected PMU without the need for a separate communications interface. The client should enable Fast Operate Transmit on the serial port connected to the PMU. This can be accomplished with Global Setting EPMU := Y, Port Settings PROTO := PMU, FASTOP := Y, and PMUMODE set to either CLIENTA or CLIENTB.

The client can request a Fast Operate Configuration Block when the relay is in the nontransmitting mode, and the relay will respond with a message, which includes codes that define the circuit breaker and remote bit control points that are available via Fast Operate commands.

Once the control points are identified, the Fast Operate Output (FOP) Control Bits can be assigned to SELOGIC equations in the client's SELOGIC freeform protection logic settings. FOP Control Bits take the form FOP*p_n*, where *p* is the serial port (F, 1, 2, or 3) and *n* is the bit number from 01–32. The bit number can correspond to a circuit breaker or remote bit control in the local relay, identified in the Fast Operate Configuration Block.

A change to any FOP*p_n* value will cause the client to transmit a Fast Operate remote bit control message on **PORT p**. If the FOP control bit asserts, the message will contain the opcode to set the corresponding control bit in the PMU. If it deasserts, the message will contain the opcode to clear the control bit. The remote device will send a Fast Operate message no later than 20 ms after it detects a change in the FOP bit.

The PMU will process Fast Operate requests regardless of whether synchrophasors are being transmitted, as long as serial port setting FASTOP := Y and PMUMODE is set to SERVER. When FASTOP := N, the relay will ignore Fast Operate commands. Use the FASTOP := N option to lock out any control actions from that serial port if required by your company operating practices.

SEL Fast Operate commands are discussed in *SEL Fast Meter, Fast Operate, Fast SER Messages, and Fast Message Data Access on page 15.34*.

The PMU can also process the Fast Operate commands embedded in the extended frame of the IEEE C37.118 command frame. This way you can accomplish both synchrophasor measurement and control by using the same IEEE C37.118 protocol on both serial and Ethernet interfaces. This way is also independent of the FASTOP setting.

Ethernet Fast Operate Operation

Fast Operate commands can be issued from a host device to control the function of remote bits and breaker operation in the relay. When coupled with synchrophasor measurements, Fast Operate commands can provide control to system events.

The implementation using the extended frame in the IEEE C37.118 synchrophasor packet makes it possible to send Fast Operate commands and synchrophasor data over the same Ethernet session. The Fast Operate command is embedded in the extended frame of the IEEE C37.118 command frame. See the following example for configuration and setup of the IEEE C37.118 extended frame implementation.

Example 18.1 Synchrophasor Control Application

Refer to *Table 18.14* for an example of a PMU communications network with an SVP collecting and analyzing synchrophasor data in the network, based on a programmed power flow and voltage regulation scheme. Each of the depicted PMU/IEDs are connected to a load, feeder line, or generation facility streaming synchrophasors to the SVP.

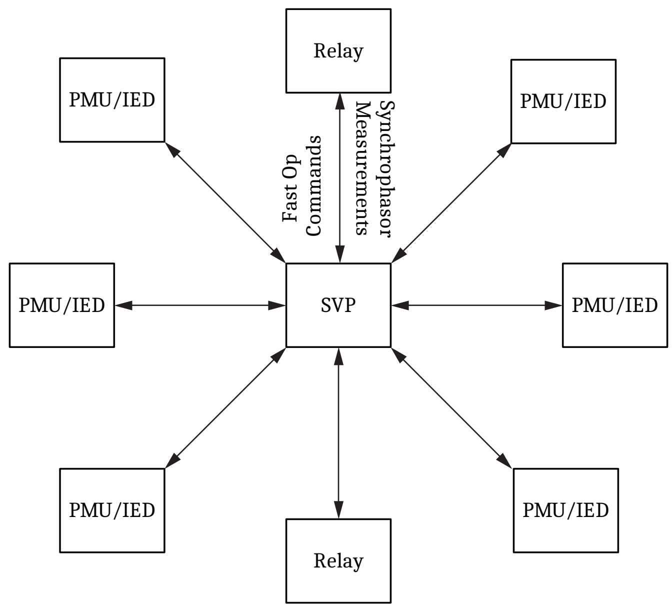


Figure 18.7 Synchrophasor Control Application

Should you need to change the relay protection scheme because of system configuration or to shed bus load to maintain voltage quality, you can program your SVP to send control commands to the relay according to an algorithm. You can set a remote bit in the relay to change the Group settings for an alternative protection scheme or send a **PULSE** command to the circuit breaker to disconnect load from the system.

To set the relay for such a control scenario, first configure synchrophasors for the IEEE C37.118 protocol. *Figure 18.8* depicts one way to configure synchrophasors for transport. In this SEL-487E example, all of the S- and T-terminal phase currents and Z-terminal voltages, along with the positive-sequence values, are transmitted in polar floating-point format at a message rate of 60 messages per second. The filter settings are configured for a fast response with phase compensation.

```
Synchronized Phasor Configuration Settings

MFRMT   := C37.118  MRATE   := 60       PMAPP   := 1        PMLEGCY := N
NUMPHDC := 1


Synchrophasor Data Configuration 1

PMSTN1  := "PMU Control"
PMID1   := 1



Phasors Included in the Data 1

Terminal Name, Relay Word Bit, Alternate Terminal Name

1: Z
2: S
3: T


PHDV1   := ALL      PHDI1   := ALL      PHNR1   := F        PHFMT1  := P
FNR1    := F

Phasor Aliases in Data Configuration 1
 (Phasor Name, Alias Name)

Synchrophasor Analog Quantities in Data Configuration 1
 (Analog Quantity Name, Alias Name)


Synchrophasor Digitals in Data Configuration 1
 (Digital Name, Alias Name)

TREA1   := NA
TREA2   := NA
TREA3   := NA
TREA4   := NA
PMTRIG  := NA
PMTEST  := NA
VZCOMP  := 0.00     ISCOMP  := 0.00     ITCOMP  := 0.00     PMFRQA  := S
PHCOMP  := Y


Synchronized Phasor Recorder Settings

EPMDR   := N

Synchronized Phasor Real Time Control Settings

RTCRATE := 2        MRTCDLY := 500
```

Figure 18.8 PMU Global Settings

Next, configure the Ethernet port to transmit synchrophasor data and accept Fast Operate commands. To enable an Ethernet port to accept Fast Operate commands, simply set FASTOP := Y.

```
SEL Protocol Settings

AUTO    := Y        FASTOP  := Y        TERTIM1 := 1
TERSTRN := "\005"
TERTIM2 := 0
```

Figure 18.9 Enabling Fast Operate Messages on PORT 5

Using the C37.118 extended frame option to transport Fast Operate commands it is necessary to setup only one TCP/UDP session (see *Figure 18.10*).

```
Phasor Measurement Configuration

EPMIP   := Y        PMOTS1  := UDP_T
PMOIPA1 := "192.168.1.3"
PMOTCP1 := 4712     PMOUDP1 := 4713     PMOTS2  := OFF
```

Figure 18.10 Ethernet PORT 5 Settings for Communications Using C37.118 Extended Fame

The relay is now ready to start transmitting synchrophasors and receive Fast Operate commands from the SVP.

Real-Time Control

The PMU can be configured to process IEEE C37.118 synchrophasor data received from two remote PMUs over serial ports. The PMU processes the remote PMU data, time-aligns them with the local data, and makes them available as analogs and digitals. Use the local synchrophasor analogs and as many as two remote sets of synchrophasor analogs in SELOGIC equations to do real-time control (RTC) applications.

Table 18.21 shows the serial port settings that need to be configured for RTC applications.

Table 18.21 Serial Port Settings for RTC

Setting	Description	Default
PMUMODE[a]	PMU Mode (CLIENTA, CLIENTB, SERVER)	SERVER
RTCID[b]	Remote PMU Hardware ID (1–65534)	1
PMODC[c]	PMU Output Data Configuration (1–5)	1

[a] Set PROTO := PMU to enable (on this port) the Synchrophasor Protocol selected by Global setting MFRMT.
[b] Setting hidden when PMUMODE := SERVER.
[c] Only available when PMUMODE := SERVER.

Descriptions for the settings in *Table 18.21* are as follows.

PMUMODE

Selects whether the port is operating as a synchrophasor server (source of data) or a client (consumer of data). When the port is intended to be a source of synchrophasor data, set this setting to SERVER. The Global setting MFRMT determines the format of the transmitted data. When using the port to receive synchrophasor data from another device, set this setting to either CLIENTA or CLIENTB. Only two ports may be configured as client ports and they must be uniquely configured for Channel A or Channel B. When a port is configured to receive synchrophasor data, the port will only receive data that uses the IEEE C37.118 format, regardless of the MFRMT setting.

RTCID

Expected synchrophasor ID from remote relay.

When the PMU is operating as a synchrophasor client (PMUMODE set to CLIENTA or CLIENTB), it will only accept incoming messages that contain this ID. Make sure this ID matches the ID configured in the remote relay.

PMODC

Select the data configuration set to be sent out from that port. This setting is only available when the PMUMODE=SERVER.

Table 18.22 shows the Global settings that need to be configured for RTC applications.

NOTE: The maximum channel delay is available in the **COM RTC** command.

Table 18.22 Global Settings for RTC

Setting	Description	Default
RTCRATE	Remote Messages per Second (1, 2, 5, 10, or 50 when NFREQ := 50) (1, 2, 4, 5, 10, 12, 15, 20, 30, or 60 when NFREQ := 60)	2
MRTCDLY	Maximum RTC Synchrophasor Packet Delay (20–1000 ms)	500

Descriptions for the settings in *Table 18.22* are as follows.

RTCRATE

Rate at which to expect messages from the remote synchrophasor device.

When the PMU is operating as a synchrophasor client (PMUMODE set to CLIENTA or CLIENTB), the relay will only accept incoming messages at this rate. Make sure the remote synchrophasor source(s) is configured to send messages at this same rate.

MRTCDLY

Selects the maximum acceptable delay for received synchrophasor messages.

When the PMU is operating as a synchrophasor client (PMUMODE set to CLIENTA or CLIENTB), the relay only accepts incoming messages that are not older than allowed by this setting. When determining an appropriate value for this setting, consider the channel delay, the transfer time at the selected baud rate, plus add some margin for internal delays in both the remote and local relay.

When you use the PMU for synchrophasor acquisition, the delayed and aligned analog quantities specific to that relay are available. Be aware that these quantities are only valid when RTCROK is asserted and only for the enabled channels. The specific channel quantities are also valid whenever their respective RTCROK*p* Relay Word bit is set (see *Table 18.10*).

When using the relay as a synchrophasor client, the Relay Word bits in *Table 18.23* indicate the state of the synchronization.

Table 18.23 Synchrophasor Client Status Bits

Name	Description
RTCEN*p*[a]	Asserts for one processing interval when a valid message is received on Channel *p*.
RTCROK*p*[a]	Asserts for one processing interval when data are aligned for Channel p. Use this bit to condition usage of the Channel *p* data.
RTCROK	Asserts for one processing interval when data for all enabled channels are aligned. Use this bit to condition general usage of the aligned synchrophasor data.
RTCDLY*p*[a]	This bit is asserted when the last received valid message on Channel *p* is older than MRTCDLY.
RTCSEQ*p*[a]	This bit is asserted when the processed received message on Channel *p* is the expected next-in-sequence. It is deasserted if it is not. The deassertion implies that one or more packets of information were lost. Use this bit to condition usage of Channel *p* data in applications where sequential data are required.
RTCCFG*p*[a]	Indicates Channel *p* is successfully configured.

[a] p = A or B.

When received, synchrophasor messages contain digital data. These data are stored in the Remote Synchrophasor Relay Word bits in *Figure 18.24*.

Table 18.24 Remote Synchrophasor Data Bits

Name	Description
RTC*p*D[16][a]	First 16 digitals received in synchrophasor message on Channel *p*. Only valid when RTCROK*p* is asserted.

[a] p = A or B.

Set MRTCDLY for the maximum expected communications channel delay in milliseconds. Any data arriving later than this time are rejected. The RTCDLY*p* Relay Word bit indicates this condition. Use the MRTCDLY to constrain the maximum longest operating time of the system. Set the RTCRATE to the rate of synchrophasor data being sent by remote relay. This is the MRATE setting on the remote relay.

Several Relay Word bits are useful for monitoring system status. Add RTCCFG*p* and RTCDLY*p* to the SER.

The RTCCFG*p* Relay Word bit is asserted after the two relays have communicated configuration data successfully. RTCCFG*p* deassertion indicates that the system has changed, perhaps because of a setting change in one of the relays.

If the RTCCFG*p* Relay Word bit indicates a new configuration, you can issue the **RTC** command to ensure that the data being received have not changed. The **RTC** command displays a description of the synchrophasor data being received. Use this command to ensure that the remote value that you chose for the SELOGIC equation is the correct value to compare with the local synchrophasor value.

The RTCDLYA bit asserts when synchrophasor data have not been received on Channel A within the window you set with the local MRTCDLY setting (100 ms in this example). If the RTCDLYA asserts, consider three options. First, the MRTCDLY setting can be increased. However, the MRTCDLY setting is your way of guaranteeing operation within a certain time. Increasing MRTCDLY allows for communications channels with longer transmission delay, but at the cost of increasing the maximum time of operation. A second option is to improve the communications channel so that it operates within the required MRTCDLY setting time. A final option is available if the assertion of MRTCDLY results from a temporary communications channel disruption. In this case, putting RTCDLYA in the SER provides warning.

The **COM RTC** command also provides information for monitoring system status. *Figure 18.11* shows a **COM RTC** command response. Use the maximum packet delay field to monitor the communications channel delay. This information can help you choose an appropriate value for the MRTCDLY setting.

```
Summary for RTC channel A
Port:              2
ID:                8
Present Status:    Receiving
Max Packet Delay:  50 msec
Message Rate:      60 msgs/sec

Summary for RTC channel B
Port:              1
ID:                9
Present Status:    Receiving
Max Packet Delay:  40 msec
Message Rate:      60 msgs/sec
```

Figure 18.11 Example COM RTC Command Response

Real-Time Control Example

Figure 18.12 shows an application example using SEL-411L relays. In this example, Area 2 supplies power to Area 1 and Area 3. An important contingency is loss of both Link 1 and Link 2. In such a case, the generators in Area 2 accelerate. Alternative paths between Area 2 and Area 1 can also become stressed beyond their design limits. A simple solution is to measure the phase angle between Area 1 and Area 2. When the angle exceeds a predetermined limit, control the generation to avoid exceeding system limits.

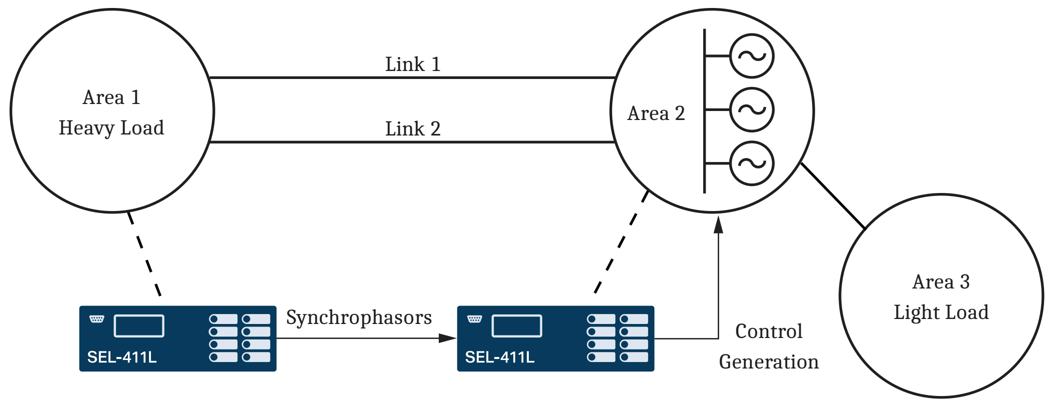


Figure 18.12 Real-Time Control Application

Figure 18.13 shows the SELOGIC for the relay controlling the generator (called the local relay in this example). Lines 1 and 2 store phasor data into PMV53 and PMV54 so they can be viewed through use of the **MET PMV** command. Line 3 computes the angle difference between the local and remote relays. RTCAP02 is the remote V1Y angle. Lines 4–10 unwrap the phase angle when the difference exceeds ±180 degrees.

RTCROKA pulses true whenever a good synchrophasor message is received. For purposes of this example, we need it to hold true until the next message is received. To achieve this, lines 11–13 implement a timer to extend this bit by 1.75 cycles. A message is expected every 1 cycle; the additional 0.75 cycles covers any jitter that may occur in the rate or message receipt. Line 14 calculates a qualification signal consisting of the local and remote quality indicators. RTCROKA is the local indicator that has been extended as PCT01. RTCAD16 is the remote quality indicator. *Figure 18.14* shows its construction at the remote relay.

Line 15 computes absolute value of the angle. Line 16 checks the angle against the reference value. In this case, the reference value is 10 degrees.

The final result, PSV03, asserts when the relay receives a synchrophasor message with an angle difference exceeding 10 degrees.

```
Protection 1
1: PMV53 := V1YPMAD
2: PMV54 := RTCAP02
3: PMV55 := V1YPMAD - RTCAP02
4: PSV01 := PMV55 >= 180.000000
5: PMV01 := -180.000000
6: PSV02 := PMV55 <= PMV01
7: PMV01 := PMV55 + 360.000000
8: PMV02 := PMV55 - 360.000000
9: PMV55 :=NOT PSV01*PMV55+PSV01*PMV02
10: PMV55 :=NOT PSV02*PMV55+PSV02*PMV01
11: PCT01PU := 0.000000
12: PCT01DO := 1.750000
13: PCT01N := R_TRIG RTCROKA
14: PSV01 := PCT01Q AND RTCAD16
15: PMV56 := ABS(PMV55)
16: PSV03 :=(PMV56 > 10.000000) AND PSV01
```

Figure 18.13 Local Relay SELOGIC Settings

Figure 18.14 shows the SELOGIC settings for the remote relay. Set PSV64 to indicate that the sending data are correct. These data are sent with the synchrophasor data in the IEEE C37.118 data packet and are received by the local relay as RTCAD16. The RTCAD16 qualification on line 11 of the local relay (see *Figure 18.13*) contains this remote data quality indicator. A local relay quality indicator also qualifies line 11.

```
1: PSV64 := TSOK AND PMDOK
```

Figure 18.14 Remote Relay SELOGIC Settings

Set the remote relay Global settings according to *Figure 18.15*. Set the number of digitals (NUMDSW) to one. In this case, the relay sends SELOGIC values PSV49–PSV64 in the IEEE C37.118 data packet. This is how the remote TSOK AND PMDOK qualification maps to the local RTCAD16 Relay Word bit. Set the PMU application (PMAPP) to fast, because this is a protection application. Therefore, you must choose a filter for faster response. Also set the synchrophasor enable Global setting to yes (EPMU = Y). The MRTCDLY and RTCRATE settings are set but not used by the remote relay.

```
Synchronized Phasor Measurement Settings

MFRMT   := C37.118  MRATE   := 60      PMAPP   := F       PHCOMP  := Y
PMSTN   := "REMOTE RTC"
PMID    := 8
PHDATAV := V1       VCOMP   := 0.00    PHDATAI := NA      IWCOMP  := 0.00
IXCOMP  := 0.00     PHNR    := F       PHFMT   := P       FNR     := F
NUMANA  := 0        NUMDSW  := 1
TREA1   := NA
TREA2   := NA
TREA3   := NA
TREA4   := NA
PMTRIG  := NA
MRTCDLY := 100
RTCRATE := 60

Time and Date Management

IRIGC   := C37.118
```

Figure 18.15 Remote Relay Global Settings

Set the local relay Global settings according to *Figure 18.16*. It is important for synchrophasors to be enabled (EPMU = Y), the application to be fast (PMAPP = F), the compensation settings to be set correctly (VYCOMP, VZCOMP, IWCOMP, and IXCOMP), and for IRIGC = C37.118.

Set MRTCDLY for the maximum expected communications channel delay in milliseconds. Any data arriving later than this time are rejected. The RTCDLYA Relay Word bit indicates this condition. Use the MRTCDLY to constrain the maximum longest operating time of the system. Set the RTCRATE to the rate of synchrophasor data being sent by remote relay. This is the MRATE setting on the remote relay.

The other Global settings are not relevant to this application.

```
Synchronized Phasor Measurement Settings

MFRMT   := C37.118  MRATE   := 60      PMAPP   := F       PHCOMP  := Y
PMSTN   := "LOCAL RTC"
PMID    := 4
PHDATAV := V1       VCOMP   := 0.00    PHDATAI := NA      IWCOMP  := 0.00
IXCOMP  := 0.00     PHNR    := F       PHFMT   := P       FNR     := F
NUMANA  := 0        NUMDSW  := 0

TREA1   := NA
TREA2   := NA
TREA3   := NA
TREA4   := NA
PMTRIG  := NA
MRTCDLY := 100
RTCRATE := 60

Time and Date Management

IRIGC   := C37.118
```

Figure 18.16 Local Relay Global Settings

Set the port settings for the port that sends the synchrophasor data on the remote relay, according to *Figure 18.17*.

```
Protocol Selection

PROTO   := PMU

Communications Settings

SPEED   := 57600    STOPBIT := 1       RTSCTS  := N

SEL Protocol Settings

FASTOP  := N

PMUMODE := SERVER
```

Figure 18.17 Remote Relay Port Settings

Set the port settings for the port that receives the synchrophasor data on the local relay, according to *Figure 18.18*. Notice that the RTCID setting must match the PMID setting of the remote relay.

```
Protocol Selection

PROTO   := PMU

Communications Settings

SPEED   := 57600    STOPBIT := 1       RTSCTS  := N

SEL Protocol Settings

FASTOP  := N

PMUMODE := CLIENTA
RTCID   := 8
```

Figure 18.18 Local Relay Port Settings

Several Relay Word bits are useful for monitoring system status. Add RTCCFGA and RTCDLYA to the SER.

The RTCCFGA Relay Word bit is asserted after the two relays have communicated configuration data successfully. RTCCFGA deassertion indicates that the system has changed, perhaps because of a setting change in one of the relays.

If the RTCCFGA Relay Word bit indicates a new configuration, you can issue the **RTC** command to ensure that the data being received have not changed. The **RTC** command displays a description of the synchrophasor data being received. Use this command to ensure that the remote value that you chose for the SELOGIC equation (for example, RTCAP02 in *Figure 18.13*) is the correct value to compare with the local synchrophasor value.

The RTCDLYA bit asserts when synchrophasor data have not been received within the window you set with the local MRTCDLY setting (100 ms in this example). If the RTCDLYA asserts, consider three options. First, the MRTCDLY setting can be increased. However, the MRTCDLY setting is your way of guaranteeing operation within a certain time. Increasing MRTCDLY allows for communications channels with longer transmission delay, but at the cost of increasing the maximum time of operation. A second option is to improve the communications channel so that it operates within the required MRTCDLY setting time. A final option is available if the assertion of RTCDLY results from a temporary communications channel disruption. In this case, putting RTCDLYA in the SER provides warning.

The **COM RTC** command also provides information for monitoring system status. *Figure 18.19* shows a **COM RTC** command response. Use the maximum packet delay field to monitor the communications channel delay. This information can help you choose an appropriate value for the MRTCDLY setting.

```
Summary for RTC channel A
Port:              2
ID:                8
Present Status:    Receiving
Max Packet Delay:  50 msec
Message Rate:      60 msgs/sec

Summary for RTC channel B
Port:              1
ID:                9
Present Status:    Receiving
Max Packet Delay:  40 msec
Message Rate:      60 msgs/sec
```

Figure 18.19 Example COM RTC Command Response

PMU Recording Capabilities

The PMU can be configured to record synchrophasor data by setting EPMDR := Y. Select one of the data configuration q you want to record using SPMDR setting where q = 1–NUMPHDC. Create a recording trigger using PMTRIG SELOGIC setting. On the rising edge of PMTRIG, the PMU starts recording synchrophasor data. The duration and the pretrigger duration of the recording are user-settable.

NOTE: Select PMTRIG trigger conditions to assert PMTRIG only once during a four-hour period if EPMDR = Y (i.e., synchrophasor recording is enabled).

The PMU stores these files in the SYNCHROPHASOR subdirectory with .PMU extension. Use FILE READ or File Transfer Protocol (FTP) to retrieve these stored data files. The file is in binary format and IEEE C37.118 data format compliant.

The file starts with a Configuration 2 frame followed by the data frames as shown below.

<Configuration 2 Frame>

<Data Frame 1>

<Data Frame 2>

.

.

.

<Data Frame *t*>

<Data Frame *t*+1>

.

.

.

<Data Frame *n*>

where:

t = the number of pretrigger data frames, and is equal to PMPRE • MRATE.

n = the total number of data frames, and is equal to PMLER • MRATE.

<Data Frame *t*+1> is the first data frames with Bit 11 in the STAT field (PMTRIG) asserted.

The recorded file has the following file naming convention.

yymmdd,hhmmss,0,aaa,bbb,ccc.PMU

where,

yymmdd, hhmmss = the UTC time stamp of the first data frame in the file with bit 11 (PMTRIG) asserted

aaa = the last three characters of the PMSTN*q* setting (after removing characters “ / \ < > * | : ; [ ] $ % { } and the spaces)

bbb = the last three characters of the PMID*q*

ccc = the last three characters of the CONAM setting (after removing the spaces)

Additional PMTRIG assertions are ignored during recording.

Table 18.25 shows the setting name, description, and default value to help configure the data recording.

Table 18.25 PMU Recording Settings

Setting	Description
EPMDR[a]	Enable PMU Data Recording (Y, N)
SPMDR[b]	Select Data Configuration for PMU Recording (1–NUMPHDC)
CONAM[c]	Company Name (1–5 characters)
PMLER[b]	Length of PMU Triggered Data (2–120 s)
PMPRE[b]	Length of PMU Pretriggered Data (1–20 s)

[a] This setting is forced to N if MFRMT = FM.
[b] This setting is hidden if EPMRD = N.
[c] Global Setting.

Descriptions for the settings in *Table 18.25* are as follows.

EPMDR

Use the EPMDR setting to enable synchrophasor data recording. This setting is hidden when EPMU := N. When EPMDR = Y, phasor measurement data recording will begin on the rising edge of PMTRIG. Any subsequent PMTRIG assertions during the allotted recording period (PMLER) will not result in another PMU data recording being started. The relay will store synchrophasor measurement data as a IEEE C37.118 binary format file that can be retrieved from the relay by using FTP. Synchrophasor data are recorded into a file with extension *.PMU.

SPMDR

The SPMDR setting provides a means for selecting any one of the enabled data configuration 1–NUMPHDC for synchrophasor data recording.

PMLER

PMLER sets the total length of the synchrophasor data recording, in seconds. The PMLER time includes the PMPRE time. For example, if PMLER is set for 30 seconds of PMU recorded data, and PMPRE is set for 10 seconds of pretrigger data, the final recording will contain 10 seconds of pretrigger data and 20 seconds of triggered data for a total report time of 30 seconds.

PMPRE

The PMPRE setting sets the length of the pretrigger data within the synchrophasor data recording. The PMPRE data begins at the PMTRIG point of the recording, and extends back in time (previous time to the trigger event) for the designated amount of time.

SECTION 19

Digital Secondary Systems

Some SEL-400 series relays can receive analog and binary inputs from a digital secondary system (DSS). DSS technology uses merging units to measure currents and voltages and perform substation control operations. This technology provides flexible solutions, reduces the cost of copper, and improves overall safety in the substation.

Refer to *Table 19.1* to select your DSS of interest.

Table 19.1 SEL DSS Technologies

DSS Technology	Supported Relays	SEL Supported Merging Units	Supported Features			Page Link
			Selective Protection Disabling	Multiple Point-to-Point Direct Connections	Custom Topologies	
TiDL (T-Protocol)	SEL-411L-2 SEL-421-7 SEL-451-6 SEL-487B-2 SEL-487E-5	SEL-TMU	Yes	Yes	Yes	*TiDL (T-Protocol) on page 19.1*
TiDL[a] (EtherCAT)	SEL-421-4, -5 SEL-451-5 SEL-487B-1 SEL-487E-3, -4	SEL-2240 Axion Nodes	No	No	No	*TiDL (EtherCAT) on page 19.17*
Sampled Values (IEC 61850-9-2LE)	SEL-411L-2 SEL-421-7 SEL-451-6 SEL-487B-2 SEL-487E-5	SEL-401 SEL-421-7 SEL-451-6 Other IEC 61850-9-2LE-Compliant Publishers	Yes	No	Yes	*IEC 61850-9-2 Sampled Values (SV) on page 19.23*

[a] TiDL (EtherCAT) technology is no longer offered.

Time-Domain Link (TiDL)

TiDL (T-Protocol)

The TiDL (T-Protocol) relays identified in *Table 19.1* receive analog and binary input data from connected SEL-TMUs. A TiDL system communicates over direct fiber-optic connections between relays and SEL-TMUs.

Designing and implementing a TiDL system uses the following the general process.

- ➤ Design a TiDL system from one-line diagram
- ➤ Configure a TiDL system in SEL Grid Configurator
- ➤ Connect and commission the TiDL system
- ➤ Operate the TiDL system

For an example configured TiDL substation and a guide for setting up your first TiDL system, see the *SEL-400 Series TiDL QuickStart Guide* available on selinc.com. For detailed information on the SEL-TMU, refer to the *SEL TiDL Merging Unit Instruction Manual*.

Figure 19.1 highlights a high-level SEL TiDL substation.

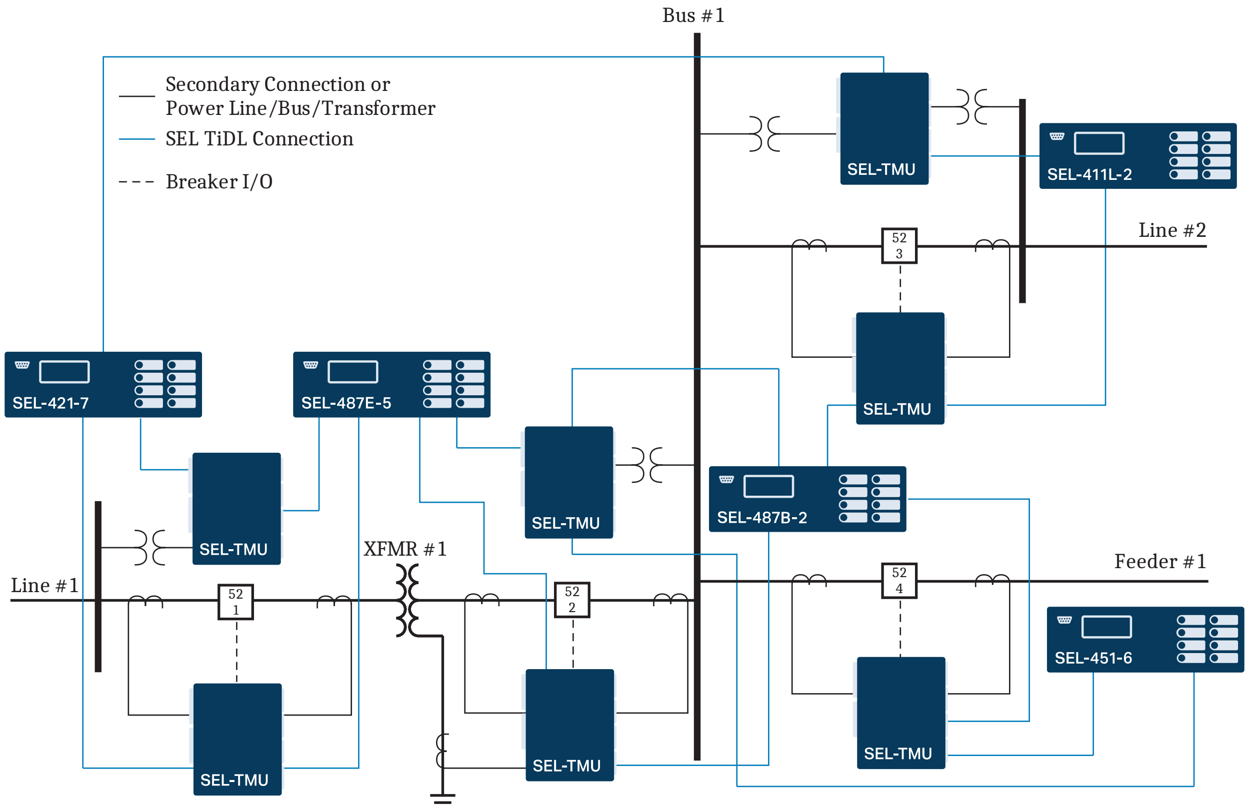


Figure 19.1 TiDL High-Level Substation Overview

Some of the benefits of a TiDL system include:

- ➤ No external time source required for relay and merging unit synchronization
- ➤ SEL TiDL relays and SEL-TMUs communicate via a nonroutable protocol that does not offer interactive remote user access. These features minimize security complexity and the associated compliance costs in a DSS.
- ➤ Simplified system configuration through SEL Grid Configurator software:
  - ➢ Custom topology configuration
  - ➢ Commissioning through SEL Grid Configurator
  - ➢ Commissioning report providing the present system level overview.

SEL TiDL relays can communicate with as many as eight SEL-TMUs. An SEL-TMU can then communicate with as many as four SEL TiDL relays.

A SEL TiDL system has a fixed channel delay of 1 millisecond. See *Section 1: Specifications* in the product-specific manual to see the link budget specifications of the TiDL (T-Protocol) communications ports.

When configuring a TiDL system in SEL Grid Configurator (see *TiDL Mapping on page 19.4*), create the SEL-TMUs by SEL-TMU type (either 4CT/4PT or 8CT), then map to the appropriate relay TiDL ports according to your TiDL substation requirements. When a commissioning attempt occurs (see *Commissioning TiDL Systems on page 19.14*), the relay checks that the SEL-TMU type physically connected to each relay TiDL port matches your configuration. If all connected SEL-TMUs match the expected SEL-TMU type, the relay successfully commissions that system and creates a correlation lock between each commissioned relay TiDL port and its unique SEL-TMU that was connected during the commissioning process. Once commissioned, each relay TiDL port will only accept incoming data from the unique SEL-TMU it commissioned. This provides additional security to a DSS. Should an SEL-TMU need to be replaced, see *Replacing SEL-TMUs on page 19.17*.

Selective Protection Disabling

See *Section 5: Protection Functions* of the product-specific instruction manual for channel status bits and the role they play in providing selective protection disabling in cases where analog data are lost.

Important Selective Protection Disabling Considerations

When an SEL-TMU is connected to multiple TiDL relays, the following situations can result in a momentary communication loss with the shared relays:

- Modifying the TiDL I/O map.
- Decommissioning a connected relay on an active SEL-TMU port.
- Initiating an SEL-TMU firmware upgrade to a connected relay.

Implement selective protection disabling in the other connected relays to avoid an adverse impact on relay protection functions.

TiDL Binary Input and Output Behavior

When a relay is commissioned, 300-, 400-, and 500-level I/O are mapped from SEL-TMUs.

Binary inputs are user-settable with default settings that make the binary inputs behave as level-sensitive inputs. The default settings for input and dropout thresholds are modified by the nominal voltage of the I/O board local to the relay. See *TiDL Binary Input Settings on page 19.10* for additional information on binary input settings. If the relay loses communications with the SEL-TMU, the relay binary inputs mapped to that SEL-TMU will remain at their last known value until communications are restored.

Because binary outputs on an SEL-TMU can be shared among the connected TiDL relays, each TiDL relay maps the status of the SEL-TMU binary outputs to local output status bits local to each relay (OUT*xxx*S). For example, if a relay has the SEL-TMU binary output OUT01 mapped to OUT301 locally, the OUT301S Relay Word bit indicates the state of OUT01 to the local relay. See *Binary Outputs* of the *SEL-TMU Instruction Manual* for a description of output behavior during a loss of communications with the SEL-TMU.

Binary inputs and outputs do not have to map to the same I/O in each connected relay. For example, OUT01 on the SEL-TMU could map to OUT301 of the SEL TiDL relay connected to SEL-TMU **PORT 1**, OUT307 of the SEL TiDL relay connected to SEL-TMU **PORT 2**, OUT405 of the SEL TiDL relay connected to SEL-TMU **PORT 3**, and OUT503 of the SEL TiDL relay connected to SEL-TMU

PORT 4. In such a case, the output control equation for OUT01 can be considered as $OUT01_{TMU}$:= $OUT301_{Relay\ 1}$ + $OUT307_{Relay\ 2}$ + $OUT405_{Relay\ 3}$ + $OUT503_{Relay\ 4}$.

Decommissioned Relay I/O Statuses

When a TiDL relay is decommissioned, all I/O Relay Word bit statuses revert to their default deasserted state.

TiDL Mapping

When configuring your TiDL I/O mapping, first add devices to your SEL Grid Configurator workspace according to your TiDL substation requirements. *Figure 19.2* shows the process for adding a device to a folder or just to the overall workspace. All TiDL devices added to a SEL Grid Configurator workspace are available for mapping purposes, not just those co-located within the same folder.

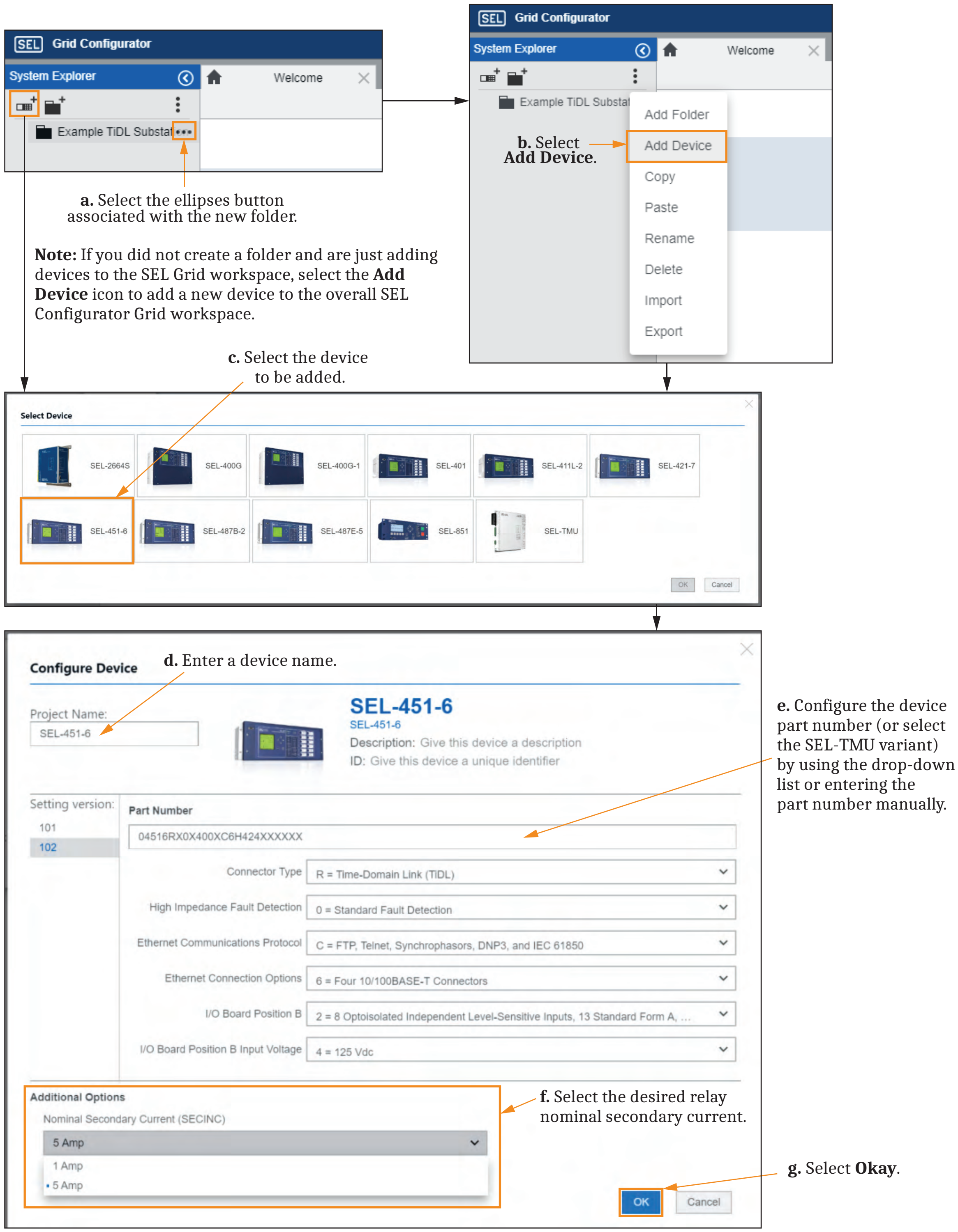


Figure 19.2 Adding a Device to the SEL Grid Configurator Workspace

Repeat the steps in *Figure 19.2* to add all remaining devices in your TiDL substation. Next, enable the TiDL I/O Map (Port 6) of the relay you are currently configuring in SEL Grid Configurator, as shown in *Figure 19.3*.

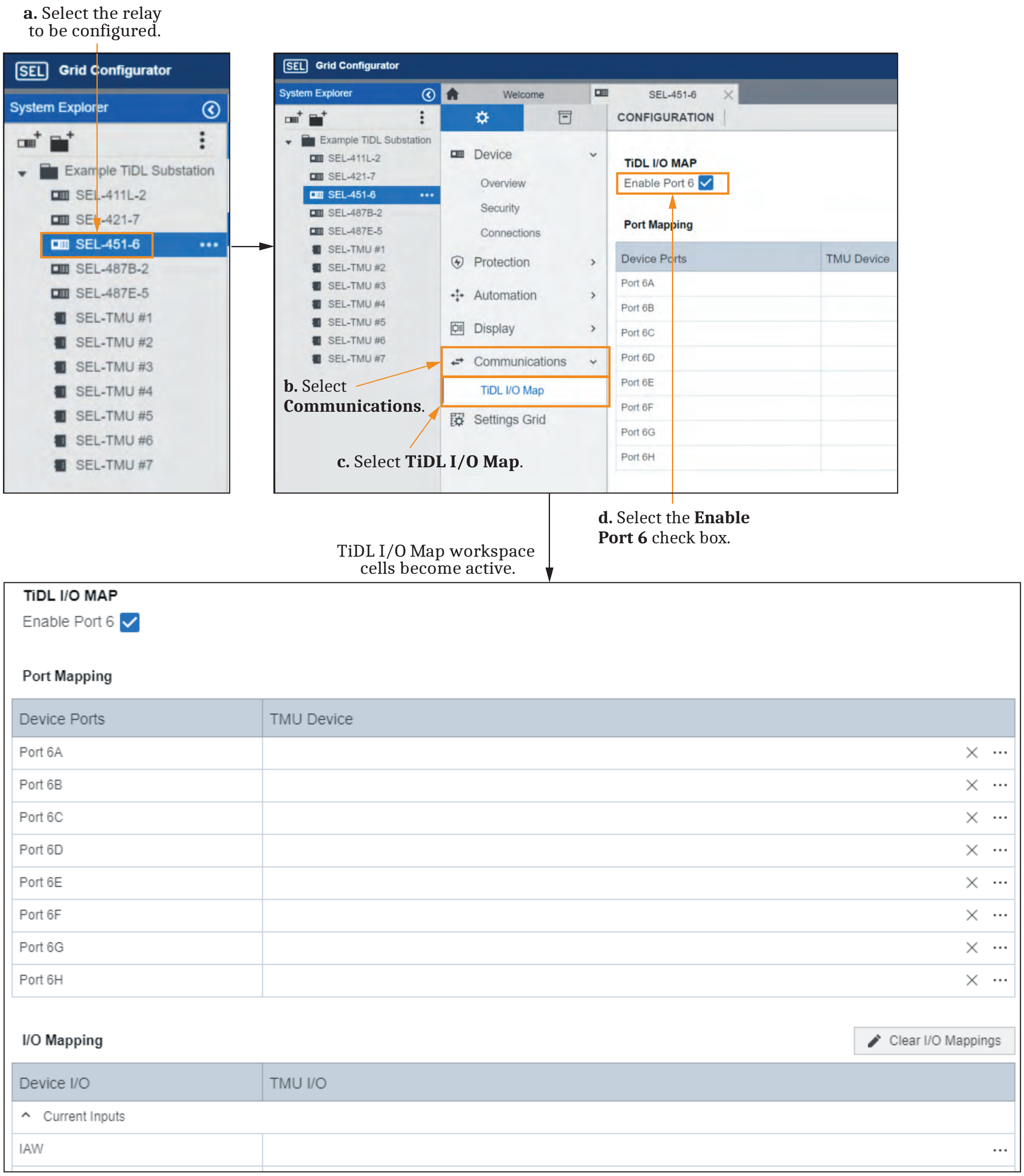
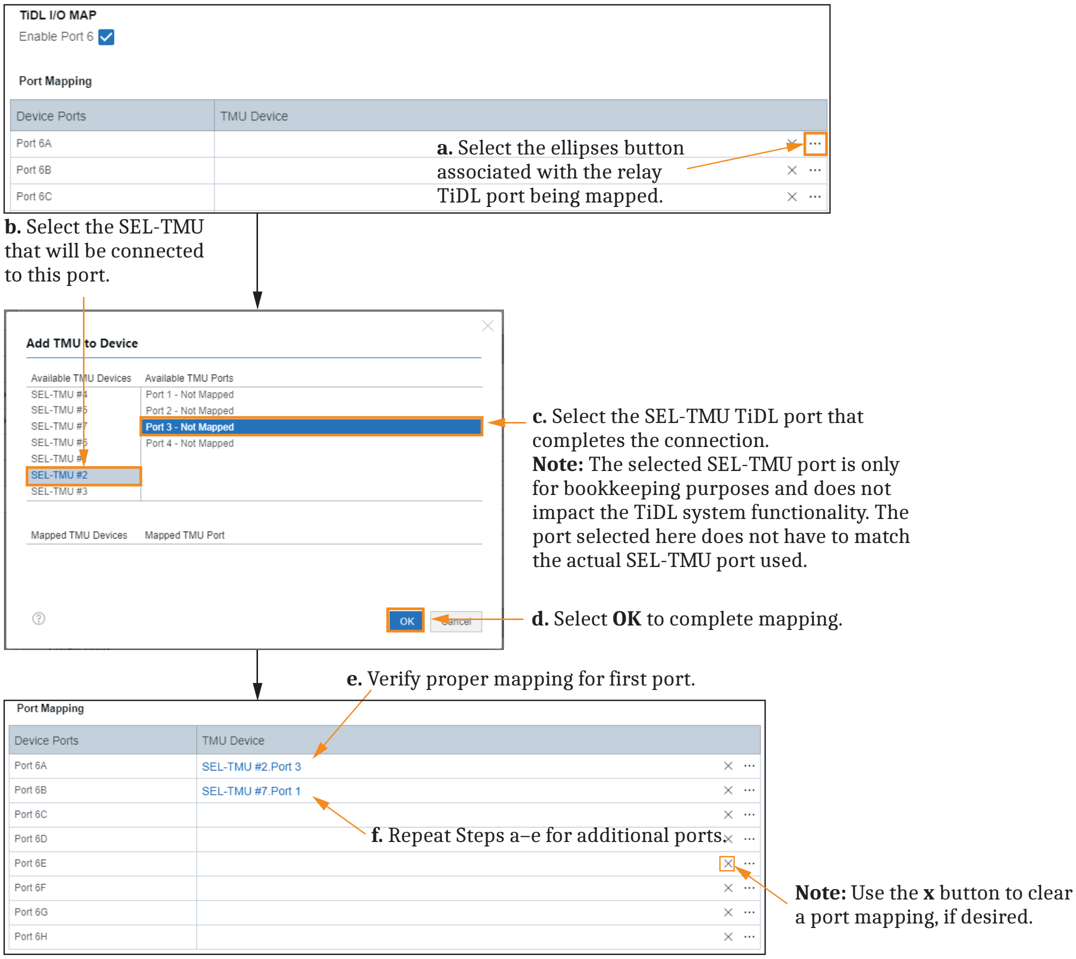


Figure 19.3 Navigating to the TiDL I/O Map Workspace

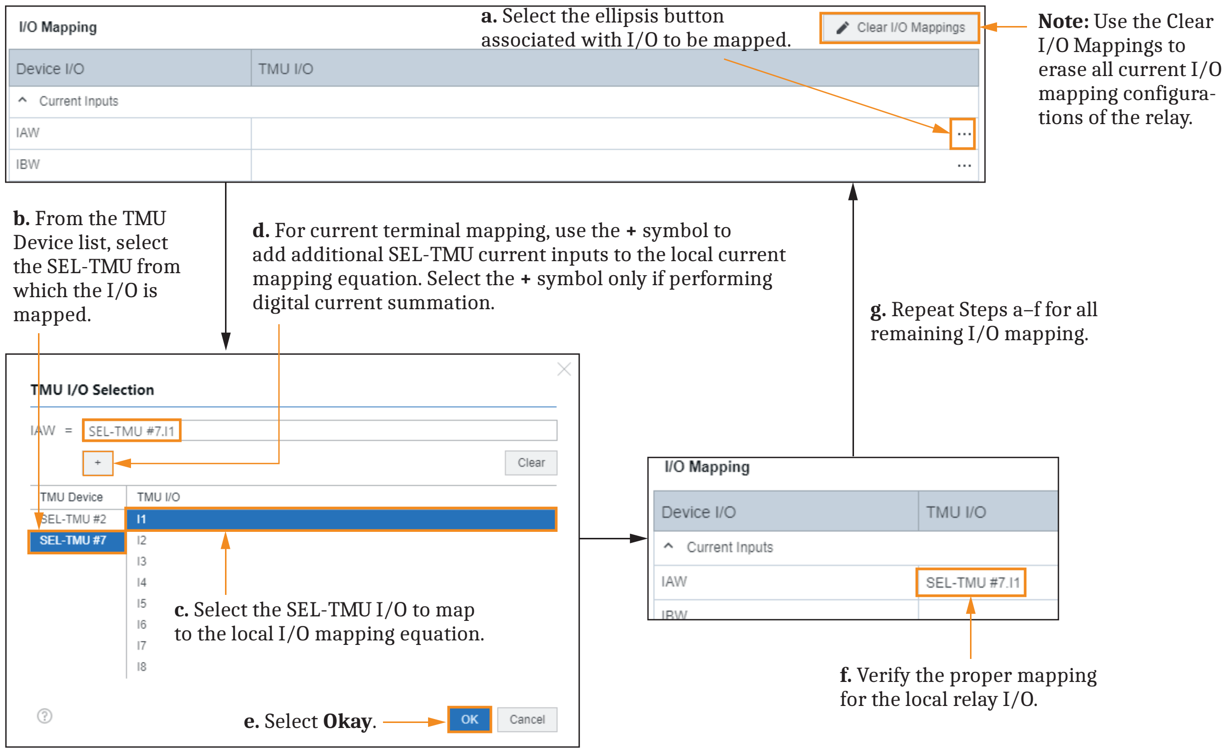
Next, configure your TiDL relay and SEL-TMU port mapping by following the process shown in *Figure 19.4*.



NOTE: You can use all SEL-TMUs in the SEL Grid Configurator workspace to create a topology mapping.

Figure 19.4 Configure Port Mapping

Proceed to configuring your I/O mapping. You can only use I/O from the SEL-TMUs configured as mapped to your relay from *Figure 19.4* when configuring your relay I/O mapping. *Figure 19.5* shows the process for configuring I/O mapping.



Note: Only SEL-TMU devices that have been mapped to a relay port (see ①) appear in the list of SEL-TMU devices from which you can map I/O.

① See Figure 19.4.

Figure 19.5 Configure I/O Mapping

SEL TiDL Relay Nominal Secondary Current

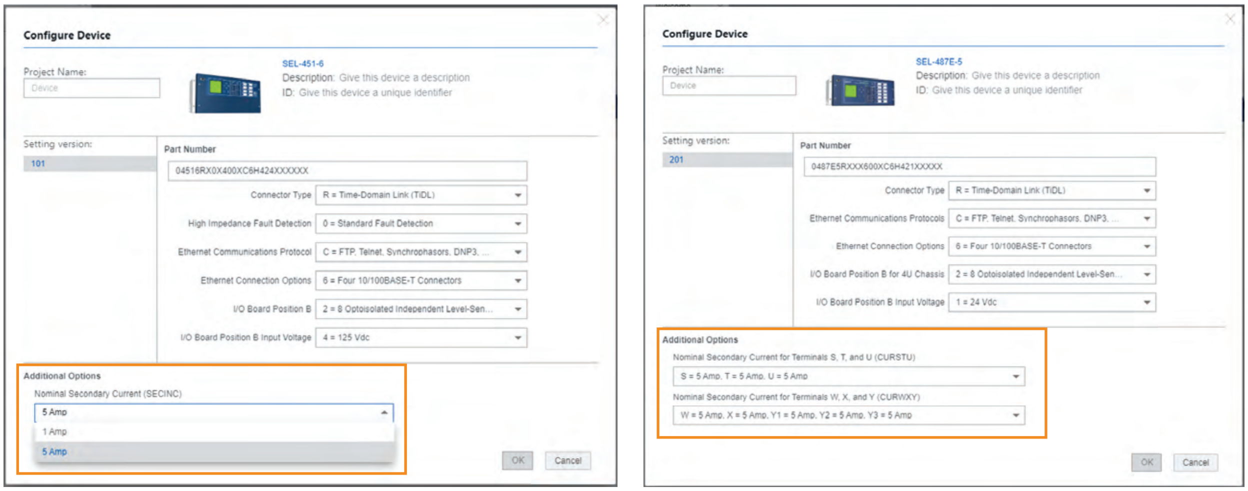
NOTE: In the SEL-451-6 R401 firmware, the **CFG CTNOM** command defaults all relay settings, which will also decommission the relay's TiDL mapping. SEL Grid Configurator can only configure the nominal secondary current of the SEL-451-6 in firmware versions R402 and newer.

The SEL-400 devices accept 1A or 5A CTs. Configure an SEL TiDL relay via SEL Grid Configurator (see *Figure 19.11*) or the **CFG CTNOM** command to set the nominal secondary current for its mapped CT inputs. The SEL TiDL relays follow the same makeup of nominal CT inputs as their corresponding traditional relay version. This means that for SEL TiDL relays, with the exception of the SEL-487E-5, all CT terminals share the same nominal secondary. The SEL-487E-5 provides options for modifying the nominal secondary on a per-terminal basis.

By default, the relay assumes 5A nominal secondaries.

When the **CFG CTNOM** command is issued by either SEL Grid Configurator or through an ASCII terminal and only if the nominal secondary is changed (i.e., changing from 5A nominal to 1A nominal, or 1A nominal to 5A nominal), Global and Group settings are forced to default, then the relay restarts.

When you are adding a device to the SEL Grid Configurator System Explorer, select the applicable secondary current options for the device. *Figure 19.6(a)* shows options for an SEL-451-6 and *Figure 19.6(b)* shows options for a SEL-487E-5. From the selected secondary current options, SEL Grid Configurator creates a device with defaults and settings ranges based on the nominal secondary currents.



(a) (b)

Figure 19.6 Configure Device Nominal Secondary Current Configuration

To see the configured nominal secondary current of a device in SEL Grid Configurator, see the SEL Grid Configurator settings of SECINC (in relays other than the SEL-487E-5) or CURSTU and CURXYZ (in the SEL-487E-5).

Reading Settings in SEL Grid Configurator

When reading settings from a device in SEL Grid Configurator, you can do one of the following:

- ➤ Read settings to a device that already exists in the SEL Grid Configurator workspace
- ➤ Add a device to the SEL Grid Configurator workspace by using the retrieved settings

For the first case, if you read settings for a device that already exists in the SEL Grid Configurator workspace, the following can occur:

- ➤ The configuration in SEL Grid Configurator matches the relay configuration and settings are automatically loaded.
- ➤ A discrepancy exists between SEL Grid Configurator and the relay. In this case, SEL Grid Configurator alerts and asks the user what the nominal secondary current configuration should be.

For the second case, if you add a device to SEL Grid Configurator by using the retrieved settings, SEL Grid Configurator creates a device with a nominal secondary current configuration that matches the relay configuration in your project.

Modifying Previously Configured Nominal Secondary Current

If a device in SEL Grid Configurator requires updating the nominal secondary current, follow the process outlined in *Figure 19.7*.

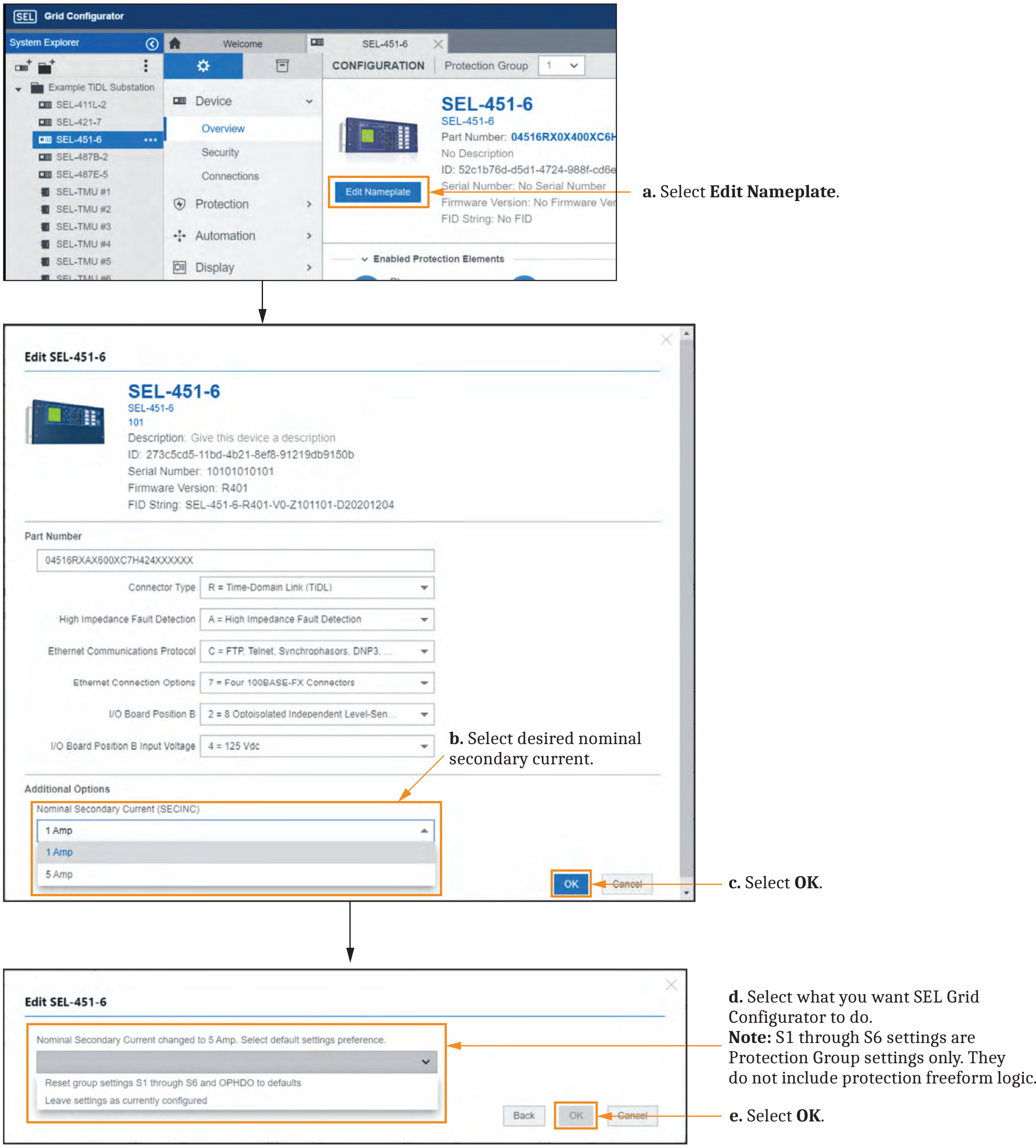


Figure 19.7 Modifying Nominal Secondary Current Configuration

TiDL Binary Input Settings

The SEL TiDL relay binary inputs that are mapped from SEL-TMUs behave as user-settable inputs. Pickup and dropout levels are also set independently per relay. This means that an SEL-TMU binary input that is shared among multiple relays does not require the same pickup and dropout thresholds configured in each relay; they can be set differently. Although you can set shared inputs independently, SEL typically recommends to set settings for shared inputs consistently among the connected relays.

By default, all binary inputs have settings determined by the additional I/O board in slot Position B of the local relay. All virtual I/O default to the threshold levels similar to the level-sensitive board through the GINP setting. If the mapped binary inputs all share the same pickup, dropout, etc. settings but are different from the default, change the GINP, GINDF, etc. settings and leave EICIS := N. However, if the mapped binary inputs require different settings on a per input basis, follow the process outlined in *Figure 19.4*.

You can send binary input settings to a relay prior to, during, or any time following a TiDL relay commissioning without needing to re-commission your TiDL relay.

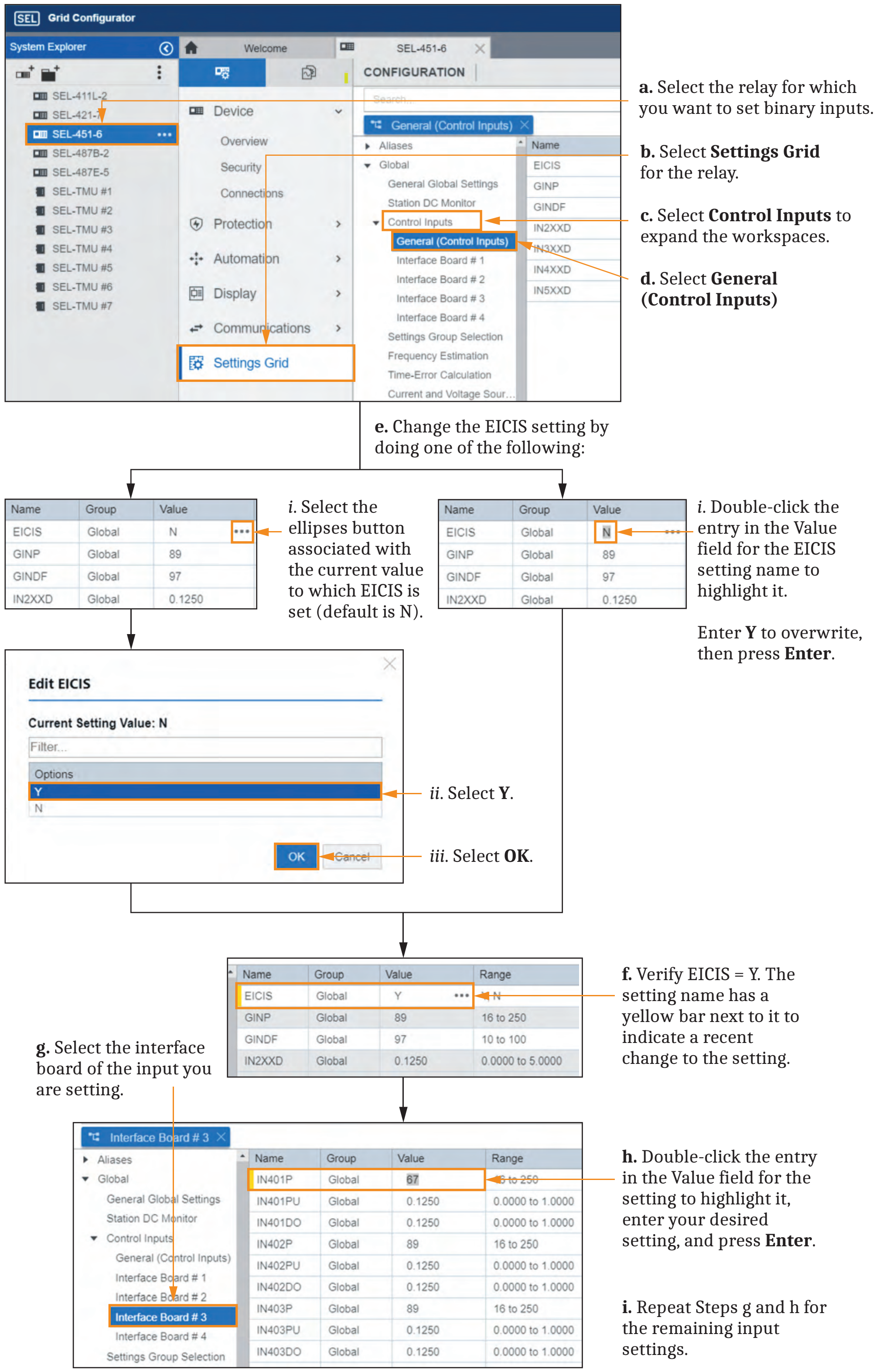


Figure 19.8 Binary Input Settings Flow Diagram

SEL Grid Configurator Aliasing

SEL Grid Configurator provides an option of aliasing the SEL-TMU I/O. Through aliasing the SEL-TMU I/O, you can make the mapping configuration more intuitive. *Figure 19.9* shows the steps for aliasing SEL-TMU I/O.

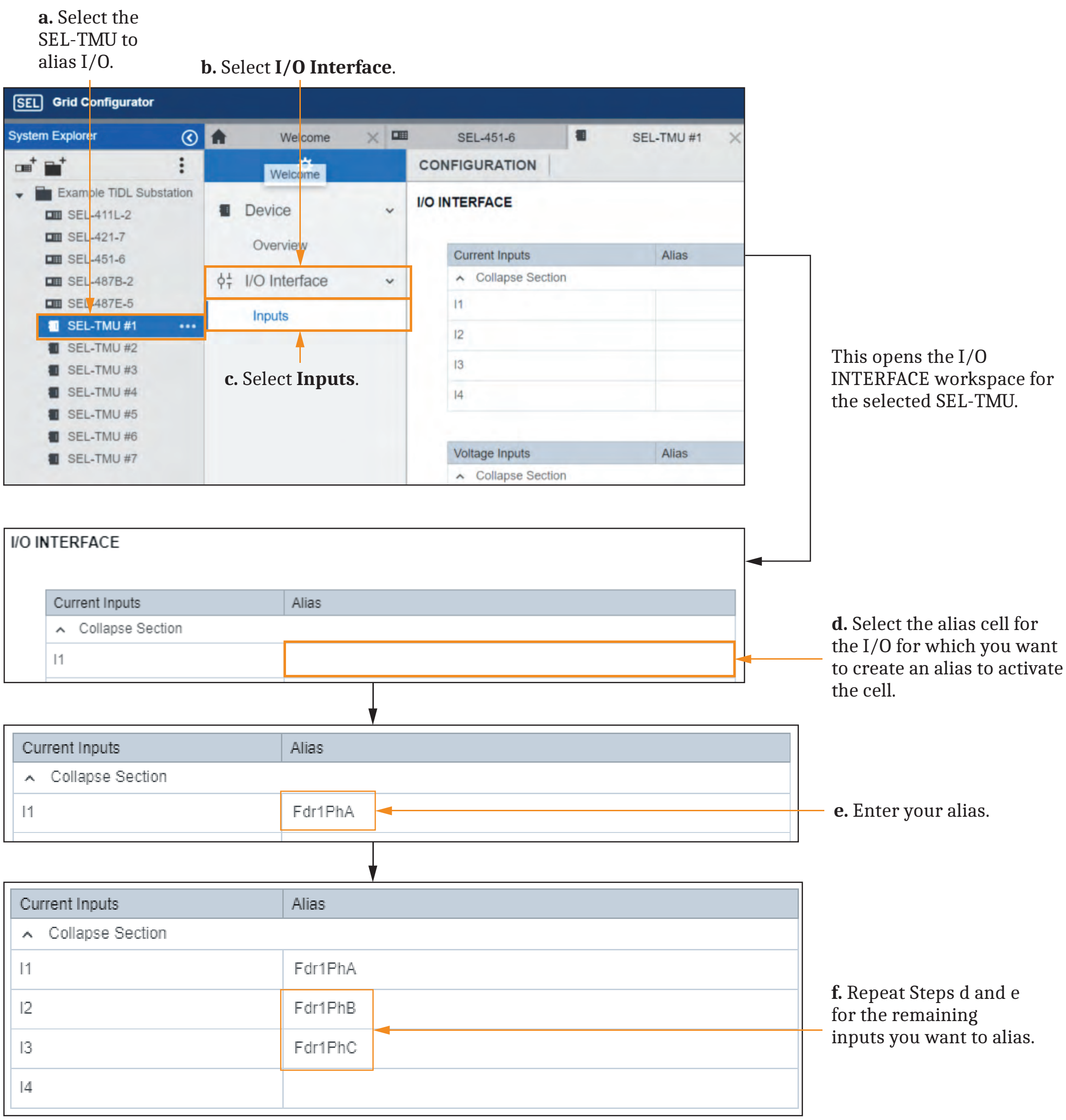


Figure 19.9 Creating Aliases for SEL-TMU I/O

Once the alias is created, it appears in the TMU I/O Selection dialog box. The original I/O name appears in parentheses following the alias name.

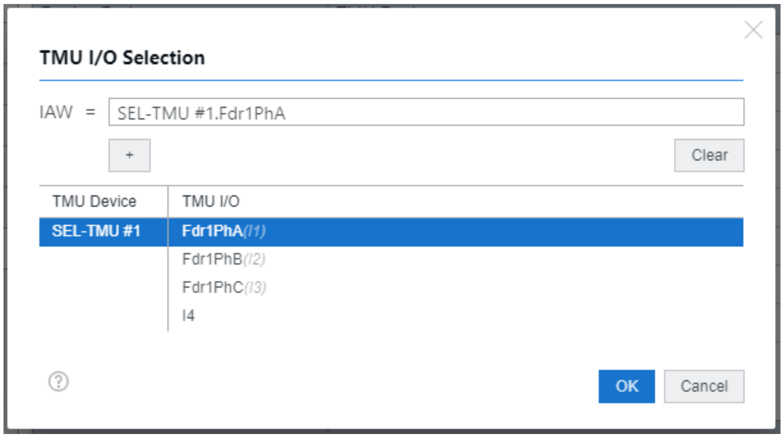
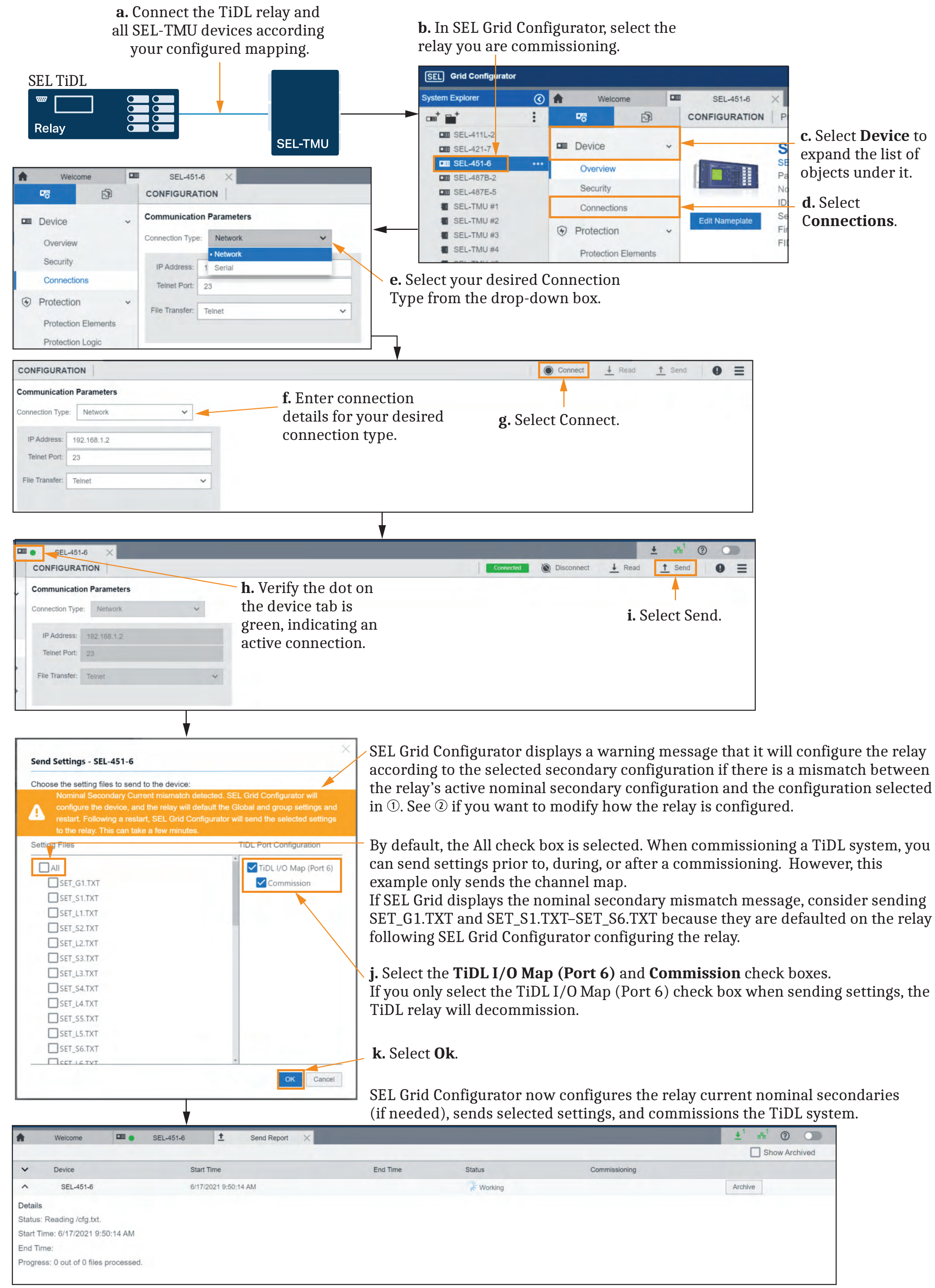


Figure 19.10 Aliases Shown in TMU I/O Selection Dialog Box

Commissioning TiDL Systems

NOTE: To decommission a TiDL system use the **R_S** command, send a TiDL channel map without selecting **Commission**, or send an empty TiDL channel map.

Figure 19.11 shows the process for commissioning a TiDL system. Each TiDL system (a TiDL relay and the connected SEL-TMU TiDL ports) is commissioned independently with no impact to other relays and SEL-TMUs already in service (outside of shared SEL-TMU outputs that you can now control through the newly commissioned relay).



① See Figure 19.6; ② See Figure 19.7

Figure 19.11 SEL TiDL Relay Commissioning

Following a commissioning attempt, the result is provided, as shown in *Figure 19.12*. For successful attempts, you can generate a commissioning report that includes a record of the relay and SEL-TMUs commissioned. For failed attempts, SEL Grid Configurator displays error messages that indicate the reason why the commissioning attempt failed. In addition to the provided commissioning report, following any commissioning attempt, a SER entry is recorded to indicate a commissioning attempt and the result (successful, unsuccessful, etc.).

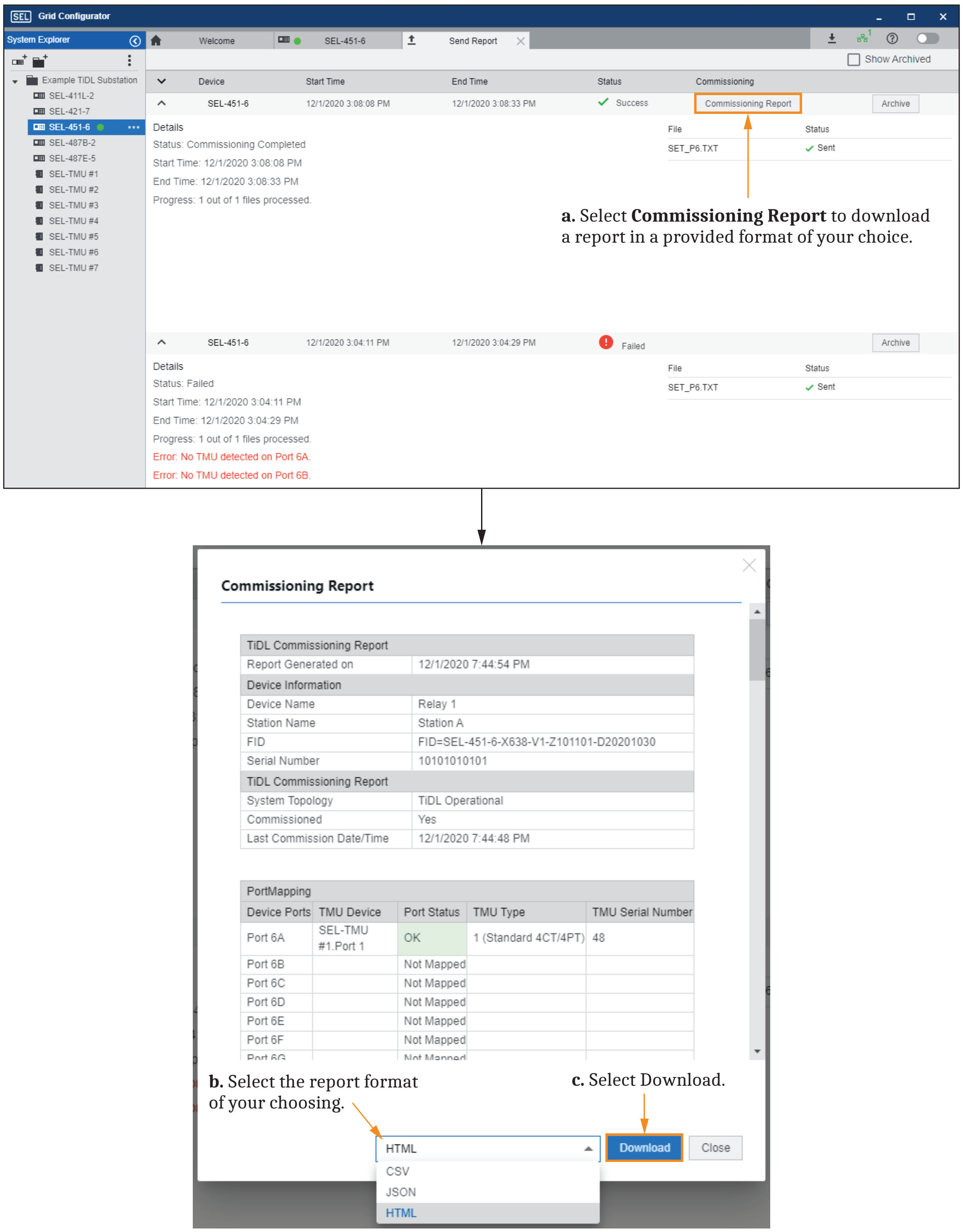


Figure 19.12 TiDL Commissioning Report

TiDL System Troubleshooting

Use the **STA T** command (see *STA T on page 14.62*) to view the current operational status of your TiDL system.

For commissioned SEL-TMUs, the **STA T** command indicates OK for an SEL-TMU device that is communicating and properly commissioned or an error if the corresponding SEL-TMU is not communicating with the relay. Check the fiber connection between the relay and SEL-TMU. Use the **VEC** command (see *VECTOR on page 14.73*) to obtain relevant SEL-TMU diagnostics, then contact SEL technical support.

Ports that are not mapped according to the configured topology are indicated as Not Mapped in the **STA T** command response.

Replacing SEL-TMUs

Anytime a commissioned SEL-TMU is replaced, each TiDL system that uses the SEL-TMU in mapping must be recommissioned by following the process outlined in *Figure 19.11*.

TiDL (EtherCAT)

NOTE: TiDL (EtherCAT) technology is no longer offered. It is recommended to use TiDL (T-Protocol).

The TiDL (EtherCAT) relays identified in *Table 19.1* can receive analog and binary inputs from the SEL-2240 Axion. The Axion provides the analog and binary data over an IEC 61158 EtherCAT, TiDL network. This technology provides very low and deterministic latency over point-to-point architecture. Point-to-point architecture eliminates the need for time synchronization between the Axion nodes and the relay. In addition, it eliminates the complex communications network often associated with DSS and simplifies the programming and installation process.

SEL-400 series relays with TiDL can receive as many as eight fiber links from as many as eight Axion nodes. Not all nodes have to supply analog data—some can supply digital input and output (I/O) only. The firmware will recognize and validate the connected Axion modules and determine if they match a predefined supported topology. The supported topologies are balanced between copper reduction and the number of required Axion nodes. Refer to *Section 2: Installation* in the product-specific instruction manuals to review the supported TiDL topologies.

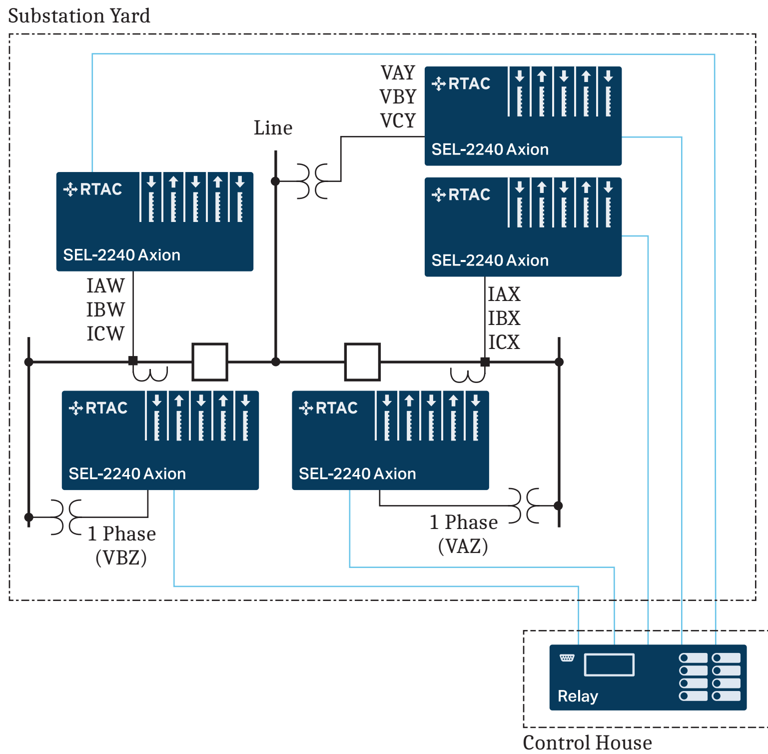


Figure 19.13 Sample TiDL System Topology

SEL-400 series relays that support TiDL are only available in a 4U chassis. These relays support an I/O board on the relay, and, when applicable, main board I/O. These I/Os will be mapped to the 100- and 200-level inputs and outputs. Axion modules provide additional I/O by using the internal digital Relay Word bits for the 300, 400, and 500 levels of the relays. Note that when the relay part number supports TiDL, all output settings for I/O are available. Correctly set these outputs for what is installed because all output settings will be available but all may not be physically installed in your system.

Relay Word bits IO300OK, IO400OK, and IO500OK indicate the status of installed I/O boards in standard relays or whether an Axion module is commissioned. These bits can also identify whether a board is installed or when an Axion I/O module fails.

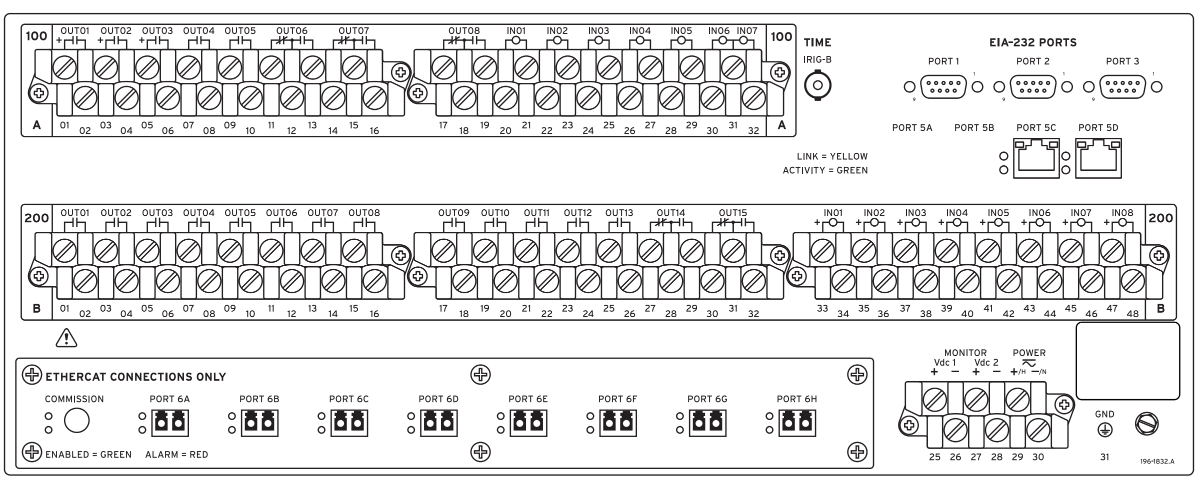


Figure 19.14 Rear Panel of Relays With TiDL

TiDL applications use the SEL-2240 Axion, which is a fully integrated analog and digital I/O control solution suitable for DSS. An Axion node consists of a 10-slot, 4-slot, or dual 4-slot chassis that is configurable to contain a power module and combinations of CT/PT, digital input (DI), or digital output (DO) modules.

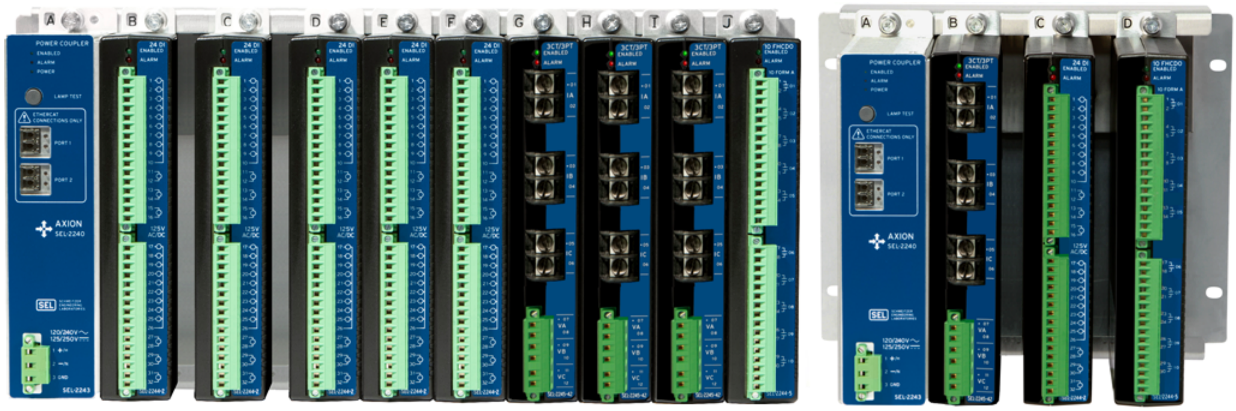


Figure 19.15 Axion Chassis

Each chassis requires a SEL-2243 Power Coupler (see *Figure 19.16*). This module supplies power to the rest of the node and transmits the data to the relay through fiber-optic communication. See the *SEL-2240 Axion Instruction Manual* for more information.

Figure 19.16 SEL-2243 Power Coupler

The SEL-2244-2 Digital Input Module (see *Figure 19.17*) consists of 24 optoisolated inputs that are not polarity-dependent. These inputs can be configured to respond to ac or dc control signals. The TiDL system maps as many as 72 DI points to the relay. For more information on DI mapping, refer to *Section 2: Installation* in the product-specific instruction manuals.

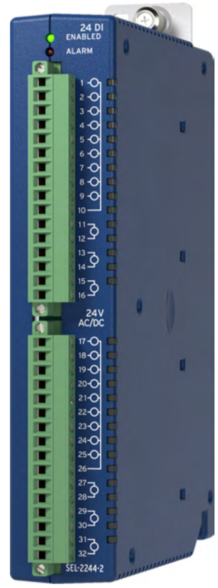


Figure 19.17 SEL-2244-2 Digital Input Module

The SEL-2244-5 Fast High-Current Digital Output Module (see *Figure 19.18*) consists of ten fast, high-current output contacts. The TiDL system can map as many as 48 DO points to the relay. For more information on DO mapping, refer to *Section 2: PC Software*.

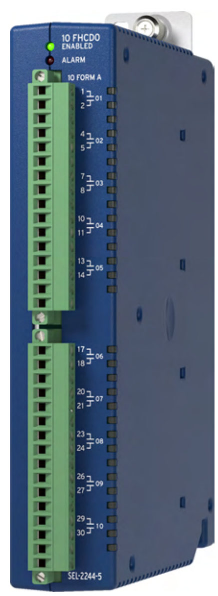


Figure 19.18 SEL-2244-5 Fast High-Current Digital Output Module

The SEL-2245-42 AC Analog Input Module (see *Figure 19.19*) provides protection-class ac analog input (CT/PT) and can accept three voltage and three current inputs. The module samples at 24 kHz and is 1 A or 5 A software-selectable. Depending on the supported fixed topology, multiple CT/PT input modules can function in each node. Some topologies only support one CT/PT module per node. See the supported topologies in *Section 2: Installation* in the product-specific instruction manual for more information.

Figure 19.19 SEL-2245-42 AC Analog Input Module

A simple commissioning process identifies the connected TiDL system and verifies it matches one of the supported relay topologies. Once the commissioning process is complete, the topology is stored in memory. At each additional relay startup, the firmware validates that the connected modules match those of the stored configuration. It recognizes if any CT/PT modules within the node have changed.

Secondary injection testing takes place at each Axion node. Test sources are required to inject voltages and current to the Axion node to verify correct installation and mapping. Monitoring of the voltages and currents will remain in the control house at the relay location.

TiDL (EtherCAT) Settings

NOTE: The relay must be configured using the **CFG CTNOM n** command before the settings are transferred to the relay to avoid erasing the transferred settings. The commands used to set the nominal current in the relay will default all settings after the commands are issued. Changing the SECINC, CURSTU, or CURWXY settings in QuickSet will not change the rest of the settings in QuickSet back to default but will provide an error if any of the current settings are now out of range. In addition, when the relay is connected to QuickSet, the software reads the configuration of the relay and appropriately updates this setting automatically; however, this setting must work offline and develop settings when not connected to the relay.

In TiDL (EtherCAT) relays, there are configurable settings that are specific to those applications in QuickSet. These settings are needed to help configure QuickSet and control attributes such as setting ranges, defaults, and functionality. These settings are not part of the actual relay firmware, and therefore are not sent to the relay at the time the settings transfer. SECINC is one of these configurable settings. SECINC determines the nominal current input for the connected Axion units. In the relay, the user issues an ASCII command, **CFG CTNOM *n***, to set the relay firmware to the correct nominal current being received from the TiDL Axion units. Once the command has been used to set the nominal current value from the Axion units, use QuickSet to set SECINC (see *Figure 19.20*) to that same nominal value to adjust all QuickSet setting ranges to the appropriate scales.

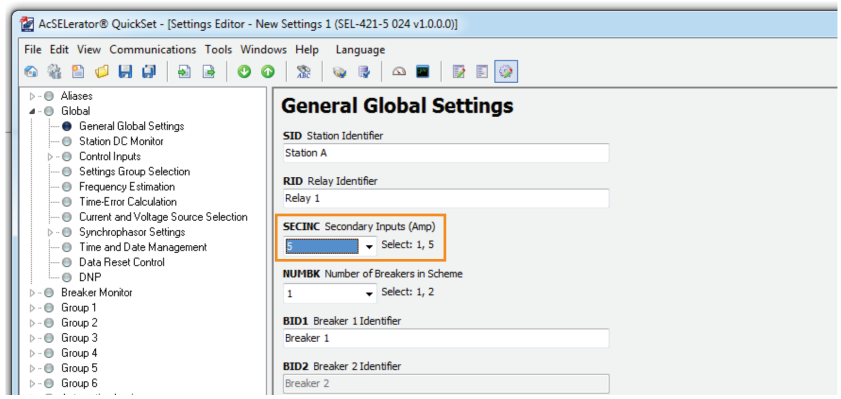


Figure 19.20 SECINC Setting

Some relays, such as the SEL-487E, have multiple setting combinations. The QuickSet settings for the SEL-487E, CURSTU and CURWXY, are shown in *Figure 19.21*. and are used instead of SECINC. For more information on the settings options, review the **CFG CTNOM** command operation in *Section 2: Installation* of the product-specific instruction manual.

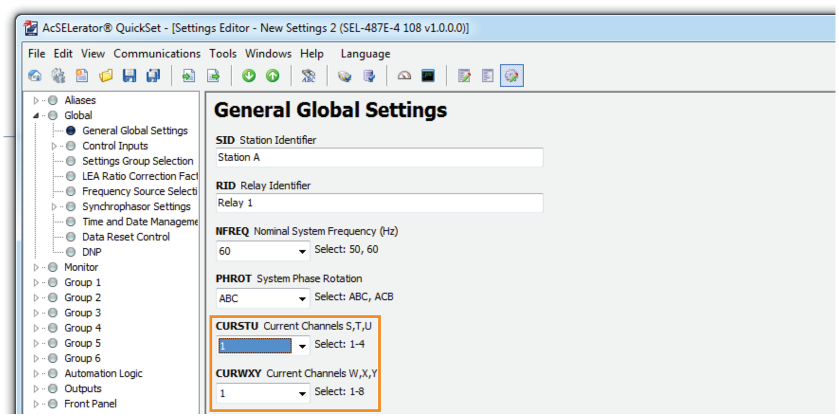


Figure 19.21 SEL-487E Nominal Current Selection

If at the time the relay settings are transferred, the QuickSet settings SECINC, CURSTU, or CURWXY do not match the nominal current set in the relay by the **CFG CTNOM** command, the settings transfer is rejected and an error message is displayed.

For relays that do not support DSS, the SECINC setting is grayed out in QuickSet (see *Figure 19.22*). Settings CURSTU and CURWXY are also grayed out in the SEL-487E.

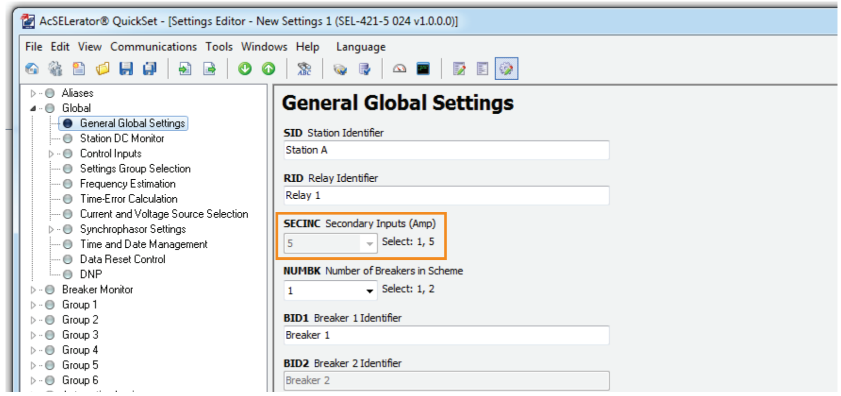


Figure 19.22 SECINC Disabled

IEC 61850-9-2 Sampled Values (SV)

Some SEL-400 series relays are available with the capability to either publish or subscribe to analogs in accordance with the UCA International Users Group's "Implementation Guideline for Digital Interface to Instrument Transformers Using IEC 61850-9-2," The 9-2LE guideline is a subset of IEC 61850-9-2 and specifies, among other things, logical devices, data set contents, sampling rates, the time-synchronization method, and the message format. The 9-2LE guideline clarified ambiguities in the 9-2 standard, improving interoperability between SV devices from different manufacturers.

Architecture

9-2LE uses OSI Layer 2 multicast messages on standard Ethernet network architecture. Merging units sample analog values, convert them to digital signals, and then publish them over the Ethernet network. Two key components of SV messages (besides the current and voltage data) are the destination MAC address and the application ID, or APPID. Relays, meters, DFRs, and other devices on the network can selectively subscribe to the SV streams they need for their application based on these attributes. Because SV streams only carry current and voltage measurements, to accommodate digital input and output data or controls, IEC 61850 GOOSE must also be configured on the network. This network, which carries data essential for the first level of basic substation processes, is known as the process bus. Another network commonly associated with IEC 61850 is known as the station bus, which carries station-level communications such as SCADA.

The process bus allows a single merging unit to share its data with multiple devices and for a single device to receive data from multiple merging units. To align these data, 9-2LE requires time synchronization for all devices. This can also be accomplished over either the process bus or the station bus network via IEEE 1588 or Precision Time Protocol (PTP). Alternatively, SEL SV devices can be synchronized via IRIG-B. Because of the bandwidth requirements and message types that can be present on the process bus, optimal SV performance requires a well-engineered process bus and station bus network.

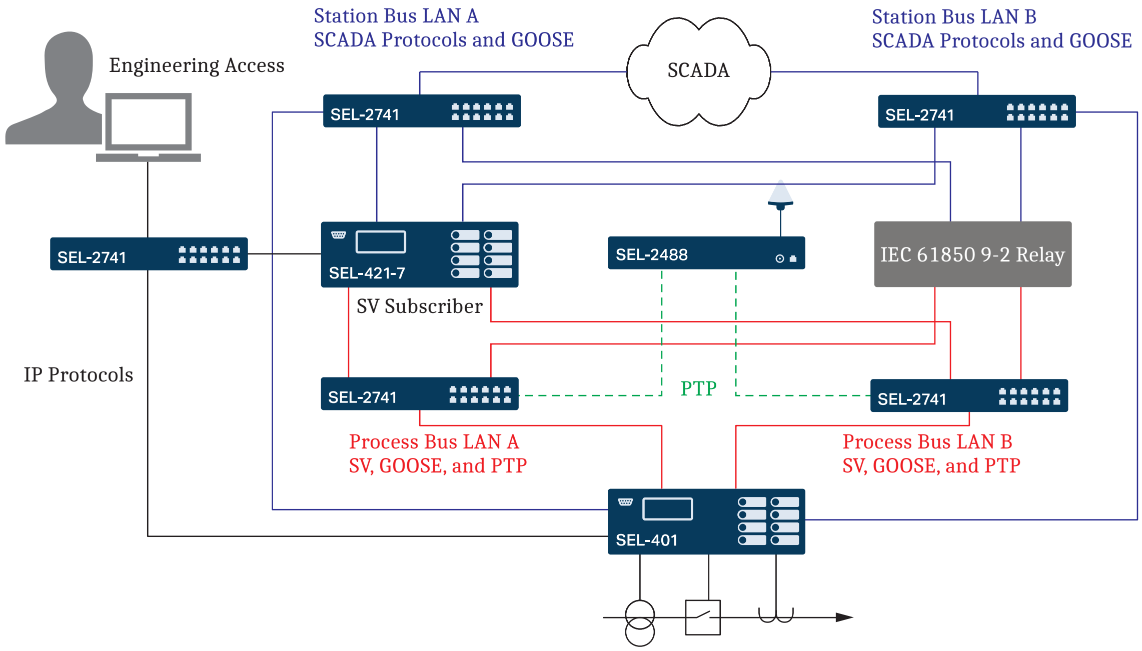


Figure 19.23 Example SV Network

Refer to *Section 17: IEC 61850 Communication* for information on process bus and station bus designations for the four-port and five-port Ethernet cards.

Benefits of a 9-2LE SV System

Some of the benefits of a 9-2LE SV system include:

- Set the relay as you would conventional SEL-400 series relays through use of QuickSet or SEL Grid Configurator and ACSELERATOR Architect SEL-5032 Software.
- Decrease costs through copper reduction and data sharing.
- Increase safety in the substation by removing high-energy cables from the control house. This also eliminates the concern of an open circuited CT when a relay is removed from service.

SV Publication

SV Publication Capability

Some SEL-400 series relays are available with the capability for SV publication. Enabling SV publication through settings—PORT 5 setting SVTXEN > 0 or via Configured IED Description (CID) file—enables the merging unit functionality of the device. The SV publication capability of each SEL SV publishing devices is identical, so throughout this section, SEL devices with SV publication enabled are referred to as SV publishers.

The SV publisher digitizes the data from its voltage and current inputs, records its current state of time synchronization, scales these values to primary units by using the CT and PT ratio settings, and then transmits these values in accordance with the 9-2LE guideline. SEL SV publishers support the “MSVCB01” model of the multicast SV control block described in the guideline, which includes a single application service data unit (ASDU). The transmission rate is 80 samples per nominal frequency cycle. If the nominal frequency setting of the SV publisher NFREQ = 50 Hz or 60 Hz, the SV transmission rate is 4000 or 4800 samples per second, respectively.

The SV publisher can publish as many as seven SV streams simultaneously. SV publication is independent of the protection elements, so protection functionality remains secure even when the SV publisher is publishing the maximum number of SV streams.

Because multiple SV streams may be received by a single subscriber, all streams usually require time-alignment to a time source with an accuracy of <1 µs. SV messages indicate the synchronization state of the SV publisher at the time the sample was taken. This value, smpSynch in the SV message, will be 0, 1, or 2, to indicate whether the merging unit was synchronized with a global time source (2), a local time source (1), or an internal clock (0). If the SV publisher is synchronized with an IEEE 1588 PTP time source that uses the PTP Power Profile (C37.238), the smpSynch value is equal to the ID of the grandmaster clock, usually a value between 5 and 254. The subscriber can also operate in the local time mode with a single time source accuracy of >1 µs.

Though SV messages do not contain an actual time stamp, they do include a value, smpcnt (sample count), that the publisher increments for each message that it transmits, which represents the time at which the sample was taken. For every SV message that the SV publisher transmits, smpcnt increments until it reaches a value of 4799 on a 60 Hz system, or 3999 on a 50 Hz system. At the top of the second, smpcnt resets to 0. Smpcnt can be used to calculate the time stamp of the message in relation to the most recent top of a second by multiplying it by the transmission interval (208.33 µs for a 60 Hz system or 250 µs for a 50 Hz system). For example, a message with smpcnt=699 on a 50 Hz system was taken 699 • 250 µs = 174.75 ms after the top of the second.

SV Publisher Configuration

Architect provides support for the configuration of the SEL SV publisher via a GUI. This interface provides the most flexible configuration of SV publications, including the creation of customized SV data sets. This mechanism is very similar to the configuration of GOOSE publications. For more information, see *IEC 61850 Configuration on page 17.47*.

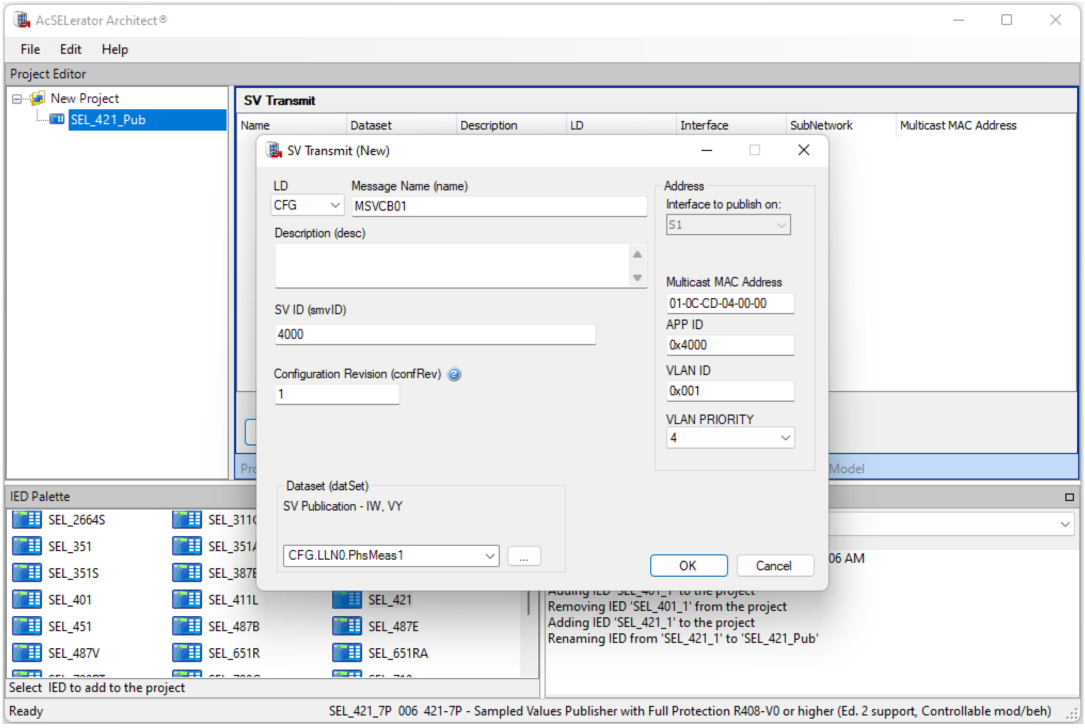


Figure 19.24 Example Architect SV Publication Configuration

Architect includes ICD files for the SEL-401, SEL-421-7, and SEL-451-6 SV publishers. ICD files of SV publishers contain default SV data sets, which contain combinations of the current and voltage terminals available on the publisher, i.e., W and Y, W and Z, X and Y, or X and Z. You can choose to publish any of these preconfigured data sets or create and publish a custom data set that conforms to the 9-2LE guideline. This feature is useful if you need the SV publisher to send anything other than all phases (A, B, C, and neutral) of a current or voltage terminal in an SV stream.

SV publications may also be configured via **PORT 5** settings through QuickSet or an ASCII terminal window. You can use **PORT 5** settings to quickly configure SV streams that do not require much customization. All phases (A, B, C, and neutral) of a current or voltage terminal must be mapped to an SV stream, and each stream must contain at least one set of voltage or current terminal phase quantities.

SV Publisher Startup

When initially turned on, the SV publisher **ENABLED** LED illuminates as soon as protection functionality is enabled, typically within 10 seconds, but there can be an additional delay of approximately 6 seconds before the initial SV publication is transmitted. Once the SV publisher has begun transmitting SV streams, they can be temporarily disabled for the following conditions:

- **PORT 5** settings are modified
- A new CID file configuration is enabled
- Power is cycled

SV publications stop if the SV publisher is disabled (EN Relay Word bit = False), the **PORT 5** setting EPORT is set to “N”, or the processor fails. SV publications will not resume unless the disabling condition is addressed.

SV Publisher Diagnostics and Testing

Once SV publication is configured and enabled, new commands are available to verify configuration, diagnose and troubleshoot SV communications, and aid in commissioning and testing: **COM SV** and **TEST SV**.

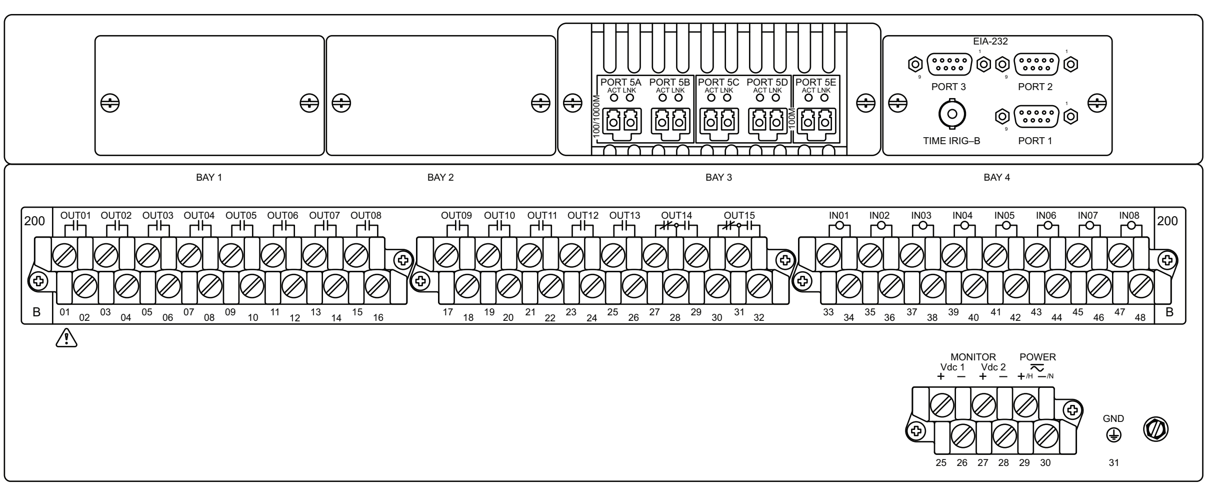
The **COM SV** command displays information about the SV streams that the unit is configured to publish. The data includes the SV destination MAC address, Application ID, message name, data set name, VLAN ID, and priority if the SV publisher is configured via CID file. If the publisher is configured via PORT 5 settings, the data set name remains blank because it is not used in PORT 5 settings, and therefore unavailable. For more information on the **COM SV** command, see *Section 9: ASCII Command Reference* in the product-specific manual.

The **TEST SV** command places the SV publisher into TEST SV mode. In this mode, it replaces the current and voltage data of all SV configured streams with predefined signals for a period of 15 minutes. Also, the SV publisher asserts the test bit in the quality attribute of each current and voltage to identify it as test data. Note that the SV publisher remains in normal mode, and does not enter IEC 61850 Test mode. This does not affect metering or protection functions on the SV publisher. The **COM SV** command indicates whether the SV publisher is in TEST SV mode by displaying the information at the top of the response. Refer to the **TEST SV** command description in *Section 9: ASCII Command Reference* in the product-specific manual for more information.

SV Subscriber

SV Subscriber Functionality

SEL SV subscribers do not have current or voltage input terminals like conventional relays. SV subscribers also do not have internal instrument transformers. Conventional relays are typically ordered from the factory with either 1 A or 5 A nominal CTs, which provide the full range of measured values for the current input terminals. Before or during installation, SEL SV SV subscribers must be configured with the same nominal current value of the merging unit for proper operation. The ASCII command **CFG CTNOM *n***, where *n* is 1 or 5, must be used to configure the SV subscriber with the nominal current value of the subscribed merging unit. Refer to the *Section 9: ASCII Command Reference in the SEL-421-7 Instruction Manual* for more information on the **CFG CTNOM** command.



Five-port Ethernet card ordering option depicted.

Figure 19.25 SEL-421-7 SV Subscriber, 4U Rear Panel

SV Subscribers, such as the SEL-421-7 SV Subscriber, must be configured to subscribe to 9-2LE-compliant SV streams to enable any protection functions. When configured via **PORT 5** settings, all phases (A, B, and C) of a current or voltage terminal must come from an SV stream, and terminals cannot be mapped more than once. When configured using Architect, as many as three streams can be summed and mapped to a single terminal. The SEL-411L-2, SEL-421-7, and SEL-451-6 SV Subscribers can receive as many as four streams when configured through **PORT 5** settings, and the SEL-487E-5 and SEL-487B-2 SV Subscribers can receive as many as seven streams when configured through **PORT 5** settings. All SV subscribers can receive as many as seven streams when configured through use of a CID file.

Once SV subscriptions are configured and are being received, the SV subscriber provides a suite of protection functionality. Refer to the specific product instruction manual for a list of available protection functions.

Note that IEC 61850-9-2LE only covers the publication and subscription of analog data. To communicate digital input and output data or controls, IEC 61850 GOOSE must be configured and optimized on either the process bus or the station bus.

SV Subscriber Configuration

Architect provides support for the configuration of the SEL SV subscriber via a GUI. This interface provides the most flexible configuration of SV publications, including the creation of customized SV data sets. This mechanism is very similar to the configuration of GOOSE publications. For more detailed information, see *IEC 61850 Configuration on page 17.47*.

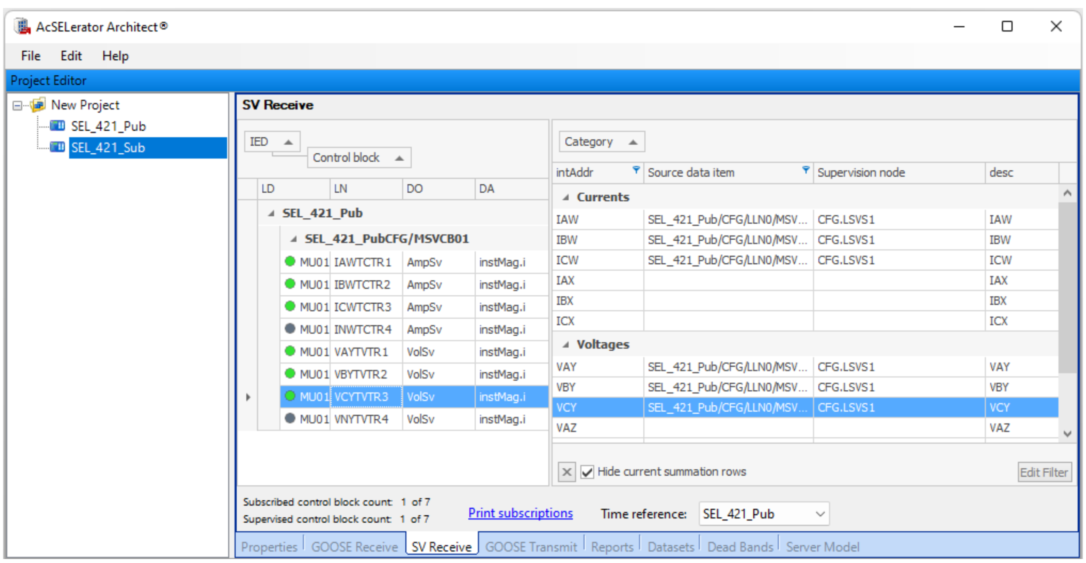


Figure 19.26 Example Architect SV Subscription Configuration

When configuring the SV subscriber, SV subscriptions are accomplished in the same manner as GOOSE subscriptions. Simply drag a published current into an appropriate current slot, or a published voltage into a voltage slot in the SV subscriber **SV Receive** tab. Note that even though a publisher may have a neutral current or voltage value in its publication, the SEL subscriber does not have a neutral current or voltage slot to map it into. Finally, configure the time reference of the subscriber (which selects the device whose smpSynch value all other subscribed messages must match) by selecting the device name from the dropdown list labeled **Time Reference**. See *Subscription Reference Stream on page 17.35* for more information about the reference stream. Architect also allows as many as three received current streams to be summed and mapped to a single relay current terminal.

SV subscriptions may also be configured via PORT 5 settings through QuickSet or an ASCII terminal window. PORT 5 settings can be used to quickly configure SV subscriptions that do not require much customization. All phases (A, B, C) of a current or voltage terminal must be mapped to an SV subscription. Please note that regardless of the configuration method, you cannot map a current or voltage phase value into more than one subscriber slot.

SV Subscriber Startup

When initially turned on, the SV subscriber ENABLED LED illuminates as soon as protection functionality is enabled, which can take as long as 17 seconds but will typically be within 10 seconds. Once the SV subscriber has begun accepting SV streams, SV processing can be temporarily disabled for the following conditions:

- PORT 5 settings are modified
- A new CID file configuration is enabled
- Power is cycled

SV subscriptions are disabled if the SV subscriber is disabled (EN Relay Word bit = False), the PORT 5 setting EPORT is set to “N”, or the processor fails. SV subscriptions do not resume unless the disabling condition is addressed. When SV subscriptions are disabled, so is the primary means of data acquisition for the relay. Take care to recognize when such a condition occurs, generate appropriate warnings or alarms, and resolve any issues.

SV Subscriber Diagnostics and Testing

Once SV subscriptions are configured and enabled, new commands are available to verify configuration, diagnose and troubleshoot SV communications, and aid in commissioning and testing: **COM SV** and **TEST SV**.

The **COM SV** command displays information about the SV streams to which the unit has been configured to subscribe. The data includes the SV destination MAC address, Application ID, message name, data set name, VLAN ID, and priority if the information is available. If information is not available, the field remains blank. The **COM SV** command also provides statistics for individual subscribed SV streams and any error conditions that are currently present or were present during the previous 30 seconds. For more information on the **COM SV** command, see *Section 9: ASCII Command Reference* in the product-specific manual.

See *Table 14.45* for detailed explanations of the information provided in the **COM SV** command.

If any subscribed SV streams are lost, the SV subscriber can still be able to provide some subset of metering and protection functionality, depending on what data are in the missing stream(s). For example, consider an SV subscriber that has two active subscriptions with the first one providing one set of terminal currents and voltages, and the other providing another set of currents. If the second subscription is lost, the SV subscriber can still provide metering data and some degree of overcurrent and LOP protection with the data available from the first stream. Refer to the product-specific instruction manual for available protection features.

NOTE: TEST SV is an SEL proprietary mode. For the IEC 61850-compliant modes, see IEC 61850 Simulation Mode on page 17.38 and IEC 61850 Mode/Behavior on page 17.38.

The **TEST SV** command places the SV subscriber into SEL's TEST SV mode. In this mode, it accepts any subscribed messages with or without the test bit of the quality attribute set. The data that the SV subscriber receives while in TEST SV mode are processed as valid data, so take care to ensure that outputs are blocked to prevent any undesired operations. The **MET** command reflects the received data as actual data, even with the test bit asserted. The **COM SV** command indicates whether the SV subscriber is in TEST SV mode by displaying the information at the top of the response. Refer to the TEST SV command description in *Section 9: ASCII Command Reference* of the product-specific manual for more information.

The health of the incoming SV subscription data channels can be monitored with the SV subscription Relay Word bits SVSALM, SVS*mm*OK, and SVCC, and the SVND*mm* (where *mm* is the SV stream number 01–07) analog quantities. The SVS*mm*OK Relay Word bits are asserted when subscription *mm* is configured and data conforming with the 9-2LE guideline is being actively received from it. The SVCC (SV coupled clocks mode) Relay Word bit is asserted when the SV subscriber is synchronized with the same smpSynch value as the subscription reference stream. The SVND*mm* analog quantities indicate the measured channel delay of each subscription and are compared with the PORT 5 CH_DLY setting to generate an alarm condition as described in the following.

The SVSALM Relay Word bit is a general purpose alarm that will assert for the following conditions:

- The SV subscriber has lost sync with the device providing its reference stream
- One or more subscribed SV streams network delays exceed the CH_DLY setting
- One or more subscribed SV streams are no longer being received (lost)
- One or more subscribed SV streams have a subscription status SVS*mm*OK bit that is not set.

The SV subscriber also provides analog channel status Relay Word bits, which are useful for supervising protection based on the state of SV communications for each current and voltage channel. These bits include *nnn*OK and *nnn*BK bits, where *nnn* is the product-specific current or voltage channel that can potentially be mapped to data from an incoming SV stream, for example, IAW, IBW, ICW, VAY, VBY, VCY, etc. in the SEL-421-7 SV Subscriber. The *nnn*OK bits asserts for all data channels that are mapped to a subscribed SV stream and have data actively being received from it. The *nnn*BK bits are the inverse of the *nnn*OK bits.

See *Section 5: Protection Functions* of the product-specific manual for more information on SV status logic.

APPENDIX A

Manual Versions

The date code at the bottom of each page of this manual reflects the creation or revision date.

Table A.1 lists the firmware versions, revision descriptions, and corresponding instruction manual date codes.

Table A.1 Instruction Manual Revision History (Sheet 1 of 11)

Date Code	Summary of Revisions
20250214	General ➤ Removed references to the product literature DVD and firmware CD. Section 2 ➤ Updated *Table 2.1: SEL Software*. Section 9 ➤ Added note to *ERAQc (Analog Quantities)*. Section 12 ➤ Added note to *Active Setting Group Changes.* ➤ Updated *Table 12.27: Protocol Selection (Five-Port Ethernet Card)*. Section 13 ➤ Updated *Table 13.2: First Execution Bit Operation on Startup* and *Table 13.25: SEL-400 Series SELOGIC Control Equation Programming Summary*. Section 17 ➤ Updated *Introduction to IEC 61850* and *IEC 61850 Operation*. ➤ Added *LPHD*. ➤ Updated *Table 17.28: Logical Device: CFG (Configuration), Table 17.29 Logical Device: CON (Remote Control),* and *Table 17.30: Logical Device: ANN (Annunciation)*. ➤ Added *Potential Client and Automation Application Issues With Edition 2 and 2.1 Upgrades* and *Backward Compatibility With Edition 1 Devices*. Appendix B ➤ Updated *Important Considerations*.
20241211	Section 15 ➤ Updated *Figure 15.2: Example 4U Rear-Panel Layout in Relay With Bay Cards*.
20241022	Section 1 ➤ Updated *Common Features.* Section 7 ➤ Updated *Energy Metering.* Section 10 ➤ Added note to *TEST SV Command* and *Example 10.4: Checking Data Acquisition With the TEST SV Command.* ➤ Updated *Figure 10.8: MET Command Response.* Section 12 ➤ Updated *Table 12.14: IP/Network Configuration* and *Table 12.28: IP/Network Configuration, Table 12.51: Event Reporting.* Section 13 ➤ Updated *Table 13.10: Conditioning Timer Parameters.*

Table A.1 Instruction Manual Revision History (Sheet 2 of 11)

Date Code	Summary of Revisions
	Section 14 ➤ Added *COM HSR*. ➤ Updated *COM PRP*. ➤ Added note to *TEST SV*. ➤ Updated *Table 14.148: SV Output Values During TEST SV Mode*. Section 15 ➤ Updated *Table 15.1: Relay Communications Protocols* and *Table 15.4: Ethernet Protocol Options.* ➤ Updated *Network Connection by Using PRP Operating Mode* and *Redundant Ethernet Ports (Five-Port Ethernet Card).* Section 17 ➤ Updated *Coupled Clocks Mode.* ➤ Added *Freewheeling Mode*. ➤ Updated *Subscription Reference Stream.* ➤ Added note to *SV Data Set*. ➤ Updated *Table 17.27: Logical Device: CON (Remote Control)* and *Table 17.28: Logical Device: ANN (Annunciation)*. Section 19 ➤ Updated *TiDL Binary Input and Output Behavior.*
20240710	Section 2 ➤ Updated *Table 2.1: SEL Software.* Appendix B ➤ Updated *Table B.1: SEL-400 Series Relays Supporting Ethernet Firmware Upgrades*.
20240509	Section 9 ➤ Updated *Figure 9.1: Input Processing* and *Figure 9.2: Input Processing of SEL-400 Series Relays Supporting DSS Technology*. Section 10 ➤ Updated *Table 10.7: Secondary Quantities for the SEL-401, SEL-421-7, and SEL-451-6 SV Publishers*. Section 11 ➤ Updated *Time Source Selection*. ➤ Updated *Figure 11.3: TLOCAL and TGLOBAL Logic*. Section 17 ➤ Updated *SEL SV Publisher* and *IEC 61850 Configuration*. ➤ Updated *Table 17.28: Logical Device: ANN (Annunciation)*. Section 19 ➤ Updated *Table 19.1: SEL DSS Technologies*. ➤ Updated *Architecture* and *SV Publisher Configuration*.
20240229	Section 9 ➤ Updated *Figure 9.1: Input Processing*. Section 11 ➤ Updated *Time Source Selection*. ➤ Updated *Figure 11.3: TLOCAL and TGLOBAL Logic.*
20231219	Section 13 ➤ Updated *Conditioning Timers* and *Sequencing Timers*.
20231207	Section 8 ➤ Updated *Circuit Breaker Inactivity Time Elapsed.* Section 11 ➤ Updated *PTP Over PRP Networks*.

Table A.1 Instruction Manual Revision History (Sheet 3 of 11)

Date Code	Summary of Revisions
	Section 12 ➤ Updated *Table 12.49: SER Chatter Criteria* and *Table 12.51: Event Reporting*. **Section 14** ➤ Updated *Table 14.37: COM PTP Command* and *Table 14.129: STA T SEL-TMU Error Messages and User Action*. **Section 17** ➤ Updated *Reports*. ➤ Updated *Table 17.30: PICS for A-Profile Support* and *Table 17.31: PICS for T-Profile Support*. ➤ Updated *MMS Conformance*. ➤ Updated *Table 17.43: Basic Conformance Statement, Table 17.44: ACSI Models Conformance Statement,* and *Table 17.45: ACSI Service Conformance Statement*. **Section 18** ➤ Updated *Introduction*. **Section 19** ➤ Updated *Table 19.1: SEL DSS Technologies*. ➤ Updated *SV Subscriber Functionality*. **Appendix B** ➤ Updated *A Set PORT 5 Settings MAXACC, EETHFWU, and EPAC* under *Method 4: Using FTP*. ➤ Updated *Time-Domain Link (TiDL) Centrally Controlled Firmware Upgrade (For Relays Supporting T-Protocol)*. **Appendix C** ➤ Added note under *Physical Ports*. ➤ Updated *Table C.1: IP Port Numbers*.
20230830	**Section 3** ➤ Updated *Figure 3.8: Relay Status, Figure 3.9: Relay Status, Figure 3.28: Terminal Screen MET Metering Quantities*, and *Figure 3.36: Sample HIS Command Output in the Terminal*. **Section 10** ➤ Updated *Figure 10.6: Enter TEST SV Mode in the Relay, Figure 10.8: MET Command Response*, and *Figure 10.10: Relay Status From a STATUS A Command on a Terminal*. **Section 11** ➤ Updated *Figure 11.4: Sample TIM Q Command Response*. **Section 14** ➤ Updated *Figure 14.1: Sample COM PRP Command Response, Figure 14.2: Sample COM PTP Command Response, Figure 14.8: Sample ETH Command Response for the Two-Port Ethernet Card, Figure 14.9: Sample ETH Command Response for the Five-Port Ethernet Card, Figure 14.17: Sample TIME Q Command Response With IRIG*, and *Figure 14.18: Sample Time Q Command Response With PTP*. **Section 15** ➤ Updated *Figure 15.11: MET T Command Response* and *Figure 15.17: Example Telnet Session*.
20230317	**Section 1** ➤ Updated *Parallel Redundancy Protocol (PRP)* in *Common Features*. **Section 3** ➤ Updated *Making an Ethernet Telnet Connection*, *Making an Ethernet Web Server (HTTP) Connection*, *Communications Ports Access Levels*, and *Viewing SER Records*. ➤ Updated *Figure 3.8: Relay Status, Figure 3.9: Relay Status, Figure 3.11: Checking Relay Status From the Front-Panel LCD, Figure 3.28: Terminal Screen MET Metering Quantities,* and *Figure 3.36: Sample HIS Command Output in the Terminal*. **Section 4** ➤ Updated *Figure 4.39: Sample Status Warning and Trip EVENT SUMMARY Screens*. **Section 6** ➤ Added note to *Autoreclose Logic Diagrams*.

Table A.1 Instruction Manual Revision History (Sheet 4 of 11)

Date Code	Summary of Revisions
	Section 8 ➤ Added note to *Breaker History*. ➤ Updated *Figure 8.10: Breaker History Report*. Section 9 ➤ Updated *Settings Section of the Event Report*. Section 10 ➤ Updated *Figure 10.6: Enter TEST SV Mode in the Relay* and *Figure 10.8: MET Command Response*. ➤ Updated *Status*. ➤ Updated *Figure 10.11: Example Compressed ASCII Status Message*. ➤ Updated *Table 10.10: Troubleshooting for Relay Self-Test Warnings and Failures*. Section 11 ➤ Updated *PTP Timekeeping* and *Time Quality Indications*. Section 14 ➤ Added *COM PRP*. ➤ Updated *Figure 14.1: Sample COM PRP Command Response, Figure 14.2: Sample COM PTP Command Response,* and *Figure 14.8: Sample ETH Command Response for the Two-Port Ethernet Card*. ➤ Added *Figure 14.9: Sample ETH Command Response for the Five-Port Ethernet Card*. ➤ Updated *Figure 14.13: Sample ID Command Response From Ethernet Card, Figure 14.17: Sample TIME Q Command Response With IRIG, Figure 14.18: Sample Time Q Command Response With PTP*, and *Figure 14.19: Sample VER Command Response*. Section 15 ➤ Updated *Figure 15.9: Example PRP Network Using SEL-400 Series Relays With Five-Port Ethernet Cards, Figure 15.11: MET T Command Response*, and *Figure 15.17: Example Telnet Session*. Section 17 ➤ Updated *Figure 17.6 GOOSE Quality Attributes*. ➤ Updated *Station Bus and Process Bus (Four-Port Ethernet Card)*. ➤ Added *Station Bus and Process Bus (Five-Port Ethernet Card)*. ➤ Updated *IEC 61850 Messaging (Four-Port Ethernet Card)*. ➤ Added *IEC 61850 Messaging (Five-Port Ethernet Card)*. ➤ Updated *IEC 61850 Configuration*. ➤ Updated *Table 17.26: Logical Device: CFG (Configuration)* and *Table 17.28: Logical Device: ANN (Annunciation)*. Section 19 ➤ Updated *IEC 61850-9-2 Sampled Values (SV)*. Appendix B ➤ Added *Important Considerations for the Five-Port Ethernet Card* and *Resolving Communications Card Firmware Mismatch*.
20230112	Section 2 ➤ Updated *Table 2.1: SEL Software*. Section 17 ➤ Updated *Table 17.27: Logical Device: CFG (Configuration), Table 17.28: Logical Device: CON (Remote Control), Table 17.29: Logical Device: ANN (Annunciation), Table 17.45: ACSI Models Conformance Statement,* and *Table 17.46: ACSI Service Conformance Statement*. Appendix B ➤ Updated *Important Considerations, Ethernet Firmware Upgrades, Relay Firmware Upgrade Procedure,* and *Verify IEC 61850 Operation (Optional)*. ➤ Added *Return Relay to Service*. ➤ Removed *TiDL Firmware Upgrade (For TiDL [EtherCAT] Relays Only)*.
20220928	Section 7 ➤ Updated *Table 7.2: Instantaneous Metering Accuracy—Voltages, Currents, and Frequency*.

Table A.1 Instruction Manual Revision History (Sheet 5 of 11)

Date Code	Summary of Revisions
	Section 14 ➤ Added note for the **PULSE** command. Section 18 ➤ Updated to IEC/IEEE 60255-118-1:2018 (IEEE Std C37.118 2011, 2014a).
20220523	Section 7 ➤ Updated *Table 7.2: Instantaneous Metering Accuracy—Voltages, Currents, and Frequency*. Section 9 ➤ Updated *Data Processing*. Section 10 ➤ Updated *Example 10.4: Checking Data Acquisition With the TEST SV Command.* ➤ Updated *Relay Self-Tests*. ➤ Updated *Table 10.9: Troubleshooting Procedures*. Section 11 ➤ Updated *IRIG-B Timekeeping*, *PTP Timekeeping,* and *Time Quality Indications*. Section 12 ➤ Updated *Table 12.10: FTP Configuration*, *Table 12.12: Telnet Configuration*, and *Table 12.25: PTP Settings*. Section 13 ➤ Updated *Table 13.9: Conditioning Timer Quantities* and *Table 13.25: SEL-400 Series SELOGIC Control Equation Programming Summary*. Section 14 ➤ Updated *Table 14.40: Accessible Information for Each SV Publication*. Section 15 ➤ Updated *Table 15.4: Ethernet Card Network Configuration Settings* and *Table 15.7: FTP Settings*. ➤ Updated *Precision Time Protocol (PTP), Channel Monitoring,* and *Settings*. Section 17 ➤ Updated *Local/Remote Control Authority*, *Reports*, *SV Network Delays,* and *Change Mode Via MMS or SELOGIC*. ➤ Updated *Table 17.27: Logical Device: CFG (Configuration)*. Section 19 ➤ Updated *Table 19.1: SEL DSS Technologies*. ➤ Updated *Time-Domain Link (TiDL)* and *IEC 61850-9-2 Sampled Values (SV)*. Appendix B ➤ Updated *Upgrade* and *Resolving Model Mismatch*. Appendix C ➤ Updated *Physical Ports* and *T-Protocol Ports*. Glossary ➤ Updated definitions for *Axion, Digital Secondary System (DSS), SEL-TMU, Selective Protection Disabling,* and *Time-Domain Link (TiDL)*.
20210817	Section 17 ➤ Added *Control Interlocking* under *IEC 61850 Operation*.
20210701	Section 2 ➤ Updated *Table 2.1: SEL Software*. ➤ Updated *SEL Grid Configurator Software*. Section 5 ➤ Updated *Bay Control Screens*. Section 9 ➤ Updated *Triggering Data Captures and Event Reports*.

Table A.1 Instruction Manual Revision History (Sheet 6 of 11)

Date Code	Summary of Revisions
	Section 11 ➤ Updated *Time Triggering the Relay*. Section 16 ➤ Updated *Figure 16.9 Add Binary Inputs to SER Point List*. Section 19 ➤ Updated *Table 19.1: SEL DSS Technologies*. ➤ Updated *Time-Domain Link (TiDL)*. Appendix B ➤ Updated *Table B.1: SEL-400 Series Relays Supporting Ethernet Firmware Upgrades*.
20210514	Section 2 ➤ Updated *Table 2.1: SEL Software*. Section 3 ➤ Added *Communications Ports Access Control*. Section 12 ➤ Updated *Table 12.5: Protocol Selection*. Section 15 ➤ Updated *Figure 15.14: Example Telnet Session*. Section 16 ➤ Updated *Table 16.12: SEL-421 Port 3 Example Settings*. Section 17 ➤ Updated *Table 17.27: Logical Device: CON (Remote Control)*. Section 19 ➤ Updated *Table 19.1: SEL DSS Technologies*. Appendix B ➤ Updated *Table B.1: SEL-400 Series Relays Supporting Ethernet Firmware Upgrades*. ➤ Updated *Set Port 5 Settings MAXACC, EETHFWU, and EPAC* and *Set Port 5 Settings MAXACC, EETHFWU, and EPAC*. Appendix C ➤ Updated *Local Accounts*.
20210326	Section 6 ➤ Updated *Figure 6.11: One Circuit Breaker Single-Pole Cycle State (79CY1), Figure 6.12: One Circuit Breaker Three-Pole Cycle State (79CY3), Figure 6.13: Two Circuit Breakers Single-Pole Cycle State (79CY1) When E79 := Y, Figure 6.14: Two Circuit Breakers Single-Pole Cycle State (79CY1) When E79 := Y1, Figure 6.15: Two Circuit Breakers Three-Pole Cycle State (79CY3) When E79 := Y,* and *Figure 6.16: Two Circuit Breakers Three-Pole Cycle State (79CY3) When E79 := Y1*. Section 19 ➤ Updated *Table 19.1: SEL DSS Technologies*. Appendix B ➤ Updated *Table B.1: SEL-400 Series Relays Supporting Ethernet Firmware Upgrades*.
20210209	Section 2 ➤ Updated *Table 2.1: SEL Software*. Section 14 ➤ Updated *CFG CTNOM*. Section 19 ➤ Updated *Time-Domain Link (TiDL)*. ➤ Updated *Table 19.1: SEL DSS Technologies*. Appendix B ➤ Updated *Table B.1: SEL-400 Series Relays Supporting Ethernet Firmware Upgrades* and *Table B.3: Firmware Upgrade Scenarios and Available Methods*.

Table A.1 Instruction Manual Revision History (Sheet 7 of 11)

Date Code	Summary of Revisions
20201204	Preface ➤ Updated *Manual Overview*. ➤ Updated *Safety Marks*. Section 2 ➤ Added *Table 2.1: SEL Software*. Section 3 ➤ Updated *Figure 3.37: Sample Event Oscillogram*. Section 5 ➤ Updated *Remote Bits*. ➤ Updated *Analog Display*. Section 6 ➤ Updated *Figure 6.19 Voltage Check Element Logic (EISYNC := N)* and *Figure 6.20 Voltage Check Element Logic (EISYNC := Y)*. Section 10 ➤ Updated *Table 10.9: Troubleshooting Procedures*. Section 11 ➤ Added note to *CFG CTNOM*. ➤ Updated *CFG NFREQ* and *STA T*. ➤ Added note to *TEST FM*. Section 12 ➤ Added *TiDL (Port 6)*. Section 14 ➤ Added *STA T* and added information to *VEC*. Section 15 ➤ Added note to *SEL Fast Meter, Fast Operate, Fast SER Messages, and Fast Message Data Access*. Section 17 ➤ Added *IEC 61850 Simulation Mode*. ➤ Updated *GOOSE Performance*. ➤ Updated *Table 17.27 Logical Device: ANN (Annunciation)*. Section 18 ➤ Updated section to include the impact of DSS channel delay. Section 19 ➤ Added *Table 19.1: SEL DSS Technologies*. ➤ Added *TiDL (T-Protocol)*. Appendix B ➤ Added *TiDL Centrally Controlled Firmware Upgrade*. ➤ Updated *Table B.3 Firmware Upgrade Scenarios and Available Methods*. ➤ Updated *Time-Domain Link (TiDL) Centrally Controlled Firmware Upgrade (For Relays Supporting T-Protocol)* and *TiDL Firmware Upgrade (For TiDL [EtherCAT] Relays Only)*. Appendix C ➤ Added *T-Protocol Ports*. ➤ Updated to include references for in-service relay firmware verification. Glossary ➤ Updated for DSS and TiDL.
20201009	Section 17 ➤ Added *Relay Output Contact Behavior Following a Power Cycle*.
20200520	Section 13 ➤ Updated text to include Automation SELOGIC conditioning timers.

Table A.1 Instruction Manual Revision History (Sheet 8 of 11)

Date Code	Summary of Revisions
20200424	**Section 18** ➤ Updated *Control Capabilities*.
20200401	**Section 2** ➤ Added *SEL Grid Configurator Software*. **Section 4** ➤ Updated *Figure 4.15: Enter Password Screen*. **Section 5** ➤ Updated for SEL-400G. **Section 9** ➤ Updated for SEL-400G. ➤ Removed *Table 9.1: Report Settings*. **Section 14** ➤ Updated for SEL-400G. **Section 18** ➤ Updated for SEL-400G.
20200229	**Section 4** ➤ Updated *Figure 4.15: Enter Password Screen*. ➤ Added *Figure 4.16: Invalid Password Screen*. **Section 5** ➤ Updated *Figure 5.1: Disconnect Switch Close Logic* and *Figure 5.2: Disconnect Switch OPEN Logic*. **Section 6** ➤ Updated text and figures to include new EISYNC setting. **Section 10** ➤ Updated *Table 10.9: Troubleshooting Procedures*. **Section 11** ➤ Updated text in *PTP Over PRP Networks*. **Section 12** ➤ Updated notes for *Table 12.25: PTP Settings*. **Section 14** ➤ Updated *Figure 14.7: Sample ETH Command Response*. ➤ Updated *Table 14.43: Warning and Error Codes for SV Subscriptions* and *Table 14.77: Accessible GOOSE IED Information*. ➤ Added *Table 14.78: Warning and Error Codes for GOOSE Subscriptions*. **Section 15** ➤ Added text regarding wildcard usage ➤ Added *Table 15.19: FTP and MMS Wildcard Usage Examples* and *Table 15.20: Ymodem Wildcard Usage Examples*. **Section 16** ➤ Updated *Figure 16.4: Sample Response to SHO D Command*, *Figure 16.5: Sample Custom DNP3 Analog Input Map Settings*, *Figure 16.6: DNP3 Application Network Diagram*, and *Figure 16.8: DNP3 LAN/WAN Application Example Ethernet Network*. **Section 17** ➤ Updated text and figures in *IEC 61850 Configuration*. ➤ Updated *Table 17.20: Logical Device: CFG (Configuration)* and *Table 17.21: Logical Device: ANN (Annunciation)*. **Section 18** ➤ Updated *Equation 18.4*. **Appendix B** ➤ Added text and tables for *Upgrading With Digitally Signed Firmware Upgrade Files*.

Table A.1 Instruction Manual Revision History (Sheet 9 of 11)

Date Code	Summary of Revisions
20191210	Section 14 ➤ Added margin note regarding the SEL-487E in *CLOSE n*.
20181115	Section 15 ➤ Updated margin note in *Precision Time Protocol (PTP)*.
20180910	Section 10 ➤ Added *IEC 61850 Mode/Behavior and Simulation Mode* in *Testing Features and Tools*. ➤ Added *IEC 61850 Testing* in *Test Methods*. ➤ Updated *Table 10.7: Alarm Relay Word Bits*. Section 12 ➤ Updated *Table 12.9: IP Configuration*, *Table 12.11: HTTP Server Configuration*, and *Table 12.12: Telnet Configuration*. ➤ Added *Table 12.14: IEC 61850 Mode/Behavior Configuration*. ➤ Updated *Table 12.15: Sampled Value Receiver Configuration* and *Table 12.16: Sampled Value Transmitter Configuration*. ➤ Added *Table 12.17: Sampled Value Channel Delay Settings*. Section 14 ➤ Updated *COM SV* in *Command Description*. ➤ Updated *Figure 14.3: GOOSE Command Response*. ➤ Updated *STA A*, *TEST DB2*, and *TEST DB2 OFF* in *Command Description*. ➤ Updated *TEST SV* in *Command Description*. Section 17 ➤ Updated *GOOSE Processing* in *IEC 61850.* ➤ Updated *Primary/Secondary Scale Factor* in *Sampled Values*. ➤ Added *Current Summation* in *Sampled Values*. ➤ Updated *Figure 17.6: Independent Bus Mode With PTP Time Synchronization on the Process Bus*, *Figure 17.7: Independent Bus Mode With PTP Time Synchronization on the Station Bus*, and *Figure 17.8: Merged Bus Mode With PTP Time Synchronization*. ➤ Updated *GOOSE and SV Messaging* in *Sampled Values*. ➤ Updated *IEC 61850 Simulation Mode*. ➤ Added *IEC 61850 Mode/Behavior*. ➤ Updated *Table 17.17: IEC 61850 Settings*. ➤ Updated *Figure 17.18: Add ICD to Project Tree*. ➤ Updated *Mode*, *Behavior*, and *Health* under *Logical Nodes*. ➤ Updated *Table 17.18: Logical Device: CFG (Configuration)*. ➤ Updated *Table 17.35: Basic Conformance Statement* and *Table 17.37: ACSI Service Conformance Statement*. Section 18 ➤ Updated *Table 18.26: PMU Recording Settings*. ➤ Updated *CONAM* in *PMU Recording Capabilities*.
20180630	Section 5 ➤ Added *Rack Type Breaker Mosaics* and *Status-Only Disconnects* to *Bay Control Front-Panel Operations*. ➤ Added 89CTL*m* to *Disconnect Logic*. ➤ Added 89CTL01 and 52*m*RACK, 52*m*TEST to *Disconnect Assignments*. ➤ Added *Disconnect Front-Panel Control Enable* to *Disconnect Information*.
20180329	Section 3 ➤ Updated *Reading Oscillograms, Event Reports, and SER.* Section 4 ➤ Added information on setting combinations to *Front-Panel Menus and Screens*. Section 9 ➤ Updated *Oscillography* and *Event Reports, Event Summaries, and Event Histories*. Section 11 ➤ Added information to *Events Directory* in *Virtual File Interface*.

Table A.1 Instruction Manual Revision History (Sheet 10 of 11)

Date Code	Summary of Revisions
20171006	**Section 16** ➤ Updated *Table 16.8: Relay DNP3 Object List*. **Section 17** ➤ Updated for IEC 61850 configuration. **Appendix B** ➤ Updated to help preserve IEC 61850 configuration during a firmware upgrade.
20170714	**Section 2** ➤ Updated *Table 2.2: QuickSet HMI Tree View Functions*. ➤ Updated *Figure 2.20: Retrieving an Event History* and *Figure 2.22: Sample Event Oscillogram*. **Section 9** ➤ Updated *Figure 9.1: Input Processing* to include Sampled Values data acquisition. ➤ Added *Figure 9.2: Input Processing of SEL-400 Series Relays With SV Remote Data Acquisition*. ➤ Updated *Generating Raw Data Oscillograms*, and added *Figure 9.7: An Overcurrent Application Via Remote Data Acquisition* through *Figure 9.9: Filtered Event Reports From SEL-401 and SEL-421*. **Section 10** ➤ Added Sequence of Events Recorder to *Table 10.6: Troubleshooting Procedures*. ➤ Added *Table 10.7: Troubleshooting for Relay Self-Test Warnings and Failures.* **Section 11** ➤ Added *PTP Over PRP Networks*. ➤ Added *Global Time Source vs Local Time Source*. **Section 12** ➤ Added a footnote to *Table 12.5: Protocol Selection* for the EPORT setting. ➤ Added *Table 12.14: SV Receiver Configuration* and *Table 12.15: SV Transmitter Configuration*. ➤ Added a footnote to *Table 12.23: PTP Settings* for setting PTPPRO. ➤ Removed note that PTP is not supported in PRP mode. **Section 14** ➤ Added references to IEC Sampled Values. ➤ Added a note that the CFG NFREQ command is not available in IEC Sampled Values relays. ➤ Updated *Figure 14.2: Sample ETH Command Response*. ➤ Updated *Figure 14.11: Sample VER Command Response*. **Section 15** ➤ Updated *Figure 15.6: Using Internal Ethernet Switch to Add Networked Devices*. **Section 16** ➤ Updated *Table 16.8: Relay DNP Object List*. **Section 17** ➤ Added text for IEC Sampled Values. ➤ Updated *Table 17.3: Relay Logical Devices*. ➤ Added *Sampled Values*. ➤ Added *Simulation Mode*. ➤ Added *Example 17.1: SV Application*. ➤ Updated *Table 17.27: Basic Conformance Statement.* ➤ Updated *Table 17.28: ACSI Models Conformance Statement*. ➤ Updated *Table 17.29: ACSI Service Conformance Statement*. **Section 18** ➤ Added a note regarding Sampled Values-subscribing relays. **Section 19** ➤ Added *IEC 61850-9-2 Sampled Values (SV)*.

Table A.1 Instruction Manual Revision History (Sheet 11 of 11)

Date Code	Summary of Revisions
	Appendix C ➤ Updated text for LNKFAIL and LNKFL2. Glossary ➤ Added terms for IEC Sampled Values, Parallel Redundancy Protocol, and real-time control.
20170428	Section 19 ➤ Updated *Figure 19.4: SEL-2243 Power Coupler*.
20170326	Section 15 ➤ Updated Ethernet Communications for information on MMS inactivity. Appendix B ➤ Updated *TiDL Firmware Upgrade*.
20161215	Preface ➤ Updated to describe the new section, *Section19: Remote Data Acquisition*. Section 1 ➤ Updated to introduce TiDL technology. Section 3 ➤ Added information on TiDL system input and output handling. Section 7 ➤ Added information about leading and lagging power factor Relay Word bits. Section 9 ➤ Described the impact of the ERDIG setting on event report handling. ➤ Added a note about SER storage limitations. Section 10 ➤ Added information on TiDL system commissioning. ➤ Described additional diagnostics. ➤ Described module replacement in Axion nodes for the TiDL system. Section 11 ➤ Improved the description of the TSOK Relay Word bit. Section 12 ➤ Added the ERDIG report setting. Section 14 ➤ Added **CFG CTNOM** and **CFG NFREQ** commands. ➤ Clarified the **TEST DB2 A** operation. Section 15 ➤ Updated SNTP accuracy. Section 18 ➤ Updated typographical information in *Figure 18.5: UDP_S Connection*. Section 19 ➤ Added as a new section. Appendix B ➤ Updated to describe firmware upgrades to the TiDL system. Appendix C ➤ Updated to describe cybersecurity aspects of EtherCAT ports. Glossary ➤ Added terms related to TiDL systems.
20160518	➤ Initial version.

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APPENDIX B

Firmware Upgrade Instructions

These instructions guide you through the process of upgrading the firmware in the device. Note that these instructions are only intended for upgrading firmware from an older revision to a newer revision. Downgrading firmware—going from a newer to an older revision—should not be attempted. It will result in the loss of relay calibration, MAC addresses, and other device configuration information. Contact SEL if you need to downgrade the firmware in a relay.

The firmware upgrade will be either a standard release or a point release. A standard release adds new functionality to the firmware beyond the specifications of the existing version. A point release is reserved for modifying firmware functionality to conform to the specifications of the existing version.

A standard release is identified by a change in the R-number of the device firmware identification (FID) string.

Existing firmware:

FID=SEL-411L-**R100**-V0-Z001001-Dxxxxxxxx, or

FID=SEL-411L-1-**R100**-V0-Z001001-Dxxxxxxxx

Standard release firmware:

FID=SEL-411L-**R101**-V0-Z001001-Dxxxxxxxx, or

FID=SEL-411L-1-**R101**-V0-Z001001-Dxxxxxxxx

A point release is identified by a change in the V-number of the device FID string.

Existing firmware:

FID=SEL-411L-R100-**V0**-Z001001-Dxxxxxxxx, or

FID=SEL-411L-1-R100-**V0**-Z001001-Dxxxxxxxx

Point release firmware:

FID=SEL-411L-R100-**V1**-Z001001-Dxxxxxxxx, or

FID=SEL-411L-1-R100-**V1**-Z001001-Dxxxxxxxx

Required Equipment

You will need the following items before beginning the firmware upgrade process:

- Personal computer (PC)
- Terminal emulation software that supports Xmodem/CRC or Ymodem protocol (if upgrading over a serial port connection)
- SEL-C234A cable, SEL-C662 USB to EIA-232, or equivalent (if upgrading over a serial port connection).
- A relay with Telnet-enabled Ethernet ports, a Telnet connection, and a Telnet user interface that supports Ymodem file transfer (if performing an upgrade over Ethernet).
- A relay with HTTP-enabled Ethernet ports and an HTTP Ethernet connection (if upgrading via a web browser). This is the most user-friendly method to complete an upgrade.
- A relay with FTP-enabled Ethernet ports and an FTP Ethernet connection (if upgrading over FTP) and an FTP user interface that supports FTP file transfer.
- .z19, .s19, or .zds firmware upgrade file (.z19 requires SELBOOT R205 or a newer R2*xx* SELBOOT version; .zds requires SELBOOT R300 or newer)
- SELBOOT firmware upgrade file (if necessary; based on the existing SELBOOT revision of the relay)
- Relay Firmware Upgrade Instructions

Optional Equipment

These items help you manage relay settings and understand procedures in the relay upgrade process:

- ACSELERATOR QuickSet SEL-5030 Software (also contains a firmware upload tool that helps to automate this process over a serial-port connection)
- ACSELERATOR Architect SEL-5032 Software (manages IEC 61850 GOOSE, Manufacturing Message Specification [MMS], and SV Configured IED Description [CID] files)
- SEL-5037 Grid Configurator Software (for relays supported by SEL Grid Configurator)
- Appropriate SEL-400 series relay manual

Important Considerations

If upgrading an SEL-451-5, SEL-421-4, or SEL-421-5 from firmware revision R309 or earlier to firmware revision R311 and later, upgrade to R310 before upgrading to R311 and later. Similarly, if upgrading an SEL-487V-0 or SEL-487V-1 from firmware revision R107 or earlier to firmware revision R109 and later, upgrade to R108 before upgrading to R109 and later. Failure to do so will result in the reset of relay settings back to factory defaults.

In some unusual cases, such as loss of relay power during the firmware file transfer process, it is possible for data, including relay settings and the IEC 61850 CID file to be lost. Before beginning the firmware upgrade process, save relay settings (including the IEC 61850 CID file, if applicable), as indicated in *C Save Settings and Other Data on page B.12*.

Important Considerations for the Five-Port Ethernet Card

If installing a five-port Ethernet card for the first time, perform the conversion in this order:

Step 1. Install the required boot firmware (SELBOOT). Refer to Appendix A of the relay-specific instruction manual for compatible SELBOOT versions.

Step 2. Install the required relay firmware. Refer to Appendix A of the relay-specific instruction manual for compatible firmware versions.

Step 3. Follow the *Removing and Installing SEL-400 Series Relay Ethernet Cards* instruction sheet included with your conversion kit.

Upgrading With Digitally Signed Firmware Upgrade Files

NOTE: R2xx SELBOOT versions only support serial-port firmware upgrades with .s19 or .z19 firmware upgrade files. R3xx SELBOOT versions only support .zds digitally signed firmware upgrade files over a serial or Ethernet connection.

The firmware versions identified in *Table B.1* support .zds firmware upgrade files, which can be used to upgrade the relay over a serial or Ethernet connection. The .zds firmware upgrade files can only be sent to relays running SELBOOT R300 or newer.

To prepare relays to accept digitally signed Ethernet firmware upgrades, perform the following:

1. Upgrade SELBOOT to R300 or newer over a serial connection with a .s19 SELBOOT upgrade file.
2. Upgrade relay firmware to a relay version identified in *Table B.1* over a serial connection with a .zds firmware upgrade file.

Once the relay has a firmware version identified in *Table B.1* installed, you can upgrade the relay over an Ethernet connection to any new firmware version above the initial firmware version outlined in the table.

NOTE: Relay firmware versions identified in Table B.1 require SELBOOT R300 or newer because only .zds firmware upgrade files are provided. Firmware .s19 and .z19 upgrade files are not created for these firmware versions.

Table B.1 SEL-400 Series Relays Supporting Ethernet Firmware Upgrades

SEL Relay	Firmware Versions Supporting Ethernet Firmware Upgrades
SEL-400G	All released firmware versions
SEL-401	R407 and newer
SEL-411L-A, -B	All released firmware versions
SEL-411L-0, -1	R126 and newer
SEL-411L-2	All released firmware versions
SEL-421-4, -5	R327 and newer
SEL-421-7	R407 and newer
SEL-451-A	All released firmware versions
SEL-451-5	R324 and newer
SEL-451-6	R401 and newer
SEL-487B-1	R315 and newer
SEL-487B-2	R401 and newer
SEL-487E-3, -4	R318 and newer
SEL-487E-5	R401 and newer

Digitally signed firmware-upgrade files are compressed to reduce file-transfer times and are digitally signed by SEL through use of a secure hash algorithm. The signature ensures that the file has been provided by SEL and that the contents have not been altered. Once uploaded to the relay, the signature of the firmware file is verified with a public key that is stored on the relay. If the relay cannot verify the signature, the file is rejected.

The name of the digitally signed firmware file is of the form r*nnn*-v*y*4*xx*.zds or s*nnn*-v*y*4*xx*, where r*nnn* is the standard-release relay firmware identifier, s*nnn* is the standard-release SELBOOT firmware identifier, v*y* is the point-release identifier, and 4*xx* identifies the SEL-400 series relay. Differentiation between relay model variants is handled by the standard-release firmware identifier. See the list (at the beginning of this section) of firmware versions that support digitally signed firmware upgrades to find the standard-release firmware variants of the same relay model.

Ethernet Firmware Upgrades

NOTE: The relay pulses the SALARM bit and writes an entry to the relay SER log whenever a firmware upgrade is attempted over Ethernet. Monitoring this bit and reviewing the SER log can help identify possible unauthorized firmware upgrade attempts.

For relays that support firmware upgrades over Ethernet, you can send the .zds firmware upgrade files via FTP or HTTP protocols to a relay running SELBOOT version R300 or newer and a relay firmware version identified in *Table B.1*. FTP and HTTP are plaintext protocols and do not inherently support message encryption (of relay passwords, etc.). Because of this, SEL strongly recommends using between the relay and your network a security gateway that provides encrypted communications along with SEL SDN technology to harden your network cybersecurity.

Relay Firmware Upgrade Procedure

NOTE: The .z19 files are compressed versions of the .s19 files. These will load into the relay much faster than the .s19 files, but you must have relay SELBOOT version R205 or a newer R2xx SELBOOT version to use these files. Both the .z19 and .s19 files can only be used to upgrade relay firmware over a serial-port connection and can only be sent to a relay with SELBOOT that does not support digitally signed firmware upgrades.

NOTE: The .zds files are digitally signed upgrade files. These upgrade files provide the fastest way to upgrade firmware on a relay, but the relay must be running SELBOOT version R300 or newer to use these files.

NOTE: When you are upgrading relay firmware over a serial connection, SEL strongly recommends that you upgrade firmware at the location of the relay and with a direct connection from the PC to one of the relay serial ports. Do not load firmware from a remote location; problems can arise that you will not be able to address from a distance. When upgrading at the substation, do not attempt to load the firmware into the relay through an SEL communications processor.

The upgrade kit you received contains the firmware needed to upgrade the SEL-400 series relays. The kit may also contain firmware needed to upgrade the SELBOOT program. See *Table B.2* to identify which firmware files you received in the upgrade kit.

Table B.2 Firmware Upgrade Files

Product	File Name[a]	File Type
SEL-400 series relays SELBOOT	s*nnn*4*xx*.s19, s*nnn*-v*y*4*xx*.s19, or s3*nn*-v*y*4*xx*.zds	SEL-400 series SELBOOT firmware
SEL-400 series relays (prior to firmware releases identified in *Table B.1*)	r*nnn*4*xx*.s19 or r*nnn*4*xx*.z19	SEL-400 series relay firmware
SEL-400 series relays after SEL started offering point releases (prior to firmware releases identified in *Table B.1*)	r*nnn*-v*y*4*xx*.s19 or r*nnn*-v*y*4*xx*.z19	SEL-400 series relay firmware
SEL-400 series relays with SELBOOT versions supporting .zds upgrade files	r*nnn*-v*y*4*xx*.zds	SEL-400 series relay firmware digitally signed upgrade file

[a] nnn in the file name will always represent the device firmware revision number.
y represents that point release version number.
4xx represents the product name.

The firmware upgrade can be performed in one of four ways. Methods 1 and 2 are provided for upgrading over a serial connection. Methods 3 and 4 are provided for upgrading over an Ethernet connection. When upgrading over a serial connection, you can upgrade using .s19, .z19, or .zds files depending on the SELBOOT firmware the relay is running. When upgrading over an Ethernet connection, you can only upgrade using a .zds file and the relay must currently be running a SELBOOT firmware version that supports digitally signed upgrade files and a relay firmware version that supports Ethernet firmware upgrades (see *Table B.1*).

- Method 1: Use the Firmware Loader provided within QuickSet. The Firmware Loader automates the firmware upgrade process and is the preferred method. The Firmware Loader can be used to upgrade only relay firmware (r*nnn*4*xx* files or r*nnn*-vy4*xx*). If upgrading SELBOOT (s*nnn*4*xx* or s*nnn*-vy4*xx*) firmware is required, use Method 2.
- Method 2: Connect to the relay in a terminal session and upgrade the firmware by using the steps documented in *Method 2: Using a Terminal Emulator on page B.11*.
- Method 3: Connect to the relay over an Ethernet web browser and use the steps documented in *Method 3: Using a Web Browser on page B.17*.
- Method 4: Connect to the relay over an Ethernet FTP connection and use the steps documented in *Method 4: Using FTP on page B.20*.

NOTE: Relays supported only by SEL Grid Configurator (e.g., TiDL relays, etc.) should only use Methods 2–4.

Determine Which Upgrade Method to Use

Table B.3 helps you determine which firmware upgrade method you would like to use based on your upgrade scenario. From the links provided in *Table B.3*, you can use the link to easily move ahead to the method of your choosing. For help in identifying which scenario you fall under, see *Identify Firmware Versions on the Relay on page B.6*.

Table B.3 Firmware Upgrade Scenarios and Available Methods (Sheet 1 of 2)

Upgrade Scenario	Available Methods
Upgrading SELBOOT firmware from an R2*xx* SELBOOT version to a newer R2*xx* SELBOOT version	Upgrade with a .s19 SELBOOT upgrade file via *Method 2: Using a Terminal Emulator on page B.11*
Upgrading SELBOOT firmware from an R2*xx* SELBOOT version to an R3*xx* SELBOOT version	Upgrade with a .s19 SELBOOT upgrade file via *Method 2: Using a Terminal Emulator on page B.11*
Upgrading SELBOOT firmware from an R3*xx* SELBOOT version to a newer R3*xx* SELBOOT version on a relay running a relay firmware version prior to one identified in *Table B.1*.	Upgrade with a .zds SELBOOT upgrade file via *Method 2: Using a Terminal Emulator on page B.11*
Upgrading SELBOOT firmware from an R3*xx* SELBOOT version to a newer R3*xx* SELBOOT version on a relay running relay firmware identified in *Table B.1*.	Upgrade with a .zds SELBOOT upgrade file via one of the following: *Method 2: Using a Terminal Emulator on page B.11* *Method 3: Using a Web Browser on page B.17* (Using a web browser is the most user-friendly option) *Method 4: Using FTP on page B.20*

Table B.3 Firmware Upgrade Scenarios and Available Methods (Sheet 2 of 2)

Upgrade Scenario	Available Methods
Upgrading relay firmware on a relay running any R2*xx* SELBOOT version	Upgrade with a .s19 or .z19 relay firmware upgrade file via one of the following: *Method 1: Using QuickSet Firmware Loader on page B.6* *Method 2: Using a Terminal Emulator on page B.11*
Upgrading relay firmware on a relay currently running an R3*xx* SELBOOT version and a relay firmware version prior to a version identified in *Table B.1*.	Upgrade with a .zds SELBOOT upgrade file via one of the following: *Method 1: Using QuickSet Firmware Loader on page B.6* *Method 2: Using a Terminal Emulator on page B.11*
Upgrading relay firmware on a relay currently running an R3*xx* SELBOOT version and a relay firmware version identified in *Table B.1*.	Upgrade with a .zds relay firmware upgrade file via one of the following: *Method 1: Using QuickSet Firmware Loader on page B.6* *Method 2: Using a Terminal Emulator on page B.11* *Method 3: Using a Web Browser on page B.17* (Using a web browser is the most user-friendly option) *Method 4: Using FTP on page B.20*

NOTE: Relays supported only by SEL Grid Configurator (e.g., TiDL relays, etc.) should only use Methods 2–4.

Identify Firmware Versions on the Relay

To determine the SELBOOT and relay firmware versions the relay is currently running, do the following:

Step 1. Establish a serial or Telnet terminal session between the relay and a personal computer.

Step 2. In the relay terminal line, type **ID <Enter>**.

The relay responds with the following:

```
"FID=SEL-4xx-x-Rxxx-V0-Zxxxxxx-Dxxxxxxxx","xxxx"
"BFID=SLBT-4XX-Rxxx-V0-Zxxxxxx-Dxxxxxxx","xxxxx"
"CID=xxx","xxxx"
"DEVID=xxxxxxx","xxxx"
"DEVCODE=xx","xxxx"
"PARTNO=xxxxxxxxxxxxxxx","xxxx"
"SERIALNO=xxxxxxxxxx","xxxx"
"CONFIG=xxxxxxxx","xxxx"
"SPECIAL=xxxxx","xxxx"
```

Step 3. Locate the relay firmware identification (FID) string and the Boot firmware identification (BFID) string.

Step 4. See *Table B.3* for upgrade methods available based on the firmware versions currently operating on the relay.

Method 1: Using QuickSet Firmware Loader

To use the QuickSet Firmware Loader, you must have QuickSet. See *Section 2: PC Software* for instructions on how to obtain and install the software. Once the software is installed, perform the firmware upgrade as follows.

A Obtain Firmware File

NOTE: The Firmware Loader can be used to load only relay firmware (rnnn4xx or rnnn-vy4xx) on relays supported by QuickSet. This method cannot be used to upgrade firmware on relays only supported by SEL Grid Configurator.

Contact SEL customer service for the firmware file. The file name is of the form r*nnn*4*xx* or r*nnn*-v*y*4*xx*, where r*nnn* is the firmware revision number, v*y* indicates the point release number, and 4*xx* indicates the relay type. The firmware file name extensions are .s19, .z19, and .zds. Copy the firmware file to an easily accessible location on the PC.

Firmware is designed to be used with specific relays. A list of relay serial numbers is provided as part of the firmware upgrade package. The firmware provided is for use with the listed relays only. Attempts to upgrade relays not listed might not be successful and can result in relay failure.

B Remove Relay From Service

Step 1. If the relay is in use, follow your company practices for removing a relay from service. Typically, these practices include disabling input and output control functions.

Step 2. Apply power to the relay.

Step 3. Connect a communications cable and determine the port speed.

If using the EIA-232 front port to upgrade firmware, determine the port speed as follows:

a. From the relay front panel, press the **ENT** pushbutton.
b. Use the arrow pushbuttons to navigate to SET/SHOW.
c. Press the **ENT** pushbutton.
d. Use the arrow pushbuttons to navigate to PORT.
e. Press the **ENT** pushbutton.
f. Use the arrow pushbuttons to navigate to the relay serial port you plan to use (usually the front port, **PORT F**).
g. Press the **ENT** pushbutton.
h. Use the arrow pushbuttons to navigate to **Communication Settings**.
i. Press the **ENT** pushbutton to view the selected port communications settings. Write down the value for each setting.
j. Once the port settings have been recorded, press the **ESC** pushbutton four times to return to the MAIN MENU.
k. Connect an SEL-C234A EIA-232 serial cable, SEL-C662 USB to EIA-232 converter, or equivalent communications cable to the relay serial port and to the PC.

C Establish Communications With the Relay

NOTE: Once serial port communication is established, it is recommended to set the SELBOOT Max Baud setting to the highest possible port speed available (typically 115200 bps). This will reduce the time needed to read settings and events from the relay.

Use the **Communications > Parameters** menu of QuickSet to establish a connection using the communications settings determined in *Step 3* under *B Remove Relay From Service on page B.7*. See *Section 2: PC Software* for additional information.

D Save Settings and Other Data

It is possible for data to be lost during the firmware upgrade process. Follow the steps in this section carefully to ensure that important data are saved.

Step 1. For SEL-400 series relays with optional IEC 61850 protocol configured, follow the steps in section *Verify IEC 61850 Operation (Optional) on page B.22* to save the CID file and send it back to the relay after the firmware upgrade.

Step 2. Select **Tools > Firmware Loader** and follow the onscreen prompts.

Step 3. In the Step 1 of 4 window of the Firmware Loader (as shown in *Figure B.1*), select the ellipsis button and browse to the location of the firmware file. Select the file and select **Open**.

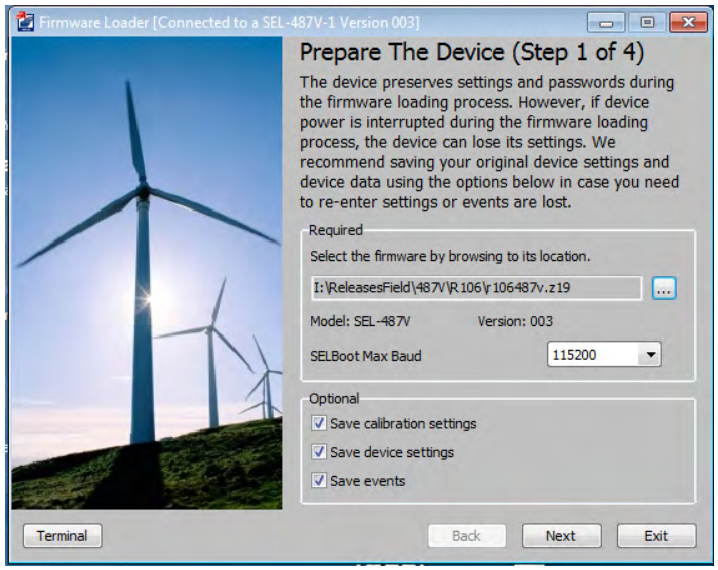

Figure B.1 Prepare the Device (Step 1 of 4)

Step 4. Select the **Save calibration settings** check box in the Step 1 of 4 window of the Firmware Loader. These factory settings are required for proper operation of the relay and must be reentered in the unlikely event they are erased during the firmware upgrade process. The Firmware Loader saves the settings in a text file on the PC.

Step 5. Select the **Save device settings** check box if you do not have a copy of the relay settings. It is possible for relay settings to be lost during the upgrade process.

Step 6. Select the **Save events** check box if there are any event reports that have not been previously saved. The event history is cleared during the upgrade process.

Step 7. Select **Next**.

The Firmware Loader reads the calibration settings and saves them in a text file on the PC. Make note of the file name and the location.

If **Save device settings** was selected, the Firmware Loader reads all of the settings from the relay. The software may ask if you want to merge the settings read from the relay with existing design templates on the PC. Select **No, do not merge settings with Design Template**. The Firmware Loader will suggest a name for the settings, but the suggested name can be modified as desired.

If **Save events** was selected, the **Event History** window will open to allow the events to be saved. See *Section 2: PC Software* for more information.

Step 8. If you use the Breaker Wear Monitor, select the **Terminal** button in the lower left portion of the Firmware Loader to open the terminal window. From the Access Level 1 prompt, issue the **BRE** command and record the internal and external trip counters, internal and external trip currents for each phase, and breaker wear percentages for each phase.

Step 9. Enable Terminal Logging capture (see *Section 2: PC Software*) and issue the following commands to save stored data. It is possible for these data to be lost during the firmware upgrade process.

a. **MET E**—accumulated energy metering

b. **MET D**—demand and peak demand

c. **MET M**—maximum/minimum metering

d. **COMM A** and **COMM B**—MIRRORED BITS communications logs

e. **PROFILE**—Load Profile

f. **SER**—Sequential Events Records

E Start SELBOOT

In the Step 2 of 4 window of the Firmware Loader, select **Next** to disable the relay and enter SELBOOT (see *Figure B.2*).

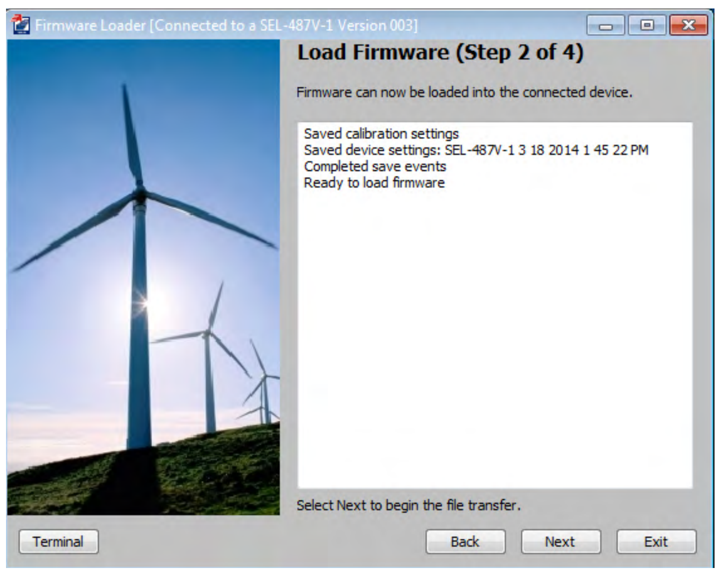

Figure B.2 Load Firmware (Step 2 of 4)

F Maximize Port Data Rate

This step is performed automatically by the software.

G Upload New Relay Firmware

This step is performed automatically by the software. The software will erase the existing firmware and start the file transfer to upload the new firmware. Upload progress will be shown in the **Transfer Status** window. The entire firmware upload process can take longer than 10 minutes to complete.

When the firmware upload is complete, the relay will restart. The Firmware Loader automatically reestablishes communications and issues an **STA** command to the relay.

In cases where the relay does not restart within two minutes of the firmware upload completion (as indicated by the PC application), and no error messages appear on the relay HMI, turn the relay off and back on again. The firmware loader application should then resume. Answer **Yes** if the Firmware Loader prompts you to continue.

H Verify Relay Self-Tests

The Step 3 of 4 window of the Firmware Loader will indicate that it is checking the device status and when the check is complete (see *Figure B.3*).

The software will notify you if any problems are detected. You can view the relay status by opening the terminal using the Terminal button in the lower left portion of the Firmware Loader. If status failures are shown, open the terminal and see *Troubleshooting on page B.24*.

Select **Next** to go to the completion step.

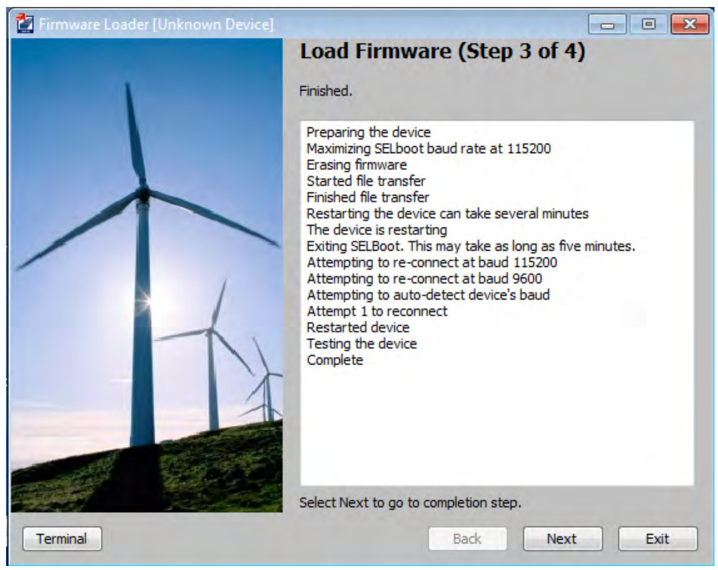

Figure B.3 Load Firmware (Step 3 of 4)

I Verify Relay Settings

If there are no failures, the relay will enable. In the Step 4 of 4 window (see *Figure B.4*), the Firmware Loader will give you the option to compare the device settings. If any differences are found, the software will provide the opportunity to restore the settings.

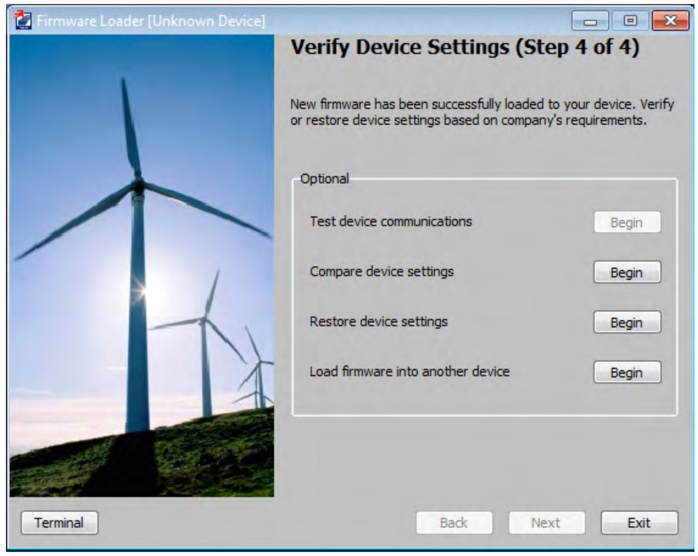

Figure B.4 Verify Device Settings (Step 4 of 4)

Method 2: Using a Terminal Emulator

These instructions assume you have a working knowledge of your PC terminal emulation software. In particular, you must be able to modify the serial communications parameters (data speed, data bits, parity, and similar parameters), disable any hardware or software flow control in the computer terminal emulation software, select a transfer protocol (1K Xmodem, for example), and transfer files (send and receive binary files).

The programs (firmware) that run in the SEL-400 series relays reside in Flash memory. To load new firmware versions, follow these instructions. The SEL-400 series relays have two programs that you may need to upgrade: the regular, or "executable" program and the SELBOOT program.

A Obtain Firmware File

Contact SEL customer service for the firmware file. For relay firmware, the file name is of the form r*nnn*4*xx* or r*nnn*-v*y*4*xx*, where r*nnn* is the firmware revision number, v*y* indicates the point release number, and 4*xx* indicates the relay type. For SELBOOT firmware, the file name is of the form s*nnn*4xx or s*nnn*-v*y*4xx, where s*nnn* is the SELBOOT revision number and 4xx indicates that the SELBOOT version is for SEL-400 series relays. The firmware file name extensions are .s19, .z19, and .zds. Copy the firmware file to an easily accessible location on the PC.

Firmware is designed to be used with specific relays. A list of relay serial numbers is provided as part of the firmware upgrade package. The firmware provided is for use with the listed relays only. Attempts to upgrade relays not listed might not be successful and can result in relay failure.

B Prepare the Relay

If the relay is in service, follow your company practices for removing a relay from service. Typically, these practices include disabling input and output control functions.

C Save Settings and Other Data

It is possible for data to be lost during the firmware upgrade process. Follow the steps in this section carefully to ensure that important data are saved.

Enter Access Level 2

NOTE: Once serial port communication is established, it is recommended to set the port SPEED setting to the highest possible port speed available (typically 57600 bps in Access Level 2). This will reduce the time needed to read settings and events from the relay.

Step 1. Using the communications terminal, at Access Level 0, type **ACC <Enter>**.

Step 2. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 3. Type **2AC <Enter>**, and then type the correct password to go to Access Level 2.

You will see the Access Level 2 =>> prompt.

For more information, see *Making an EIA-232 Serial Port Connection on page 3.4*.

Backup Relay Settings

The relay preserves the settings and passwords during the firmware upgrade process. However, if relay power is interrupted during the firmware upgrade process, the relay can lose the settings. Make a copy of the original relay settings in case you need to reenter settings.

NOTE: In addition to all of the normal settings classes, log in to Access Level C and save the SET_CM.TXT file.

Use one of the following methods to backup relay settings.

- ➤ If you have not already saved copies of the relay settings, use QuickSet to read and save the relay settings.

  See *Create and Manage Relay Settings on page 2.21*.

- ➤ Alternatively, you can use the terminal to download all the relay settings.

  See the **FILE READ** command under *FILE on page 14.37*.

  For file retrieval procedures see *Reading Oscillograms, Event Reports, and SER on page 3.46*.

- ➤ If you have IEC 61850 configurations and you have not already saved copies of the CID file, use Architect to read and save the CID file. See *Verify IEC 61850 Operation (Optional) on page B.22* for details.

D Start SELBOOT

Step 1. Establish/confirm binary transfer terminal communication.

Use a terminal program that supports 1K Xmodem transfer protocol to communicate with the relay.

Step 2. Prepare to control the relay at Access Level 2. If the relay is not already at Access Level 2, use the procedure in *Enter Access Level 2 on page B.12*.

Step 3. Start the relay SELBOOT program.

a. Type **L_D <Enter>**.

If running a R2*xx* SELBOOT version, the relay responds with the following message:

`Disable relay to send or receive firmware (Y/N)?`

If running a R3*xx* SELBOOT version, the relay responds with the following message:

`Disable relay and transition to SELBoot (Y/N)?`

b. Type **Y <Enter>**.

The relay responds with the following message:

`Are you sure (Y/N)?`

c. Type **Y <Enter>**.

The relay responds with the following message:

`Relay Disabled`

Step 4. Wait for the SELBOOT program to load.

The front-panel LCD screen displays the SELBOOT R*yyy* firmware number (e.g., `SELBOOT R209`). R*yyy* is the SELBOOT revision number and is a different revision number from the relay firmware revision number. The LCD also displays the present relay firmware (e.g., `SEL-451-5-R324`), and `INITIALIZING`.

When finished loading the SELBOOT program, the relay responds to the terminal with the SELBOOT !> prompt; the LCD shows the SELBOOT and relay firmware revision numbers.

Step 5. Press **<Enter>** to confirm that the relay is in SELBOOT; you will see another SELBOOT !> prompt.

Establish a High-Speed Serial Connection

Step 1. At the SELBOOT prompt, type **BAU 115200 <Enter>** (see *Figure B.7*).

Step 2. Set your terminal program for a data speed of 115200 bps.

Step 3. Press **<Enter>** to check for the SELBOOT !> prompt indicating that serial communication at 115200 bps is successful.

E Upload New SELBOOT Firmware to the Relay

NOTE: Loading the incorrect SELBOOT firmware to the relay may cause the relay to malfunction, requiring factory repair.

NOTE: Do not cycle power to the relay during the SELBOOT firmware upgrade process. Doing so may cause the relay to malfunction, requiring factory repair.

Upgrading SELBOOT firmware in SEL-400 series relays is typically not required as part of a normal relay firmware upgrade process. However, core functions of the relay are occasionally enhanced, and the SELBOOT firmware must be upgraded to enable the enhanced functions. If a SELBOOT upgrade for the relay is not indicated in your upgrade kit, skip this step and continue on to *F Upload New Relay Firmware on page B.14*. See *Table B.2* for file names.

To begin the relay SELBOOT upgrade, start at the SELBOOT !> prompt.

Step 1. Type **REC BOOT** command at the SELBOOT prompt, and answer **Y** when prompted to erase the existing SELBOOT firmware.

If the relay is running a R2*xx* SELBOOT version, the relay responds with:

```
!>REC BOOT <Enter>
Caution! -  This command erases the SELboot firmware.
Are you sure you want to erase the existing firmware? (Y/N)
```

If the relay is running a R3*xx* SELBOOT version, the relay responds with:

```
!>REC BOOT <Enter>
Caution! This command erases the SELBoot firmware.
Do not interrupt power during SELboot upload
or the device may require factory reprogramming.

Are you sure you want to erase the existing firmware (Y/N)?
```

Step 2. The relay will prompt you to begin the file transfer. Press any key to begin the file transfer to the relay.

Step 3. Select Xmodem as your file transfer method, then point the sending software tool to the relay SELBOOT file (s*nnn*4xx.s19, s*nnn*-v*y*4xx.s19 or s3*nn*-v*y*4xx.zds) that is to be uploaded to the relay.

Upon successful negotiation of the new SELBOOT firmware file, the old SELBOOT software will be erased, and the new SELBOOT firmware will be written to the Flash memory of the relay. The relay will then automatically restart using the new SELBOOT firmware.

```
Erasing old SELboot

Writing new SELboot to flash

Press any key to begin transfer, then start transfer at the PCC
Restarting SELboot
```

Step 4. Once the relay has restarted, revert back to *Table B.3* and determine your relay firmware upgrade method.

F Upload New Relay Firmware

If you are only upgrading SELBOOT, you can skip this step and continue to *G Return Serial Data Speed to Nominal Operating Speed and Exit SELBOOT on page B.15*.

Step 1. From the SELBOOT !> prompt, type **REC <Enter>**.

If running a R2*xx* SELBOOT version, the relay responds with the prompt shown in *Figure B.5*.

```
!>BAU 115200 <Enter>
!><Enter>

!>REC <Enter>
Caution! - This command erases the device firmware.
If you erase the firmware, new firmware must be loaded into the device
before it can be put back into service.
Are you sure you want to erase the existing firmware? (Y/N) Y <Enter>
Erasing

Erase successful
Press any key to begin transfer, then start transfer at the PCCC <Enter>
```

Figure B.5 Transferring New Firmware

If running a R3*xx* SELBOOT version, the relay responds with the prompt shown in *Figure B.6*.

```
!>REC <Enter>
Caution! This command erases the firmware.
If you erase the firmware then new firmware
must be loaded before returning the IED to service.

Are you sure you want to erase the existing firmware (Y/N)?
Press any key to begin transfer and then start transfer at the terminal.
```

Figure B.6 Transferring New Firmware

Step 2. When prompted with `Are you sure you want to erase the existing firmware? (Y/N)`, type **Y <Enter>**.

The relay responds, `Erasing`, and erases the existing firmware. The front-panel LCD shows `ERASING MEMORY`.

When finished erasing, the relay responds, `Erase successful`, and prompts you to press any key to begin transferring the new firmware. The front-panel LCD shows only the SELBOOT program revision number.

Step 3. Press **<Enter>** to begin uploading the new firmware.

Step 4. Start the **Transfer** or **Send** process in your terminal emulation program.

Use 1K Xmodem for fast transfer of the new firmware to the relay.

Step 5. Point the terminal program to the location of the new firmware file (the file that ends in .s19, .z19, and .zds).

NOTE: The relay displays one or more "C" characters while waiting for your PC terminal emulation program to send the new firmware. If you do not start the transfer quickly (within about 18 seconds), the relay times out and responds `Remote system is not responding`. If this happens, begin again at F Upload New Relay Firmware on page B.14.

Step 6. Begin the file transfer.

The typical transfer time at 115200 bps with 1K Xmodem is 10 to 20 minutes. The LCD screen shows `SELBOOT Ryyy LOADING CODE` while the relay loads the new firmware.

Step 7. Wait for firmware load completion.

If the relay responds with the message `Transfer failed — Model mismatch`, please refer to *Troubleshooting on page B.24*.

When finished loading the new firmware, the relay responds, `Transfer completed successfully` and displays the SELBOOT !> prompt. The LCD screen displays `SELBOOT Ryyy SEL-4xx-Rnnn`, where *yyy* is the SELBOOT revision number, 4*xx* is the particular model of the SEL-400 series relay being upgraded, and *nnn* is the firmware revision number of the relay, e.g., R100 SEL-421-R105.

G Return Serial Data Speed to Nominal Operating Speed and Exit SELBOOT

Step 1. Type **<Enter>** to confirm relay communication.

The terminal displays the SELBOOT !> prompt.

Step 2. Type **BAU 9600 <Enter>** to reduce the data speed to your nominal serial communications speed (9600 bps in this example).

Step 3. Set your terminal emulation program to match the nominal data speed.

Step 4. Type **<Enter>** to confirm that you have reestablished communication with the relay.

The relay responds with the SELBOOT !> prompt.

Step 5. Type **EXI <Enter>** to exit the SELBOOT program.

After a slight delay, the relay responds with the following message:

```
CAUTION: Initial relay restart. DO NOT cycle power during
this time. Please wait 3 minutes for restart completion.
```

Step 6. Following the expected relay restart time from *Step 5*, proceed to *H Verify Relay Self-Tests on page B.16*.

H Verify Relay Self-Tests

Step 1. Press **<Enter>** and confirm that the Access Level 0 = prompt appears on your terminal screen.

Step 2. Remove input power to the relay.

a. Allow at least 10 seconds during the removal of relay power to ensure that the power supply has shut down.

b. Reapply input power to the relay.

c. Wait 10 minutes after startup of the relay to allow the relay to detect any hardware changes made during the upgrade process.

Step 3. Enter Access Level 1 using the **ACC** command and Access Level 1 password.

Step 4. Enter Access Level 2 using the **2AC** command and Access Level 2 password.

Step 5. Type **VER <Enter>** to confirm the new firmware.

Step 6. Match the firmware revision number with the FID number on the screen.

Step 7. Type **STA <Enter>** to check the relay status and accept new hardware changes if needed.

Step 8. Verify that all relay self-test parameters are within tolerance. (The relay compares the settings before and after the upgrade process and displays an upgrade warning if settings are dissimilar. You can find details in the upgrade report file.)

Step 9. View the front-panel **ENABLED** LED and confirm that the LED is illuminated.

Unless there is a serious problem, the **ENABLED** LED illuminates without any intervention, and the relay retains all settings.

If the relay does not enable within five minutes of the `Initial relay restart` message, contact your Technical Service Center or the SEL factory for assistance (see *Technical Support on page B.26*).

I Verify Relay Settings

Step 1. Prepare to control the relay at Access Level 2; use the procedure in *Enter Access Level 2 on page B.12*.

Step 2. Type **VER <Enter>** to confirm the new firmware.

Step 3. Match the firmware revision number with the FID number on the screen.

Step 4. Use one of the following methods to review your settings.

➢ Use the QuickSet **Read** menu.

If the settings do not match the settings that you recorded in *Backup Relay Settings on page B.12*, use QuickSet to restore relay settings.

➢ Type **SHOW <Enter>**.

You can reissue the settings with the **SET** commands (see *Section 9: ASCII Command Reference* of the product-specific instruction manual for information on the **SHOW** and **SET** commands).

Step 5. Type **STA <Enter>** to check relay status.

Step 6. Verify that all relay self-test parameters are within tolerance.

Method 3: Using a Web Browser

NOTE: The relay pulses the SALARM bit and writes an entry to the relay SER log whenever a firmware upgrade is attempted over Ethernet. Monitoring this bit and reviewing the SER log can help identify possible unauthorized firmware upgrade attempts.

To upgrade firmware through use of the web browser, the HTTP server must be enabled for the Ethernet ports. SEL recommends enabling Telnet in case you need to perform any ASCII terminal commands (inputting settings, etc.).

Never use the web browser to downgrade firmware on a relay.

A Set PORT 5 Settings MAXACC, EETHFWU, and EPAC

To upgrade relay firmware by using the web browser, the PORT 5 settings MAX-ACC and EETHFWU must be set to 2 or C, and Y, respectively. In the web browser login page, Access Level 2 is provided as a user-selectable login access level. If EETHFWU is set to N, upgrading firmware over an Ethernet connection is disabled. If EPAC = Y, ensure Relay Word bit E2AC is asserted to allow Level 2 access.

B Obtain Firmware File

Contact SEL customer service for the firmware file. For relay firmware, the file name is of the form r*nnn*4*xx* or r*nnn*-v*y*4*xx*, where r*nnn* indicates the firmware revision number, v*y* indicates the point-release number, and 4*xx* indicates the relay type. For SELBOOT firmware, the file name is of the form s*nnn*-v*y*4xx, where s*nnn* is the SELBOOT revision number, and 4xx indicates that the SEL-BOOT version is for SEL-400 series relays. The firmware file name extensions are .s19, .z19, and .zds. Only the .zds file can be used when using the web browser. Copy the .zds digitally signed firmware upgrade file to an easily accessible location on the PC.

Firmware is designed to be used with specific relays. A list of relay serial numbers is provided as part of the firmware upgrade package. The firmware provided is for use with the listed relays only. Attempts to upgrade relays not listed might not be successful and can result in relay failure.

C Remove Relay From Service

Step 1. If the relay is in use, follow your company practices for removing a relay from service. Typically, these include changing settings, or disconnecting external voltage sources or output contact wiring, to disable relay control functions.

Step 2. Apply power to the relay.

D Read IEC 61850 CID File Through Architect

Step 1. Establish an FTP connection between the relay and your computer in Architect.

Step 2. Download the CID file by using the IP address of the relay.

E Prepare the Relay (Save Relay Settings and Other Data)

Create a Telnet connection in QuickSet or SEL Grid Configurator (for relays supported by SEL Grid Configurator) and read both settings and event reports stored on the relay. If you prefer using FTP to pull settings and reports, and FTP is enabled on the Ethernet ports, see *E Establish Communications With the Relay and Read Settings on page B.21* for pulling events and reports over FTP.

F Establish a Web Browser Connection With the Relay

Step 1. Establish communication between your personal computer and the relay through a web browser (HTTP) connection. See *HTTP (Hypertext Transfer Protocol) Server on page 15.20* for more information.

G Upload New Firmware

NOTE: Access level passwords are not encrypted in any way by the Web Server when logging in.

Step 1. To upload new firmware, log in to Access Level 2 of the web server. Select **2AC** from the Access Level dropdown box. Enter the respective Access Level 1 and 2 passwords and select the **Login** button.

Step 2. Once logged in verify communication with the correct relay by checking the Relay Identifier (RID setting) and Substation Identifier (SID setting) next to the SEL icon in the upper left corner of the web browser page. Choose **System > Firmware Upgrade** from the left pane, which brings up the page shown in *Figure B.7*. This page also displays feedback from the previous firmware upgrades. If the prior firmware upgrade was successful, the page displays **Previous firmware upgrade successful. Date:** ***mm/dd/yy*** **Time:** ***hh:mm:ss***. If the prior firmware upgrade failed, the page displays **Previous firmware upgrade failed. Date:** ***mm/dd/yy*** **Time:** ***hh:mm:ss***, with an error message below. If no prior firmware upgrade has occurred (which is the case for a new unit from the factory), the page displays, **Previous firmware upgrade information is unavailable.**

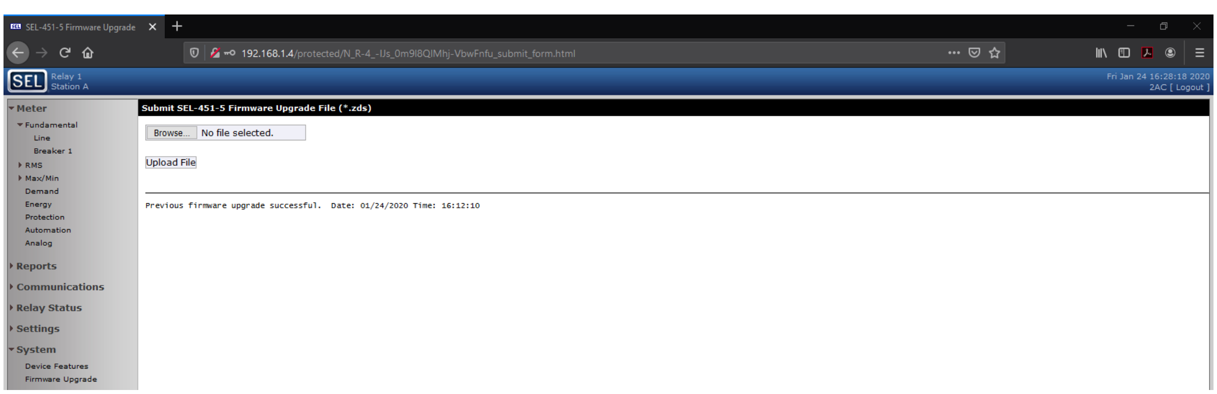

Figure B.7 Firmware Upload File Selection Page

Step 3. To search for your firmware file, select the **Browse** button. The format of this file must be .zds. If upgrading relay firmware, the name of the file sent can be either r*nnn*-vy4*xx*.zds or RELAY.ZDS. If upgrading SELBOOT firmware, the name of the file can be s3*nn*-vy4*xx*.zds or SELBOOT.ZDS.

NOTE: The relay automatically disables during the firmware upgrade process then enables following a successful upgrade.

Step 4. To submit, select **Upload File**. Once the upload has started, it cannot be canceled. During the upload process the relay remains enabled and continues normal operation.

Step 5. Once the firmware file is transferred to the device, the relay disables and attempts to restart using the new firmware.

Step 6. When the firmware upload process is complete, the message shown in *Figure B.8* is displayed by the web server. The HTTP session closes after the upload is complete and the firmware upgrade takes place. The message displayed indicates how long the firmware upgrade process will take. The relay automatically enables after a successful firmware upgrade.

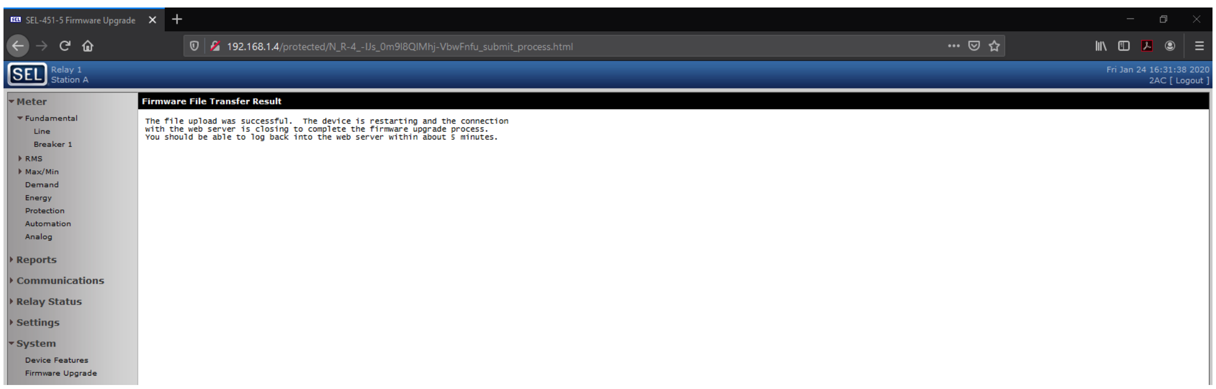

Figure B.8 Firmware Upgrade Confirmation

H Verify Firmware

Step 1. Re-establish an HTTP connection with the relay after the displayed expected upgrade time or monitor the link status with the relay and then re-establish a connection when the relay reports as online.

Step 2. Select **System > Device Features** from the left pane and verify the relay FID or BFID matches the firmware to which you expected to upgrade.

I Check Web Browser Upgrade Messages

After the firmware upgrade is completed and once you have logged back into Access Level 1 of the web server, you can check the relay self-tests by selecting **Relay Status > Self Tests** in the left pane. The following table provides messages displayed in the web browser and the message meaning.

Table B.4 Ethernet Firmware Upgrade User Messages (Sheet 1 of 2)

User Message	Relay Condition
Previous upgrade information is not available.	No previous firmware upgrade using a .zds file has occurred
Previous upgrade successful.	The previous firmware upgrade with a .zds file was successful.

Table B.4 Ethernet Firmware Upgrade User Messages (Sheet 2 of 2)

User Message	Relay Condition
Previous upgrade failed.	A previous attempt to upgrade firmware failed. Contact SEL Support if this occurs.
The file upload was successful. The device is restarting and the connection with the web server is closing to complete the firmware upgrade process. You should be able to log back into the web server within about 5 minutes.	The relay successfully received and validated the .zds file and will now load the firmware and automatically restart and enable the new firmware.
Invalid upgrade file.	The .zds file was not successfully received or validated by the relay.
Model mismatch.	The .zds file is for firmware for a different SEL-400 series relays model.
Settings modification in progress on another interface.	Settings within the relay are currently being modified through another connection.
Upgrade in progress on another interface.	A firmware upgrade is currently being performed through another connection.

J Verify Relay Settings

To verify the settings are correct for your relay, choose **Show Settings** in the left pane. Verify that these match the settings saved earlier (see *G Upload New Firmware on page B.18*). Note that calibration settings are not viewable via the web server, a terminal connection is needed to verify these settings. If the settings do not match, reenter the settings saved earlier.

Method 4: Using FTP

NOTE: The relay pulses the SALARM bit and writes an entry to the relay SER log whenever a firmware upgrade is attempted over Ethernet. Monitoring this bit and reviewing the SER log can help identify possible unauthorized firmware upgrade attempts.

To upgrade firmware through use of FTP, FTP must be enabled for the Ethernet ports. SEL recommends enabling Telnet in case you need to perform any ASCII terminal commands (inputting settings, etc.). SEL recommends a software interface on your PC because it can help you visualize and simplify the file-transfer process. Become familiar with the FTP interface of your choosing prior to attempting a firmware upgrade over FTP.

Never use FTP to downgrade firmware on a relay.

A Set PORT 5 Settings MAXACC, EETHFWU, and EPAC

To upgrade firmware by using FTP, the PORT 5 settings MAXACC and EETHFWU must be set to 2 or C, and Y, respectively. If EETHFWU is set to N, upgrading firmware over an Ethernet connection is disabled. If EPAC = Y, ensure Relay Word bit E2AC is asserted to allow Level 2 access. Also, if FTP anonymous logins are enabled (FTPANMS := Y), the **UPGRADE** directory is hidden from FTP and Ethernet upgrades over FTP are not allowed.

B Obtain Firmware File and Rename File for FTP File Transfer

Contact SEL customer service for the firmware file. For relay firmware, the file name is of the form r*nnn*-v*y*4*xx*, where r*nnn* indicates the firmware revision number, v*y* indicates the point-release number, and 4*xx* indicates the relay type. For SELBOOT firmware, the file name is of the form s*nnn*4xx, where s*nnn* is the SELBOOT revision number and 4xx indicates that the SELBOOT version is for SEL-400 series relays. The firmware file name extensions are .s19, .z19, and .zds. Only the .zds file can be used when using FTP. Copy the .zds digitally signed firmware upgrade file to an easily accessible location on the PC.

Firmware is designed to be used with specific relays. A list of relay serial numbers is provided as part of the firmware upgrade package. The firmware provided is for use with the listed relays only. Attempts to upgrade relays not listed might not be successful and can result in relay failure.

If upgrading relay firmware, rename the provided r*nnn*-v*y*4*xx*.zds firmware upgrade file to RELAY.ZDS by right-clicking the file on your PC and selecting **Rename**. Based on FTP file transfer and relay directories, the relay must receive the file as the name RELAY.ZDS.

If upgrading SELBOOT firmware, rename the provided s3*nn*-v*y*4*xx*.zds SELBOOT upgrade file to SELBOOT.ZDS by right-clicking the file on your PC and selecting **Rename**. Because of the FTP file transfer and relay directories, the relay must receive the SELBOOT upgrade file as the name SELBOOT.ZDS.

C Remove Relay From Service

Step 1. If the relay is in use, follow your company practices for removing relays from service. Typically, these include changing settings or disconnecting external voltage sources or output contact wiring to disable relay functions.

Step 2. Apply power to the relay.

D Read IEC 61850 CID File Through Architect

Step 1. Establish an FTP connection between the relay and your computer in Architect.

Step 2. Download the CID file by using the IP address of the relay.

E Establish Communications With the Relay and Read Settings

Step 1. Establish an FTP connection between your personal computer and relay in the FTP software interface of your choosing. The username is 2AC and the password is your Access Level 2 password. FTP is used on Port 21 of the relay, so ensure in the connections window the IP address of your relay you are upgrading is correct and the FTP port is assigned to 21.

Step 2. In the FTP user interface, in the relay file list, navigate to the **SETTINGS** folder.

Step 3. Download all .TXT files stored in this folder from the relay. Note that the **SEL_ALL.TXT** file is a read-only file and cannot be sent back to the relay.

Step 4. In the relay file list menu, navigate back to the main root folder, then navigate to the **REPORTS** folder. Download all .TXT files stored in this folder from the relay.

Step 5. In the relay file list menu, navigate back to the main root folder, then navigate to the **EVENTS** folder. Download all events of interest.

F Send Firmware

Step 1. With the FTP connection established in *E Establish Communications With the Relay and Read Settings on page B.21*, in your FTP software interface, point to the renamed relay RELAY.ZDS file if upgrading relay firmware, or the renamed SELBOOT SELBOOT.ZDS upgrade file if upgrading SELBOOT firmware on your PC. On the relay side, navigate to the **UPGRADE** folder and open it.

Step 2. Send the renamed RELAY.ZDS or SELBOOT.ZDS file to the **UPGRADE** file directory folder of the relay. Select **Yes** to the overwrite question, if prompted.

NOTE: The relay automatically disables during the firmware upgrade process then enables following a successful upgrade.

Once the file is loaded to the relay, the relay verifies the file and then accepts the file if the file is verified by the keying algorithm. If the relay accepts the file, the previous firmware is removed and the new firmware is installed. It is important to note that once the relay successfully loads the new firmware, it automatically restarts and enables the firmware. During this process, you will lose the FTP connection, and you must re-establish the FTP connection if required to perform *Step 3* after approximately five minutes. The relay automatically enables after a successful firmware upgrade.

Step 3. During this upgrade process, you will lose the FTP connection, and you must re-establish the FTP connection after approximately five minutes or when the link status with the relay shows the relay online. Re-establish the FTP connection, then navigate to the relay **UPGRADE** directory and read the error file ERR.TXT. Open the .txt file on your PC and review for any error messages. If the firmware upgraded properly, no errors occurred during the upgrade process and the file is empty. If messages are contained within the file, see *Table B.4* for the error message and what the error means.

G Verify Firmware

Step 1. Establish a Telnet connection with the relay after the displayed expected upgrade time or monitor the link status with the relay and then establish a connection when the relay reports as online.

Step 2. Issue the **ID** command and verify the relay FID or BFID matches the firmware to which you expected to upgrade.

H Verify Relay Settings

Step 1. Establish the same FTP connection as identified in *E Establish Communications With the Relay and Read Settings on page B.21*.

Step 2. Navigate to the relay root directory, then the relay **SETTINGS** directory.

Step 3. Read the **UPGRADE_RPT.TXT** file from the relay. Open the .TXT file on your PC and see if there are any unexpected settings changes. Contact SEL Support (selinc.com/support/) at any time for further assistance.

Verify IEC 61850 Operation (Optional)

The SEL-400 series relays with optional IEC 61850 protocol require the presence of one valid CID file to enable the protocol. You should only transfer a CID file to the relay if you want to implement a change in the IEC 61850 configuration or restore the relay CID file after a firmware upgrade in which the CID file is removed. If you transfer an invalid CID file, the relay will disable the IEC 61850 protocol because it no longer has a valid configuration. To restart IEC 61850 protocol operation, you must transfer a valid CID file to the relay.

NOTE: The five-port Ethernet card uses a ClassFileVersion 007 or higher CID file for IEC 61850 configuration. Use Architect to create a CID file for the five-port Ethernet card.

Perform the following steps to verify that the IEC 61850 protocol is still operational and if not, re-enable it. This procedure assumes that IEC 61850 was operational with a valid CID file immediately before initiating the firmware upgrade. If the IEC 61850 protocol was not configured prior to the upgrade, skip to *Return Relay to Service on page B.24*. Refer to the *Section 17: IEC 61850 Communication* for help with IEC 61850 configuration.

Step 1. Issue the **STA**, **ID**, and **GOO** commands.

Step 2. Verify that there are no error messages regarding IEC 61850 or CID file parsing.

If the responses to the **STA**, **ID**, or **GOO** commands contain IEC 61850 or CID error messages, continue with the following steps to re-enable the IEC 61850 protocol. Otherwise, skip to *Method 2: Using a Terminal Emulator on page B.11*.

If the IEC 61850 protocol has been disabled because of an upgrade-induced CID file incompatibility, you can use Architect to create and send a compatible CID file to the relay.

Step 3. In the Telnet session, issue the **STA**, **ID**, and **GOO** commands.

Step 4. Verify that no IEC 61850 error messages are in the **STA** or **ID** command responses.

Step 5. Verify the GOOSE transmitted and received messages are as expected.

Relays being upgraded from firmware that did not support a local-time UTC offset setting (UTCOFF) to firmware that does support the UTCOFF setting may show incorrect time stamps in Demand Metering and Breaker Monitor report data that was recorded by the relay prior to the firmware upgrade.

The time stamps shown for the Demand Metering and Breaker Monitor data recorded prior to the firmware upgrade will show UTC time plus an eight-hour local time offset, along with any applicable daylight-saving time adjustment.

This only affects time stamps recorded and stored by the relay prior to the firmware upgrade. All time stamps in Demand Metering and Breaker Monitoring following the firmware upgrade will be UTC time with the local time offset setting (UTCOFF) and daylight-saving time applied.

No other reports (Event History, Event Summary, SER, etc.) are affected.

Time-Domain Link (TiDL) Centrally Controlled Firmware Upgrade (For Relays Supporting T-Protocol)

The SEL-TMUs will be selectively upgraded through connected relays.

Relays that share common SEL-TMUs can be upgraded independently without affecting other devices (relays and SEL-TMUs) in the TiDL system. When an SEL-TMU is being upgraded, the relays connected to this SEL-TMU detects a loss in communication and implements selective protection disabling. See *Selective Protection Disabling on page 19.3* for details.

Return Relay to Service

NOTE: Converting to the five-port Ethernet card introduces a third MAC address. Follow your company networking guidelines to update your Ethernet switch configurations to integrate the five-port Ethernet card into your network.

Step 1. Open a terminal window.

Step 2. Use the **ACC** command with the associated password to enter Access Level 1.

Step 3. Issue the **ID** command and compare the firmware revision (R*nnn* or R*nnn*-V*y*) displayed in the FID string against the number from the firmware envelope label. If the numbers match, proceed to *Step 5*.

Step 4. For a mismatch between a displayed FID and the firmware envelope label, re-attempt the upgrade or contact SEL for assistance.

Step 5. If you use the Breaker Wear Monitor, type **BRE <Enter>** to check the data to see if the relay retained breaker wear data through the upgrade procedure. If the relay did not retain these data, use the **BRE W** command to reload the percent contact wear values recorded in *D Save Settings and Other Data on page B.7*.

Step 6. Apply current and voltage signals to the relay.

Step 7. Type **MET <Enter>** or use the QuickSet HMI to verify that the current and voltage signals are correct.

Step 8. Use the **TRI** and **EVE/CEV** commands or **Tools > Events > Get Events** menu in QuickSet to verify that the magnitudes of the current and voltage signals you applied to the relay match those displayed in the event report. If these values do not match, check the relay settings and wiring.

Step 9. Autoconfigure the SEL communications processor port if you have an SEL communications processor connected to the relay. This step re-establishes automatic data collection between the SEL communications processor and the relay. Failure to perform this step can result in automatic data collection failure when cycling communications processor power.

Follow your company procedures for returning a relay to service.

Troubleshooting

Resolving Model Mismatch

When uploading a new firmware file to the relay, SELBOOT checks the relay model number (for example, 451, 421, 487) to ensure that the firmware being loaded into the relay is correct for the relay model. If the relay responds with `Transfer failed — Model mismatch` when a firmware upload is attempted, it is because the relay model number does not match. This may be because the firmware file is not correct, or the relay model number stored in the relay memory was corrupted by an interruption of the file upload.

To remedy this problem, first ensure you are sending the correct file to the relay. *Table B.2* shows the file names used for the firmware files. Verify that the model number in the firmware file matches the model of the relay and then reattempt the upload. If the upload fails again or if SELBOOT is inaccessible, contact SEL for assistance.

Resolving Communications Card Firmware Mismatch

The COMM CARD FIRMWARE MISMATCH error indicates that the five-port Ethernet card is installed, but either the relay firmware or SELBOOT is not compatible with the Ethernet card. To resolve the error, verify SELBOOT R302 or later is installed and load any relay firmware that supports the five-port Ethernet card. Refer to Appendix A of the relay-specific instruction manual for compatible firmware versions. If supported firmware is already loaded, reload the firmware. If the error persists, contact SEL for assistance.

Resolving Status Failure Message Response to STA Command

If a status failure message is returned in response to the **STA** command, perform the following steps.

Step 1. Use the **ACC** and **2AC** commands with the associated passwords to enter Access Level 2.

Step 2. Type **STA C <Enter>**. Answer **Y <Enter>** to the `Reboot the relay and clear status` prompt. The relay will respond with `Rebooting the relay`. Wait for about 30 seconds, then press **<Enter>** until you see the Access Level 0 = prompt.

Step 3. Use the **ACC** command with the associated password to enter Access Level 1.

Step 4. Type **STA <Enter>**.

If there are no fail messages and you are using Method 1, select **Next** in Step 3 of 4 of the Firmware Loader and go to *I Verify Relay Settings on page B.16*.

If there are no fail messages and you are using Method 2, go to *I Verify Relay Settings on page B.16*.

If there are fail messages, continue with *Step 5*.

NOTE: Step 7 causes the loss of settings and other important data. Be sure to retain relay settings and other data downloaded from the relay at the start of the firmware upgrade process. Relay calibration level settings will not be lost.

Step 5. Use the **2AC** command with the associated password to enter Access Level 2.

Step 6. Use the **CAL** command and type the corresponding password to enter Access Level C.

Step 7. Type **R_S <Enter>** to restore factory-default settings in the relay.

The relay asks whether to restore default settings. If the relay does not accept the **R_S** command, contact SEL for assistance.

Step 8. Type **Y <Enter>**.

The relay can take as long as two minutes to restore default settings. The relay then reinitializes, and the **ENABLED** LED illuminates. This LED is labeled either **EN** or **ENABLED**, depending on the relay model.

Step 9. Press **<Enter>** to check for the Access Level 0 = prompt indicating that serial communication is successful.

Step 10. Use the **ACC** and **2AC** commands and type the corresponding passwords to reenter Access Level 2.

Step 11. Use the **CAL** command and type the corresponding password to enter the relay Calibration settings level.

Step 12. Type **SHO C <Enter>** to verify the relay calibration settings.

If using Method 1 and the settings do not match the settings contained in the text file you recorded in *C Save Settings and Other Data on page B.12*, contact SEL for assistance.

If using Method 2 and the settings do not match the settings contained in the text file you recorded in *B Prepare the Relay on page B.11*, contact SEL for assistance.

Step 13. Use the **PAS *n*** (*n* = 0, 1, 2, B, P, A, O, C) command to set the relay passwords.

Step 14. Restore the relay settings.

Step 15. If any failure status messages still appear on the relay display, see the Testing and Troubleshooting section in your relay instruction manual or contact SEL for assistance.

Technical Support

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

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APPENDIX C

Cybersecurity Features

The SEL-400 series relays have a number of security features to assist users with meeting their cybersecurity design requirements.

Ports and Services

Physical Ports

NOTE: Connect SEL devices only to trusted networks.

The SEL-400 series relays include four serial ports and an Ethernet communications card with as many as five ports. Each physical serial port and Ethernet port can be individually disabled using the EPORT setting. By default, all of the ports are enabled.

SEL recommends that unused communications ports be disabled.

SEL-400 series relays with a TiDL configuration also have eight ports. These are always enabled, but they have a very limited functionality, as described below.

IP Ports

When using Ethernet, there are a number of possible IP ports available within the relay. Many of these IP port numbers are configurable. All IP ports can be disabled and are disabled by default. *Table C.1* describes each of these.

Table C.1 IP Port Numbers

IP Port Default	Port Selection Setting	Network Protocol	Default Port State	Port Enable Setting	Purpose
21	--	TCP	Disabled	FTPSERV	FTP protocol access for file transfer of settings and reports
23	TPORT	TCP	Disabled	ETELNET	Telnet access for general engineering terminal access
80	HTTPPOR	TCP	Disabled	EHTTP	Web server access to read various relay information
102	--	TCP	Disabled	E61850	IEC 61850 Manufacturing Message Specification (MMS) for SCADA functionality
123	SNTPPOR	UDP	Disabled	ESNTP	SNTP time synchronization
319/320	--	UDP	Disabled	EPTP	Precision Time Protocol (PTP) time synchronization
4712/ 4713	PMOTCP1/ PMOUDP1	TCP/UDP	Disabled	PMOTS1	Synchrophasor data output, session 1
4722/ 4713	PMOTCP2/ PMOUDP2	TCP/UDP	Disabled	PMOTS2	Synchrophasor data output, session 2
20000	DNPPNUM	TCP/UDP	Disabled	EDNP	DNP3 for SCADA functionality

Note that IP traffic is only supported on station bus ports, so process bus ports have no open IP ports. See *Ethernet Communications on page 15.6* for more information on these settings.

Segregating Ethernet Ports

NOTE: Isolated IP mode is not available when using the five-port Ethernet card. Configure a ClassFileVersion 007 or higher CID file for the five-port Ethernet card to define which ports publish GOOSE traffic.

In some operating modes, the enabled Ethernet ports support both IP traffic and layer 2 protocols (i.e., IEC 61850 GOOSE). If NETMODE = ISOLATEIP, then one port only permits GOOSE traffic. This allows this port to be routed outside of a security perimeter while retaining the ability to perform basic monitoring and control. See *Redundant Ethernet Ports (Two- or Four-Port Ethernet Card) on page 15.10* for more information on this mode.

T-Protocol Ports

SEL-400 series relays with a TiDL configuration that supports T-Protocol have eight TiDL communications ports. These ports communicate with SEL-TMUs. The ports are used exclusively for exchanging analog and digital data with SEL-TMUs; they will not recognize any other types of communications.

Once the system is configured and commissioned, the relay only communicates with the associated SEL-TMUs that were commissioned during the relay commissioning process. Any other traffic on these ports is ignored.

EtherCAT Ports

SEL-400 series relays with a TiDL configuration that supports EtherCAT have eight EtherCAT ports. These communicate with Axion nodes. The ports are used exclusively for exchanging analog and digital data with Axions; they will not recognize any other types of communication.

Once the system is configured and commissioned, the relay will only communicate with recognized Axions. Any other traffic on these ports will be ignored. After commissioning, the loss of communications to any configured Axion or Axion module will cause the relay to disable.

Authentication and Authorization Controls

Local Accounts

SEL-400 series relays support eight levels of access, as described in the *Access Levels and Passwords on page 3.7*. Refer to this section to learn how each level is accessed and what the default passwords are. It is good security practice to change the default passwords of each access level and to use a unique password for each level.

Relays have the capability to limit the level of access on a port basis. The maximum access level setting may be used on each port to restrict these authorization levels. This permits you to operate under the principle of “least privilege,” restricting ports to the levels needed for the functions performed on those ports. In addition, you can use the EPAC setting on each port to restrict read or write access as defined by the Global SELOGIC equations EACC and E2AC.

Each relay supports strong passwords of as many as 12 characters including any printable character, allowing users to select complex passwords if they so choose. SEL recommends that passwords contain a minimum of eight characters containing at least one of each of the following: lowercase letter, uppercase letter, number, and special character.

Authentication Failures

When three successive login attempts fail as a result of an incorrect password entry, the relay locks out login attempts on that port for 30 seconds. It also pulses the BADPASS Relay Word bit.

Malware Protection Features

Firmware Hash Verification

SEL provides firmware hashes as an additional tool to verify the integrity of SEL firmware upgrade files. This helps ensure that the firmware received from the factory is complete and unaltered prior to sending the firmware to the SEL device. Verify that the firmware file in your possession is a known good SEL firmware release by comparing the calculated hash value of the firmware in your possession with the hash value provided at selinc.com/products/firmware/.

Operating System/Firmware

SEL-400 series relays are embedded devices that do not allow additional software to be installed. SEL-400 series relays include a self-test that continually checks running code against the known good baseline version of code in nonvolatile memory. This process is outlined in more detail in the document titled *The SEL Process for Mitigating Malware Risk to Embedded Devices* located at selinc.com/mitigating_malware/.

SEL-400 series relays run in an embedded environment for which there is no commercial anti-virus software available.

Software/Firmware Verification

SEL-400 series relays have the ability to install firmware updates in the field. Authenticity and integrity of firmware updates can be verified by using the Firmware Hash page at selinc.com/products/firmware/.

See **Firmware Verification** available at selinc.com/products/firmware for information that can help verify that currently installed firmware on an SEL relay is complete and unaltered.

Logging Features

Internal Log Storage

The Sequential Event Recorder (SER) log is a useful tool for capturing a variety of relay events. In addition to capturing state changes of user selected Relay Word bits, it captures all startups, settings changes, and group switches. See *Sequential Events Recorder (SER) on page 9.28* for more information about SER.

Alarm Reporting

The relay provides the following Relay Word bits that are useful for monitoring relay access:

- ➤ BADPASS—Pulses for one second if a user enters three successive bad passwords.
- ➤ ACCESS—Set while any user is logged into Access Level B or higher.
- ➤ ACCESSP—Pulses for one second whenever a user gains access to an Access Level of B or higher.
- ➤ PASSDIS—Set if the password disable jumper is installed.
- ➤ BRKENAB—Set if the breaker control enable jumper is installed.
- ➤ LINK5A, LINK5B, LINK5C, LINK5D, LINK5E—Set while the link is active on the respective Ethernet port. Loss-of-link can be an indication that an Ethernet cable has been disconnected.

NOTE: The relay can take as long as 6 ms to detect and report the loss of link on an active port (assert LNKFAIL or LNKFL2).

- ➤ LNKFAIL—Set if link is lost on any active station bus port. For relays with only two Ethernet ports, LNKFAIL asserts if link is lost on either port.
- ➤ LNKFL2—Set if link is lost on the active process bus port (Ethernet 87L ports or Sampled Values (SV) ports in devices with those capabilities). Once detected, the loss of the active port on the process bus causes immediate failover if the backup port has a good data link. If this is the case, failover may occur too quickly for the SER scanner to register the assertion and deassertion of LNKFL2.

These bits can be mapped for SCADA monitoring via DNP3, IEC 61850, or SEL Fast Message. They can also be added to the SER log for later analysis and assigned to output contacts for alarm purposes.

Physical Access Security

Physical security of cybersecurity assets is a common concern. Typically, relays are installed within a control enclosure that provides physical security. Other times, they are installed in boxes within the switch yard. The relay provides some tools that may be useful to help manage physical security, especially when the unit is installed in the switch yard.

You can monitor physical ingress by wiring a door sensor to one of the relay contact inputs. This input can then be mapped for SCADA monitoring or added to the SER log so that you can detect when physical access to the relay occurs.

It is also possible to wire an electronic latch to a relay contact output. You could then map this input for SCADA control.

Configuration Control Support

Product Version Information

The SEL-400 series relay firmware revision number (FID) provides the current firmware version/patch level. The FID can be obtained using the **STATUS** command.

Settings Version Information

All settings changes are logged to the SER log. Analysis of this log will let you determine if any unauthorized settings changes occurred.

The relay also stores a hash code for each settings class in the CFG.txt file. After configuring the device, you can read the CFG.txt file and store it for future reference. You can then periodically read this file from the relay and compare it to the stored reference. If any of the hash codes have changed, then you know that a settings class has been modified.

Backup and Restore

SEL-400 series relays support the export and import of settings and configuration by using ACSELERATOR QuickSet SEL-5030 Software and ACSELERATOR Architect SEL-5032 Software. Settings can also be imported and exported as files by using any file transfer mechanism.

Decommissioning

NOTE: Do not do this when sending in the relay for service at the factory. SEL needs to be able to see how the relay was configured to properly diagnose any problems.

It is often desirable to erase the settings from the relay when it is removed from service. You can completely erase all the configuration settings from the relay by using the following procedure.

Step 1. Go to Access Level C.

Step 2. Execute the **R_S** command to restore the device to factory-default settings.

Step 3. Allow the relay to restart.

Step 4. Go to Access Level C.

Step 5. Execute the **R_S** command again to set the backup copy of settings to factory default.

Step 6. Allow the relay to restart.

Once this procedure is complete, all internal instances of all user settings and passwords will be erased.

Vulnerability Notification Process

Security Vulnerability Process

SEL provides security disclosure alerts to customers, and SEL instruction manuals document all releases. SEL security vulnerability disclosures are described in *The SEL Process for Disclosing Security Vulnerabilities* located at selinc.com.

Emailed Security Notification

You can sign up to receive email notifications when SEL releases security vulnerability notices and service bulletins at selinc.com/support/security-notifications/.

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Glossary

a Contact A breaker auxiliary contact (ANSI Standard Device Number 52A) that closes when the breaker is closed and opens when the breaker is open.

a Output A relay control output that closes when the output relay asserts.

b Contact A breaker auxiliary contact (ANSI Standard Device Number 52B) that opens when the breaker is closed and closes when the breaker is open.

b Output A relay control output that opens when the output relay asserts.

c Contact A breaker auxiliary contact that can be set to serve either as an a contact or as a b contact.

c Output An output with both an a output and b output sharing a common post.

3U, 4U, 5U, 6U, 7U, 9U The designation of the vertical height of a device in rack units. One rack unit, U, is approximately 1.75 in or 44.45 mm.

A Abbreviation for amps or amperes—a unit of electrical current flow.

ABS Operator An operator in math SELOGIC control equations that provides absolute value.

AC Ripple The peak-to-peak ac component of a signal or waveform. In the station dc battery system, monitoring ac ripple provides an indication of whether the substation battery charger has failed.

Acceptance Testing Testing that confirms that the relay meets published critical performance specifications and requirements of the intended application. Such testing involves testing protection elements and logic functions when qualifying a relay model for use on the utility system.

Access Level A relay command level with a specified set of relay information and commands. Except for Access Level 0, you must have the correct password to enter an access level.

Access Level 0 The least secure and most limited access level. No password protects this level. From this level, you must enter a password to go to a higher level.

Access Level 1 A relay command level you use to monitor (view) relay information. The default access level for the relay front panel.

Access Level 2 The most secure access level where you have total relay functionality and control of all settings types.

Access Level A A relay command level you use to access all Access Level 1 and Access Level B (Breaker) functions plus Automation, Alias, Global, Front Panel, Report, Port, and DNP3 settings.

Access Level B A relay command level you use for Access Level 1 functions plus circuit breaker control and data.

Access Level O A relay command level you use to access all Access Level 1 and Access Level B (Breaker) functions plus Output, Alias, Global, Front Panel, Report, Port, and DNP3 settings.

Access Level P — A relay command level you use to access all Access Level 1 and Access Level B (Breaker) functions plus Protection, SELOGIC, Alias, Global, Group, Breaker Monitor, Front Panel, Report, Port, and DNP3 settings.

ACSELERATOR Architect SEL-5032 Software — Architect is an add-on to the QuickSet Suite that uses the IEC 61850 Substation Configuration Language to configure SEL IEDs.

ACSELERATOR QuickSet SEL-5030 Software — A Windows-based program that simplifies settings and provides analysis support.

ACSI — Abstract Communications Service Interface for the IEC 61850 protocol. Defines a set of objects, a set of services to manipulate and access those objects, and a base set of data types for describing objects.

Active Settings Group — The settings group that the relay is presently using from among six settings groups available in the relay.

ADC — Analog to Digital Converter. A device that converts analog signals into digital signals.

Admittance — The reciprocal of impedance, I/V.

Advanced Settings — Settings for customizing protection functions; these settings are hidden unless you set EADVS := Y and EGADVS := Y.

Alias — An alternative name assigned to Relay Word bits, analog quantities, default terminals, and bus-zone names.

Analog Quantities — Variables represented by such fluctuating measurable quantities as temperature, frequency, current, and voltage.

AND Operator — Logical AND. An operator in Boolean SELOGIC control equations that requires fulfillment of conditions on both sides of the operator before the equation is true.

ANSI Standard Device Numbers — A list of standard numbers used to represent electrical protection and control relays. The standard device numbers used in this instruction manual include the following:

21	Distance element
24	Volts/Hertz Element
25	Synchronism-check element
27	Undervoltage Element
32	Directional Elements
49	Thermal Element
50	Overcurrent Element
51	Inverse-Time Overcurrent Element
52	AC Circuit Breaker
59	Overvoltage Element
67	Definite-Time Overcurrent
79	Recloser
86	Breaker Failure Lockout
89	Disconnect

These numbers are frequently used within a suffix letter to further designate their application. The suffix letters used in this instruction manual include the following:

P	Phase Element
G	Residual/Ground Element
N	Neutral/Ground Element
Q	Negative-Sequence (3I2) Element

Anti-Aliasing Filter A low-pass filter that blocks frequencies too high for the given sampling rate to accurately reproduce.

Apparent Power, S Complex power expressed in units of volt-amperes (VA), kilovolt-amperes (kVA), or megavolt-amperes (MVA). Accounts for both real (P) and reactive (Q) power dissipated in a circuit: S = P + jQ. This is power at the fundamental frequency only; no harmonics are included in this quantity.

Arcing Resistance The resistance in the arc resulting from a power line fault.

ASCII Abbreviation for American Standard Code for Information Interchange. Defines a standard set of text characters. The relay uses ASCII text characters to communicate using front-panel and rear-panel EIA-232 serial ports on the relay and through virtual serial ports.

ASCII Terminal A terminal without built-in logic or local processing capability that can only send and receive information.

Assert To activate. To fulfill the logic or electrical requirements needed to operate a device. To set a logic condition to the true state (logical 1) of that condition. To apply a closed contact to a relay input. To close a normally open output contact. To open a normally closed output contact.

AT Modem Command Set Dialing String Standard The command language standard that Hayes Microcomputer Products, Inc. developed to control autodial modems from an ASCII terminal (usually EIA-232 connected) or a PC containing software allowing emulation of such a terminal.

Autoconfiguration The ability to determine relay type, model number, metering capability, port ID, data rate, passwords, relay elements, and other information that an IED (an SEL-2020/2030 communications processor) needs to automatically communicate with relays.

Automatic Messages Messages including status failure and status warning messages that the relay generates at the serial ports and displays automatically on the front-panel LCD.

Automatic Reclose Automatic closing of a circuit breaker after a breaker trip by a protective relay.

Automation Variables Variables that you include in automation SELOGIC control equations.

Autoreclose-Drive-to-Lockout A logical condition that drives the autoreclose function out of service with respect to a specific circuit breaker.

Autotransformer A transformer with at least two common windings.

AX-S4 MMS “Access for MMS” is an IEC 61850, UCA2, and MMS client application produced by SISCO, Inc., for real-time data integration in Microsoft Windows-based systems supporting OPC and DDE. Included with AX-S4 MMS is the interactive MMS Object Explorer for browser-like access to IEC 61850/UCA2 and MMS device objects.

Axion Another term for the SEL-2240. The Axion is an integrated, modular input/output and control solution suited for utility and industrial applications. In TiDL (EtherCAT) systems, it is used for data acquisition and control.

Bandpass Filter A filter that passes frequencies within a certain range and blocks all frequencies outside this range.

Bay Primary plant including disconnects, circuit breaker, CTs, PTs, power transformer, etc.

Bay Control Front-panel control (open and close) of the transformer circuit breakers and disconnects (isolators).

Best Choice Ground Directional Element Logic An SEL logic that determines the directional element that the relay uses for ground faults.

Bit Label The identifier for a particular bit.

Bit Value Logical 0 or logical 1.

Block Trip Extension Continuing the blocking signal at the receiving relay by delaying the dropout of Relay Word bit BT.

Blocking Signal Extension The blocking signal for the DCB (directional comparison blocking) trip scheme is extended by a time delay on dropout timer to prevent unwanted tripping following current reversals.

Bolted Fault A fault with essentially zero impedance or resistance between the shorted conductors.

Boolean Logic Statements Statements consisting of variables that behave according to Boolean logic operators such as AND, NOT, and OR.

Breaker Auxiliary Contact An electrical contact associated with a circuit breaker that opens or closes to indicate the breaker position. A Form A breaker auxiliary contact (ANSI Standard Device Number 52A) closes when the breaker is closed and opens when the breaker is open. A Form B breaker auxiliary contact (ANSI Standard Device Number 52B) opens when the breaker is closed and closes when the breaker is open.

Breaker-and-a-half Configuration A switching station arrangement of three circuit breakers per two circuits; the two circuits share one of the circuit breakers.

Breaker Differential Differential zone of protection configured exclusively across the tie breaker; the breaker differential protects only the area between the two tie-breaker CTs.

Buffered Report IEC 61850 IEDs can issue buffered reports of internal events (caused by trigger options data-change, quality-change, and data-update). These event reports can be sent immediately or buffered (to some practical limit) for transmission, such that values of data are not lost because of transport flow control constraints or loss of connection. Buffered reporting provides Sequence-of-Events (SOE) functionality.

Busbar Electrical junction of two or more primary circuits. For a single busbar, there could be multiple bus-zones; there can be more bus-zones than busbars, but not more busbars than bus-zones.

Bus Coupler (see also Tie Breaker)
Equipment with at least a CT and circuit breaker, connecting two busbars when the circuit breaker is closed. Disconnects of other terminals at the station (feeders, lines, etc.) are normally arranged in parallel with the bus coupler. Closing two or more disconnects of the other terminals bypasses the bus coupler, forming a connection without a circuit breaker between two or more busbars.

Busbar Protection Element
Each busbar protection elements comprise a differential element, a directional element, and a fault detection logic.

Bus Sectionalizer (see also Buscoupler)
Equipment with at least a CT and circuit breaker, connecting two busbars when the circuit breaker is closed.

Bus-Zone-to-Bus-Zone Connection Variable
SELOGIC variable stating the conditions when the relay merges two zones to form a single protection zone.

Bus-Zone (see also Protection Zone)
Area of protection formed by a minimum of two terminals.

C37.118
IEEE C37.118, Standard for Synchrophasor Measurements for Power Systems.

C37.238
IEEE C37.238, Standard Profile for Use of IEEE 1588 Precision Time Protocol in Power System Applications.

Capacitor Bank
Assembly of a number of capacitor units.

Capacitor Element
Device consisting of two electrodes separated by a dielectric.

Capacitor Unit
Assembly of a number of capacitor elements.

Category
A collection of similar relay settings.

CCVT
Capacitively coupled voltage transformer that uses a capacitive voltage divider to reduce transmission voltage to a level safe for metering and relaying devices. See CVT.

Checksum
A method for checking the accuracy of data transmission involving summation of a group of digits and comparison of this sum to a previously calculated value.

Check Zone
Protection zone formed by two or more terminals where the differential calculation is independent of the status of the disconnect auxiliary contacts.

CID
Checksum identification of the firmware.

CID File
IEC 61850 Configured IED Description file. XML file that contains the configuration for a specific IED.

Circuit Breaker Failure Logic
This logic within the relay detects and warns of failure or incomplete operation of a circuit breaker in clearing a fault or in performing a trip or close sequence.

Circuit Breaker History Report
A concise circuit breaker event history that contains as many as 128 events. This breaker history report includes circuit breaker mechanical operation times, electrical operation times, interrupted currents, and dc battery monitor voltages.

Circuit Breaker Report
A full report of breaker parameters for the most recent operation. These parameters include interrupted currents, number of operations, and mechanical and electrical operating times among many parameters.

Class The first level of the relay settings structure including Global, Group, Breaker Monitor, Port, Report, Front Panel, DNP3 settings, Protection SELOGIC control equations, Automation SELOGIC control equations, and Output SELOGIC control equations.

Cold Start Turning a system on without carryover of previous system activities.

Combined Winding Mathematical combination (in the SEL-451) of currents from two separate sets of CT on the same voltage level, typical of breaker-and-a-half busbar configurations.

Commissioning Testing Testing that serves to validate all system ac and dc connections and confirm that the relay, auxiliary equipment, and SCADA interface all function as intended with your settings. Perform such testing when installing a new protection system.

Common Class Components Composite data objects that contain instances of UCA standard data types.

Common Data Class IEC 61850 grouping of data objects that model substation functions. Common Data Classes include Status information, Measured information, Controllable status, Controllable analog, Status settings, Analog settings, and Description information.

Common Inputs Relay control inputs that share a common terminal.

Common Time Delay Both ground and phase distance protection follow a common time delay on pickup.

Common Zone Timing Both ground and phase distance protection follow a common time delay on pickup.

Communications Protocol A language for communication between devices.

Communications-Assisted Tripping Circuit breaker tripping resulting from the transmission of a control signal over a communications medium.

Comparison Boolean SELOGIC control equation operation that compares two numerical values. Compares floating-point values such as currents, total counts, and other measured and calculated quantities.

Computer Terminal Emulation Software Software such as Microsoft HyperTerminal or ProComm Plus that can be used to send and receive ASCII text messages and files via a computer serial port.

COMTRADE Abbreviation for Common Format for Transient Data Exchange. The relay supports the IEEE Std C37.111–1999 and C37.111-2013, Common Format for Transient Data Exchange (COMTRADE) for Power Systems.

Conditioning Timers Timers for conditioning Boolean values. Conditioning timers either stretch incoming pulses or allow you to require that an input take a state for a certain period before reacting to the new state.

Contact Input See Control Input.

Contact Output See Control Output.

Control Input Relay inputs for monitoring the state of external circuits. Connect auxiliary relay and circuit breaker contacts to the control inputs.

Control Output Relay outputs that affect the state of other equipment. Connect control outputs to circuit breaker trip and close coils, breaker failure auxiliary relays, communications-assisted tripping circuits, and SCADA systems.

Coordination Timer A timer that delays an overreaching element so that a downstream device has time to operate.

COS Operator Operator in math SELOGIC control equations that provides the cosine function.

Counter Variable or device such as a register or storage location that either records or represents the number of times an event occurs.

Cross-Country Fault A cross-country fault consists of simultaneous separate single phase-to-ground faults on parallel lines.

CT Current transformer.

CT Subsidence Current Subsidence current appears as a small exponentially decaying dc current with a long time constant. This current results from the energy trapped in the CT magnetizing branch after the circuit breaker opens to clear a fault or interrupt load.

CTR Current transformer ratio.

Current Compensation Adjustment of the current signals to nullify any standing unbalance current.

Current Reversal Guard Logic Under this logic, the relay does not key the transmitter and ignores reception of a permissive signal from the remote terminal when a reverse-looking element detects an external fault.

Current Transformer Saturation The point of maximum current input to a CT; any change of input beyond the saturation point fails to produce any appreciable change in output.

CVT Capacitive voltage transformer that uses a capacitive voltage divider to reduce transmission voltage to a level safe for metering and relaying devices. See CCVT.

CVT Transient Blocking Logic that prevents transient errors on capacitive voltage transformers from causing false operation of Zone 1 mho elements.

CVT Transient Detection Logic Logic that detects transient errors on capacitive voltage transformers.

Data Attribute In the IEC 61850 protocol, the name, format, range of possible values, and representation of values being communicated.

Data Bit A single unit of information that can assume a value of either logical 0 or logical 1 and can convey control, address, information, or frame check sequence data.

Data Class In the IEC 61850 protocol, an aggregation of classes or data attributes.

Data Label The identifier for a particular data item.

Data Object In the IEC 61850 protocol, part of a logical node representing specific information (status or measurement, for example). From an object-oriented point of view, a data object is an instance of a data class.

DC Offset A dc component of fault current that results from the physical phenomenon preventing an instantaneous change of current in an inductive circuit.

DCB (Directional Comparison Blocking): A communications-assisted protection scheme. A fault occurring behind a sending relay causes the sending relay to transmit a blocking signal to a remote relay; the blocking signal interrupts the tripping circuit of the remote relay and prevents tripping of the protected line.

DCE Devices: Data communications equipment devices (modems).

DCUB (Directional Comparison Unblocking): A communications-assisted tripping scheme with logic added to a POTT scheme that allows high-speed tripping of overreaching elements for a brief time during a loss of channel. The logic then blocks trip permission until the communications channel guard returns for a set time.

Deadband: The range of variation an analog quantity can traverse before causing a response.

Deassert: To deactivate. To remove the logic or electrical requirements needed to operate a device. To clear a logic condition to its false state (logical 0). To open the circuit or open the contacts across a relay input. To open a normally open output contact. To close a normally closed output contact.

Debounce Time: The time that masks the period when relay contacts continue to move after closing; debounce time covers this indeterminate state.

Default Data Map: The default map of objects and indices that the relay uses in DNP3 protocol.

Delta: A phase-to-phase series connection of circuit elements, particularly voltage transformers or loads.

Demand Meter: A measuring function that calculates a rolling average or thermal average of instantaneous measurements over time.

Differential Element: The differential element calculates current differences across a zone of protection.

Digital Secondary System (DSS): A protection system that uses merging units to perform signal gathering and control.

Direct Tripping: Local or remote protection elements provide tripping without any additional supervision.

Directional Element: The directional element determines the direction of power flow at a point in the power system.

Directional Start: A blocking signal provided by reverse reaching elements to a remote terminal used in DCB communications-assisted tripping schemes. If the fault is internal (on the protected line), the directional start elements do not see the fault and do not send a blocking signal. If the fault is external (not on the protected line), the directional start elements start sending the block signal.

Directional Supervision: The relay uses directional elements to determine whether protective elements operate based on the direction of a fault relative to the relay.

Disabling Time Delay: A DCUB scheme timer (UBDURD) that prevents high-speed tripping following a loss-of-channel condition.

Disconnect (Isolator): Mechanical switch that isolates primary equipment such as circuit breakers from the electrical system.

Distance Calculation Smoothness
A relay algorithm that determines whether the distance-to-fault calculation varies significantly or is constant.

Distance Protection Zone
The area of a power system where a fault or other application-specific abnormal condition should cause operation of a protective relay.

DMTC Period
The time of the demand meter time constant in demand metering.

DNP (Distributed Network Protocol)
Manufacturer-developed, hardware-independent communications protocol.

Dropout Time
The time measured from the removal of an input signal until the output signal deasserts. You can set the time, in the case of a logic variable timer, or the dropout time can be a result of the characteristics of an element algorithm, as in the case of an overcurrent element dropout time.

DTE Devices
Data terminal equipment (computers, terminals, printers, relays, etc.).

DTT (Direct Transfer Trip)
A communications-assisted tripping scheme. A relay at one end of a line sends a tripping signal to the relay at the opposite end of the line.

Dumb Terminal
See ASCII terminal.

DUTT (Direct Underreaching Transfer Trip)
A communications-assisted tripping scheme. Detection of a Zone 1 fault at either end of a line causes tripping of the local circuit breaker as well as simultaneous transmission of a tripping signal to the relay at the opposite end of the line. The scheme is said to be underreaching because the Zone 1 relays at both ends of the line reach only 80 percent (typically) of the entire line length.

Dynamic Zone Selection
The process by which the currents from the CTs are assigned to or removed from the differential calculations as a function of the Boolean value (logical 0 or logical 1) of a particular SELOGIC equation.

ECB (EtherCAT Communications Board)
A circuit board mounted within the relay that has eight EtherCAT fiber connections for creating a TiDL (EtherCAT) system.

Echo
The action of a local relay returning (echoing) the remote terminal permissive signal to the remote terminal when the local breaker is open or a weak infeed condition exists.

Echo Block Time Delay
A time delay that blocks the echo logic after dropout of local permissive elements.

Echo Duration Time Delay
A time delay that limits the duration of the echoed permissive signal.

ECTT (Echo Conversion to Trip)
An element that allows a weak terminal, after satisfaction of specific conditions, to trip by converting an echoed permissive signal to a trip signal.

EEPROM
Electrically Erasable Programmable Read-Only Memory. Nonvolatile memory where relay settings, event reports, SER records, and other nonvolatile data are stored.

EHV
Extra high voltage. Voltages greater than 230 kV.

EIA-232
Electrical definition for point-to-point serial data communications interfaces, based on the standard EIA/TIA-232. Formerly known as RS-232.

EIA-485 — Electrical standard for multidrop serial data communications interfaces, based on the standard EIA/TIA-485. Formerly known as RS-485.

Electrical Operating Time — Time between trip or close initiation and an open-phase status change.

Electromechanical Reset — Setting of the relay to match the reset characteristics of an electromechanical overcurrent relay.

End-Zone Fault — A fault at the farthest end of a zone that a relay is required to protect.

Energy Metering — Energy metering provides a look at imported power, exported power, and net usage over time; measured in MWh (megawatt-hours).

Equalize Mode — A procedure where substation batteries are overcharged intentionally for a preselected time to bring all cells to a uniform output.

ESD (Electrostatic Discharge) — The sudden transfer of charge between objects at different potentials caused by direct contact or induced by an electrostatic field.

EtherCAT (Ethernet for Control Automation Technology) — An Ethernet-based network protocol for high-speed control networks that require real-time performance and ease of network configuration.

Ethernet — A network physical and data link layer defined by IEEE 802.2 and IEEE 802.3.

Event History — A quick look at recent relay activity that includes a standard report header; event number, date, time, and type; fault location; maximum fault phase current; active group at the trigger instant; and targets.

Event Report — A text-based collection of data stored by the relay in response to a triggering condition, such as a fault or ASCII TRI command. The data show relay measurements before and after the trigger, in addition to the states of protection elements, relay inputs, and relay outputs each processing interval. After an electrical system fault, use event reports to analyze relay and system performance.

Event Summary — A shortened version of stored event reports. An event summary includes items such as event date and time, event type, fault location, time source, recloser shot counter, pre-fault and fault voltages, currents, and sequence current, and MIRRORED BITS communications channel status (if enabled).

The relay sends an event report summary (if automessaging is enabled) to the relay serial port a few seconds after an event.

External Fuse — Fuse external to a capacitor unit (usually mounted on the unit).

EXP Operator — Math SELOGIC control equation operator that provides exponentiation.

F_TRIG — Falling-edge trigger. Boolean SELOGIC control equation operator that triggers an operation upon logic detection of a falling edge.

Fail-Safe — Refers to an output that is open during normal relay operation and closed when relay power is removed or if the relay fails. Configure alarm outputs for fail-safe operation.

Falling Edge — Transition from logical 1 to logical 0.

Fast Hybrid Control Output — A control output similar to, but faster than, the hybrid control output. The fast hybrid output uses an insulated-gate bipolar junction transistor (IGBT) to interrupt (break) high inductive dc currents and to very rapidly make and hold the current until a metallic contact operates, at which time the IGBT turns off and the metallic contact holds the current. Unlike the hybrid control output, this output is not polarity-sensitive—reversed polarity causes no misoperations.

Fast Meter SEL binary serial port command used to collect metering data with SEL relays.

Fast Operate SEL binary serial port command used to perform control with SEL relays.

Fast Message SEL binary serial port protocol used for Fast SER, Fast Message Synchrophasors, and resistance temperature detector (RTD) communications.

Fault Detection Logic Logic that distinguishes between internal and external faults.

Fault-Type Identification Selection Logic the relay uses to identify balanced and unbalanced faults (FIDS).

FID Relay firmware identification string. Lists the relay model, firmware version and date code, and other information that uniquely identifies the firmware installed in a particular relay.

Firmware The nonvolatile program stored in the relay that defines relay operation.

Flash Memory A type of nonvolatile relay memory used for storing large blocks of nonvolatile data.

Flashover A disruptive discharge over the surface of a solid dielectric in a gas or liquid.

Float High The highest charging voltage supplied by a battery charger.

Float Low The lowest charging voltage supplied by a battery charger.

Free-Form Logic Custom logic creation and execution order.

Free-Form SELogic Control Equations Free-form relay programming that includes mathematical operations, custom logic execution order, extended relay customization, and automated operation.

FTP File Transfer Protocol.

Function In IEC 61850, task(s) performed by the substation automation system, i.e., by application functions. Generally, functions exchange data with other functions. Details are dependent on the functions involved.

Functions are performed by IEDs (physical devices). A function may be split into parts residing in different IEDs but communicating with each other (distributed function) and with parts of other functions. These communicating parts are called logical nodes.

Function Code A code that defines how you manipulate an object in DNP3 protocol.

Functional Component Portion of a UCA GOMSFE brick dedicated to a particular function including status, control, and descriptive tags.

Fundamental Frequency The component of the measured electrical signal with a frequency equal to the normal electrical system frequency, usually 50 Hz or 60 Hz. Generally used to differentiate between the normal system frequency and any harmonic frequencies present.

Fundamental Power Power calculated with components of the measured electrical signal with a frequency equal to the normal electrical system frequency, usually 50 Hz or 60 Hz.

Fuse Device that opens the circuit in which it is connected to provide overcurrent protection.

Fuseless Capacitor Bank A capacitor bank without internal or external fuses.

Global Settings General settings including those for relay and station identifiers, number of breakers, date format, phase rotation, nominal system frequency, enables, station dc monitoring, control inputs, settings group selection, data reset controls, frequency tracking, time and date management, and current and voltage source selection.

GOMSFE Generic Object Model for Substation and Feeder Equipment; a system for presenting and exchanging IED data.

GOOSE IEC 61850 Generic Object Oriented Substation Event. GOOSE objects can quickly and conveniently transfer status, controls, and measured values among peers on an IEC 61850 network.

GPS Global Positioning System. Source of position and high-accuracy time information.

Ground Directional Element Priority The order the relay uses to select directional elements to provide ground directional decisions (relay setting ORDER).

Ground Distance Element A mho or quadrilateral distance element the relay uses to detect faults involving ground along a transmission line.

Ground Fault Loop Impedance The impedance in a fault-caused electric circuit connecting two or more points through ground conduction paths.

Ground Overcurrent Elements Elements that operate by comparing a residual-ground calculation of the three-phase inputs with the residual overcurrent threshold setting. The relay asserts ground overcurrent elements when a relay residual current calculation exceeds ground current setting thresholds.

Ground Quadrilateral Distance Protection Ground distance protection consisting of a four-sided characteristic on an R-X diagram.

Ground Return Resistance Fault resistance that can consist of ground path resistance typically in tower footing resistance and tree resistance.

Grounded Capacitor Bank Capacitor bank with a solid connection to ground.

Guard-Present Delay A timer that determines the minimum time before the relay reinstates permissive tripping following a loss-of-channel condition in the DCUB communications-assisted tripping scheme (relay setting GARD1D).

GUI Graphical user interface.

Harmonics Frequencies that are multiples of the frequency of the power system; 100 Hz is the second harmonic of a 50 Hz power system.

Harmonic Restraint Method by which harmonics are used to desensitize differential elements, thereby avoiding misoperations during inrush conditions.

Harmonic Blocking Method by which harmonics are used to block differential elements thereby avoiding misoperations during inrush conditions.

Hexadecimal Address A register address consisting of a numeral with an “h” suffix or a “0x” prefix.

High-Resolution Data Capture Reporting of 3 kHz low-pass analog filtered data from the power system at each event trigger or trip at high-sample rates of 8000 samples/second, 4000 samples/second, 2000 samples/second, and 1000 samples/second.

High-Speed, High-Current Interrupting Control Output A control output similar to, but faster than, the hybrid control output. The high-speed, high-current interrupting output uses an insulated-gate bipolar junction transistor (IGBT) to interrupt (break) high inductive dc currents and to very rapidly make and hold the current until a metallic contact operates, at which time the IGBT turns off and the metallic contact holds the current. Unlike the hybrid control output, this output is not polarity-sensitive—reversed polarity causes no misoperations.

HMI Human-machine interface.

Homogeneous System A power system with nearly the same angle (less than $\angle 5°$ difference) for the impedance angles of the local source, the protected line, and the remote source.

HSR High-Availability Seamless Redundancy Protocol, as defined in IEC 62439-3 for network redundancy and seamless failover.

HV High voltage. System voltage greater than or equal to 100 kV and less than 230 kV.

Hybrid Control Output Contacts that use an insulated-gate bipolar junction transistor (IGBT) in parallel with a mechanical contact to interrupt (break) high inductive dc currents. The contacts can carry continuous current, while eliminating the need for heat sinking and providing security against voltage transients. These contacts are polarity-dependent and cannot be used to switch ac control signals.

IA, IB, IC Measured A-Phase, B-Phase, and C-Phase currents.

ICD File IEC 61850 IED Capability Description file. XML file that describes IED capabilities, including information on logical node and GOOSE support.

IEC 61850 Internationally standardized method of communications and integration conceived with the goal of supporting systems of multivendor IEDs networked together to perform protection, monitoring, automation, metering, and control.

IEC 61850-9-2 IEC 61850 standard that defines mapping of Sampled Values data onto ISO 8802-3.

IED Intelligent electronic device.

IEEE Institute of Electrical and Electronics Engineers, Inc.

IG Residual current, calculated from the sum of the phase currents. In normal, balanced operation, this current is very small or zero.

IGBT Insulated-gate bipolar junction transistor.

Inboard CT (bushing CT) Current transformer physically positioned in such a way that the CT is bypassed when the feeder is on transfer.

Independent Zone Timing The provision of separate zone timers for phase and ground distance elements.

Infinite Bus A constant-voltage bus.

Input Conditioning The establishment of debounce time and assertion level.

Instance A subdivision of a relay settings class. Group settings have several subdivisions (Group 1–Group 6), while the Global settings class has one instance.

Instantaneous Meter Type of meter data presented by the relay that includes the present values measured at the relay ac inputs. The word "Instantaneous" is used to differentiate these values from the measurements presented by the demand, thermal, energy, and other meter types.

Internal Fuse Fuse inside a capacitor unit.

IP Address An identifier for a computer or device on a TCP/IP network. Networks using the TCP/IP protocol route messages based on the IP address of the destination. The format of an IP address is a 32-bit numeric address written as four numbers separated by periods. Each number can be zero to 255. For example, 1.160.10.240 could be an IP address.

IRIG-B A time-code input that the relay can use to set the internal relay clock.

ISO 8802-3 Defines Ethernet for local area and metropolitan area networks.

Jitter Time, amplitude, frequency, or phase-related abrupt, spurious variations in duration, magnitude, or frequency.

L/R Circuit inductive/resistive ratio.

LAN Local Area Network. A network of IEDs interconnected in a relatively small area, such as a room, building, or group of buildings.

Latch Bits Nonvolatile storage locations for binary information.

LED Light-emitting diode. Used as indicators on the relay front panel.

Left-Side Value LVALUE. Result storage location of a SELOGIC control equation.

Line Impedance The phasor sum of resistance and reactance in the form of positive-sequence, negative-sequence, and zero-sequence impedances of the protected line.

LMD SEL distributed port switch protocol.

LN Operator Math SELOGIC control equation operator that provides natural logarithm.

Load Encroachment The load-encroachment feature allows setting of phase overcurrent elements and phase distance elements independent of load levels.

Local Bits The Relay Word bit outputs of local control switches that you access through the front panel of the relay. Local control switches replace traditional panel-mounted control switches.

Lockout Relay An auxiliary relay that prevents operation of associated devices until it is reset either electrically or by hand.

Logical 0 A false logic condition, dropped out element, or deasserted control input or control output.

Logical 1 A true logic condition, picked up element, or asserted control input or control output.

Logical Node In IEC 61850, the smallest part of a function that exchanges data. A logical node (LN) is an object defined by its data and methods. Each logical node represents a group of data (controls, status, measurements, etc.) associated with a particular function.

Loss of Channel Loss of guard and no permissive signal from communications gear in a DCUB (directional comparison unblocking scheme) for either two or three terminal lines.

Loss of Guard No guard signal from communications gear.

Loss of Potential Loss of one or more phase voltage inputs to the relay secondary inputs.

Low-Level Test Interface An interface that provides a means for interrupting the connection between the relay input transformers and the input processing module and allows inserting reduced-scale test quantities for relay testing.

MAC Address The Media Access Control (hardware) address of a device connected to a shared network medium, most often used with Ethernet networks.

Maintenance Testing Testing that confirms that the relay is measuring ac quantities accurately and verifies correct functioning of auxiliary equipment, scheme logic, and protection elements.

Math Operations Calculations for automation or extended protection functions.

Math Operators Operators that you use in the construction of math SELOGIC control equations to manipulate numerical values and provide a numerical base-10 result.

Maximum Dropout Time The maximum time interval following a change of input conditions between the deassertion of the input and the deassertion of the output.

Maximum/Minimum Meter Type of meter data presented by the relay that includes a record of the maximum and minimum of each value, along with the date and time that each maximum and minimum occurred.

Mechanical Operating Time Time between trip initiation or close initiation and the change in status of an associated circuit breaker auxiliary 52A normally open contacts.

Merging Unit A device that converts analog signals to digital signals and transmits them as IEC 61850-9-2 data.

Mho Characteristic A directional distance relay characteristic that plots a circle for the basic relay operation characteristic on an R-X diagram.

MIRRORED BITS Communications Patented relay-to-relay communications technique that sends internal logic status, encoded in a digital message, from one relay to the other. Eliminates the need for some communications hardware.

MMS Manufacturing messaging specification, a data exchange protocol used by UCA.

MOD Motor-operated disconnect.

Model Model of device (or component of a device) including the data, control access, and other features in UCA protocol.

Motor Running Time The circuit breaker motor running time. Depending on your particular circuit breaker, you can use the motor running time to monitor the charge time of the circuit breaker springs or the running time of the compressor motor.

MOV Metal-oxide varistor.

MVA Mega Volt-Ampere. Typical unit for expressing the capacity of a power transformer, e.g., 100MVA.

Negation Operator A SELOGIC control equation math operator that changes the sign of the argument. The argument of the negation operation is multiplied by –1.

Negative-Sequence A configuration of three-phase currents and voltages. The currents and voltages have equal magnitude and a phase displacement of 120°, and have clockwise phase rotation with current and voltage maxima that occur differently from that for positive-sequence configuration. If positive-sequence maxima occur as ABC, negative-sequence maxima occur as ACB.

Negative-Sequence Current Supervision Pickup An element allowed to operate only when a negative-sequence current exceeds a threshold.

Negative-Sequence Directional Element An element that provides directivity by the sign, plus or minus, of the measured negative-sequence impedance.

Negative-Sequence Impedance Impedance of a device or circuit that results in current flow with a balanced negative-sequence set of voltage sources.

Negative-Sequence Overcurrent Elements Elements that operate by comparing a negative-sequence calculation of the three-phase secondary inputs with negative-sequence overcurrent setting thresholds. The relay asserts these elements when a relay negative-sequence calculation exceeds negative-sequence current setting thresholds.

Negative-Sequence Voltage-Polarized Directional Element These directional elements are 32QG and 32Q. 32QG supervises the ground distance elements and residual directional-overcurrent elements; 32Q supervises the phase distance elements.

NEMA National Electrical Manufacturers' Association.

Neutral Impedance An impedance from neutral to ground on a device such as a generator or transformer.

No Current/Residual Current Circuit Breaker Failure Protection Logic Logic for detecting and initiating circuit breaker failure protection with a logic transition, or when a weak source drives the fault or a high-resistance ground fault occurs.

Nondirectional Start A blocking signal provided by nondirectional-overcurrent elements to a remote terminal used in DCB communications-assisted tripping schemes. The nondirectional start elements start sending the block signal.

Nonhomogeneous System A power system with a large angle difference (>5° difference) for the impedance angles of the local source, the protected line, and the remote source.

Nonvolatile Memory Relay memory that persists over time to maintain the contained data even when the relay is de-energized.

NOT Operator A logical operator that produces the inverse value.

Operate Current Differential current (vector sum) between current(s) that enter a point, and current(s) that leave that point.

OR Operator Logical OR. A Boolean SELOGIC control equation operator that compares two Boolean values and yields either a logical 1 if either compared Boolean value is logical 1 or a logical 0 if both compared Boolean values are logical 0.

OSI Open Systems Interconnect. A model for describing communications protocols. Also an ISO suite of protocols designed to this model.

Out-of-Step Blocking Blocks the operation of phase distance elements during power swings.

Out-of-Step Tripping Trips the circuit breaker(s) during power swings.

Outboard CT Current transformer physically positioned in such a way that the CT remains in circuit when the feeder is on transfer.

Over/Underpower Elements Elements that calculate the forward and reverse power flow and compare the result against settable thresholds.

Over/Undervoltage Elements Elements that calculate the system voltage and compare the result against settable thresholds.

Over/Underfrequency Elements Elements that calculate the power system frequency and compare the result against settable thresholds.

Overlap Configuration Configuration of the tie-breaker protection whereby the area between the tie-breaker CTs are part of two bus-zones, i.e., a fault between the tie-breaker CTs is common to two bus-zones.

Override Values Test values you enter in Fast Meter, DNP3, and communications card database storage.

Parentheses Operator Math operator. Use paired parentheses to control the execution of operations in a SELOGIC control equation.

PC Personal computer.

Peak Demand Metering Maximum demand and a time stamp for phase currents, negative-sequence and zero-sequence currents, and powers. The relay stores peak demand values and the date and time these occurred to nonvolatile storage once per day, overwriting the previously stored value if the new value is larger. Should the relay lose control power, the relay restores the peak demand information saved at 23:50 hours on the previous day.

Phase Distance Element A mho distance element the relay uses to detect phase-to-phase and three-phase faults at a set reach along a transmission line.

Phase Overcurrent Element Elements that operate by comparing the phase current applied to the secondary current inputs with the phase overcurrent setting. The relay asserts these elements when any combination of the phase currents exceeds phase current setting thresholds.

Phase Rotation The sequence of voltage or current phasors in a multiphase electrical system. In an ABC phase rotation system, the B-Phase voltage lags the A-Phase voltage by 120°, and the C-Phase voltage lags B-Phase voltage by 120°. In an ACB phase rotation system, the C-Phase voltage lags the A-Phase voltage by 120°, and the B-Phase voltage lags the C-Phase voltage by 120°.

Phase Selection Ability of the relay to determine the faulted phase or phases.

Pickup Time The time measured from the application of an input signal until the output signal asserts. You can set the time, as in the case of a logic variable timer, or the pickup time can be a result of the characteristics of an element algorithm, as in the case of an overcurrent element pickup time.

Pinout The definition or assignment of each electrical connection at an interface. Typically refers to a cable, connector, or jumper.

PMU Phasor measurement unit. A device that measures and publishes synchrophasor data.

Polarizing Memory A circuit that provides a polarizing source for a period after the polarizing quantity has changed or gone to zero.

Pole Discrepancy A difference in the open/closed status of circuit breaker poles. The relay continuously monitors the status of each circuit breaker pole to detect open or close conditions among the three poles.

Pole-Open Logic Logic that determines the conditions that the relay uses to indicate an open circuit breaker pole.

Pole Scatter Deviation in operating time between pairs of circuit breaker poles.

Port Settings Communications port settings such as Data Bits, Speed, and Stop Bits.

Positive-Sequence A configuration of three-phase currents and voltages. The currents and voltages have equal magnitude and a phase displacement of 120°. With conventional rotation in the counter-clockwise direction, the positive-sequence current and voltage maxima occur in ABC order.

Positive-Sequence Current Restraint Factor, a2 This factor compensates for highly unbalanced systems with many untransposed lines and helps prevent misoperation during CT saturation. The a2 factor is the ratio of the magnitude of negative-sequence current to the magnitude of positive-sequence current (I2/I1).

Positive-Sequence Current Supervision Pickup An element that operates only when a positive-sequence current exceeds a threshold.

Positive-Sequence Impedance Impedance of a device or circuit that results in current flow with a balanced positive-sequence set of voltage sources.

POTT (Permissive Overreaching Transfer Trip) A communications-assisted line protection scheme. At least two overreaching protective relays must receive a permissive signal from the other terminal(s) before all relays trip and isolate the protected line.

Power Factor The cosine of the angle by which phase current lags or leads phase voltage in an ac electrical circuit. Power factor equals 1.0 for power flowing to a pure resistive load.

PPS Pulse per second from a GPS receiver. Previous relays had a TIME 1k PPS input.

Primitive Name The predefined name of a quantity within the relay.

Process Bus Network bus for IED communication at the bay level.

Protection and Automation Separation Segregation of protection and automation processing and settings.

Protection Settings Group Individual scheme settings for as many as six different schemes (or instances).

Protection-Disabled State Suspension of relay protection element and trip/close logic processing and de-energization of all control outputs.

Protection Zone (also see Bus-Zone) Area of protection formed by a minimum of one bus-zone. A protection zone can include more than one bus-zone. For example, merging two bus-zones results in a single protection zone. When no bus-zones are merged, a protection zone and a bus-zone have the same meanings.

PRP Parallel Redundancy Protocol, as defined in IEC 62439-3 for network redundancy and seamless failover.

PT Potential transformer. Also referred to as a voltage transformer or VT.

PTP Precision Time Protocol, as defined in IEEE 1588 for high-accuracy clock synchronization.

PTR Potential transformer ratio.

Quadrilateral Characteristic A distance relay characteristic on an R-X diagram consisting of a directional measurement, reactance measurement, and two resistive measurements.

Qualifier Code Specifies type of range for DNP3 objects. With the help of qualifier codes, DNP3 master devices can compose the shortest, most concise messages.

R_TRIG Rising-edge trigger. Boolean SELOGIC control equation operator that triggers an operation upon logic detection of a rising edge.

RAM Random Access Memory. Volatile memory where the relay stores intermediate calculation results, Relay Word bits, and other data.

Reactance Reach The reach of a distance element in the reactive (X) direction in the R-X plane.

Real Power Power that produces actual work. The portion of apparent power that is real, not imaginary.

Reclose The act of automatically closing breaker contacts after a protective relay trip has opened the circuit breaker contacts and interrupted current through the breaker.

Relay Word Bit A single relay element or logic result. A Relay Word bit can equal either logical 1 or logical 0. Logical 1 represents a true logic condition, picked up element, or asserted control input or control output. Logical 0 represents a false logic condition, dropped out element, or deasserted control input or control output. Use Relay Word bits in SELOGIC control equations.

Remapping The process of selecting data from the default map and configuring new indices to form a smaller data set optimized to your application.

Remote Bit A Relay Word bit with a state that is controlled by serial port commands, including the **CONTROL** command, a binary Fast Operate command, DNP3 binary output operation, or a UCA control operation.

Report Settings Event report and Sequential Events Recorder (SER) settings.

Residual Current The sum of the measured phase currents. In normal, balanced operation, this current is very small or zero.

Residual Directional Overcurrent Element A residual overcurrent element allowed to operate in only the forward or reverse direction.

Residual Overcurrent Protection Overcurrent protection that operates at conditions exceeding a threshold of system unbalance ($3I_0 = I_A + I_B + I_C$).

Resistance Blinder An operate boundary in the resistive direction of a ground quadrilateral distance element.

Resistive Reach The reach of a distance element in the resistive (R) direction in the R-X plane.

Restraint Current Sum of the absolute values of current(s) entering a point, and leaving that point. Used as basis to calculate the reference (setting) value for differential elements.

Restricted Earth Fault Differential element that augments the phase differential element by providing sensitive protection against ground faults close to the neutral of a grounded-wye transformer. The element compares the phase angle of zero-sequence quantities from the transformer neutral with zero-sequence quantities from as many as five line CTs.

Retrip A subsequent act of attempting to open the contacts of a circuit breaker after the failure of an initial attempt to open these contacts.

Reverse Fault A fault operation behind a relay terminal.

Rising Edge Transition from logical 0 to logical 1, or the beginning of an operation.

RMS Root-mean-square. This is the effective value of the current and voltage measured by the relay, accounting for the fundamental frequency and higher-order harmonics in the signal.

Rolling Demand A sliding time-window arithmetic average in demand metering.

RTC Real-Time Control. A method for exchanging synchrophasor control data.

RTD Resistance Temperature Detector.

RTU Remote Terminal Unit.

RXD Received data.

SCADA Supervisory control and data acquisition.

SCD File IEC 61850 Substation Configuration Description file. XML file that contains information on all IEDs within a substation, communications configuration data, and a substation description.

SCL IEC 61850 Substation Configuration Language. An XML-based configuration language that supports the exchange of database configuration data among different software tools that can be from different manufacturers. There are four types of SCL files used within IEC 61850: CID, ICD, SCD, and SSD.

SDN Software-defined networking.

SEL-TMU A merging unit used in TiDL (T-Protocol) systems.

Selective Protection Disabling A feature that allows for selectively disabling protection elements that are impacted by a loss of DSS data and allow non-impacted protection functions to remain operational.

Self-Description A feature of GOMSFE in the UCA2 protocol. A master device can request a description of all of the GOMSFE models and data within the IED.

Self-Test A function that verifies the correct operation of a critical device subsystem and indicates detection of an out-of-tolerance condition. The relay has self-tests that validate the relay power supply, microprocessor, memory, and other critical systems.

SELOGIC Control Equation A relay setting that allows you to control a relay function (such as a control output) using a logical combination of relay element outputs and fixed logic outputs.

SELOGIC Expression Builder A rules-based editor within the QuickSet software program for programming SELOGIC control equations.

SELOGIC Math Variables Math calculation result storage locations.

Sequencing Timers Timers designed for sequencing automated operations.

Sequential Events Recorder A relay function that stores a record of the date and time of each assertion and deassertion of every Relay Word bit in a list that you set in the relay. A Sequential Events Recorder (SER) provides a useful way to determine the order and timing of events of a relay operation.

SER Sequential Events Recorder or the relay serial port command to request a report of the latest 1000 sequential events.

Series-Compensated Line A power line on which the addition of series capacitance compensates for excessive inductive line impedance.

Settle/Settling Time Time required for an input signal to result in an unvarying output signal within a specified range.

SFP Small form-factor pluggable transceiver module.

Shot Counter A counter that records the number of times a recloser attempts to close a circuit breaker.

Shunt Admittance The admittance resulting from the presence of a device in parallel across other devices or apparatus that diverts some current away from these devices or apparatus.

Shunt Capacitance The capacitance between a network connection and any existing ground.

Shunt Current The current that a parallel-connected high-resistance or high-impedance device diverts away from devices or apparatus.

SIN Operator Operator in math SELOGIC control equations that provides the sine function.

Single-CT Application Tie breaker with only one CT available for busbar protection.

Single-Pole Trip A circuit breaker trip operation that occurs when one pole of the three poles of a circuit breaker opens independently of the other poles.

Single Relay Application (Bus Protection) Stations with as many as 21 per-phase CTs require only one SEL-487B. Stations with more than 21 and as many as 54 per-phase CTs require three SEL-487B relays.

SIR Source-to-line impedance ratio.

SNTP Simple Network Time Protocol. A network protocol for time synchronization.

SOTF (Switch-Onto-Fault Protection Logic) Logic that provides tripping if a circuit breaker closes into a zero-voltage bolted fault, such as would happen if protective grounds remained on the line following maintenance.

Source Impedance The impedance of an energy source at the input terminals of a device or network.

SQRT Operator Math SELOGIC control equation operator that provides square root.

SSD File IEC 61850 System Specification Description file. XML file that describes the single-line diagram of the substation and the required logical nodes.

Stable Power Swing A change in the electrical angle between power systems. A control action can return the angular separation between systems to less than the critical angle.

Station Bus Network bus for IED communication between the bay and station levels.

Status Failure A severe out-of-tolerance internal operating condition. The relay issues a status failure message and enters a protection-disabled state.

Status Warning Out-of-tolerance internal operating conditions that do not compromise relay protection, yet are beyond expected limits. The relay issues a status warning message and continues to operate.

Strong Password A mix of valid password characters in a six-character combination that does not spell common words in any portion of the password. Valid password characters are numbers, upper- and lowercase alphabetic characters, "." (period), and "-" (hyphen).

Subnet Mask The subnet mask divides the local node IP address into two parts, a network number and a node address on that network. A subnet mask is four bytes of information and is expressed in the same format as an IP address.

Subsidence Current See CT subsidence current.

SV Sampled Values, as defined in Part 9-2 of IEC 61850.

SV Channel A single-phase voltage or current transmitted as an integer value containing its magnitude and phase angle.

SV Stream Multicast packets containing a fixed data set transmitted periodically. In the case of 9-2LE, SV streams contain four currents and four voltages and are transmitted at a rate of 80 samples per cycle.

Synch Reference A phasor the relay uses as a polarizing quantity for synchronism-check calculations.

Synchronism-Check Verification by the relay that system components operate within a preset frequency difference and within a preset phase angle displacement between voltages.

Synchronized Phasor A phasor calculated from data samples using an absolute time signal as the reference for the sampling process. The phasors from remote sites have a defined common phase relationship. Also known as Synchrophasor.

TAP Full-load secondary current that the relay uses to convert ampere values to dimensionless per-unit values.

TAP Tappings on some power transformer windings, used for voltage/reactive power flow control.

TAP (Point) Point in each phase that divides the capacitor bank into two parts.

TCB A circuit board mounted within the relay that has eight T-Protocol fiber-optic connections for creating a TiDL system.

Telnet An IP for exchanging terminal data that connects a computer to a network server and allows control of that server and communication with other servers on the network.

Terminal-to-Bus-Zone Connection Variable SELOGIC variable stating the conditions when the relay considers the current input from a particular terminal in the differential calculations of a particular bus-zone.

Terminal Emulation Software Software that can be used to send and receive ASCII text messages and files via a computer serial port.

Thermal Demand Thermal demand is a continuous exponentially increasing or decreasing accumulation of metered quantities (used in demand metering).

Thermal Withstand Capability The capability of equipment to withstand a predetermined temperature value for a specified time.

Three-Phase Fault A fault involving all three phases of a three-phase power system.

Three-Pole Trip A circuit breaker operation that occurs when the circuit breaker opens all three poles at the same time.

Three-Relay Application Stations with more than 21 and as many as 54 per-phase CTs require three SEL-487B relays. Stations with as many as 21 per-phase CTs require only one SEL-487B.

Tie Breaker See Bus Coupler and Bus Sectionalizer.

Time Delay on Pickup The time interval between initiation of a signal at one point and detection of the same signal at another point.

Time Dial A control that governs the time scale of the time-overcurrent characteristic of a relay. Use the time-dial setting to vary relay operating time.

Time-Delayed Tripping Tripping that occurs after expiration of a predetermined time.

Time-Domain Link (TiDL) A technology that uses TiDL merging units to provide CT and PT inputs that are communicated to the relay by using direct fiber-optic connections.

Time Error A measurement of how much time an ac powered clock would be ahead or behind a reference clock, as determined from system frequency measurements.

Time-Overcurrent Element An element that operates according to an inverse relationship between input current and time, with higher current causing faster relay operation.

Time Quality An indication from a GPS clock receiver that specifies the maximum error in the time information. Defined in IEEE C37.118.

Torque Control A method of using one relay element to supervise the operation of another.

Total Clearing Time The time interval from the beginning of a fault condition to final interruption of the circuit.

Tower Footing Resistance The resistance between true ground and the grounding system of a tower.

Transformer Impedance The resistive and reactive parameters of a transformer looking in to the transformer primary or secondary windings. Use industry accepted open-circuit and short-circuit tests to determine these transformer equivalent circuit parameters.

Tree Resistance Resistance resulting from a tree in contact with a power line.

TVE Total Vector Error. A measurement of accuracy for phasor quantities that combines magnitude and angle errors into one quantity. Defined in IEEE C37.118.

TXD Transmitted data.

UCA2 Utility Communications Architecture. A network-independent protocol suite that serves as an interface for individual IEDs.

UCA 61850-9-2LE Guideline for implementation of IEC 61850-9-2 created by the UCAIug to facilitate interoperability. The guideline can be considered a subset, or profile, of the IEC 61850-9-2 standard, which defines requirements for certain parts of the standard, including data mode implementation, data set descriptions, time synchronization, transfer rates, and sampling rates. Also referred to as 9-2LE.

UCAIug Utility Communications Architecture International Users Group.

Unbalanced Current Element Element that calculates the percentage difference between the three phase currents.

Unbalanced Fault All faults that do not include all three phases of a system.

Unbuffered Report IEC 61850 IEDs can issue immediate unbuffered reports of internal events (caused by trigger options data-change, quality-change, and data-update) on a "best efforts" basis. If no association exists, or if the transport data flow is not fast enough to support it, events may be lost.

Unconditional Tripping Protection element tripping that occurs apart from conditions such as those involving communication, switch-onto-fault logic, etc.

Ungrounded Capacitor Bank Capacitor bank with no intentional connection to ground. (A bank with a PT connected between the bank's neutral point and ground is considered ungrounded.)

Unstable Power Swing A change in the electrical angle between power systems for which a control action cannot return the angular separation between systems to an angle less than the critical angle.

Untransposed Line A transmission line with phase conductors that are not regularly transposed. The result is an unbalance in the mutual impedances between phases.

User ST Region in GOOSE for user-specified applications.

VA, VB, VC Measured A-Phase-to-neutral, B-Phase-to-neutral, and C-Phase-to-neutral voltages.

VAB, VBC, VCA Measured or calculated phase-to-phase voltages.

VG Residual voltage calculated from the sum of the three phase-to-neutral voltages, if connected.

Virtual Terminal Connection A mechanism that uses a virtual serial port to provide the equivalent functions of a dedicated serial port and a terminal.

Volatile Storage A storage device that cannot retain data following removal of relay power.

Voltage Compensation Adjustment of the voltage signals to nullify any standing unbalance voltage.

VT Voltage transformer. Also referred to as a potential transformer or PT.

Warm Start The reset of a running system without removing and restoring power.

Weak Infeed Logic Logic that permits rapid tripping for internal faults when a line terminal has insufficient fault current to operate protective elements.

Winding Transformer winding, synonymous with "terminal."

Wye A phase-to-neutral connection of circuit elements, particularly voltage transformers or loads. To form a wye connection using transformers, connect the nonpolarity side of each of three voltage transformer secondaries in common (the neutral), and take phase-to-neutral voltages from each of the remaining three leads. When properly phased, these leads represent the A-Phase-, B-Phase-, and C-Phase-to-neutral voltages. This connection is frequently called 'four-wire wye,' alluding to the three phase leads plus the neutral lead.

XML Extensible Markup Language. This specification developed by the W3C (World Wide Web Consortium) is a pared-down version of SGML designed especially for web documents. It allows designers to create their own customized tags, enabling the definition, transmission, validation, and interpretation of data among applications and organizations.

Zero-Sequence A configuration of three-phase currents and voltages with currents and voltages that occur simultaneously, are always in phase, and have equal magnitude ($3I_0 = I_A + I_B + I_C$).

Zero-Sequence Compensation Factor A factor based on the zero-sequence and positive-sequence impedance of a line that modifies a ground distance element to have the same reach as a phase distance element.

Zero-Sequence Impedance Impedance of a device or circuit resulting in current flow when a single voltage source is applied to all phases.

Zero-Sequence Mutual Coupling Zero-sequence current in an unbalanced circuit in close proximity to a second circuit induces voltage into the second circuit. When not controlled by protection system design and relay settings, this situation can cause improper operation of relays in both systems.

Zero-Sequence Overcurrent Element Overcurrent protection that operates at conditions exceeding a threshold of system unbalance.

Zero-Sequence Voltage-Polarized Directional Element
An element that provides directionality by the sign, plus or minus, of the measured zero-sequence impedance.

Z-Number
That portion of the relay FID string that identifies the proper QuickSet software relay driver version and HMI driver version when creating or editing relay settings files.

Zone Time Delay
Time delay associated with the forward or reverse step distance and zone protection.