SEL-487B-1

Bus Differential and Breaker Failure Relay

Instruction Manual

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SEL SCHWEITZER ENGINEERING LABORATORIES

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Preface

This manual provides information and instructions for installing, setting, configuring, and operating the SEL-487B 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.

Manual Overview

The SEL-487B instruction manual set consists of two volumes:

- SEL-487B Instruction Manual
- SEL-400 Series Relays Instruction Manual

Read the sections that pertain to your application to gain valuable information about using the SEL-487B. For example, to learn about relay protection functions, read the protection sections of this manual and skim the automation sections. You can concentrate on the operation sections or on the automation sections of this manual as your job needs and responsibilities dictate. An overview of each manual section and section topics follows.

SEL-487B Instruction Manual

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

Section 1: Introduction and Specifications. Introduces SEL-487B Relay features, summarizes relay functions and applications, and 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 and how to install optional communications cards (such as the Ethernet Card).

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

Section 4: Front-Panel Operations. Describes the LCD display messages and menu screens that are unique to the SEL-487B.

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 POTT, DCB, DCUB, and DTT. Provides trip logic diagrams, and current and voltage source selection details. Also describes basic 87L communications channel options and configuration parameters.

Section 6: Protection Application Examples. Provides examples of configuring the SEL-487B for some common applications.

Section 7: Metering, Monitoring, and Reporting. Describes SEL-487B-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 ACSELERATOR QuickSet SEL-5030 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-487B 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.

Appendix B: Converting Settings From SEL-487B-0 to SEL-487B-1. Describes differences in settings, Relay Word bits, analog quantities, and DNP3 maps between these versions of the relay.

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 display 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 time keeping 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-487B 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 the 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 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	A, B, +, −, C	Input A is compared to Input B. Output C asserts if Input A is greater than Input B.
Input Flag	A	Input A comes from other logic.
OR	A, B, C	If either Input A or Input B asserts, Output C asserts.
Exclusive OR	A, B, C	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	A, B, C	If neither Input A nor Input B asserts, Output C asserts.
AND	A, B, C	If Input A and Input B assert, Output C asserts.
AND w/ Inverted Input	A, B, C	If Input A asserts and Input B deasserts, Output C asserts. Inverter "O" inverts any input or output on any gate.
NAND	A, B, C	If Input A and/or Input B deassert, Output C asserts.
Time-Delayed Pick Up and/or Time-Delayed Drop Out	A, X, Y, B	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	A, X, Y, B	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	S, Q, R	Input S asserts Output Q until Input R asserts. Output Q deasserts or resets when Input R asserts.
Falling Edge	A ⎿ B	Output B asserts at the falling edge of Input A.
Rising Edge	A ⎾ B	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®	MIRRORED BITS®
ACSELERATOR QuickSet®	SELOGIC®
Connectorized®	

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 and Specifications

The SEL-487B provides bus current differential protection, circuit breaker failure protection, and backup overcurrent protection. Equipped with four interface boards, the relay has a total of 103 inputs (74 common inputs and 29 independent inputs) and 40 outputs. It is configurable in either a three-relay or a single-relay application. The relay has 21 analog current inputs and 3 analog voltage inputs. For buses with no more than seven terminals, use one SEL-487B in a single-relay application. For buses with as many as 21 terminals, use three SEL-487B relays in a three-relay application; each relay provides as many as six dedicated zones of protection.

The SEL-487B has separate protection and automation SELOGIC control equation programming areas with extensive protection and automation programming capabilities. You can organize automation SELOGIC control equation programming into 10 blocks of 100 program lines each, for a total of 1000 lines of automation programming. Use as many as 100 lines in the separate protection programming area to program custom protection functions. With the flexibility of the expanded SELOGIC control equations, the relay is suitable for custom protection and control schemes.

Communications interfaces include standard SEL ASCII and enhanced MIRRORED BITS communications protocols. Establish Ethernet connectivity with the optional Ethernet card. With the Ethernet card, you can employ common industry communications tools, including Telnet, FTP, IEC 61850 Edition 2.1, and DNP3 LAN/WAN protocols.

Included with the SEL-487B is the ACSELERATOR QuickSet SEL-5030 Software program. Use QuickSet to assist you in setting, controlling, and acquiring data from the relays both locally and remotely. ACSELERATOR Architect SEL-5032 Software is included with purchase of the optional Ethernet card with IEC 61850 protocol support. Architect enables you to view and configure IEC 61850 settings via a graphical user interface (GUI), tightly integrated with QuickSet.

Combining the simple and robust hardware design with extensive self-testing provides relay reliability and enhances relay availability.

This section introduces the SEL-487B and provides information on the following topics:

- *Features on page 1.2*
- *Models and Options on page 1.4*
- *Applications on page 1.5*
- *Product Characteristics on page 1.8*
- *Specifications on page 1.10*

Features

The SEL-487B contains many protection, automation, and control features. *Figure 1.1* presents a simplified functional overview of the relay.

ANSI NUMBERS/ACRONYMS AND FUNCTIONS	
27/59	Over- and Undervoltage
50	Overcurrent (Phase)
50BF	Breaker Failure Overcurrent
51	Time-Overcurrent (Phase)
87	Current Differential

ADDITIONAL FUNCTIONS	
16 SEC	Access Security (Serial, Ethernet)
85 RIO	SEL MIRRORED BITS Communications
DFR	Event Reports
LGC	SELOGIC Control Equations
MET	High-Accuracy Metering
RTU	Remote Terminal Unit
SBM	Station Battery Monitor
SER	Sequential Events Recorder

ADDITIONAL FEATURES
Open CT Detection
Three Independent Check Zones
Disconnect Status and Monitoring Logic for 60 Disconnects
Single-Relay Application: 2 Three-Phase Zones for as many as 7 Terminals
Two-Relay Application: 3 Three-Phase Zones for as many as 10 Terminals
Three-Relay Application: 6 Single-Phase Zones for as many as 21 Terminals

[1] Copper or Fiber Optic * Optional Feature

Figure 1.1 SEL-487B Relay Basic Functions in a Double-Bus Application

The SEL-487B features include the following:

Bus Protection. The SEL-487B provides differential protection for the following: single bus, double bus, double bus with transfer, breaker-and-a-half, triple bus arrangements, generators and motors, shunt capacitor banks, autotransformers, and reactors.

Second Trip Criterion. Each of the six elements includes a second trip criterion. This criterion consists of the OR combination of a directional element in parallel with a fault detection element.

Check Zone Capability. If your protection philosophy calls for an overall check zone, use as many as three independent check zones available in the relay.

Voltage Elements. Phase, negative-, and/or zero-sequence elements are available as additional trip criteria for trip supervision.

Breaker Failure. Select the type of breaker failure protection (internal or external) on a terminal-by-terminal basis. Internal breaker failure protection provides breaker failure trip and breaker retrip for 21 terminals. Open-phase detection ensures current-element reset in less than one cycle. For the external breaker failure protection, select the external breaker failure option. With this option, the relay accepts inputs from breaker failure relays installed in the feeder protection panels.

Differential Protection. Innovative algorithms switch the relay to a high-security mode during through-fault conditions. While in the high-security mode, the algorithm does not block the differential elements, thus avoiding unnecessary time delays for clearing faults evolving from external to internal faults.

Overcurrent Elements. Each of the 21 terminals provides one level of phase instantaneous (50) and one level of time-overcurrent (51) protection.

CT Open-Circuit Detection. Use the independent sensitive differential element in each zone to detect CT open circuit, short circuit, or incorrect CT polarity.

Minimum CT Requirement. The relay requires primary CTs that shall reproduce the primary current without saturation for at least 2 ms after external fault inception.

Dynamic Station Configuration. Wire the disconnect (89) auxiliary contacts to the relay to assign the current inputs dynamically to the correct differential measuring element. Instead of disabling bus protection during disconnect switching, use this feature to provide bus protection during switching operations, when the safety of personnel is at high risk.

CT Ratio Mismatch. Mismatched CTs of ratios as high as 10:1 can be installed. For example, this means you can install the new feeder with a CT ratio of 2000/5 to existing bus systems that all have CT ratios of 200/5.

Expanded SELogic Control Equations. Modify and set custom relay applications with PLC-style (programmable logic controller, IEC 61131-3) SELogic control equation programming that includes math and comparison functions. Use counters and multifunction timers for greater application flexibility, i.e., perform advanced PLC functions within the relay. The SEL-487B has separate protection and automation SELogic control equation programming areas. These programming areas provide ample protection programming capability and 10 blocks of 100-line automation programming capability (1000 lines).

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 the initial programming and maintenance much easier.

Metering. View metering primary or secondary information for phase currents and angles of all 21 terminals, phase voltages and angles, CT polarities, and the operating and restraint values from all protection zones.

Oscillography and Event Reporting. Record raw currents of all 21 current terminals and 3 voltages in a single report. Investigate relay internal logic points and power system performance with event report phasor analysis.

Sequential Events Recorder (SER). Record 1000 system entries from 250 monitoring points, including settings changes, restarts, and Relay Word bit elements that you select. Set element names to easily understood aliases.

Digital Relay-to-Relay Communication. Use Mirrored Bits communications to monitor internal element conditions between relays within a substation and between substations using communication channels (SEL fiber-optic transceivers to send a direct transfer trip, for example).

Ethernet Communications Capability. Implement control and data gathering capabilities via substation LANs (local area networks) and company WANs (wide area networks) with the optional Ethernet card. Employ the FTP protocol for system data acquisition.

Increased Security. The SEL-487B divides control and settings into seven relay access levels; the relay has separate breaker, protection, automation, and output access levels, among others. Set unique passwords for each access level.

Computer Software. Use the rules-based settings editor, the QuickSet software, to develop settings offline.

Settings Reduction. Internal relay programming shows only the settings for the functions and elements you have enabled.

Models and Options

Consider the following options when ordering and configuring the SEL-487B.

- Chassis size
  - 7U and 9U (U is one rack unit—44.45 mm or 1.75 in)

The 9U chassis size supports as many as four additional expansion I/O boards. For applications not requiring as many contact I/O points, the 7U chassis size supports as many as two additional expansion I/O boards. For the three-relay application, three units are required. Features not labeled as ordering options are standard.

Table 1.1 Interface Board Information

Board Name	Inputs	Description	Outputs	Description
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
INT4	18	Two sets of 9 common optoisolated, level-sensitive	8	Standard Form A
	6	Optoisolated, independent, level-sensitive		

- Voltage ranges for the inputs on the main board as well as for the inputs on the four interface boards
  - 24 Vdc
  - 48 Vdc
  - 110 Vdc
  - 125 Vdc
  - 220 Vdc
  - 250 Vdc
- Power supply (ordering option)
  - 24–48 Vdc
  - 48–125 Vdc or 110–120 Vac
  - 125–250 Vdc or 110–240 Vac
- Secondary current inputs (ordering option)
  - 1 A nominal or 5 A nominal CT inputs
- Communications card (ordering option)
  - Ethernet card with combinations of 10/100BASE-T and 100BASE-FX media connections on each of two ports
- Secondary voltage inputs (standard feature)
  - 300 V maximum per voltage input

- Ethernet communication protocols
  - Standard (FTP, Telnet, DNP3, PRP)
  - Standard plus IEC 61850 Edition 2.1
- Connector type for PT and CT inputs
  - Screw-terminal block inputs (standard feature)
  - Connectorized (ordering option)
- 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.

Contact the SEL factory or your local Technical Service Center for particular part number and ordering information (see *Technical Support on page xxvii in the Preface*). You can also view the latest part number and ordering information on the SEL website at selinc.com.

Applications

NOTE: TiDL (EtherCAT) technology is no longer offered in the SEL-487B-1. TiDL (T-Protocol) is available in the SEL-487B-2.

Use the SEL-487B for most bus protection applications. For information on connecting the relay, see *Section 2: Installation*. See *Section 6: Protection Application Examples* for discussions of protection and automation applications using the SEL-487B. The figures in this subsection illustrate common relay applications. Each SEL-487B has 21 analog current inputs (I01–I21) and three analog voltage inputs (V01, V02, and V03).

The SEL-487B-1 Relay supports DSS through use of the SEL-2240 Axion. The Axion provides analog and digital data over an IEC 61158 EtherCAT TiDL network. This technology provides very low and deterministic latency over a point-to-point architecture. The SEL-487B-1 Relay can receive as many as eight fiber-optic links from as many as eight Axion nodes. See *Section 2: Installation* for more details about TiDL (EtherCAT) applications.

Single Busbar—As Many As 7 Terminals

Use one SEL-487B for the application in *Figure 1.2*. In this application, the relay has 2 three-phase bus-zones available. Wire the disconnect status to the relay to dynamically assign the terminal currents to the differential elements for each zone.

Figure 1.2 Single SEL-487B Protecting Double Bus Sections With Bus Tie Breaker

Breaker-and-a-Half Busbar Configuration

Figure 1.3 shows a station with a breaker-and-a-half busbar configuration. For this configuration, and with seven or fewer terminals on either busbar, use one SEL-487B per busbar.

Figure 1.3 Two Single SEL-487B Relays Protecting the Two Busbars in a Breaker-and-a-Half Busbar Configuration

Triple Busbar—As Many As 21 Terminals

Figure 1.4 shows a triple busbar layout (i.e., two main busbars and a transfer bus).

Figure 1.4 Three SEL-487B Relays Protect 2 Main Busbars and a Transfer Busbar, 1 Bus Coupler, and 17 Terminals

Table 1.2 Application Highlights (Sheet 1 of 2)

Application	Key Feature
High number of terminals and zones	Three-relay applications provide six zones of protection for as many as 21 terminals.
Complex busbar arrangements	Flexible zone selection logic uses the disconnect auxiliary contacts to dynamically assign the currents to the correct zones.
Wide range of bus applications	A variety of bus applications are available: single bus, double bus, double bus with transfer, breaker-and-a-half, triple bus arrangements.
High-speed tripping	The SEL-487B features fast differential elements and fast closing trip outputs with total tripping times of less than one cycle.
Minimum CT requirements	The differential elements are secure when the CTs reproduce the primary current without saturating for at least 2 ms after external fault inception.
Open CT detection	The open CT detection elements use delta IOP/IRT to reliably detect failed CTs within each differential zone.
Terminals with different CT ratios	The SEL-487B accepts a CT mismatch of 10:1 in any one zone or combination of zones; for example, 250/5 to 2500/5.

Table 1.2 Application Highlights (Sheet 2 of 2)

Application	Key Feature
Fast resetting internal breaker failure protection	The SEL-487B includes breaker failure protection with retrip for each terminal. Open-phase detection ensures current-element reset in less than one cycle.
External breaker failure relays	Set any terminal to "external breaker failure" to still use the trip logic in the relay, but the breaker failure initiation is from an external breaker failure relay.
Backup overcurrent protection	Each terminal has instantaneous and inverse time-overcurrent elements.
Check zone as trip criterion	Configure any of the six zones as an overall check zone or use any of the three the available independent check zones.
Voltage as trip supervision	Choose from phase, negative-, or zero-sequence voltage to supervise the differential elements.
End-zone protection	Use SELOGIC control equations to configure end-zone protection for faults between the feeder circuit breaker and the CT.
Fault between tie breaker and CT	The SEL-487B includes logic to accelerate tripping for a fault between the tie breaker and CT. Further logic ensures the security of the healthy zone when the tie breaker is closed onto a fault.
Direct transfer trip	Use MIRRORED BITS communications to send a trip to the remote end of the line.
Auxiliary relays	The SEL-487B requires no auxiliary relays for zone selection.
SCADA applications analog and digital data acquisition for station-wide functions	The SEL-487B can acquire analog and digital data for station-wide functions.
Communications capability	These protocols are included in the relay: SEL Compressed ASCII, SEL Fast Messaging (SEL Fast Meter, SEL Fast Operate, SEL Fast SER), SEL ASCII, Enhanced MIRRORED BITS communications, Ymodem File Transfer, DNP3 Serial. Additionally, you can choose these optional protocols: Ethernet, IEC 61850, FTP, Telnet, DNP3 LAN/WAN.
Customized protection and automation schemes	The SEL-487B includes separate protection and automation SELOGIC control equation programming areas. Use timers and counters in expanded SELOGIC control equations for complete flexibility.

Product Characteristics

Each SEL-400 Series Relay shares common features but has unique characteristics. *Table 1.3* summarizes the unique characteristics of the SEL-487B Relay.

Table 1.3 SEL-487B Relay Characteristics (Sheet 1 of 2)

Characteristic	Value
Standard Processing Rate	12 times per cycle
Battery Monitor	One
Autorecloser	none
MBG Protocol	Not supported
SELOGIC	
Protection Free Form	100 lines
Automation Free Form	10 blocks of 100 lines each
SELOGIC Variables	64 protection 256 automation
SELOGIC Math Variables	64 protection 256 automation

Table 1.3 SEL-487B Relay Characteristics (Sheet 2 of 2)

Characteristic	Value
Conditioning Timers	16 protection 32 automation
Sequencing Timers	32 protection 32 automation
Counters	32 protection 32 automation
Latch Bits	32 automation 32 protection
Control	
Remote Bits	96
Breakers	21: 1–21 (open control only)
Disconnects	60 (status only)
Bay Control	Not supported
Metering	
Maximum/Minimum Metering	Not supported
Energy Metering	Not supported

Additionally, the SEL-487B does not support the following typical SEL-400 Series features:

- Synchrophasors
- One-line diagrams on the front panel
- Breaker close operations
- Circuit breaker monitor
- Communications with the SEL-2600A RTD Module

Specifications

Note: TiDL (EtherCAT) technology is no longer offered in the SEL-487B-1. TiDL (T-Protocol) is available in the SEL-487B-2. If the relay is using TiDL (EtherCAT), the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay. Element operate times will also have this small added delay.

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 Current Inputs (Secondary Circuits)

Note: Current transformers are Measurement Category II.

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

1 A Nominal:	18.2 A
5 A Nominal:	91 A

Continuous Thermal Rating

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

Saturation Current (Linear) Rating

1 A Nominal:	20 A
5 A Nominal:	100 A

A/D Current Limit

Note: Signal clipping may occur beyond this limit.

1 A Nominal:	49.5 A
5 A Nominal:	247.5 A

One-Second Thermal Rating

1 A Nominal:	100 A
5 A Nominal:	500 A

One-Cycle Thermal Rating (Peak)

1 A Nominal:	250 A
5 A Nominal:	1250 A

Burden Rating

1 A Nominal:	≤0.1 VA @ 1 A
5 A Nominal:	≤0.5 VA @ 5 A

AC Voltage Inputs

Three-phase, four-wire (wye) connections are supported.

Rated Voltage Range:	55–250 V_{L-N}
Operational Voltage Range:	0–300 V_{L-N}
Ten-Second Thermal Rating:	600 Vac
Burden:	≤0.1 VA @ 125 V

Frequency and Rotation

System Frequency:	50/60 Hz
Phase Rotation:	ABC

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:	<35 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 at 48 Vdc, 160 ms at 125 Vdc per IEC 60255-26:2013
Burden:	<35 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 at 125 Vdc, 250 ms at 250 Vdc per IEC 60255-26:2013
Burden:	<35 W, <90 VA

Control Outputs

Standard

Make:	30 A
Carry:	6 A continuous carry at 70°C 4 A continuous carry at 85°C
1 s Rating:	50 A
MOV Protection (Maximum Voltage):	250 Vac, 330 Vdc
Pickup/Dropout Time:	≤6 ms, resistive load
Update Rate:	1/12 cycle

Breaking Capacity (10,000 Operations) per IEC 60255-23:1994

24 Vdc	0.75 A	L/R = 40 ms
48 Vdc	0.50 A	L/R = 40 ms
125 Vdc	0.30 A	L/R = 40 ms
250 Vdc	0.20 A	L/R = 20 ms

Cyclic Capacity (10,000 Operations) per IEC 60255-23:1994

Rate: 2.5 cycles/second for 4 seconds followed by 2 minutes idle for thermal dissipation

24 Vdc	0.75 A	L/R = 40 ms
48 Vdc	0.50 A	L/R = 40 ms
125 Vdc	0.30 A	L/R = 40 ms
250 Vdc	0.20 A	L/R = 20 ms

Hybrid (High-Current Interrupting)

Make:	30 A
Carry:	6 A continuous carry at 70°C 4 A continuous carry at 85°C
1 s Rating:	50 A
MOV Protection (Maximum Voltage):	330 Vdc
Pickup/Dropout Time:	≤6 ms, resistive load
Update Rate:	1/12 cycle

Breaking Capacity (10,000 Operations) per IEC 60255-23:1994

24 Vdc	10.0 A	L/R = 40 ms
48 Vdc	10.0 A	L/R = 40 ms
125 Vdc	10.0 A	L/R = 40 ms
250 Vdc	10.0 A	L/R = 20 ms

Cyclic Capacity (10,000 Operations) per IEC 60255-23:1994
Rate: 2.5 cycles/second for 4 seconds followed by 2 minutes idle for thermal dissipation

24 Vdc	10.0 A	L/R = 40 ms
48 Vdc	10.0 A	L/R = 40 ms
125 Vdc	10.0 A	L/R = 40 ms
250 Vdc	10.0 A	L/R = 20 ms

Note: Do not use hybrid control outputs to switch ac control signals. These outputs are polarity-dependent.

High-Speed, High-Current Interrupting

Make:	30 A
Carry:	6 A continuous carry at 70°C 4 A continuous carry at 85°C
1 s Rating:	50 A
MOV Protection (Maximum Voltage):	250 Vac/330 Vdc
Pickup Time:	≤10 µs, resistive load
Dropout Time:	≤8 ms, resistive load
Update Rate:	1/12 cycle

Breaking Capacity (10,000 Operations) per IEC 60255-23:1994

24 Vdc	10.0 A	L/R = 40 ms
48 Vdc	10.0 A	L/R = 40 ms
125 Vdc	10.0 A	L/R = 40 ms
250 Vdc	10.0 A	L/R = 20 ms

Cyclic Capacity (10,000 Operations) per IEC 60255-23:1994
Rate: 2.5 cycles/second for 4 seconds, followed by 2 minutes idle for thermal dissipation

24 Vdc	10.0 A	L/R = 40 ms
48 Vdc	10.0 A	L/R = 40 ms
125 Vdc	10.0 A	L/R = 40 ms
250 Vdc	10.0 A	L/R = 20 ms

Note: Make rating per IEEE C37.90-2005.
Note: Per IEC 61810-2:2005.
Note: Do not use hybrid control outputs to switch ac control signals.

Control Inputs

Main Board:	5 inputs with no shared terminals 2 inputs with shared terminals
INT4 Interface Board:	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
Sampling Rate:	2 kHz

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 150.3–264.0 Vac rms; Dropout <93.2 Vac rms
250 Vac:	Pickup 170.6–264.0 Vac rms; Dropout <106 Vac rms

Communications Ports

EIA-232:	1 Front and 3 Rear
Serial Data Speed:	300–57600 bps

Communications Card Slot for Optional Ethernet Card

Ordering Options:	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

Communications Ports for Optional TiDL (EtherCAT) Interface

EtherCAT Fiber-Optic Ports:	8
Data Rate:	Automatic
Connector Type:	LC fiber
Protocols:	Dedicated EtherCAT
Class 1 LASER/LED	
Wavelength:	1300 nm
Fiber Type:	Multimode
Link Budget:	11 dB
Min. TX Power:	–20 dBm
Min. RX Sensitivity:	–31 dBm
Fiber Size:	50–200 µm
Approximate Range:	2 km

Data Rate: 100 Mbps

Typical Fiber Attenuation: –2 dB/km

Time Inputs

IRIG-B Input—Serial Port 1

Input: Demodulated IRIG-B

Rated I/O Voltage: 5 Vdc

Operating 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

Operating 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—Ethernet Port 5A, 5B

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 Sync Intervals when communicating directly with master clock

IRIG Time Output

Capable of driving 300 ohm termination with <200 ns propagation delay

The IRIG time output does not support high-accuracy IRIG-B timekeeping.

Operating Temperature

–40° to +85°C (–40° to +185°F)

Note: LCD contrast impaired for temperatures below –20° and above +70°C.

Humidity

5% to 95% without condensation

Weight (Maximum)

4U Rack Unit (TiDL [EtherCAT] only): 6.4 kg (14.1 lb)

7U Rack Unit: 16.8 kg (36.9 lb)

9U Rack Unit: 20.8 kg (45.9 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 (Ethernet and IRIG-B)
Note: Cables connected to EIA-232 communications ports shall be less than 10 m in length for Zone A compliance.
Zone B:
±2 kV: communication ports (except Ethernet and IRIG-B)
Note: Cables connected to EIA-232 communications ports shall be less than 10 m in length for Zone B compliance.

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 C37.111-1999 and -2013, *IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems*.

Event Reports

Length: 0.25–24 seconds (depending on LER setting)

Resolution: 4 and 12 samples/cycle

Volatile Memory: 3 seconds of back-to-back event reports sampled at 8 kHz

Nonvolatile Memory: At least 4 event reports of a 3-second duration sampled at 8 kHz

Oscillography

Volatile Memory:	3 seconds of back-to-back event reports sampled at 8 kHz
Nonvolatile Memory:	At least 5 event reports of a 3-second duration sampled at 8 kHz

Event Summary

Storage:	100 summaries

Sequential Events Recorder

Storage:	1000 entries
Trigger Elements:	250 relay elements
Resolution:	0.5 ms for contact inputs
Resolution:	1/12 cycle for all elements

Processing Specifications

AC Voltage and Current Inputs

12 samples per cycle, 3 dB low-pass analog filter cut-off frequency of 646 Hz, ±5%

Digital Filtering

Full-cycle cosine after low-pass analog filtering

Protection and Control Processing

12 times per power system cycle

Control Points

96 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

Number of Zones:	6
Number of Check Zones:	3
Number of Terminals:	
Three-Relay Application:	21
Single-Relay Application:	7
Pickup Range:	0.10–4.00 pu
Pickup Accuracy:	1 A nominal: ±5% ± 0.02 A 5 A nominal: ±5% ± 0.10 A
Slope 1	
Setting Range:	15%–90%
Slope 2	
Setting Range:	50%–90%

Supervising Differential Element

Quantity:	9 total, 1 per zone (6 standard zones, 3 check zones)
Setting Range:	0.05–3.00 pu
Accuracy:	±5% ± 0.02 • I_{NOM}

Incremental Restraint and Operating Threshold Current Supervision

Setting Range:	0.1–10.0 pu
Accuracy:	±5% ± 0.02 • I_{NOM}

Sensitive Differential Current Alarm

Quantity:	9 total, 1 per zone (6 standard zones, 3 check zones)
Setting Range:	0.05–1.00 pu
Accuracy:	±5% ± 0.02 • I_{NOM}
Timer Setting Range:	50–6000 cycles

Instantaneous/Definite-Time Overcurrent Elements

Phase Current Setting Range	
5 A Model:	OFF, 0.25–100.00 A secondary, 0.01 A steps
1 A Model:	OFF, 0.05–20.00 A secondary, 0.01 A steps
Accuracy (Steady State)	
5 A Model:	±0.05 A, ±3% of setting
1 A Model:	±0.01 A, ±3% of setting
Transient Overreach:	<5% of setting
Timer Setting Range:	0.00–99999.00 cycles, 1/6-cycle steps
Timer Accuracy:	±0.1% of settings ±1/6 cycle
Maximum Operating Time:	1.5 cycles

Time-Overcurrent Elements

Pickup Range	
5 A Model:	0.25–16.00 A secondary, 0.01 A steps
1 A Model:	0.05–3.20 A secondary, 0.01 A steps
Accuracy (Steady State)	
5 A Model:	±0.05 A, ±3% of setting
1 A Model:	±0.01 A, ±3% of setting
Time Dial Range	
US:	0.50–15.00, 0.01 steps
IEC:	0.05–1.00, 0.01 steps
Curve Timing Accuracy:	±1.50 cycles, ±4% of curve time (for current between 2 and 30 multiples of pickup)
Reset:	1 power cycle or Electromechanical Reset Emulation time

Under- and Overvoltage Elements (27, 59)

Processing Rate:	1/6 cycle
Phase Under- and Overvoltage (2 Level/Phase)	
Setting Range:	2.00–300 V_{L-N} in 0.01 steps
Accuracy:	±3% of setting, ±0.5 V
Transient Overreach:	<5% of pickup
Maximum Delay:	1.5 cycles
Zero- and Negative-Sequence Overvoltage Elements	
Setting Range:	2.00–300 V_{L-N} in 0.01 steps
Accuracy:	±5% of setting, ±1 V
Transient Overreach:	<5% of setting
Maximum Delay:	1.5 cycles

Breaker Failure Instantaneous Overcurrent

Setting Range	
5 A Model:	0.50–50 A, 0.01 A steps
1 A Model:	0.10–10.0 A, 0.01 A steps
Accuracy	
5 A Model:	±0.05 A, ±3% of setting
1 A Model:	±0.01 A, ±3% of setting
Transient Overreach:	<5% of setting
Maximum Pickup Time:	1.5 cycles
Maximum Reset Time:	<1 cycle
Timers Setting Range:	0–6000 cycles, 1/12-cycle steps (BFPU*nn*, RTPU*nn*) 0–1000 cycles, 1/12-cycle steps (BFISP*nn*, BFIDO*nn*)
Time Delay Accuracy:	1/12 cycle, ±0.1% of setting

Disconnect Monitor

Number:	60
Timer Setting Range:	0–99999 cycles, 1 cycle step

Breaker Status

Number:	21

Coupler Security Logic

Number:	4
Timer Setting Range:	0–1000 cycles, 1/12 cycle step

Control Input Timers

Setting Range	
Pickup:	0.00–30 ms
Dropout:	0.00–30 ms

Station DC Battery System Monitor Specifications

Rated Voltage:	24–250 Vdc
Operational Voltage Range:	0–350 Vdc
Input Sampling Rate:	2 kHz
Processing Rate:	1/6 cycle
Operating Time:	≤1.5 seconds (element DC1R) ≤1.5 cycles (all elements but DC1R)
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 (DC1RP) ±3% ±2 Vdc (all elements but DC1RP)

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 (2.5–15 A sec)
1 A Model:	±0.2% plus ± 0.8 mA (0.5–3.0 A sec)

Phase Current Angle

All Models:	±0.2° in the current range (0.5–3.0) • I_{NOM}

Differential Currents per Zone (Steady State)

IOP, IRT:	±5.0% ± 0.02 • I_{NOM}
IOPCZ, IRTCA:	±5.0% ± 0.02 • I_{NOM}

Voltages

Phase Voltage Magnitude

300 V Maximum Inputs:	±2.5% ± 1 V (5–33.5 V) ±0.1% (33.5–300 V)

Phase Angle

300 V Maximum Inputs:	±1.0° (5–33.5 V) ±0.5° (33.5–300 V)

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SECTION 2

Installation

The first steps in applying the SEL-487B relay are installing and connecting the relay. This section describes common installation features and particular installation requirements for the physical configurations of the SEL-487B. You can order the relay in panel-mount or rack-mount versions, in a 9U horizontal orientation, with as many as four interface boards, or in a 7U version, with as many as two interface boards. This section contains drawings of typical ac and dc connections to the SEL-487B (*Figure 2.42* and *Figure 2.43*). Use these drawings as a starting point for planning your particular relay application.

To install and connect the relay safely and effectively, you must be familiar with relay configuration features, options, and relay jumper configuration. You should plan relay placement, cable connection, and relay communication carefully.

Consider the following when installing the SEL-487B:

- *Shared Configuration Attributes on page 2.1*
- *Plug-In Boards on page 2.13*
- *Jumpers on page 2.15*
- *Relay Placement on page 2.21*
- *Connection on page 2.23*
- *AC/DC Connection Diagrams on page 2.46*

It is also very important to limit access to the SEL-487B settings and control functions by using passwords. For information on relay access levels and passwords, see *Access Levels and Passwords on page 3.7 in the SEL-400 Series Relays Instruction Manual*.

For more introductory information on using the SEL-487B, 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-487B. This section discusses the main shared features of the relay.

Relay Sizes

SEL produces the SEL-487B in a 9U panel-mount or rack-mount version, horizontal orientation, or in a 7U panel-mount or rack-mount version. The 9U version is capable of supporting as many as four optional I/O boards, and the 7U version is capable of supporting as many as two optional I/O boards.

Front-Panel Templates

The front-panel template is shown in *Figure 2.1*. The SEL-487B 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* and *Figure 2.2* show the front-panel pocket areas and openings; dashed lines denote the pocket areas.

Figure 2.1 Front-Panel Diagram, Panel-Mount Option, 9U Version, Showing the Front Panel With LCD, Navigation Pushbuttons, Programmable LEDs, Reset, and Programmable Pushbuttons

Figure 2.2 Front-Panel Diagram, Panel-Mount Option, 7U Version, Showing the Front Panel With LCD, Navigation Pushbuttons, Programmable LEDs, Reset, and Programmable Pushbuttons

Rear Panels

Figure 2.3 and *Figure 2.4* show examples of a rear panel with fixed terminal block analog inputs.

Connector Types

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

Connection to the relay I/O and Battery 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 keyed (see *Figure 2.21*), so you can replace the screw-terminal connector on the rear panel only where you removed the screw-terminal connector. 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 PT and CT 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 PT and CT secondaries.

Connectorized

The Connectorized SEL-478B features receptacles that accept plug-in/plug-out connectors for terminating PT and CT inputs. This requires ordering a wiring harness (SEL-WA0487B) with mating plugs and wire leads. *Figure 2.5* shows the relay with Connectorized CT and PT analog inputs. (See *Connectorized on page 2.30* for more information.)

Time-Domain Link

NOTE: TiDL (EtherCAT) technology is no longer offered in the SEL-487B-1. TiDL (T-Protocol) is available in the SEL-487B-2.

The TiDL (EtherCAT) SEL-487B has eight fiber-optic EtherCAT connections instead of the standard CT and PT analog inputs (see *TiDL (EtherCAT) Connections on page 2.32* for more information).

Figure 2.3 Rear-Panel Diagram of SEL-487B With Four Interface Boards (9U Version)

Figure 2.4 Rear-Panel Diagram of SEL-487B With Two Interface Boards (7U Version)

Figure 2.5 Rear-Panel Diagram of SEL-487B Connectorized Boards (7U Version)

Figure 2.6 EtherCAT Board for TiDL

Secondary Circuits

The SEL-487B presents a low burden to the CT and PT secondaries (see *Specifications on page 1.10*).

The relay accepts 21 analog current inputs from the power system. CT inputs are labeled as follows: I01, I02–I21. Because the relay impedance is low, the current elements can be wired in series with current elements from other relays.

Figure 2.7 shows the CT connections of the A-phase unit in a three-relay application. Current Input IA01 enters the relay at Terminal Y01 and leaves the relay at Terminal Y02 for input to other relays.

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

Figure 2.7 CT Connections for a Three-Relay Application

Figure 2.8 shows the CT connections if the SEL-487B is the last relay in the CT circuit. For a single-relay application, Current Input IA enters the relay at Terminal Y01, Input IB at Terminal Y03, and Input IC at Terminal Y05. Form the wye or star point by connecting Terminals Y02, Y04, and Y06 together and include the return wire to the CT on any one of these three terminals.

Figure 2.8 CT Connections for a Single-Relay Application When the SEL-487B Is the Last in the CT Circuit

Figure 2.9 shows the CT connections for a single-relay application when other devices are connected downstream of the SEL-487B. Current Input IA enters the relay at Terminal Y01 and leaves the relay at Terminal Y02 for input to other devices. B-phase and C-phase are wired similarly.

Figure 2.9 CT Connections for a Single-Relay Application When the SEL-487B Is in Series With Other Relays

For 5 A relays, the rated nominal input current, I_{NOM}, is 5 A. For 1 A relays, the rated nominal input current, I_{NOM}, is 1 A. Continuous input current for both relay types is 3 • I_{NOM} (or 4 • I_{NOM} at +55°C). See *AC Current Inputs (Secondary Circuits) on page 1.10* for complete CT input specifications.

The relay also accepts one set of three, six-wire potentials from power system PT secondaries at inputs V01, V02, and V03. The nominal line-to-neutral input voltage for the PT inputs is 67 volts with a maximum voltage rating of 300 volts and a burden of less than 0.1 VA at 125 V, L-N. The PT inputs and elements are independent of each other for both the single-relay or three-relay applications.

NOTE: TiDL (EtherCAT) technology is no longer offered in the SEL-487B-1. TiDL (T-Protocol) is available in the SEL-487B-2.

Relays that use the TiDL (EtherCAT) system do not contain secondary circuits on the relay. The secondary circuit uses an SEL-2240 Axion to supply the voltages and currents through a direct fiber link; however, the nominal current must be selected to appropriately apply scaling through various protection functions. The relay, by default, assumes 5 A as the nominal current selection. If you use 1 A scaling, use the **CFG CTNOM** command (see *Table 14.28 in the SEL-400 Series Relays Instruction Manual* for more information). The SEL-2245-42 AC Analog Input Module also sets its internal calculations based on this command. The relay internally transmits these data to the Axion modules and adjusts the appropriate scaling in the Axion module when this command is used.

In addition to the CT nominal values, TiDL relays also require you to set the nominal frequency by issuing the **CFG NFREQ** command. At Access Level 2, issue a **CFG NFREQ 60** to set the relay to 60 Hz nominal or issue a **CFG NFREQ 50** to set the relay to 50 Hz nominal. This command changes the NFREQ setting and restarts the relay, and it is only available in TiDL relays. The relay defaults to 60 Hz, so only use this command if you want to switch to 50 Hz nominal. Issue this command after the **CFG CTNOM** command but before sending settings to the relay.

Control Inputs

Inputs into the relay are high-impedance control inputs. Use these inputs for monitoring change-of-state conditions of power system equipment. These high-isolation control inputs are ground-isolated circuits and are not polarity sensitive, i.e., the relay will detect input changes with voltage applied at either polarity. For more information on control input specifications, see *Specifications on page 1.10*.

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 published in the *Specifications on page 1.10*. You can debounce the control input pickup delay and dropout delay separately for each input as a global setting that applies to all the inputs.

AC Control Signals

Optoisolated control inputs can be used with ac control signals, within the ratings shown in *Control Inputs on page 1.11*. Specific pickup and dropout time-delay settings are required to achieve the specified ac thresholds, as shown in *Table 2.1*.

It is possible to mix ac and dc control signal detection on the same INT4 I/O interface board, provided that the two signal types are not present on the same set of combined inputs. Use standard debounce time settings (usually the same value in both the pickup and dropout settings) for the inputs being used with dc control voltages.

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
IN201PU–IN224PU, IN301PU–IN324PU, IN401PU–IN424PU, IN501PU–IN524PU	Pickup Delay	2.0 ms at 60 Hz 2.5 ms at 50 Hz (approximately 1/8 cycle)	0.625 cycles maximum (assertion)
IN201DO–IN224DO, IN301DO–IN324DO, IN401DO–IN424DO, IN501DO–IN524DO	Dropout Delay	16.5 ms at 60 Hz 20.0 ms at 50 Hz (approximately 1 cycle)	1.1875 cycles maximum (deassertion)

[a] First set Global setting EICIS := Y to gain access to the individual input pickup and dropout timer settings (only available for installed INT4 I/O interface boards).

[b] These are the only setting values that SEL recommends for detecting ac control signals. Other values may result in inconsistent operation.

The recognition times listed in *Table 2.1* are only valid when:

- The ac signal applied is at the same frequency as the power system.
- The signal is within the ac threshold pickup ranges defined in *Control Inputs on page 1.11*.
- The signal contains no dc offset.

The SEL-487B samples the optoisolated inputs at 2 kHz.

Control Outputs

Control outputs from the relay include standard outputs and high-speed (high-current interrupting) outputs. A Metal-Oxide Varistor (MOV) protects against excess voltage transients for each contact. Each output is individually isolated except Form C outputs, which share a common connection between the NC (normally closed) and NO (normally open) contacts.

The relay updates control outputs 12 times per cycle. Updating of relay control outputs does not occur when the relay is disabled. When the relay is re-enabled, the control outputs assume the state that reflects the present protection processing.

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. 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 (milliseconds) with a resistive load. The maximum pickup time for the Standard control outputs is 6 ms. *Figure 2.10* shows a representative connection for a Form A Standard control output on the main board I/O terminals.

Figure 2.10 Standard Control Output Connection

See *Control Outputs on page 1.10* 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 2.11* shows a representative connection for a Form A hybrid control output on the main board I/O terminals.

Figure 2.11 Hybrid Control Output Connection

See *Control Outputs on page 1.10* 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, the INT4 I/O interface board offers high-speed, high-current interrupting control outputs. These control outputs have a resistive load pickup time of 10 µs, which is much faster than the 6 ms pickup time of the standard and hybrid control outputs. The high-speed, high-current interrupting control outputs drop out at a maximum time of 8 ms. The maximum voltage rating is 330 Vdc. See *Control Outputs on page 1.10* for complete high-speed, high-current interrupting control output specifications.

Figure 2.12 shows a representative connection for a Form A high-speed, high-current interrupting control output on the INT4 I/O interface terminals. The HS marks are included to indicate that this is a high-speed control output.

Figure 2.12 High-Speed, High-Current Interrupting Control Output Connection, INT4

Short transient inrush current can flow at the closing of an external switch in series with open high-speed, high-current interrupting 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, high-current interrupting output circuitry charges (creating a momentary short circuit that a fast, sensitive device sees as a contact closure).

Figure 2.13 shows some possible connections for external resistors that will eliminate the false pickup transients when closing an external switch. In general, you must connect external resistors 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 2.13 Precharging Internal Capacitance of High-Speed, High-Current Interrupting Output Contacts, INT4

Main Board I/O

The SEL-487B has 9U and 7U chassis options with I/O interface on the main board. See *Figure 2.3* and *Figure 2.18* for representative views of the 9U chassis rear panel and *Figure 2.4* and *Figure 2.19* for representative views of the 7U chassis rear panel.

Every SEL-487B configuration includes the main board I/O and features these connections:

- Three hybrid (high-current interrupting) Form A outputs
- Two standard Form A outputs
- Three standard Form C outputs
- Seven level-sensitive optoisolated control inputs (five independent and two common)

IRIG-B Inputs

Supply high-accuracy time to the SEL-487B via the IRIG-B IN BNC connector on the rear of the relay. You can use the IRIG OUT BNC connector to output IRIG, but you cannot use the output signal for high-accuracy timekeeping because it lacks the IEEE C37.118 IRIG control bits. If you need high-accuracy IRIG timekeeping, do not use the IRIG OUT connection as a high-accuracy IRIG source. Instead, use the connections external to the relay to distribute the IRIG signal between relays. In a three-relay application, any one of the three units can be the reference relay; by connecting the IRIG-B signal to the IRIG-B terminal labeled IN, the relay becomes the reference relay. Connect the IRIG-B terminal labeled OUT from the reference relay to the IRIG-B terminal labeled IN of the next relay, and so on. If there is no IRIG-B available, the relays generate the synchronizing signal internally to synchronize the three relays relative to each other, although not to an absolute time reference. You can provide IRIG-B time-code format signals to the relay from many sources (SEL-2030 Communications Processor, for instance). See *Section 11: Time and Date Management in the SEL-400 Series Relays Instruction Manual* for more information on the use and benefits of high-accuracy timekeeping.

The IRIG-B serial data format consists of a 1-second frame containing 100 pulses divided into fields. 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. See *IRIG-B Input Connections on page 2.41* for information on enabling IRIG-B timekeeping.

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-487B uses the IRIG-B signal from the BNC connection (if a signal is available).

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, 77°F), the battery will operate for approximately 10 years at rated load.

When the SEL-487B 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. The battery cannot be recharged. *Figure 2.14* shows the clock battery location (at the front of the main board).

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-487B 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 15: Communications Interfaces in the SEL-400 Series Relays Instruction Manual* for more information and options for connecting your relay to the communications interfaces.

An optional Ethernet card provides Ethernet capability for the SEL-487B. An Ethernet card gives the relay access to popular Ethernet networking standards including TCP/IP, FTP, Telnet, DNP3, and IEC 61850 over local area and wide area networks. The Ethernet card with IEC 61850 support is only 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 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-487B supports as many as four interface boards. There are ordering options for the number of I/O boards, as well as the overall chassis size. A 9U chassis ordering option provides support for as many as four additional interface boards. A 7U chassis option provides support for as many as two additional interface boards. Both chassis sizes are available in rack- or panel-mount versions.

Plug-in communications cards are also available for the SEL-487B. The optional Ethernet card allows you to use TCP/IP, FTP, Telnet, DNP LAN/WAN, and IEC 61850 applications on an Ethernet network. This card is only available at the time of purchase of a new SEL-487B as a factory-installed option or as a factory-installed conversion to an existing relay.

I/O Interface Boards

When the 9U chassis size is ordered, you can choose as many as four INT4 interface boards for a total of 96 inputs and 32 outputs (all four boards installed). When the 7U chassis size is ordered, you can choose as many as two INT4 interface boards for a total of 48 inputs and 16 outputs (both boards installed). In addition to the inputs and outputs provided by the INT4 interface boards, there are also 7 inputs and 8 outputs on the main board (described in *Main Board I/O on page 2.12*). Refer to *Figure 2.3* for a view of the interface boards and the rear screw-terminal connectors associated with the interface boards.

The I/O interface boards carry jumpers that identify the board location. See *Jumpers on page 2.15* for more information on I/O board jumpers.

I/O Interface Board Inputs

The INT4 I/O interface board has two groups of nine common contacts (18 total) and six independent control inputs. All independent inputs are isolated from other inputs. These high-isolation control inputs are not polarity sensitive, i.e., you cannot damage these inputs with a reverse polarity connection.

Table 2.2 shows the I/O board input capacities and the I/O inputs on the main board. See *Control Inputs on page 1.11* for complete control input specifications.

Table 2.2 Control Inputs

Board	Independent Contact Pairs	Common Contact Pairs
INT4	6	Two sets of 9
Main Board	5	2

I/O Interface Board Outputs

The INT4 I/O interface board is available with either six high-speed and two standard output contacts, or eight standard contact outputs. *Table 2.3* shows the I/O board outputs; the table also shows the I/O outputs on the main board. See *Control Outputs on page 1.10* for complete control output specifications.

Table 2.3 Control Outputs

Board	Standard		High-Speed	Hybrid[a]
	Form A	Form C	Form A	Form A
INT4 with high-speed outputs	2	0	6	0
INT4 with standard outputs	8	0	0	0
Main Board	2	3	0	3

[a] High-current interrupting.

Ethernet Card

You can add Ethernet communications protocols to the SEL-487B by purchasing the Ethernet card option. Factory-installed in the rear relay **Port 5**, the Ethernet card provides Ethernet ports for industrial applications that process data traffic between the SEL-487B and a local area network (LAN).

Jumpers

The SEL-487B contains jumpers that configure the relay for certain operating modes. The jumpers are located on the main board and on each of the I/O interface boards.

Main Board Jumpers

The jumpers on the main board of the SEL-487B perform the following functions:

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

Figure 2.15 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 near the rear-panel serial ports; each serial port jumper is directly in front of the serial port that it controls.

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-487B front cover to view these jumpers (use appropriate ESD precautions). The password and circuit breaker jumpers are on jumper header J18 on the front of the main board.

⚠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.

There are four jumpers, denoted as D, BREAKER, PASSWORD, and A, from left to right (position D being on the left). Positions D and A are for SEL use, position PASSWORD is the password disable jumper, and position BREAKER is the circuit breaker control enable jumper. *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 J18 jumper positions and functions.

Figure 2.14 Major Component Locations on the SEL-487B Main Board

Figure 2.15 Jumper Location on the Main Board

Table 2.4 Main Board Jumpers

Jumper	Jumper Location	Jumper Position[a]	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 commands (**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. Place the jumper over one pin only for `OFF`.
[b] Also affects the availability of SCADA Control Messages and the front-panel `LOCAL CONTROL > BREAKER CONTROL`, and front-panel `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 PASSWORD on a long-term basis. The SEL-487B ships with password disable jumper PASSWORD OFF (passwords enabled).

The circuit breaker control enable jumper, BREAKER, supervises the **OPEN *n*** command, the **PULSE OUT*nnn*** command, and front-panel local bit control. To use these functions, you must install Jumper BREAKER. The relay checks the status of the circuit breaker control jumper when you issue **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-487B ships with circuit breaker Jumper BREAKER OFF. For commissioning and testing of the SEL-487B contact outputs, it may be convenient to set BREAKER ON, so that the **PULSE OUT*nnn*** commands can be used to check output wiring. BREAKER must also be set ON if SCADA (DNP, Fast Operate, IEC 61850) control of the circuit breaker is required or if the `LOCAL CONTROL > BREAKER CONTROL` screens are going to be used.

Serial Port Jumpers

Place jumpers on the main 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 JMP2, JMP3, and JMP4 positions. Refer to *Figure 2.15* for the locations of these jumpers. The SEL-487B ships with JMP2, JMP3, and JMP4 OFF (no +5 Vdc on Pin 1).

Table 2.5 Main Board Jumpers—JMP2, JMP3, and JMP4[a]

Jumper	Jumper Location	Jumper Position	Pin Connections
JMP2	Rear	OFF ON	Serial Port 3, Pin 1 = not connected Serial Port 3, Pin 1 = +5 V
JMP3	Rear	OFF ON	Serial Port 2, Pin 1 = not connected Serial Port 2, Pin 1 = +5 V
JMP4	Rear	OFF ON	Serial Port 1, Pin 1 = not connected Serial Port 1, Pin 1 = +5 V

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

Changing Serial Port Jumpers

⚠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.

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

⚠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. To change the JMP2, JMP3, and JMP4 jumpers in an SEL-487B, perform the following steps:

Step 1. Remove the relay from service.

a. Follow your company's standard for removing a relay from service.

b. Disconnect power from the SEL-487B.

c. Retain the GND connection, if possible, and ground the equipment to an ESD mat.

Step 2. Remove the communications cable connected to the front-panel serial port, if applicable.

Step 3. Remove the front panel from the SEL-487B.

Step 4. Disconnect the front-panel cable at the front panel.

Step 5. Disconnect the power cable, interface board cable(s), and input board analog cable from the main board.

Step 6. Remove rear-panel EIA-232 ports mating connectors.

a. Unscrew the keeper screws.

b. Disconnect any serial cables connected to the **PORT 1**, **PORT 2**, and **PORT 3** rear-panel receptacles.

Step 7. Remove any Ethernet and IRIG-B connections.

Step 8. Carefully pull out the drawout assembly containing the main board.

Step 9. 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 2.15*).

Step 10. Install or remove the jumper as needed.

See *Table 2.5* for jumper position descriptions.

Step 11. Reinstall the SEL-487B main board.

Step 12. Reconnect the power cable, the interface board cable(s), and the input board analog cable.

Step 13. Reattach the front panel.

Step 14. Reconnect any external cables that you removed in the disassembly process.

Step 15. Follow your company's standard procedure to return the relay to service.

I/O Interface Board Jumpers

Jumpers on the INT4 I/O interface board identify the I/O board control address (see *I/O Interface Boards on page 2.14* for more information on these boards). The jumpers on these I/O interface boards are at the front of each board, as shown in *Figure 2.16*.

Figure 2.16 Major Component Locations on the SEL-487B INT4 I/O Board

To confirm the positions of your I/O board jumpers, you can remove the front panel and inspect the jumper placements visually. *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 7U chassis has a 200-address slot for inputs IN201, IN202, etc. and outputs OUT201, OUT202, etc., and a 300-address slot for IN301, IN302, etc. A 9U chassis also has a 400-address slot and 500-address slot for as many as two additional I/O boards. 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

Description	JMP49A	JMP49B	JMP50A	JMP50B
Position A (Main Board) 1xx I/O	N/A	N/A	N/A	N/A
Position B (Expansion I/O) 2xx I/O	OFF	OFF	OFF	OFF
Position C (Expansion I/O) 3xx I/O	ON	OFF	ON	OFF
Position D (Expansion I/O) 4xx I/O	OFF	ON	OFF	ON
Position E (Expansion I/O) 5xx I/O	ON	ON	ON	ON

See *Figure 2.3* for board location details.

Relay Placement

Proper placement of the SEL-487B helps make certain that you receive years of trouble-free power system protection. Use the following guidelines for proper physical installation of the SEL-487B.

Physical Location

You can mount the SEL-487B in a sheltered indoor environment (a building or an enclosed cabinet) that does not exceed the temperature and humidity ratings for the relay.

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 relay operates in –40° to +85°C (–40° to +185°F) temperatures (see *Operating Temperature on page 1.12*). With no condensation present, the relay operates in humidity ranging from 5 percent to 95 percent.

Rack Mounting

When mounting the SEL-487B in a rack, use the reversible front flanges to either semiflush-mount or projection mount the relay.

The semiflush mount gives a small panel protrusion from the relay rack rails of approximately 1.1 inches (27.9 mm). The projection mount places the front panel approximately 3.5 inches (88.9 mm) in front of the relay rack rails.

See *Figure 2.17* for exact mounting dimensions for both the horizontal and vertical rack-mount relays. Use four screws of the appropriate size for your rack.

DIMENSION	TiDL (4U)	TWO I/O BOARD (7U)	FOUR I/O BOARD (9U)
A	6.97 (177.0)	12.22 (310.4)	15.72 (399.3)
B	4.00 (101.6)	9.25 (235.0)	12.75 (323.9)
C	8.40 (213.4)	13.65 (346.7)	17.15 (435.6)
D	6.85 (174.0)	12.10 (307.3)	15.60 (396.2)
E	N/A	2.25 (57.2)	4.75 (120.6)

Figure 2.17 Relay Chassis Dimensions

Panel Mounting

Place the panel-mount versions of the SEL-487B in a switchboard panel. See the drawings in *Figure 2.17* for panel cut and drill dimensions. Use the supplied mounting hardware to attach the relay.

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-487B is available with a main board and as many as four INT4 interface boards. The INT4 interface board is available to expand the control inputs and control outputs only. There are two relay size options: a 9U chassis capable of supporting as many as the maximum of four interface boards, or a 7U chassis capable of supporting as many as two interface boards. This subsection presents a representative sample of relay rear-panel configurations and the connections to these rear panels.

When connecting the SEL-487B, 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 2.18 and *Figure 2.19* show the rear panel of the relay with only the main board installed, and *Figure 2.3*, *Figure 2.4*, and *Figure 2.5* show the rear panel of the relay fully equipped. For clarity, the figures do not show a communications card installed in **PORT 5**.

Figure 2.18 Rear Panel With Only Main Board (9U Version)

Figure 2.19 Rear Panel With Only Main Board (7U Version)

Rear-Panel Symbols

Figure 2.20 shows important safety symbols and their descriptions. These safety symbols appear on the rear of the relay. 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 2.20 Rear-Panel Symbols

Screw-Terminal Connectors

Terminate connections to the SEL-487B screw-terminal connectors with ring-type crimp lugs. Use a #8 ring lug with a maximum width of 9.1 mm (0.36 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-487B by unscrewing the screws at each end of the connector block. 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. To replace the screw-terminal connector, confirm that you have the correct connector, push the connector firmly onto the circuit board receptacle, and 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 2.21*). If you want to move a screw-terminal connector to another circuit board receptacle or reverse the connector orientation, rearrange the receptacle keys to match the screw-terminal connector block. Use long-nosed pliers to move the keys. *Figure 2.22* shows the factory-default key positions.

Figure 2.21 Screw-Terminal Connector Keying

Figure 2.22 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 (see *Figure 2.18*. The symbol that indicates the grounding terminal is shown in *Figure 2.20*. Use 14 AWG (2.5 mm^2) or larger wire, less than 2 m (6.6 feet) in length for this connection. This terminal connects directly to the internal chassis ground of the SEL-487B.

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-487B specifies on the rear-panel serial number label. (See *Power Supply on page 1.10* for complete power input specifications.)

Figure 2.23 Power Connection Areas 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 18 AWG (0.8 mm^2) or larger size 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, either a switch/fuse combination or circuit breaker in the **POWER** leads for the SEL-487B; 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 2.7* lists the SEL-487B power supply fuse requirements. Be sure to use fuses that comply with IEC 127-2.

You can order the SEL-487B with one of three operational power input ranges listed in *Table 2.7*. Each of the three supply voltage ranges represents a power supply ordering option. As noted in *Table 2.7*, model numbers for the relay with these power supplies begin with 0487B1*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-487B power supply operates from 30 Hz to 120 Hz when ac power is used for the **POWER** input.

Table 2.7 Fuse Requirements for the Power Supply

Rated Voltage	Operational Voltage Range	Fuse F1	Fuse Description
24–48 Vdc	18–60 Vdc	T5.0AH250V	5x20 mm, time-lag, 5.0 A, high-break capacity, 250 V
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
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

The SEL-487B accepts dc power input for all three 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, connect the source with the proper polarity, as indicated by the + (Terminal Y29) and – (Terminal Y30) symbols on the power terminals. When connecting an ac power source, the + Terminal Y29 is hot (H), and the – Terminal Y30 is neutral (N). Each model of the SEL-487B 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 1.10*.

Monitor Connections (DC Battery)

Each SEL-487B monitors one dc battery system. For information on the battery monitoring function, see *Station DC Battery System Monitor on page 8.21 in the SEL-400 Series Relays Instruction Manual*. Connect the positive lead of the Battery System to Terminal Y25 and the negative lead of the Battery System to Terminal Y26. (Usually the Battery System is also connected to the rear panel POWER input terminals.) For the three-unit application and when there are two battery systems at a station, connect the second battery system to any one of the other two relays (also Terminals Y25 and Y26).

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.

Each SEL-487B has 21 current inputs and 3 voltage inputs. *Shared Configuration Attributes on page 2.1* describes these inputs in detail. Use appropriate safety precautions when connecting secondary circuits to these terminals.

To verify these connections, use SEL-487B metering (see *Examining Metering Quantities on page 3.34 in the SEL-400 Series Relays Instruction Manual*). You can also review metering data in an event report that results when you issue the **TRIGGER** command.

Fixed Terminal Blocks

Connect the secondary current circuits to the first 18 terminals on the Y terminal block (Terminals Y01–Y18) and on the Z terminal block (Terminals Z01–Z24).

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

Connect the voltage inputs to Terminals Y19–Y24 on the Y terminal block. Note the polarity dots above the odd-numbered terminals (Y01 and Y03–Y23, Z01 and Z03–Z23) for the analog inputs.

Connectorized

For the Connectorized SEL-487B, order the wiring harness kit, SEL-WA0487B. 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 **#Z01** through **#Z24** and **#Y01** through **#Y18**, 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**, 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-487B with many combinations of control inputs and control outputs. See *Main Board I/O on page 2.12* and *I/O Interface Boards on page 2.14* for information about I/O configurations. This subsection provides details about connecting these control inputs and outputs. Refer to *Figure 2.3* for representative rear-panel screw-terminal connector locations.

Control Inputs

No control input on the relay is polarity sensitive, which means you cannot damage these inputs with a reverse polarity connection. Note that the main board I/O control inputs have one set of two inputs that share a common input leg. These inputs are IN106 and IN107 found on Terminals A30, A31, and A32. 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 ACSELERATOR QuickSet SEL-5030 Software to set and verify operation of the inputs.

Control Outputs

The SEL-487B has three types of outputs:

- Standard outputs (for example: main board OUT104)
- Hybrid (high-current interrupting) outputs (for example: main board OUT101)
- High-speed, high-current interrupting (for example: INT4 board OUT01). See *Control Outputs on page 2.9* for more information.

You can connect the standard outputs and the high-speed, high-current interrupting outputs in either ac or dc circuits. Connect the 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 (high-current interrupting) contacts and HS marks on the high-speed, high-current interrupting contacts. Two pairs of Form C contacts are on the main board. The INT4 I/O interface board is available with six high-speed and two standard output contacts, or optionally, with eight standard output contacts.

Alarm Output

The SEL-487B monitors internal processes and hardware in continual self-tests. 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 OUT108 to your control system remote alarm input. *Figure 2.24* shows the configuration of the a and b contacts of control output OUT108.

Figure 2.24 Control Output OUT108

Default settings for Output OUT 107 and Output OUT108 are as follows:

OUT107 := **TNS_SW #RELAY TEST MODE**

OUT108 := **NOT (SALARM OR HALARM)**

TNS_SW is a test function programmed to Pushbutton PB4, labeled **RELAY TEST MODE**. Output OUT107 asserts when the relay is in the test mode. When the relay is operating normally, the NOT HALARM signal is at logical 1 and the b contact of control output OUT108 is open. When a Status Warning condition occurs, the relay pulses the NOT HALARM signal to logical 0 and the b contact of OUT108 closes momentarily to indicate an alarm condition. For a Status Failure, the relay disables all control outputs and the OUT108 b contact closes to trigger an alarm. Also, when relay power is off, the OUT108 b contact closes 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 include settings changes, access level changes, alarming after three unsuccessful password entry attempts, and Ethernet firmware upgrade attempts.

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 9.6* for more details.

TiDL (EtherCAT) Connections

NOTE: TiDL (EtherCAT) technology is no longer offered in the SEL-487B-1. TiDL (T-Protocol) is available in the SEL-487B-2.

The SEL-487B Relays that support TiDL have a 4U chassis. The relay supports I/O on the main board as well as one additional I/O board. The main board and additional I/O board map to the 100- and 200-level inputs and outputs. The Axion modules provide additional I/O for the 300, 400, and 500 levels and analog channels.

The protection functions remain unchanged from the standard SEL-487B Relay.

Axion Modules

The SEL-2240 Axion is a fully integrated analog and digital I/O control solution that is 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 2.25 Axion Chassis

SEL-2243 Power Coupler

Each chassis requires an SEL-2243 Power Coupler (see *Figure 2.26*). This module supplies power to the rest of the node and transmits the data to the relay through fiber-optic communication. Although the power coupler has two fiber-optic ports, only PORT 1 is currently used for TiDL.

Figure 2.26 SEL-2243 Power Coupler

The SEL-2243 has sufficient power capacity to accommodate an entire Axion node. The terminal strip at the bottom of the unit (shown in *Figure 2.26*) is the connection point for incoming power. All Axion modules have a 55-position IEC C-style connector that provides a communications and power interface to the backplane. See the *SEL-2240 Axion Instruction Manual* for more information.

SEL-2244-2 Digital Input Module

The SEL-2244-2 Digital Input Module (see *Figure 2.27*) 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 in the 300, 400, and 500 I/O board levels, based on the modules that occur in the network. Only the first 12 of 24 inputs are used in each module to help distribute the I/O around the network more efficiently. The inputs are mapped to the relay inputs based on the order in which the DI module occurs in the TiDL network.

There can be multiple DI modules in an Axion node, and the order of the DI modules will proceed from left to right in the node to determine the mapping of the inputs.

The first DI module that exists in the system, for example, on **PORT 6A**, will map to **IN301**–**IN312**, and if a second module is available on **PORT 6A**, it will map to **IN313**–**IN324**. If a second module does not exist on **PORT 6A**, **IN313**–**IN324** will be mapped from the next module appearing in the TiDL system. Mapping order determination starts with **PORT 6A** and ends with the last port, **PORT 6H**.

First SEL-2244-2 DI module	**IN301–IN312**
Second SEL-2244-2 DI module	**IN313–IN324**
Third SEL-2244-2 DI module	**IN401–IN412**
Fourth SEL-2244-2 DI module	**IN413–IN424**

Fifth SEL-2244-2 DI module	IN501–IN512
Sixth SEL-2244-2 DI module	IN513–IN524

Figure 2.27 SEL-2244-2 Digital Input Module

SEL-2244-5 Fast High-Current Digital Output Module

The SEL-2244-5 Fast High-Current Digital Output Module consists of 10 fast, high-current output contacts. The outputs use the first 8 of the10 outputs and map as follows:

First SEL-2244-5 DO Module	OUT301–OUT308
Second SEL-2244-5 DO Module	OUT309–OUT316
Third SEL-2244-5 DO Module	OUT401–OUT408
Fourth SEL-2244-5 DO Module	OUT409–OUT416
Fifth SEL-2244-5 DO Module	OUT501–OUT508
Sixth SEL-2244-5 DO Module	OUT509–OUT516

Figure 2.28 SEL-2244-5 Fast High-Current Digital Output Module

For both the DI and DO modules, use 24–12 AWG (0.2–3.31 mm^2) wire of sufficient current capacity to connect to the digital input and output terminals for your application.

The order of mapping for DO modules is the same as that for DI modules.

SEL-2245-42 AC Analog Input Module

The SEL-2245-42 AC Analog Input Module (see *Figure 2.29*) 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 *Topologies on page 2.36* for more information on supported relay topologies and their connections.

Figure 2.29 SEL-2245-42 AC Analog Input Module

Topologies

The SEL-487B Relay has a set of fixed topologies. These topologies map the voltages and currents internally in the relay to maintain existing settings and functionality. When the TiDL system is commissioned (see *Commissioning on page 2.39*), the firmware validates the connected Axion nodes and identifies if the installed CT/PT modules in the system match one of the supported topologies for the SEL-487B.

Ports listed as optional in the following topology diagrams do not require a CT/PT module to be connected to them. All other ports require a CT/PT module to be connected for the relay to verify the topology.

Port	Analogs
6A	I01, I02, I03, V01, V02, V03
6B	I04, I05, I06
6C	I07, I08, I09
6D	I10, I11, I12 (optional)
6E	I13, I14, I15 (optional)
6F	I16, I17, I18 (optional)
6G	I19, I20, I21 (optional)

Figure 2.30 Topology 1

Port	Analogs
6A	I01, I02, I03
6B	I04, I05, I06
6C	I07, I08, I09
6D	I10, I11, I12 (optional)
6E	I13, I14, I15 (optional)
6F	I16, I17, I18 (optional)
6G	I19, I20, I21 (optional)
6H	V01, V02, V03

Figure 2.31 Topology 2

Port	Analogs
6A	I01, I02, I03, V01, V02, V03
	I04, I05, I06
	I07, I08, I09
6B	I10, I11, I12 (optional)
	I13, I14, I15 (optional)
	I16, I17, I18 (optional)
	I19, I20, I21 (optional)

Note: This topology uses three or four CT/PT modules installed in one Axion node. The first module maps to the I01–I03 currents and V01–V03 voltages, the second module maps to the I04–I06 currents, and the third maps to the I07–I09 currents. Similar mapping occurs in the second Axion.

Figure 2.32 Topology 3

Commissioning

In TiDL applications, the relay receives currents from an Axion module. You must set the nominal current input of the relay to either 1 A or 5 A. Many settings and ranges of settings depend on the nominal current. Use the **CFG CTNOM** command to set the nominal current value. At Access level 2, issue a **CFG CTNOM 1** to set the relay to 1 A values or use the command **CFG CTNOM 5** to set it to 5 A values. This command is only available in relays that support TiDL technology. Note that after issuing this command, the relay settings are forced to their default values and the relay turns off and back on again to reinitialize the settings. The relay defaults to 5 A nominal, so only use this command if you are switching to a 1 A setting (see *Section 14: ASCII Command Reference in the SEL-400 Series Relays Instruction Manual* for more information). The SEL-2245-42 AC Analog Input Module also sets its internal calculations based on this command. The relay internally transmits these data to the Axion modules and adjusts the scaling in the appropriate Axion module when this command is used.

In addition to the CT nominal values, TiDL relays also require that the nominal frequency be set by issuing the **CFG NFREQ** command. At Access level 2, issue a **CFG NFREQ 60** to set the relay to 60 Hz nominal or issue a **CFG NFREQ 50** to set the relay to 50 Hz nominal. This command changes the NFREQ setting and

restarts the relay, and it is only available in TiDL relays. The relay defaults to 60 Hz. This command should be issued after the **CFG CTNOM** command but before settings are sent to the relay.

The TiDL system uses a commissioning feature to identify that the connected Axion nodes meet the requirements of the supported topologies for the applied relay. These topologies are a balance between copper reduction and number of nodes. The nodes must be connected in one of the supported topologies so that the relay will map the voltages and currents accordingly.

The SEL-487B has a new interface on its back panel that replaces the original CT and PT input connections. These standard inputs are replaced with a module interface that supports eight fiber ports, labeled PORT 6A–PORT 6H (see *Figure 2.33*).

Figure 2.33 TiDL (EtherCAT) Module Interface

Once all the Axion nodes are connected to the relay, press the COMMISSION push-button on the module interface. This process verifies that the connected ports and Axion nodes are installed according to one of the supported topologies. Once the process is complete, the topology is stored in memory. At each additional startup of the relay, the firmware validates that the connected modules match those of the stored configuration. It recognizes whether any of the CT/PT modules within the node have changed. If the topology needs to be changed (e.g., modules are added or replaced), the system will need to be recommissioned by pressing the COMMISSION pushbutton.

When the commissioning and validation of the topology is complete, the voltages and currents map according to the topology assignments (see *Topologies on page 2.36*). Secondary injection testing takes place at each Axion node. Test sources must inject voltages and currents to the Axion node to verify correct installation and mapping. Monitoring of the voltages and currents remains in the control house with the relay.

LED Status

As shown in *Figure 2.33*, the TiDL relay provides LED status indication about the network and configuration. Once the system is connected, and the COMMISSION button pressed, the LEDs will provide the status of the commissioning process. *Table 2.8* shows the status of the rear-panel LEDs for each commissioning state.

Table 2.8 TiDL (EtherCAT) LED Status (Sheet 1 of 2)

State	Description	LED Status	
Initial State	Determining if topology exists	Green COMMISSION LED	OFF
		Red COMMISSION LED	ON
		Green LED: PORT 6A–PORT 6H	OFF
		Red LED: PORT 6A–PORT 6H	ON

Table 2.8 TiDL (EtherCAT) LED Status (Sheet 2 of 2)

State	Description	LED Status	
Verify Topology	Determining if topology is supported	Green COMMISSION LED	Blinking
		Red COMMISSION LED	ON
		Green LED: PORT 6A–PORT 6H	Blinking
		Red LED: PORT 6A–PORT 6H	ON
Topology Mismatch	Connection does not match supported topology	Green COMMISSION LED	Blinking
		Red COMMISSION LED	ON
		Green LED: PORT 6A–PORT 6H	OFF—mismatched/unused
			ON—matched
		Red LED: PORT 6A–PORT 6H	Blinking—mismatched
			ON—matched
			OFF—ports unused
Topology Matched	Connection matches topology	Green COMMISSION LED	ON
		Red COMMISSION LED	OFF
		Green LED: PORT 6A–PORT 6H	ON
		Red LED: PORT 6A–PORT 6H	OFF
N/A	A commissioned port experiences an error	Green COMMISSION LED	ON
		Red COMMISSION LED	OFF
		Green LED: PORT 6A–PORT 6H	ON
		Red LED: PORT 6A–PORT 6H	Blinking—failed port

IRIG-B Input Connections

The SEL-487B 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 2.42* for other DB-9 connector pinouts and additional details.

These inputs accept the dc shift time code generator output (demodulated) IRIG-B signal with a positive edge on the time mark. For more information on IRIG-B and the SEL-487B, see *IRIG-B Inputs on page 2.12*.

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 240-1800, BNC terminator 50 ohms) 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.

When the distance between the SEL-487B 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 300 feet from the IRIG-B generator to the SEL-487B, use the BNC IRIG-B input to connect the IRIG-B input of the SEL-487B to the IRIG-B generation equipment. Make this connection with a 50 Ω coaxial cable assembly.

Each SEL-487B provides two IRIG-B BNC connectors, labeled IN and OUT. The IRIG OUT connector does not support high-accuracy IRIG timekeeping. It lacks the C37.118 IRIG Control Bits.

Step 1. Referring to the external source connections in *Figure 2.34*, connect the IRIG-B signals to the IN connection of Relay A to update the clock of Relay A.

Step 2. Connect the OUT connection of Relay A to the IN connector of Relay B to update the clock in Relay B.

A similar connection between Relay B and Relay C updates the time in Relay C.

NOTE: The IRIG OUT connection works regardless of the type of external time source connected to the relay.

Figure 2.34 Time Synchronization Connections Between Three Relays

In the absence of an external IRIG-B signal, connect the relays as shown by the internal source connections in *Figure 2.34*. Connected this way, Relay B uses the clock of Relay A as time reference, and Relay C uses the clock of Relay B as time reference.

Communications Ports Connections

The SEL-487B has three rear-panel EIA-232 serial communications ports labeled PORT 1, PORT 2, and PORT 3 and one front-panel port, PORT F. For information on serial communications, see *Establishing Communication on page 3.3 in the SEL-400 Series Relays Instruction Manual.*

In addition, the rear panel features a **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-487B, see *Section 10: Communications Interfaces* in this manual and *Section 15: Communications Interfaces, Section 16: DNP3 Communication*, and *Section 17: IEC 61850 Communication in the SEL-400 Series Relays Instruction Manual*.

Serial Ports

The SEL-487B serial communications ports use EIA-232 standard signal levels in a D-subminiature 9-pin (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 2.34 shows the configuration of 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 QuickSet along with the SEL-C234A cable provides communication with the relay in most cases.

Figure 2.35 SEL-487B-to-Computer DB-9 Connector

Serial Cables

Using an improper cable can cause numerous problems or failure to operate, so be sure to specify the proper cable for application of your SEL-487B. Several standard SEL communications cables are available for use with the relay. The following list provides rules and practices you should follow for successful communication using EIA-232 serial communications devices and 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.

- 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.
- You should 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.

- EIA-232 communications cable lengths should never exceed 15.24 m (50 feet), and you should always use shielded cables for communications circuit lengths greater than 3.048 m (10 feet).
- 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. You should use the lowest data speed that provides an adequate data transfer rate.

Ethernet Network Connections

The optional Ethernet card for the SEL-487B comes with two ports, either A and B or C and D. You can use either installed port. These ports can work together to provide a primary and backup interface. Other operating modes (FIXED and SWITCHED) are also available. The following list describes the Ethernet card port options.

- 10/100BASE-T. 10 Mbps or 100 Mbps communications using Cat 5 cable (category 5 twisted-pair) and an RJ45 connector
- 100BASE-FX. 100 Mbps communications over multimode fiber-optic cable using an LC connector

Ethernet Card Rear-Panel Layout

⚠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 end of an optical cable connected to an optical output.

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

Rear-panel layouts for the three Ethernet card port configurations are shown in *Figure 2.36–Figure 2.41*.

Figure 2.36 Two 100BASE-FX Port Configuration on Ports 5A and 5B

Figure 2.37 Two 100BASE-T Port Configuration on Ports 5A and 5B

Figure 2.38 100BASE-FX and 10/100BASE-T Port Configuration on Ports 5A and 5B

Figure 2.39 Two 100BASE-FX Port Configuration on Ports 5C and 5D

⚠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 and transceivers, are not user serviceable. Return units to SEL for repair or replacement.

Figure 2.40 Two 10/100BASE-T Port Configuration on Ports 5C and 5D

Figure 2.41 100BASE-FX and 10/100BASE-T Port Configuration on Ports 5C and 5D

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 SEL-487B Ethernet card is compatible with standard UTP cables 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 cables or shield UTP cables, 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 enclosure.

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

You can apply the SEL-487B to different power system busbar layouts. *Figure 2.42* shows one particular application scheme with connections that represent typical interfaces to the relay for a single zone layout. *Figure 2.43* depicts typical connections for a three-relay application.

Figure 2.42 Typical External AC/DC Connections for a Single-Relay Application

Figure 2.43 Typical External AC/DC Connections for a Three-Relay Application

SECTION 3

Testing

This section contains guidelines for determining and establishing test routines for the SEL-487B relay. 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* addresses the concepts related to testing. This section provides supplemental information specific to testing the SEL-487B.

This section includes the following topics:

- *Low-Level Test Interface on page 3.1*
- *Relay Test Connections on page 3.4*
- *Checking Relay Operation on page 3.7*
- *Technical Support on page 3.23*

The SEL-487B 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

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 two calibrated input modules and the 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 J14 and J24, the analog or low-level test interface connections. Receptacle J24 is on the right side of the main board, with J14 located 5 cm (2 inches) behind J20; for a locating diagram, see *Figure 2.14*.

Figure 3.1 shows the connections for low-level interface J24 and *Figure 3.2* the connections for low-level interface J14. Apply only the nominal voltage levels and current levels listed in the figures to the relay. Never apply voltage signals greater than 6.6 V peak-to-peak sinusoidal signal (2.33 Vrms) to the low-level test interface. To use the low-level test interface, remove the ribbon cable from the main board J14 and J24 receptacles and substitute a test cable with the signals specified in *Figure 3.1* and *Figure 3.2*.

⚠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.

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

Input Module Output (J3): 66.6 mV at Nominal Current (1 A or 5 A).
446 mV at Nominal Voltage (67 V_{LN}).

Processing Module Input (J24): 6.6 V_{p-p} Maximum.

U.S. Patent 5,479,315.

Figure 3.1 Low-Level Test Interface J24

Input Module Output (J3): 66.6 mV at Nominal Current (1 A or 5 A).
446 mV at Nominal Voltage (67 V_{LN}).

Processing Module Input (J14): 6.6 V_{p-p} Maximum.

U.S. Patent 5,479,315.

Figure 3.2 Low-Level Test Interface J14

Use signals from the Low-Level Relay Test System to test the relay processing module. Apply appropriate signals to the low-level test interface connections J14 and J24 from the Relay Test System (see *Figure 3.1* and *Figure 3.2*). 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-487B in the SEL-5401 Relay Test System Software are shown in *Table 3.1*, *Table 3.2*, *Table 3.3*, and *Table 3.4*.

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	I01	75	A
2	I02	75	A
3	I03	75	A
4	I04	75	A
5	I05	75	A
6	I06	75	A
7	I07	75	A
8	I08	75	A
9	I09	75	A
10	V01	150	V
11	V02	150	V
12	V03	150	V

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

Channel	Label	Scale Factor	Unit
1	I10	75	A
2	I11	75	A
3	I12	75	A
4	I13	75	A
5	I14	75	A
6	I15	75	A
7	I16	75	A
8	I17	75	A
9	I18	75	A
10	I19	75	A
11	I20	75	A
12	I21	75	A

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	I01	15	A
2	I02	15	A
3	I03	15	A
4	I04	15	A
5	I05	15	A
6	I06	15	A
7	I07	15	A
8	I08	15	A
9	I09	15	A
10	V01	150	V
11	V02	150	V
12	V03	150	V

Table 3.4 UUT Database Entries for SEL-5401 Relay Test System Software (Analog Input Board Z)—1 A Relay (Sheet 1 of 2)

Channel	Label	Scale Factor	Unit
1	I10	15	A
2	I11	15	A
3	I12	15	A
4	I13	15	A
5	I14	15	A
6	I15	15	A
7	I16	15	A
8	I17	15	A
9	I18	15	A

Table 3.4 UUT Database Entries for SEL-5401 Relay Test System Software (Analog Input Board Z)—1 A Relay (Sheet 2 of 2)

Channel	Label	Scale Factor	Unit
10	I19	15	A
11	I20	15	A
12	I21	15	A

Relay Test Connections

The SEL-487B is a flexible tool that you can use to implement many protection and control schemes. Although you can connect the relay to the power system in many ways, connecting basic bench test sources helps you model and understand more complex relay field connection schemes.

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

For each relay element test, you must apply ac voltage and current signals to the relay. The text and figures in this subsection describe the test source connections you need for relay protection element checks. You can use these connections to test protective elements and simulate all fault types. These examples show connections on I01, I02, and I03. You can make similar connections to any of the current inputs: I01–I21.

Connections for Three Voltage Sources and Three Current Sources

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

Figure 3.3 shows the connections to use when you have three voltage sources and three current sources available.

Figure 3.3 Test Connections Using Three Voltage and Three Current Sources

Connections for Three Voltage Sources and Two Current Sources

Figure 3.4 and *Figure 3.5* show connections to use when you have three voltage sources and two current sources. You can use the connections shown in *Figure 3.4* to simulate phase-to-phase, phase-to-ground, and two-phase-to-ground faults. Use the connections shown in *Figure 3.5* to simulate three-phase faults.

Figure 3.4 Test Connections Using Two Current Sources for Phase-to-Phase, Phase-to-Ground, and Two-Phase-to-Ground Faults

Figure 3.5 Test Connections Using Two Current Sources for Three-Phase Faults

Connections for Three Voltage Sources and One Current Source

Figure 3.6 and *Figure 3.7* show connections to use when you have three voltage sources and a single current source. You can use the connections shown in *Figure 3.6* to simulate phase-to-ground faults. Use the connections shown in *Figure 3.7* to simulate phase-to-phase faults.

Figure 3.6 Test Connections Using a Single Current Source for a Phase-to-Ground Fault

Figure 3.7 Test Connections Using a Single Current Source for a Phase-to-Phase Fault

Checking Relay Operation

Your SEL-487B comes with all functions fully checked and calibrated so that the relay operates correctly and accurately. You can test the relay to verify proper relay operation, but you do not need to test every relay element, timer, and function in this evaluation. The following checks are valuable for confirming proper SEL-487B connections and operation:

- AC connection check (metering)
- Commissioning tests
- Functional tests
- Element verification

An ac connection check uses relay metering to verify that the relay current and voltage inputs have the proper magnitude and phase angle (see *Examining Metering Quantities on page 3.34 in the SEL-400 Series Relays Instruction Manual*). 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 in the SEL-400 Series Relays Instruction Manual*). Brief functional tests and element verification confirm correct internal relay processing.

This subsection discusses tests for the following:

- Alias settings
- Zone selection function
- Sensitive differential elements
- Differential elements
- Directional element
- Voltage elements

Before you perform element tests, however, you should be aware of your substation layout and apply the appropriate settings to the relay.

Example Substation

Figure 3.8 shows an example of a substation that requires two protection zones. The station layout consists of two busbars (BUS_1 and BUS_2), a tie breaker (TB_1 and TB_2), and two feeders (FDR_1 and FDR_2).

Figure 3.8 Station Layout, Comprising a Tie Breaker, Two Feeders and Two Busbars

Use front-panel pushbuttons to simulate the disconnect auxiliary contacts for the terminal-to-bus-zone SELOGIC control equations as shown in *Figure 3.8*. *Table 3.5* shows the SELOGIC control equation assignments.

NOTE: Pushbutton labels **PB1–PB8** (shown in Figure 3.9) identify the pushbuttons for this test; these labels do not appear on the relay front panel.

Figure 3.9 Front-Panel Operator Pushbuttons

Table 3.5 Pushbutton Assignments to Simulate Disconnect Auxiliary Contacts

Pushbutton	Relay Word Bits	Description
PB5	I01BZ1V	Connects TB_1 to BUS_1 when closed
PB6	I02BZ2V	Connects TB_2 to BUS_2 when closed
PB7	I03BZ1V	Connects FDR_1 to BUS_1 when closed
PB8	I04BZ2V	Connects FDR_2 to BUS_2 when closed

Relay Settings

Apply the appropriate settings to the relay. For the relay to match the station layout in *Figure 3.8*, change the following setting categories:

- Alias settings
- Zone configuration settings
- Protection group settings
- Protection logic settings
- Front-panel settings

Alias Settings

Change the default alias names for the four analog channels to the names indicated in *Figure 3.8*. From Access Level 2, use the **SET T** command to rename the analog channels, as shown in *Figure 3.10*. Some of the alias names assigned in this example are default alias names in the relay. If an alias name is duplicated, type **Delete <Enter>** to clear the default alias names that are not relevant to this example.

```
=>>SET T <Enter>

Alias

Relay Aliases
(RW Bit,Analog Qty.,Terminal,Bus-Zone, or Check Zone, 7 Char. Alias [0-9 A-Z _])


1: IO1,"FDR_1"
?  IO1,TB_1 <Enter>
2: IO2,"FDR_2"
?  IO2,TB_2 <Enter>
3: IO3,"FDR_3"
?  IO3,FDR_1 <Enter>
4: IO4,"TRFR_1"
?  IO4,FDR_2 <Enter>
5: IO5,"TB_1"
?  BZ1, BUS_1 <Enter>
6: IO6,"TB_2"
?  BZ2, BUS_2 <Enter>
7: BZ1,"BUS_1"
?  DELETE <Enter>   (Note, this is to clear default alias settings for this
   example)
7: BZ2,"BUS_2"
?  DELETE <Enter>
7: FBFO1,"F1_BF"
?  END <Enter>
Alias
.
.
.
Save settings (Y,N) ? Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 3.10 Alias Names for the Four Analog Channels

Zone Configuration Settings

Set the terminal-to-bus-zone connections to determine when the input currents from the terminals are considered in the differential calculations. We use protection latch bits in the terminal-to-bus-zone connections to emulate disconnect auxiliary contacts (see *Protection Logic Settings on page 3.12*). *Figure 3.11* shows the steps to enter the zone configuration settings.

```
=>>SET Z <Enter>

Zone Config Group 1

Potential Transformer Ratio

Potential Transformer Ratio -VO1 (1-10000)          PTR1    := 2000   ?> <Enter>

Current Transformer Ratio

Current Transformer Ratio -IO1 (1-50000)            CTRO1   := 600    ?> <Enter>

Zone Configuration: Terminal to Bus-Zone Connections


Terminal, Bus-Zone, Polarity (P,N)
IO1BZ1C := TB_1, BUS_1, P
? TB_1, BUS_1, P <Enter>
TB_1 to BUS_1 Connection (SELogic Equation)
IO1BZ1V := DIFF_EN AND NOT TOSO1
?  PLTO7 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
IO2BZ1C := TB_2, BUS_1, P
?  TB_2, BUS_1, P <Enter>
TB_2 to BUS_1 Connection (SELogic Equation)
IO2BZ1V := DIFF_EN AND NOT TOSO2
?  PLTO8 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
IO3BZ2C := FDR_1, BUS_2, P
?  FDR_1,BUS_1,P <Enter>
FDR_1 to BUS_1 Connection (SELogic Equation)
IO3BZ1V := NA
?  PLTO9 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
IO4BZ2C := FDR_2, BUS_2, P
?  FDR_2,BUS_2,P <Enter>
FDR_2 to BUS_2 Connection (SELogic Equation)
IO4BZ2V := DIFF_EN AND NOT TOSO4
?  PLT10 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
IO5BZ1C := IO5, BUS_1, P
?  DELETE <Enter>
Terminal, Bus-Zone, Polarity (P,N)
IO6BZ2C := IO6, BUS_2, P
?  DELETE <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  END <Enter>

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


=>>
```

Figure 3.11 Zone Configuration Settings

Protection Group Settings

The sensitive differential element default settings block the differential elements from operating during CT open-circuit conditions. Disable the sensitive differential elements to prevent these elements from blocking the differential elements when we inject unbalanced test values. *Figure 3.12* shows the steps to disable the sensitive differential elements.

```
=>>SET <Enter>

Relay Configuration
Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y      ?N <Enter>
.
Save settings (Y,N)  ?Y <Enter>

=>>
```

Figure 3.12 Steps to Disable the Sensitive Differential Elements

Protection Logic Settings

We use four protection latch bits, operated from four front-panel pushbuttons to simulate disconnect auxiliary contacts. *Figure 3.13* shows the steps to program the protection latch bits.

```
=>>SET L <Enter>

1: PLT01S := NOT DIFF_EN AND PLT04 # DIFFERENTIAL ENABLED
?  > <Enter>
21:
?  PLT07S := PB5_PUL AND NOT PLT07 <Enter>
22:
?  PLT07R := PB5_PUL AND PLT07 <Enter>
23:
?  PLT08S := PB6_PUL AND NOT PLT08 <Enter>
24:
?  PLT08R := PB6_PUL AND PLT08 <Enter>
25:
?  PLT09S := PB7_PUL AND NOT PLT09 <Enter>
26:
?  PLT09R := PB7_PUL AND PLT09 <Enter>
27:
?  PLT10S := PB8_PUL AND NOT PLT10 <Enter>
28:
?  PLT10R := PB8_PUL AND PLT10 <Enter>
29:
?  END <Enter>
Protection 1

.
.
.

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

=>>
```

Figure 3.13 Steps to Program Protection Latch Bits

Front-Panel Settings

We use four protection latch bits, operated from four front-panel pushbuttons to simulate disconnect auxiliary contacts. Each front-panel pushbutton has an LED in close proximity to the pushbutton. Program these LEDs to illuminate when the pushbuttons are in the closed position. Pushbutton assertion simulates closing disconnect auxiliary contacts, assigning the input currents to the appropriate differential elements. *Figure 3.14* shows the steps to program the LEDs.

```
=>>SET F <Enter>

Front Panel

Front Panel Settings

Front Panel Display Time-Out (OFF,1-60 mins)         FP_TO   := 15     ? <Enter>
Pushbutton LED 1 (SELogic Equation)
PB1_LED := DIFF_EN # DIFFERENTIAL PROTECTION ENABLED
?  <Enter>
Pushbutton LED 2 (SELogic Equation)
PB2_LED := BF_EN # BREAKER FAILURE ENABLED
?  <Enter>
Pushbutton LED 3 (SELogic Equation)
PB3_LED := NA
?  <Enter>
Pushbutton LED 4 (SELogic Equation)
PB4_LED := TNS_SW # TEST NORMAL SWITCH ENABLED
?  <Enter>
Pushbutton LED 5 (SELogic Equation)
PB5_LED := NA
?  PLTO7 <Enter>
Pushbutton LED 6 (SELogic Equation)
PB6_LED := NA
?  PLTO8 <Enter>
Pushbutton LED 7 (SELogic Equation)
PB7_LED := NA
?  PLTO9 <Enter>
Pushbutton LED 8 (SELogic Equation)
PB8_LED := NA
?  PLT10 <Enter>
Target LED 1 (SELogic Equation)
T1_LED := 87BTR
?  END <Enter>
.
.
.
Save settings (Y,N)  ? Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 3.14 Steps to Program the LEDs

Verify the Relay Settings

Step 1. Use the serial port **SHO Z** ASCII command to generate a report similar to that shown in *Figure 3.15*.

Information shown in *Figure 3.15* is an extract of important settings, not the complete relay response.

Step 2. In particular, verify the following values:

a. PTR1, PTR2, and PTR3 are all equal to 2000.

b. CTR01, CTR02, CTR03, and CTR04 are all equal to 600.

c. TAP01, TAP02, TAP03, and TAP04 are all equal to 5.

d. The terminal-to-bus-zone settings are as shown.

```
=>>SHO Z <Enter>

Zone Config Group 1

Potential Transformer Ratio
PTR1    := 2000     PTR2    := 2000     PTR3    := 2000

Current Transformer Ratio
CTR01   := 600      CTR02   := 600      CTR03   := 600      CTR04   := 600

Zone Configuration: Terminal to Bus-Zone Connections

Terminal, Bus-Zone, Polarity (P,N)
IO1BZ1C := TB_1, BUS_1, P
TB_1 to BUS_1 Connection (SELogic Equation)
IO1BZ1V := PLT07
Terminal, Bus-Zone, Polarity (P,N)
IO2BZ1C := TB_2, BUS_1, P
TB_2 to BUS_1 Connection (SELogic Equation)
IO2BZ1V := PLT08
Terminal, Bus-Zone, Polarity (P,N)
IO3BZ1C := FDR_1, BUS_1, P
FDR_1 to BUS_1 Connection (SELogic Equation)
IO3BZ1V := PLT09
Terminal, Bus-Zone, Polarity (P,N)
IO4BZ2C := FDR_2, BUS_2, P
FDR_2 to BUS_2 Connection (SELogic Equation)
IO4BZ2V := PLT10

.
.
.

Current Normalization Factor

TAP01   := 5.00     TAP02   := 5.00     TAP03   := 5.00     TAP04   := 5.00

=>>
```

Figure 3.15 Selected Information From the Relay Response to the SHO Z Command

Selected Element Tests

Zone Selection Function

Step 1. Test the zone selection logic (terminal-to-bus-zone connection).

a. Press the PB5 pushbutton to simulate the closing of disconnect 89I01_1, assigning TB_1 to BUS_1.

b. Confirm that the relay assigns Terminal TB_1 to BUS_1, and includes the bus-zone BUS_1 in Protection Zone 1.

c. Type **MET Z1 <Enter>** to generate a Zone 1 meter report.

Figure 3.16 shows the relay response, confirming that Terminal TB_1 is an active terminal in BUS_1.

NOTE: 5 A relays are rated for continuous current injection of 15 A.

NOTE: When a terminal is active, the terminal name appears under the heading "Primary Currents." The heading "Bus-Zones in Protection Zone 1" shows the Bus-Zones in Protection Zone 1.

```
=>>MET Z1 <ENTER>

Relay 1                                    Date: 09/10/2015  Time: 07:41:32.970
Station A                                  Serial Number: 1150010001

Current Terminals in Protection Zone 1

       Primary Currents
Terminal    MAG(A)   ANG(DEG)  POL
 TB_1         0.291    -6.94    P

       Primary Voltages
Terminal    MAG(kV)  ANG(DEG)
 V01          0.002   -37.06
 V02          0.003   -53.56
 V03          0.001  -169.73

Bus-Zones in Protection Zone 1
BUS_1

=>>
```

Figure 3.16 Relay Response to the MET Z1 Command

Sensitive Differential Element

Figure 3.17 Test Connections Using Two Current Sources

Step 1. Use the test connections shown in *Figure 3.17* for this test.

Step 2. Inject the current values listed in *Table 3.6* into the relay.

Table 3.6 Current for Testing the Threshold Point, O87P

Current	Value
IA	4.8∠0°
IB	4.8∠180°

Current flows through all four terminals, but because only the PB5 pushbutton (*Step 1*, *Step a on page 3.14*) is closed, the relay only considers the CT input from TB_1.

The **CT ALARM** LED illuminates after approximately five seconds, and the relay triggers an event report. The relay does not trip, because the differential current is below the O87P threshold.

Step 3. Stop the injection. The **CT ALARM** LED turns off.

Differential Elements

The following test verifies the characteristics for two of the six differential elements in the SEL-487B. The test plots the relay characteristic at two points. The first point is at the pickup threshold (O87P); the second point is at three per-unit restraint current. Three per unit is an arbitrary value; you may use any other convenient restraint current value.

Figure 3.18 shows the default O87P setting and the default Slope 1 setting.

Use the following equation to calculate IOP(IRT), the operating current value for any specified restraint current value:

$$\mathrm{IOP(IRT)} = \frac{\mathrm{SLP1}}{100} \bullet \mathrm{IRT}$$

Equation 3.1

where:

IOP(IRT) = Operating current as a function of the restraint current
SLP1 = Differential element Slope 1 setting
IRT = Differential element restraint current

Figure 3.18 Differential Element Characteristic

Test the first point on the differential element characteristic.

Step 1. Obtain the operate current value and restraint current value.

a. Inject the current values in *Table 3.6* into the relay.

b. Type **MET DIF <Enter>**.

The current values should approximate those in *Figure 3.19*:

```
=>>MET DIF <Enter>

Relay 1                                    Date: 09/10/2015  Time: 07:41:32.970
Station A                                  Serial Number: 1150010001

Operate Currents    Restraint Currents
      (Per Unit)       (Per Unit)
ZONE     IOP              IRT
1       0.96             0.96
2       0.00             0.00
Current Reference (A)
IREF
3000

=>>
```

Figure 3.19 Example Values Below the 87O1 Element Pickup Value in Response to the MET DIF Command

Step 2. Test the threshold point, O87P. (Pushbutton **PB5** is still asserted.)

a. Type **TAR 87O1 9999 <Enter>** to monitor the status of Relay Word bit 87O1.

b. Increase current IA until the status of Relay Word bit 87O1 changes from logical 0 to logical 1.

When the bit changes state, the **TRIP**, **87 (DIFF)**, and **ZONE 1** LEDs illuminate.

c. Record the value of the injected current.

This value should be 5 A ±5% and ±0.02 • I_{NOM}.

d. Type **<Ctrl+X>** to end the scrolling of Relay Word bit 87O1 status values.

e. Type **MET DIF <Enter>** to obtain the differential operate current value and differential restraint current value.

These values should approximate the differential operate current values and differential restraint current values in *Figure 3.20*.

f. Stop the injection.

g. Press the **TARGET RESET** pushbutton.

```
=>>MET DIF <Enter>

Relay 1                                    Date: 09/10/2015  Time: 07:41:32.970
Station A                                  Serial Number: 1150010001

Operate Currents    Restraint Currents
      (Per Unit)       (Per Unit)
ZONE     IOP              IRT
1       1.02             1.02
2       0.00             0.00
Current Reference (A)
IREF
3000

=>>
```

Figure 3.20 Example Values Above the 87O1 Element Pickup Value in Response to the MET DIF Command

Test the second point on Zone 1 and Zone 2 differential element characteristic.

Step 1. Use *Equation 3.1* to calculate the per-unit operating current for a restraint current of 3 per unit.

This operating current is for the second point on the differential characteristic.

$$\begin{aligned} IOP(IRT) &= \frac{SLP1}{100} \bullet IRT \\ &= 0.6 \bullet 3 \text{ per unit} \\ &= 1.8 \text{ per unit} \end{aligned}$$

Step 2. Use *Equation 3.2* and *Equation 3.3* to calculate the two current values that result in an operating current of 1.8 per unit at a restraint current of 3 per unit.

$$\begin{aligned} I1_{pu} &= \frac{IRT + IOP(IRT)}{2} \text{per unit} \\ &= \frac{3.0 + 1.8}{2} \text{per unit} \\ &= 2.4 \text{ per unit} \end{aligned}$$

Equation 3.2

$$\begin{aligned} I2_{pu} &= IRT - I1_{pu} \text{ per unit} \\ &= 3.0 - 2.4 \text{ per unit} \\ &= 0.6 \text{ per unit} \end{aligned}$$

Equation 3.3

Step 3. Use *Equation 3.4* to convert the current values from per-unit values to current values in amperes:

$$\begin{aligned} I1_A &= TAP01 \bullet I1_{pu} \text{ A} \\ &= 5 \bullet 2.4 \text{ A} \\ &= 12.0 \text{ A} \end{aligned}$$

$$\begin{aligned} I2_A &= TAP02 \bullet I2_{pu} \text{ A} \\ &= 5 \bullet 0.6 \text{ A} \\ &= 3.0 \text{ A} \end{aligned}$$

Equation 3.4

where:

TAP01 = Terminal 01 normalization factor.

TAP02 = Terminal 02 normalization factor.

Step 4. Press pushbuttons PB6, PB7, and PB8.

Step 5. Inject the current values listed in *Table 3.7* into the relay.

Table 3.7 Current for Testing the Second Point on the Relay Characteristic

Current	Value
IA	12.0∠0°
IB	3.2∠180°

The **CT ALARM** LED illuminates after approximately five seconds, but the relay does not trip, because the differential current is below the operating value.

Step 6. Type **MET DIF <Enter>** to obtain the operate current value and restraint current value.

These values should approximate the operate current values and restraint current values shown in *Figure 3.21*:

```
=>>MET DIF <Enter>

Relay 1                                    Date: 09/10/2015  Time: 07:41:32.970
Station A                                  Serial Number: 1150010001

Operate Currents    Restraint Currents
      (Per Unit)       (Per Unit)
ZONE     IOP              IRT
1       1.76              3.04
2       1.76              3.04
Current Reference (A)
IREF
3000

=>>
```

Figure 3.21 Example Values in Response to the MET DIF Command With Two Active Zones

Step 7. Type **TAR 87R1 9999 <Enter>** to monitor the status of Relay Word bit 87R1.

Step 8. Decrease current IB until the status of Relay Word bit 87R1 changes from logical 0 to logical 1.

After this bit changes state, the TRIP, 87 (DIFF), ZONE 1, and ZONE 2 LEDs illuminate.

Step 9. Record the value of IB.

IB should be 3 A ±5% and ±0.02 • I_{NOM}.

Step 10. Type **<Ctrl+X>** to end the scrolling of the status values of Relay Word bit 87R1.

Step 11. Type **MET DIF <Enter>** to obtain the operate current value and restraint current value.

These values should approximate the operate current values and restraint current values shown in *Figure 3.22*.

```
=>>MET DIF <Enter>

Relay 1                                    Date: 09/10/2015  Time: 07:41:32.970
Station A                                  Serial Number: 1150010001

Operate Currents    Restraint Currents
      (Per Unit)       (Per Unit)
ZONE     IOP              IRT
1       1.80              3.00
2       1.80              3.00
Current Reference (A)
IREF
3000

=>>
```

Figure 3.22 Example Values in Response to the MET DIF Command With Two Differential Elements Asserted

Step 12. Turn off the test set.

Step 13. Press pushbuttons PB5–PB8 and TARGET RESET.

Directional Element

Use the steps in the following example to test the directional element. Apply the same relay settings as when testing the differential element. To test the directional element characteristic, use the test connections as shown in *Figure 3.23*.

Figure 3.23 Test Connections for Testing the Directional Element

Figure 3.24 shows the directional element characteristic, the shaded area indicating an internal fault.

Figure 3.24 Directional Element Characteristic

The test consists of two parts. In the first part, we test the threshold of the directional element. The directional element only considers terminals with current values exceeding the threshold value in the directional calculations. In the second part, we test the boundaries of the element characteristic.

Step 1. Test the threshold value by injecting the current values shown in *Table 3.8* into the relay.

Table 3.8 Current Values for Testing the Threshold Value of the Directional Element

Current	Current Injected
IA	0.2∠0°
IB	2.0∠180°

a. Type **TAR 50DS01 <Enter>** to obtain the relay response as shown in *Figure 3.25*.

b. Verify that only Relay Word bit 50DS03 has a value of logical 1.

```
=>>TAR 50DS01 <ENTER>

50DS08   50DS07   50DS06   50DS05   50DS04   50DS03   50DS02   50DS01
0        0        0        0        0        1        0        0

=>>
```

Figure 3.25 Relay Response to the TAR 50DS01 Command

c. Type **TAR 50DS01 9999 <Enter>** and slowly increase current IA.

Relay Word bit 50DS01 asserts when IA reaches a value of approximately 0.26 A.

d. Stop the injection.

e. Type **<Ctrl+X>** to end the scrolling of the Relay Word bit 50DS01 status values.

Step 2. Test the boundary values.

a. Press pushbuttons PB5 and PB7.

b. Inject the current values shown in *Table 3.9* into the relay.

Table 3.9 Current Values for Testing the Boundary Values of the Directional Element

Current	Current Injected
IA	2.0∠0°
IB	2.0∠90°

c. Type **TAR DE1F <Enter>** to obtain a relay response similar to that shown in *Figure 3.26*.

d. Verify that Relay Word bit DE1F is deasserted.

```
=>>TAR DE1F <Enter>

*        *        DE6F     DE5F     DE4F     DE3F     DE2F     DE1F
0        0        0        0        0        0        0        0
```

Figure 3.26 Relay Response to the TAR DE1F Command

e. Type **TAR DE1F 9999 <Enter>** and slowly decrease the angle of current IB.

Relay Word bit DE1F asserts when the angle reaches a value of approximately 74 degrees.

f. Quickly move the angle to –70 degrees and continue to slowly decrease the angle of current IB.

Relay Word bit DE1F deasserts when the angle reaches a value of approximately –74 degrees.

g. Type **<Ctrl+X>** to end the scrolling of the status values of Relay Word bit DE1F.

h. Stop the injection.

Voltage Elements

The SEL-487B-1 includes six overvoltage and six undervoltage elements. Each element has two pickup level settings, with a definite-time delay assigned to Level 1. The operating quantity for the input to each voltage element is selectable, with phase, zero-sequence, and negative-sequence voltage quantities available for selection. We will test the phase voltage elements for the voltage inputs.

Phase Over- and Undervoltage Elements

Figure 3.27 shows the steps to apply settings to the over- and undervoltage elements to V01.

```
=>>SET E27 <Enter>

Group 1

Relay Configuration

Enable Under Voltage Elements (N,1-6)                E27     := N      ?1 <Enter>
Enable Over Voltage Elements (N,1-6)                 E59     := N      ?1 <Enter>
Advanced Settings (Y,N)                              EADVS   := N      ? <Enter>

.
.
.

Under Voltage (27) Element 1

U/V Element 1 Operating Quantity                     27O1    := V01FIM ? <Enter>
U/V Element 1 Level 1 P/U (2.00-300 V,sec)           27P1P1  := 20.00  ?60 <Enter>
U/V Element 1 Torque Control (SELogic Eqn)
27TC1 := 1
?  <Enter>
U/V Element 1 Level 1 Delay (0.00-16000 cyc)         27P1D1  := 10.00  ? <Enter>
U/V Element 1 Level 2 P/U (2.00-300 V,sec)           27P1P2  := 15.00  ?55 <Enter>


Over Voltage (59) Element 1

O/V Element 1 Operating Quantity                     59O1    := V01FIM ? <Enter>
O/V Element 1 Level 1 P/U (2.00-300 V,sec)           59P1P1  := 76.00  ?70 <Enter>
O/V Element 1 Torque Control (SELogic Eqn)
59TC1 := 1
?  <Enter>
O/V Element 1 Level 1 Delay (0.00-16000 cyc)         59P1D1  := 10.00  ? <Enter>
O/V Element 1 Level 2 P/U (2.00-300 V,sec)           59P1P2  := 80.00  ?75 <Enter>


Trip Logic

Trip 01 (SELogic Equation)
TRO1 := 0
?  END <Enter>
.
.
.

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


=>>
```

Figure 3.27 Over- and Undervoltage Element Settings

Verify the operation of the phase over- and undervoltage elements.

Step 1. Connect a source of variable three-phase voltage to the relay as shown in *Figure 3.28*.

Figure 3.28 Test Connections for Testing the Voltage Elements

Step 2. Test the overvoltage elements by applying the voltage values shown in *Table 3.10* to the relay.

Table 3.10 Injected Voltage Values for Testing the Overvoltage Elements

Channel	Voltage Value
VA	67∠0°
VB	67∠–120°
VC	67∠120°

The voltage elements are on a per-phase basis, with V01 (A-phase) assigned to voltage Element 1. Similar steps can be followed to assign V02 (B-phase) to voltage Element 2 and V03 (C-phase) to voltage Element 3. Relay Word bits 591P1T, 591P2, 592P1T, and 592P2 are in the same row.

a. Type **TAR 591P1T 999 <Enter>** to see the status of these Relay Word bits.

b. Raise the A-phase voltage (V01) until Relay Word bit 591P1 asserts.

   The voltage should equal 70 V ±0.5 V and ±5%.

c. Continue to increase the voltage until Relay Word bit 591P2 asserts.

   The voltage should equal 75 V ±0.5 V and ±5%.

d. Type **<Ctrl+X> <Enter>** to end the scrolling of the Relay Word bits status values.

e. Stop the injection.

Step 3. Test the undervoltage elements.

a. Apply the voltage values shown in *Table 3.10* to the relay.

b. Type **TAR 271P1T 999 <Enter>** to see the status of these Relay Word bits.

c. Lower the A-phase voltage (V01) until Relay Word bit 271P1 asserts.

   The voltage should equal 60 V ±0.5 V and ±5%.

d. Continue to lower the applied voltage until Relay Word bit 271P2 asserts.

   The voltage should equal 55 V ±0.5 V and ±5%.

e. Type **<Ctrl+X> <Enter>** to end the scrolling of the Relay Word bits status values.

f. Stop the injection.

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 4

Front-Panel Operations

The SEL-487B relay front panel makes power system data collection and system control quick and efficient. Using the front panel, you can examine power system operating information, view and change port, group, and global settings, and perform relay control functions. The relay features a straightforward menu-driven control structure presented on the front-panel liquid crystal display (LCD). Front-panel targets and other LED (light-emitting diodes) indicators give a quick look at SEL-487B 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 the following:

- Reading metering
- Inspecting targets
- Accessing port, group, global, date, and time settings
- Controlling relay operations

General front-panel operations are described in *Section 4: Front-Panel Operations in the SEL-400 Series Relays Instruction Manual*. This section provides additional information that is unique to the SEL-487B. This section includes the following:

- *Front-Panel LCD Default Displays on page 4.1*
- *Front-Panel Menus and Screens on page 4.5*
- *Target LEDs on page 4.7*
- *Front-Panel Operator Control Pushbuttons on page 4.9*

Front-Panel LCD Default Displays

The SEL-487B has two screen scrolling modes: autoscrolling and manual scrolling. After the initial relay power up, or after front-panel time out, the LCD presents each of the display screens in this sequence:

- Any active (filled) alarm points screens
- Any active (filled) display points screens
- Enabled metering screens
- Zone configuration screens

If enabled, the relay displays the metering and zone configuration screens in the order listed in *Table 4.1* (see *Figure 4.4* for samples of the metering screens). This sequence comprises the `ROTATING DISPLAY`.

Table 4.1 Metering Screens Enable Settings (Sheet 1 of 2)

Name	Description	Range	Default
STA_BAT	Station Battery Screen	Y, N	N
FUND_VI	Fundamental Voltage and Current Screens	Y, N	Y

Table 4.1 Metering Screens Enable Settings (Sheet 2 of 2)

Name	Description	Range	Default
DIFF	Differential Metering	Y, N	Y
ZONECFG	Terminals Associated With Zones	Y, N	Y

Use the front-panel settings (the **SET F** command from a communications port or the **Front Panel** settings in ACSELERATOR QuickSet SEL-5030 Software) to access the metering screen enable settings. Entering a **Y** (Yes) for a metering screen enable setting results in the corresponding metering screen appearing in the ROTATING DISPLAY. Entering an **N** (No) hides the metering screen from presentation in the ROTATING DISPLAY. If all metering screen enable settings are set to **N** (No) and there are no configured display points screens, the DIFF screen appears by default in the ROTATING DISPLAY. *Figure 4.1* shows a ROTATING DISPLAY example consisting of an example alarm points screen, a display points screen, and one of the factory-default metering screens (the screen values in *Figure 4.1* are representative values).

Figure 4.1 ROTATING DISPLAY

The active alarm points are the first screens in the ROTATING DISPLAY (see *Alarm Points on page 4.7 in the SEL-400 Series Relays Instruction Manual*). Each alarm points screen shows as many as 11 alarm conditions. The SEL-487B can present a maximum of six alarm points screens.

The active display points are the next screens in the ROTATING DISPLAY (see *Display Points on page 4.10 in the SEL-400 Series Relays Instruction Manual*). Each display points screen shows as many as 11 enabled display points. (With 94 display points, the SEL-487B can present a maximum of 9 display point screens.) If a display point does not have text to display, the screen space for that display point is maintained.

METER

Factory-enabled metering screens scroll through the following metering screens:

- Differential quantities
- Zone configuration (when active)
- Fundamental Current
- Fundamental Voltage

Figure 4.2 shows the zone specific and check zone differential metering screens. The display shows the Bus-Zone number and the operating and restraint current for each active zone. An active zone is a zone with at least one terminal in the zone. Zones become inactive when there are no terminals connected to the zone or when the zone was merged with other zones. Inactive zones are not displayed. *Figure 4.2* shows an example with two zones active.

```
ROTATING DISPLAY
ZONE SPECIFIC
ZONE  IOP      IRT
 1    0.12     2.3
 2    0.05     1.0

            (PER UNIT)
Press ↵ For Menu
```

```
ROTATING DISPLAY
CHECK ZONE
ZONE  IOP      IRT
 1    0.00     2.7
 2    0.00     2.71
 3    0.00     2.7

            (PER UNIT)
Press ↵ For Menu
```

Figure 4.2 Differential Screens

Figure 4.3 shows the screen displaying the terminal(s) present in each active zone. For each active zone, the relay displays the terminals connected to that particular zone. When two zones merge, the new zone carries the zone number of the lower of the two zones. For example, when Zones 2 and 4 merge, the new combined zone becomes Zone 2.

```
ROTATING DISPLAY

TERMINALS IN ZONE 1
 TRFR_1     FEEDR_3
 TRFR_2     FEEDR_5
 FEEDR_1    FEEDR_8
   •          •
   •          •
   •          •
   •          •
   •          •
   •          •
Press ↵ For Menu
```

Figure 4.3 Terminals in Zone Screen

Figure 4.4 shows the fundamental current screens, displaying the primary current and phase angle for each terminal.

```
ROTATING DISPLAY
PRIMARY CURRENT (A)

TERM ID   MAG/ANGLE

FDR_1   214.45   45°
FDR_2   230.07   50°
FDR_3   121.49 -143°
TRFR_1   20.64 -119°
TB_1    212.32   75°
TB_1    321.44   49°

Press ↵ For Menu
```

```
ROTATING DISPLAY
PRIMARY CURRENT (A)

TERM ID   MAG/ANGLE
I07     214.45   45°
I08     230.07   50°
I09     121.49 -143°
I10      20.64 -119°
I11     212.32   75°
I12     321.44   49°

Press ↵ For Menu
```

```
ROTATING DISPLAY
PRIMARY CURRENT (A)

TERM ID   MAG/ANGLE
I13     214.45   45°
I14     230.07   50°
I15     121.49 -143°
I16      20.64 -119°
I17     212.32   75°
I18      21.44   49°

Press ↵ For Menu
```

```
ROTATING DISPLAY
PRIMARY CURRENT (A)

TERM ID   MAG/ANGLE
I19     214.45   45°
I20     230.07   50°
I21     121.49 -143°

Press ↵ For Menu
```

Figure 4.4 Fundamental Primary Current Screens

All angles are referenced to the voltage connected to voltage terminal V01. If voltage at terminal V01 is not available, the relay selects V02, and then V03. In the absence of voltage inputs, the relay references the current input of I01, provided the current is above 0.05 • I_{NOM}. If I01 is not above this current level, the relay references the current from I02, if available. If I02 is not available, the relay continues to I03, I04, and so on until it finds a current input above 0.05 • I_{NOM}.

Figure 4.5 shows the primary voltage magnitudes and angles from the three voltage inputs in kV.

```
ROTATING DISPLAY
PRIMARY VOLTAGE (kV)

TERM ID  MAG/ANGLE
V01     88.00     5°
V02     88.00 -125°
V03     88.00  115°

Press ↵ For Menu
```

Figure 4.5 Fundamental Primary Voltage Screen

Use the **SET F** command and set STA_BAT = Y to enable the station battery screen, as displayed in *Figure 4.6*.

Figure 4.6 Station Battery Screen

Front-Panel Menus and Screens

Operate the SEL-487B 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 on-site access to control and port settings. Use the following menus and screens to set the relay and perform local control actions:

- Support Screens
  - Adjust Contrast
  - Password
- MAIN MENU
  - EVENTS
  - RELAY ELEMENTS
  - LOCAL CONTROL
  - SET/SHOW
  - RELAY STATUS
  - VIEW CONFIGURATION
  - DISPLAY TEST
  - RESET ACCESS LEVEL

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-487B.

Events

Section 4: Front-Panel Operations in the SEL-400 Series Relays Instruction Manual describes viewing summary events from the front panel. *Figure 4.7* illustrates what a summary event report looks like in an SEL-487B.

Figure 4.7 EVENT SUMMARY Screen

View Configuration

You can use the front panel to view detailed information about the configuration of the firmware and hardware components in the SEL-487B. In the MAIN MENU, highlight the VIEW CONFIGURATION option by using the navigation pushbuttons. The relay presents five screens in the order shown in *Figure 4.8*. Use the navigation pushbuttons to scroll through these screens. When finished viewing these screens, press **ESC** to return to the MAIN MENU.

```
CONFIGURATION INFO
FID=SEL-487B-1-R308-
  V0-Z010005-
  D20150414
PART NUMBER: 0487B1X
  6252XC2XEH7EEXXX
S/N=0000000000
SELBOOT:
  BFID=SLBT-4XX-
  R209-V0-Z001002-
  D20150130
  CHECKSUM: 4DDF
```

```
CONFIGURATION INFO
MAINBOARD:
  CODE FLASH: 12 MB
  DATA FLASH: 52 MB
  RAM:        64 MB
  EEPROM:    128 KB

ANALOG INPUTS:
  CURRENTS:  5 A
  VOLTAGE:  67 V
```

```
CONFIGURATION INFO

INTERFACE BOARDS:
  BOARD 1:24 INPUTS
          8 OUTPUTS
  BOARD 2:NOT
          INSTALLED
  BOARD 3:NOT
          INSTALLED
  BOARD 4:NOT
          INSTALLED
EXTENDED FEATURES:
  IEC 61850
```

```
CONFIGURATION INFO

COMMUNICATIONS CARD:
  ETHERNET
    PORT A: NA
    PORT B: NA
    PORT C: COPPER
    PORT D: COPPER
```

```
CONFIGURATION INFO
IF THE CONFIGURATION
IS NOT WHAT YOU
EXPECTED, CONTACT
SEL FOR ASSISTANCE.
```

Figure 4.8 VIEW CONFIGURATION Sample Screens

Target LEDs

The SEL-487B 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. The SEL-487B provides either 16 or 24 LEDs, depending on ordering options selected.

The general operation and configuration of these LEDs is described in *Section 4: Front-Panel Operations in the SEL-400 Series Relays Instruction Manual*. Please note that the SEL-487B has the alternate behavior on the T*n*_LED bits: they latch independently of the trip condition. For a concise listing of the default programming on the front-panel LEDs, see *Front-Panel Settings on page 12.20 in the SEL-400 Series Relays Instruction Manual*.

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. *Figure 4.9* shows the arrangement of the operation and target LEDs region into several areas described in *Table 4.2*.

Figure 4.9 Factory-Default Front-Panel Target Areas (16 or 24 LEDs)

Table 4.2 Front-Panel Target LEDs

Label	Function
ENABLED, TRIP	Operational
87 (DIFF), BKR FAIL, ZONE 1, ZONE 2, ZONE 3, ZONE 4, ZONE 5, ZONE 6, 50, 51	Protection and Zone Indication
CT ALARM, 87 BLOCKED, TOS, 89 IN PROG, 89 ALARM, PT ALARM	Alarms
27[a], 59[a], V01 ON[a], V02 ON[a], V03 ON[a] BUS FAULT[a], 52 ALARM[a] IRIG LOCK[a]	Voltage Status Miscellaneous Status Clock Status

[a] Only available in 24 LED models.

Protection and Zone Indication

The SEL-487B indicates essential information about the most recent relay trip event with the LEDs of the Protection and Zone Indication area. These trip types are **87 (DIFF)**, **BKR FAIL**, **ZONE 1–6**, **50**, **51**.

The **87 (DIFF)** target LED illuminates and latches the indication, indicating operation of any one of the six SEL-487B differential elements.

The **BKR FAIL** target LED illuminates and latches the indication, indicating operation of any one of the 21 SEL-487B breaker failure elements.

The **ZONE 1–6** target LEDs illuminate and latches the indication, indicating the zone(s) in which the fault occurred.

The **50** target LED illuminates and latches the indication, indicating operation of any one of the 21 nondirectional, instantaneous elements.

The **51** target LED illuminates and latches the indication, indicating operation of any one of the 21 nondirectional, time-delayed overcurrent elements.

Alarms

The alarm area target indicators are the **CT ALARM**, **87 BLOCKED**, **TOS**, **89 IN PROG**, **89 ALARM**, **PT ALARM** LEDs.

The **CT ALARM** (current transformer) target illuminates but does not latch the indication when any one of the six sensitive differential elements times out.

The **87 BLOCKED** target illuminates and latches the indication when any one of the six Zone Supervision (Z*n*S) SELOGIC control equations becomes a logical 0.

The **TOS** (Terminal Out of Service) target illuminates but does not latch the indication when any one of the 21 terminals is out of service.

The **89 IN PROG** target illuminates but does not latch the indication when a disconnect operation is in progress on any one of the 60 disconnects.

The **89 ALARM** (Disconnect Alarm) target illuminates but does not latch the indication when the disconnect alarm 89AL asserts.

The **PT ALARM** (potential transformer) target illuminates and latches after a 240-cycle time delay, indicating the presence of a negative- or zero-sequence voltage. This function works on the assumption that all three phases from the PTs are available in the same relay with an ABC phase rotation. In a three-relay application, wire the three phases from the PTs to the same SEL-487B.

Voltage Status

The **27** target LED illuminates when any one of the terminal undervoltage elements operates.

The **59** target LED illuminates when any one of the terminal overvoltage elements operates.

The **V01 ON**, **V02 ON**, and **V03 ON** LEDs illuminate when the terminal filtered instantaneous voltages are greater than 55 V. See *Table 8.50* for setting default values. The default setting of 55 V is 82 percent of the line-to-neutral nominal voltage of 67 V to coincide with the nominal line-to-line voltage of 115 V.

Miscellaneous Status

The **BUS FAULT** target LED illuminates when a busbar fault is detected (Relay Word bit FAULT is asserted).

The **52 ALARM** target LED illuminates when the relay detects any circuit breaker alarm (Relay Word bit 52AL is asserted).

Clock Status

The **IRIG LOCK** target LED illuminates in the SEL-487B when the relay detects synchronization to an external clock with less than 500 ns of jitter (Relay Word bit TIRIG is asserted). See *IRIG-B Timekeeping on page 11.1 in the SEL-400 Series Relays Instruction Manual* for complete details.

Front-Panel Operator Control Pushbuttons

The SEL-487B front panel features large operator control pushbuttons coupled with amber annunciator LEDs for local control. *Figure 4.10* shows this region of the relay front panel with factory-default configurable front-panel label text. The SEL-487B provides either 8 or 12 pushbuttons depending on ordering options selected.

Figure 4.10 Operator Control Pushbuttons and LEDs (8 Pushbutton Version)

Factory-default programming associates specific relay functions with the pushbuttons and LEDs. The SEL-487B default setting uses only three of the pushbuttons, as listed in *Table 4.3*. For a concise listing of the default programming for the front-panel pushbuttons and LEDs, see *Front-Panel Settings on page 8.21*.

Table 4.3 Operator Control Pushbuttons and LEDs—Factory Defaults

LED	Function
87 (DIFF) ENABLED	Enable the differential protection
BKR FAIL ENABLED	Enable the breaker failure protection
RELAY TEST MODE	Enable the differential and breaker failure protection, but inhibit trip outputs

Press the operator control pushbuttons momentarily to toggle on and off the functions listed adjacent to each LED/pushbutton combination. The operator control pushbuttons and LEDs are programmable. *Figure 4.11* describes the factory defaults for the three operator controls.

There are two ways to program the operator control pushbuttons. The first is through front-panel settings PB*n*_HMI. 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, and SER. All PB*n*_HMI settings are OFF by default. 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 the **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 change the default pushbutton and 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 *Front-Panel Templates on page 2.2* for more information on changing the slide-in labels.

The SEL-487B 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 factory defaults programmed for three LEDs used are protection latches (PLT01, for example), settings groups, and Relay Word bits. The asserted and deasserted colors for the LED are determined with settings PB1COL–PB12COL (12-pushbutton version). 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.

SELogic Factory Setting	Operator Control Pushbutton	LED Label	Description
PB1_LED = DIFF_EN # Differential Protection Enabled		87 (DIFF) ENABLED	Press this operator control pushbutton enable differential protection. The corresponding **87 (DIFF) ENABLED** LED is illuminated amber indicating that DIFF_EN=1. DIFF_EN is the default alias setting for the Relay Word bit PLT01. DIFF_EN is included in the Terminal to Bus Connection Logic setting for I*qq*BZ*p*V (*qq* = 00–21, *p* = 1–6) and effectively supervises the terminal to bus-zone connection. Therefore, if PB1 is not pressed, DIFF_EN = 0 and the terminal Iqq will not be connected to bus zone BZp. To disable differential protection, press and hold this pushbutton for one second until the LED is no longer illuminated. If the LED is off, DIFF_EN = 0.
PB2_LED = BF_EN # Breaker Failure Enabled		BKR FAIL ENABLED	Press this operator control pushbutton enable breaker failure initiate settings. The corresponding **BKR FAIL ENABLED** LED is illuminated amber indicating that BF_EN = 1. BF_EN is the default alias setting for the Relay Word bit PLT02. BF_EN is included in the Breaker Failure Initiate setting for BFI01–BFI06. Therefore, if PB2 is not pressed, BF_EN = 0 and the breaker failure initiate equation cannot be true. To disable breaker failure protection, press and hold this pushbutton for one second until the LED is no longer illuminated. If the LED is off, BF_EN = 0.
PB3_LED = NA			
PB4_LED = TNS_SW # Test normal Switch Enabled		RELAY TEST MODE	Press this operator control pushbutton to disable outputs OUT101–OUT105 and close OUT107. The corresponding **RELAY TEST MODE** LED is illuminated amber indicating that TNS_SW = 1. TNS_SW is the default alias setting for the Relay Word bit PLT03. TNS_SW is included in the output equation for OUT101–OUT105. Therefore, if PB4 is pressed, TNS_SW = 1 and the output equations supervised by this Relay Word bit cannot be true and the associated outputs will not close. This is useful functionality for testing TRIP01–TRIP05 equations during commissioning, but preventing the output operation. To disable the test mode, press and hold this pushbutton for one second until the LED is no longer illuminated. If the LED is off, TNS_SW = 0.
PB5_LED = NA PB6_LED = NA PB7_LED = NA PB8_LED = NA PB9_LED = NA PB10LED = NA PB11LED = NA PB12LED = NA			

Figure 4.11 Factory-Default Operator Control Pushbuttons

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SECTION 5

Protection Functions

NOTE: If the relay is using TiDL (EtherCAT), the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay.

This section provides a detailed explanation of the SEL-487B relay protection functions. Each subsection 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.

Functions discussed in this section are listed below.

- *Busbar Protection Elements on page 5.1*
- *Check Zone Protection Elements on page 5.10*
- *Sensitive Differential Element on page 5.12*
- *Zone Supervision Logic on page 5.14*
- *Dynamic Zone Selection Logic on page 5.14*
- *Check Zone Selection on page 5.16*
- *Instantaneous/Delayed Overcurrent Elements on page 5.17*
- *Selectable Time-Overcurrent Elements (51) on page 5.18*
- *Over- and Undervoltage Elements on page 5.25*
- *Open-Phase Detection Logic on page 5.28*
- *Open CT Detection Logic on page 5.29*
- *Circuit Breaker Failure Protection on page 5.30*
- *Circuit Breaker Failure Trip Logic on page 5.34*
- *Bus Coupler/Bus Sectionalizer Configurations on page 5.36*
- *Coupler Security Logic on page 5.37*
- *Disconnect Monitor on page 5.43*
- *Zone-Switching Supervision Logic on page 5.45*
- *Differential Trip Logic on page 5.47*
- *Breaker Trip Logic on page 5.48*
- *Circuit Breaker Status Logic on page 5.49*

Busbar Protection Elements

Busbar protection philosophy traditionally calls for two-out-of-two trip criteria, where two separate measuring elements must agree before protection issues a trip signal. Realization of the two-out-of-two trip criteria can occur by using one of the combinations of measuring elements listed below:

- Dual differential element combination (main zone and check zone)
- Differential element and directional element combination (main zone and directional element)

Each combination has an advantage over the other; the weakness of one being the strength of the other. In particular, differential elements (amplitude comparators) are more vulnerable to CT saturation than directional elements (phase comparators), but directional elements (phase comparators) are more vulnerable to high-impedance faults.

CT saturation is a concern in networks with high fault currents. Poor CT selection increases the potential for CT saturation. In networks with impedance grounding, all ground faults are high-impedance faults. Although relays may have been correctly selected in the initial network design, changes in the network may adversely influence the network parameters. For example, network extensions or reduced source impedance result in higher fault current, and deterioration of the substation grounding mat at the substation may result in higher fault impedance for ground faults.

Modern busbar protection relays should not only include protection elements to allow for diverse network parameters, but the implementation of these elements in the relays must ensure continual, uncompromising relay performance, despite changes in network parameters. In general, busbar protection must comply with the following performance requirements:

- Fast operating times for all busbar faults
- Security for external faults with heavy CT saturation
- Minimum delay for evolving faults

The SEL-487B meets the above performance requirements during all system operating conditions. The relay includes six busbar protection elements for the protection of as many as six zones. Each of the six busbar protection elements consists of the following three elements (see *Figure 5.1*):

- Differential element using phasor values
- Directional element using phasor values
- Fault detection logic using instantaneous values

Figure 5.1 shows a block diagram of one of the six busbar protection elements, with only two (I01 and I02) of the available 21 current inputs connected. The relay uses the highest CT ratio (CTR_{MAX}) divided by the lowest CT ratio (CTR_{MIN}) to verify that the CT ratio mismatch for the differential protection is less than 10:1. Only CT ratios associated with terminals that are used in the terminal-to-bus-zone settings will be used to determine CTR_{MAX} and CTR_{MIN}. Because the relay accepts current inputs from CTs with a 10:1 ratio mismatch, the calculations for the differential elements are performed on per unit values. The relay uses the highest CT ratio (CTR_{MAX}) of the installed CT ratios as a reference value in converting the input currents from ampere to per unit values. Using *Equation 5.1*, the relay calculates a normalization factor value (TAP) for each terminal:

$$TAP\mathit{nn} = \frac{CTR_{MAX} \bullet I_{NOM}}{CTR\mathit{nn}}$$

Equation 5.1

where:

$TAP\mathit{nn}$ = TAP value for each terminal to convert current from ampere to per unit (*nn* = 01–21)

CTR_{MAX} = Highest CT ratio of the terminals used in the terminal-to-bus-zone settings

I_{NOM} = Nominal CT secondary current (1 A or 5 A)

$CTR\mathit{nn}$ = CT ratio of the specific terminal

Using the TAP*nn* values, the relay calculates the current in per unit values for each terminal as shown in *Equation 5.2*:

$$\mathrm{I}nn\mathrm{CR} = \frac{\mathrm{I}nn}{\mathrm{TAP}nn}\mathrm{pu}$$

Equation 5.2

where:

I*nn*CR = Per unit current for Terminals I01–I21

I*nn* = Current in amperes for Terminals I01–I21

pu = per unit

Figure 5.1 shows the block diagram for Busbar Protection Element 1, one of six busbar protection elements available in the relay. Throughout the following element descriptions, the numerical part of the Relay Word bits refers either to elements from a specific busbar protection element (1–6) or the specific terminal number (01–21). In most cases, the protection element descriptions refer to elements from Busbar Protection Element 1. For example, FDIF1 in *Figure 5.1* refers to the output from the filtered differential element of Busbar Protection Element 1. I01 and I02 refer to current inputs from Terminal I01 and Terminal I02.

Figure 5.1 Block Diagram Showing the Logic for Busbar Protection Element 1

Referring to *Figure 5.1*, after the per unit conversion, the data (I01CR and I02CR) follow two separate paths. One path is through a digital band-pass filter (DBPF) to the filtered differential element and the directional element; the other path brings the instantaneous values to the fault detection logic.

The filtered differential element uses the input currents from each terminal in a protection zone to calculate the operate and restraint currents. The directional element compares the direction of current at a reference terminal to the direction of current at all other terminals in a protection zone to calculate fault direction. Several elements combine in the fault detection logic to distinguish between internal or busbar faults (FAULT1) and external faults (CON1).

AND Gate 1 combines the OR combination of the directional element (DE1F) and internal fault element (FAULT1) with the sensitive differential element (87ST1) to supervise the filtered differential element. P87R1, the output from Gate 1, drives a security timer that controls the final output (87R1) of the busbar protection element.

The logic includes three dedicated check zones (see *Check Zone Protection Elements on page 5.10*). This flexibility provides the opportunity to configure the dual differential (main zone and check zone) element combination.

Filtered Differential Element

The following discussion refers to the Filtered Differential Element 1, (with only Terminals 01 and 02 connected to the element) but applies equally well to the remaining five filtered differential elements. Using the output quantities from the digital band-pass filter (cosine filter), the filtered differential element calculates a restraint quantity, IRT1, and an operating quantity, IOP1, according to *Equation 5.3* and *Equation 5.4*:

$$IRT1 = |I01CF| + |I02CF|$$

Equation 5.3

and

$$IOP1 = |I01CF + I02CF|$$

Equation 5.4

where:

I01CF and I02CF = Filtered per unit current values from Terminals I01 and I02

Figure 5.2 shows a block diagram of the elements necessary for obtaining the differential and restraint quantities used in the filtered differential elements. Relay Word bit FDIF1 is the output from the differential calculation. Relay Word bit 87O1 asserts when the differential current exceeds the O87P threshold. Together these two Relay Word bits form the filtered differential element characteristic.

Figure 5.2 Filtered Differential Element 1

Figure 5.3 shows the characteristic of the differential element as a straight line through the origin of the form:

$$IOP1(IRT1) = SLP1 \bullet IRT1$$

Equation 5.5

Figure 5.3 Filtered Differential Element Characteristic

For operating quantities (IOP1) exceeding the threshold level O87P and falling in the operate region of *Figure 5.3*, the filtered differential element issues an output. There are two slope settings. Slope 1 (SLP1) is effective for internal faults, and Slope 2 (SLP2) is effective for external faults. To change the slope values, first enable the advanced settings by setting EADVS := Y in Group Settings and then proceed to change the slope values. When the fault detection logic detects an external fault condition, Relay Word bit CON1 asserts. CON1 switches the slope of the differential characteristic from Slope 1 to Slope 2 to add security to the filtered differential element (see *Fault Detection Logic on page 5.7*).

Directional Element

The relay includes directional elements that supervise the filtered differential elements. In particular, the directional elements provide additional security to the filtered differential elements during external faults with heavy CT saturation conditions. Each of the six busbar protection elements has a directional element specific to that differential element.

The directional element compares the direction of current at the reference terminal to the direction of current at all other qualifying terminals in each zone. A qualifying terminal is a terminal with current value greater than the 50DSP threshold setting; the relay selects one of these currents as a reference. For each calculation, the relay uses the real part of the product of the terminal current and the conjugate of the current at the reference terminal, as depicted in *Figure 5.4*.

Figure 5.4 Torque Calculation Used in the Directional Element to Determine Fault Direction

The relay declares an internal fault condition when the direction of current at all the remaining terminals coincides with the direction of current at the reference terminal. For the directional element to begin processing, the current values of at least two terminals within the zone must exceed the 50DSP threshold. *Figure 5.5* shows the directional element characteristic, the shaded area indicating an internal fault.

Figure 5.5 Directional Element Characteristic, the Shaded Area Indicating an Internal Fault

The relay acquires the terminals within each specific protection zone from the zone selection logic. The relay determines the terminals with phase current greater than the 50DSP threshold and selects one of the currents greater than the 50DSP threshold as a reference. The relay establishes fault direction by comparing the direction of current at the reference terminal to that at the remaining terminals in the zone with phase current greater than the 50DSP threshold.

Referring to *Figure 5.6*, consider the case of four terminals in Zone 1, with inputs labeled I01CF, I02CF, I03CF, and I04CF. Further, assume that the current magnitude in terminal I04CF is below the 50DSP threshold.

Figure 5.6 Directional Element Logic

First, the directional element determines which terminals have phase current magnitude greater than the 50DSP threshold. Because the current magnitude of input I04CF is below the 50DSP threshold, the relay selects only inputs I01CF, I02CF, and I03CF for further processing. The relay selects input I01CF as the reference (IREF) and compares the direction of current I02CF (IT02) and current I03CF (IT03) to this reference. DE1F asserts only if the direction of current at both IT02 and IT03 coincides with the direction of current at the reference terminal according to the directional element characteristic shown in *Figure 5.5*.

Fault Detection Logic

The fault detection logic distinguishes between external faults (external fault detection logic) and internal faults (internal fault detection logic), as shown in *Figure 5.7*. When the fault detection logic detects an external fault, Relay Word bit CON1 asserts, and when the fault detection logic detects an internal fault, Relay Word bit FAULT1 asserts.

Figure 5.7 Fault Detection Logic That Distinguishes Between External and Internal Faults

Elements in the fault detection logic use instantaneous per unit currents to calculate a restraint quantity, IRT1R, and an operating quantity, IOP1R, according to *Equation 5.6* and *Equation 5.7*:

$$IRT1R = |(I01CR)| + |(I02CR)|$$

Equation 5.6

and

$$IOP1R = |(I01CR + I02CR)|$$

Equation 5.7

where:

I01CR and I02CR = Instantaneous per unit current from Terminals 01 and 02.

Figure 5.8 shows a block diagram of how the fault detection logic obtains restraint quantity IRT1R and operating quantity IOP1R.

Figure 5.8 Fault Detection Logic Obtaining Restraint and Operating Quantities

External Fault Detection Logic

In general, operating and restraint currents increase simultaneously for internal faults; for external faults, only the restraint current increases if there is no CT saturation. By comparing the change in operating current (ΔIOP1R) to the change in restraint current (ΔIRT1R), the relay detects external fault conditions. Because CTs can saturate during external faults, the relay asserts the external fault condition (Relay Word bit CON1) for 60 cycles after detecting an external fault. *Figure 5.9* shows the logic for detecting external fault conditions.

Figure 5.9 External Fault Detection Logic

Asserting CON1 for 60 cycles can slow relay operation for evolving faults (where the fault starts as an external fault and then develops into an internal fault). To prevent delayed tripping, CON1 resets when either the directional element (DE1F) detects an evolving fault or the internal fault detection logic (IFAULT1) confirms an internal fault condition.

Relay Word bit CON1 controls the operating mode of the relay by asserting when the relay detects an external fault. The relay operates normally with CON1 deasserted but switches to a high-security mode when CON1 asserts. High security causes the following in the relay:

- Slope 1 changes to Slope 2.
- Delay time of the adaptive security timer increases.

Resetting CON1 releases the relay from the high-security mode, and the relay operates with the normal settings.

Internal Fault Detection Logic

For the internal fault detection logic, the relay uses a characteristic similar to the filtered differential element characteristic.

Figure 5.10 shows the internal fault detection logic consisting of the instantaneous differential element, the consecutive measurement fault detection logic, and the fast fault detection logic. When the raw operate current (IOP1R) exceeds the active slope and the O87P setting, RDIF1 asserts. RDIF1 forms the input into the consecutive measurement fault detection logic and the fast fault detection logic.

The consecutive measurement fault detection logic declares an internal fault when differential current still exists on a consecutive measurement one-half cycle after the instantaneous differential element asserted. When this logic detects an internal fault, the IFAULT1 Relay Word bit asserts.

Figure 5.10 Internal Fault Detection, Instantaneous Differential Element, Consecutive Measurement Fault Detection, and Fast Fault Detection Logics

If surge (lightning) arresters are installed on busbars, a path to ground exists when these devices conduct, resulting in operating current in the differential elements. The fast fault detection logic qualifies the operating current with a time

delay to differentiate between operating current resulting from surge arrester conduction and operating current because of internal faults. If the fast fault detection logic detects an internal fault, Relay Word bit GFAULT1 asserts.

Protection Element Output Logic

Figure 5.11 shows the four conditions from the relay measuring and control logic that must be fulfilled to start the security timer (the final stage in asserting the protection element output, Relay Word bit 87R1):

- An output from the filtered differential element, FDIF1
- An output from the filtered differential element threshold, 87O1
- An output from either the directional element (DE1F) or the internal fault detection logic (FAULT1)
- No output from the sensitive differential element (87ST1) with E87SSUP := Y

① See Figure 5.47.

Figure 5.11 Differential Element Output: Final Conditions and Adaptive Security Timer

When the four differential element output logic conditions are met, the output P87R1 starts the adaptive security timer. CON1 also controls the security timer time setting; when CON1 asserts, the relay increases the time delay by 0.4 cycles to increase security for the protection element.

Table 5.1 shows operating times for the bus differential elements. *Figure 5.12* shows the average operating times (minimum of five trials) for the differential element. Operating times include the time it takes for the 87R element to assert and does not take into consideration the output contact closure time. Tests were performed for 1, 2, 3, 4, 5, 6, and 7 multiples of pickup setting. At 7 times the setting, the deviation was 0.02 cycles. These tests do not include fault resistance. Operating times are the same for 50 Hz and 60 Hz.

Table 5.1 Restrained Differential Element (87R) Operating Times (Cycles) (Sheet 1 of 2)

Multiples of Pickup	Average
1	1.48
2	0.94
3	0.85
4	0.83
5	0.52

Table 5.1 Restrained Differential Element (87R) Operating Times (Cycles) (Sheet 2 of 2)

Multiples of Pickup	Average
6	0.51
7	0.52

Figure 5.12 Average 87R Operating Times

Check Zone Protection Elements

The SEL-487B logic includes three dedicated check zones, providing the flexibility and opportunity to configure the dual differential (main zone and check zone) element combination.

Figure 5.13 shows the block diagram for a Check Zone 1 Protection Element (Check Zones 2 and 3 are similar). Throughout the following element descriptions, the numerical part of the Relay Word bits refers to the specific terminal number (01–21). I01 and I02 refer to current inputs from Terminal I01 and Terminal I02.

Figure 5.13 Block Diagram Showing Logic for Check Zone Protection Element 1

Check Zone Filtered Differential Element

Figure 5.14 shows a block diagram of the elements necessary for obtaining the differential and restraint quantities used in the check zone filtered differential elements. Relay Word bit FDIFCZ1 is the output from the check zone differential calculation. Relay Word bit 87OCZ1 asserts when the differential current exceeds the CZO87P threshold. Together these two Relay Word bits form the check zone filtered differential element characteristic.

Figure 5.14 Check Zone Filtered Differential Element 1

Check Zone External Fault Detection Logic

Figure 5.15 shows the logic for detecting external fault conditions.

Figure 5.15 Check Zone External Fault Detection Logic

To change the threshold values, first enable the advanced settings (see *Section 8: Settings* for more information on setting the relay) by setting EADVS := Y in Group Settings and then enable the check zone settings by setting ECHKZN := Y.

Check Zone Internal Fault Detection Logic

For the internal fault detection logic, the relay uses a characteristic similar to the filtered differential element characteristic.

Figure 5.16 shows the internal fault detection logic consisting of the instantaneous differential element, the consecutive measurement fault detection logic, and the fast fault detection logic. RDIFCZ1, the output from the instantaneous differential element, forms the input into the consecutive measurement fault detection logic and the fast fault detection logic.

The consecutive measurement fault detection logic declares an internal fault when differential current still exists on a consecutive measurement one-half cycle after the instantaneous differential element asserted. When this logic detects an internal fault, the Relay Word bit IFLTCZ1 asserts.

Figure 5.16 Check Zone Internal Fault Detection, Instantaneous Differential Element, Consecutive Measurements Fault Detection, and Fast Fault Detection Logics

Check Zone Protection Element Output Logic

Figure 5.17 shows the four conditions from the relay measuring and control logic that must be fulfilled to start the security timer (the final stage in asserting the Check Zone Protection Element output, Relay Word bit 87RCZ1):

- An output from the check zone filtered differential element (FDIFCZ1)
- An output from the check zone filtered differential element threshold (87OCZ1)
- An output from either the check zone directional element (DECZ1F) or the check zone internal fault detection logic (FLTCZ1)
- No output from the check zone sensitive differential element (87STCZ1) with E87SSUP := Y

Figure 5.17 Check Zone Differential Element Output: Final Conditions and Adaptive Security Timer

When the four differential element output logic conditions are met, the output P87RCZ1 starts the adaptive security timer. CONCZ1 also controls the security timer time setting; when CONCZ1 asserts, the relay increases the time delay by 0.4 cycles to increase security for the protection element.

Sensitive Differential Element

For each zone, sensitive differential elements detect differential current resulting from CT open or short circuits conditions. If such a condition exceeds a settable delay, the element asserts an alarm. There are two Relay Word bits per zone: an instantaneous Relay Word bit, 87S1, and a time-delayed Relay Word bit, 87ST1.

Use 87ST1, the time-delayed output, for alarming and supervision. Each sensitive differential element compares the sensitive differential element operating quantity, IOP1, against the S87P threshold.

Figure 5.18 Sensitive Differential Element (87S)

The status of the sensitive differential element is one of the four conditions considered in the final output logic of the differential protection element (see *Figure 5.18*). With E87SSUP := Y, the output 87ST*n* supervises the differential protection element. When E87SSUP := N the sensitive differential (87ST*n*) element does not supervise the differential protection elements (87R*n*). Setting E87SSUP := N only removes the supervision function from the differential element, but does not disable the sensitive differential elements. The sensitive differential elements are still running and available for other functions such as asserting an alarm.

The sensitive differential elements may assert under load conditions if not set properly. To prevent these elements from asserting under load conditions, set the differential threshold setting 50 percent higher than the natural out-of-balance current at the station. Be sure to measure the worst natural out-of-balance current at the station. For example, in a double busbar layout with bus-zone-to-bus-zone connections, first merge the bus-zones before making the measurement (see *Dynamic Zone Selection Logic on page 5.14* and *Bus-Zone-to-Bus-Zone Connections on page 6.33* for more information). Use the **MET DIF** command to read the per unit operating current values from each protection zone.

Check Zone Sensitive Differential Element

Figure 5.19 Check Zone Sensitive Differential Element (87S)

Each check zone has an independent sensitive differential element. There are two Relay Word bits per zone: an instantaneous Relay Word bit, 87SCZ1, and a time-delayed Relay Word bit, 87STCZ1. Use 87STCZ1, the time-delayed output, for alarming and supervision. Each sensitive differential element compares the sensitive differential element operating quantity, IOPCZ1, against the CZS87P threshold.

Zone Supervision Logic

This logic provides final supervision criteria before a trip signal is issued. *Figure 5.20* shows the logic for Differential Element 1, but similar logic is available for all six differential elements. Relay Word bit 87R1 is the output from the differential element, and Z1S is a SELOGIC control equation in the zone configuration settings. The differential trip logic uses Relay Word bit 87Z1, the output from this logic, to determine which terminals to trip. See *Differential Trip Logic on page 5.47* for more detail.

Figure 5.20 Zone and Check Zone Supervision Logic

NOTE: Setting E87ZSUP := N sets ZnS to logical 1. This setting prevents the inadvertent blocking of the differential elements.

⚠CAUTION
Setting E87ZSUP := Y enables the zone supervision in all six zones. If you do not enter any supervision conditions for a particular zone, be sure to enter a 1 at the SELOGIC control equation prompt.

Setting Z1S is a SELOGIC control equation in which you can program the conditions for supervising the differential element (87R1). For example, this is the setting in which you enter the output from the check zone differential element during check zone configuration. Consider the case where a check zone is configured and 87CZ1 is the check zone element output. Both the check zone and the sensitive differential elements must supervise the 87R1 element. With E87SSUP := Y, 87ST1 is already included in the differential element supervision (one of the four final conditions; see *Figure 5.11*). Only the check zone information is required:

Z1S := **87CZ1**

Dynamic Zone Selection Logic

Busbar protection involves assigning the appropriate input current values to the corresponding differential elements for calculation of per zone operating and restraint quantities and determining the breakers to trip for differential and breaker failure protection operation. To allow flexible substation configuration without compromising busbar protection, the relay dynamically reassigns input currents to the appropriate differential elements when the station configuration changes.

Disconnect and breaker auxiliary contacts typically provide station configuration information in the form of control inputs, entered into the relay as SELOGIC control equations. By evaluating these SELOGIC control equations, the zone selection logic assigns the currents to the appropriate differential elements. When disconnects are closed in such a way that a solid connection exists between two (or more) zones, the zones merge, and only one zone is active. The active zone after a merge is always the zone with the lowest number. For example, if Zone 3 and Zone 4 merge, Zone 3 encompasses Zone 4.

When the SELOGIC control equation representing the Terminal-to-Bus-Zone becomes a logical 1, the zone selection algorithm processes the current values associated with that particular terminal (see *Table 5.2*). When the equation is logical 0, the current values are neither processed nor considered in the differential calculations. This is also true for the trip output. When the SELOGIC control equation of a terminal is a logical 0, the differential element issues no trip signals to that terminal.

Table 5.2 Current Values Assigned to the Differential Element as a Function of the Disconnect Status

SELOGIC Control Equation	Status	Meaning in the Differential Calculation
I01BZ1V := D891	D891 = 1 (closed)	I01 is part of differential Bus-Zone 1
I01BZ1V := D891	D891 = 0 (open)	I01 is not part of differential Bus-Zone 1

where:

I01BZ1V = SELOGIC control equation declaring the conditions when Terminal 1 connects to Bus-Zone 1

D891 = input from Terminal 1 disconnect auxiliary contact that changes state when the disconnect switch changes state

To properly configure the station, the zone selection algorithm requires the following information:

- Terminals to bus-zones connections, I*qq*BZ*p*V.
- Interconnections between bus-zones, BZ*p*BZ*p*V.

where:

qq = 01–21 (Terminal 1 to Terminal 21)

p = 1–6 (Bus-Zone 1 to 6)

Both I*qq*BZ*p*V and BZ*p*BZ*p*V are SELOGIC control equation variables that you enter in the relay when using the **SET Z** command to set the relay. In QuickSet, I*qq*BZ*p*V is found in **Group > Zone Configuration > Terminal To Bus-Zone Connections** and BZ*p*BZ*p*V is found in **Group > Zone Configuration > Bus-Zone To Bus-Zone Connections**.

Selecting the Zones

The relay runs the zone selection algorithm every protection processing interval and sets the appropriate zone switching operation (ZSWOP*p*) Relay Word bits for one cycle when there is a status change in either I*qq*BZ*p*V (terminal is connected to or disconnected from a bus-zone) or BZ*p*BZ*p*V (two or more bus-zones are connected together).

Based on the SELOGIC control equations I*qq*BZ*p*V and BZ*p*BZ*p*V, the zone selection logic determines the following:

- The bus-zone(s) to be included in each protection zone
- The active terminals to be included in each protection zone
- The terminals to trip for differential and breaker failure protection operations

Table 5.3 shows the Relay Word bits available in the zone selection logic with their descriptions.

Table 5.3 Relay Word Bits in the Zone Selection Logic (Sheet 1 of 2)

Quantity	Description
ZSWOP*p*	Picks up following a change to either bus-zone-to-bus-zone or terminal-to-bus-zone conditions in Zone *p*
ZONE*p*	Differential Zone *p* is active
I*qq*BZ*p*V	Terminal *qq* connected to BZ*p*
BZ*p*BZ*p*V	A connection exists between BZ*p* and BZ*p*

Table 5.3 Relay Word Bits in the Zone Selection Logic (Sheet 2 of 2)

Quantity	Description
ZN*p*I*qq*	Terminal *qq* connected to Zone *p*
ZN*p*I*qq*T	Terminal *qq* connected to Zone *p* and will be tripped
BZ*p*BZ*p*R	A connection exists between BZ*p* and BZ*p* and the coupler is removed
Z*p*BZ*p*	Bus-Zone *p* is part of Protective Zone *p*

Check Zone Selection

The check zone function in the SEL-487B-1 differs in three ways from the check zone in the SEL-487B-0:

- Each SEL-487B-1 has three check zones
- There are no Terminal-to-Check-Zone Connection Logic settings, I*qq*CZ1V, in the SEL-487B-1
- The SEL-487B-1 includes Advance Check Zone settings

The single check zone in each SEL-487B-0 means that you can use the check zone only in a three-relay application. The three check zones in each SEL-487B-1 makes it possible to configure a check zone for each of the three phases in a single-relay application.

On the basis that terminals in the check zone are independent of the disconnect auxiliary contact status, there is no need to configure Terminal-to-Check-Zone Connection Logic (i.e., I*qq*CZ1V in the SEL-487B-0) in the SEL-487B-1. Therefore, to include a terminal in the check zone, just enter the Terminal, Check-Zone, Polarity (P,N) settings, as shown below.

```
Check Zone Configuration

Enable Check Zones at Station (Y,N)                  ECHKZN  := N      ?Y

Check Zone Configuration: Terminal to Check Zone Connections

Terminal, Check-Zone, Polarity (P,N)
?  IO1 CZ1 P
Terminal, Check-Zone, Polarity (P,N)
?  IO2 CZ1 P
Terminal, Check-Zone, Polarity (P,N)
?  IO3 CZ1 P
Terminal, Check-Zone, Polarity (P,N)
?  IO4 CZ1 P
Terminal, Check-Zone, Polarity (P,N)
?
Enable Advance Check Zone Settings (Y,N)             EADVCZ  := N      ?N
```

In QuickSet, go to **Check Zone Configuration > Terminal *qq* To Check Zone Connections** and set CT*qq*CZ*p* (*p* = 1–3) to Y to include a terminal in a check zone as shown in *Figure 5.21*.

Figure 5.21 Check Zone Settings

When you enter a check zone in the Terminal-to-Check-Zone settings, the corresponding CZONE*x* (*x* = 1–3) Relay Word bit asserts. For example, in the above example, Relay Word bit CZONE1 asserts, but not Relay Word bits CZONE2 or CZONE3. Use the **TAR** ASCII command to verify the status of these Relay Word bits.

```
=>>TAR CZONE1<Enter>
*       *       *       *       *       CZONE3  CZONE2  CZONE1
0       0       0       0       0       0       0       1
```

The Advance Check Zone Settings provide a method to configure a check zone for applications with in-board CTs (see *Example of Check Zone With In-Board (Bushing) CTs on page 6.23*).

The SEL-487B-1 still includes Check Zone Supervision setting. Use these settings to disable the entire check zone. In the following example, CZ1S is set to 1 (the default setting), meaning that the check zone is always in service.

```
Check Zone Supervision
Differential Element Check Zone Supervision (Y,N)    E87CZSP := N      ?Y
Check Zone 1 Supervision (SELogic Equation)
CZ1S := 1
```

Instantaneous/Delayed Overcurrent Elements

NOTE: If the relay is using TiDL (EtherCAT), the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay.

Each of the 21 terminals includes a single level of phase instantaneous and time-delayed overcurrent elements. *Figure 5.22* shows the logic for the 50P*nn* element. Labels FIM (Filtered, Instantaneous, Magnitude) are included for informational purposes and indicate specific processes used in the relay (see *Section 12: Analog Quantities* for more information about analog quantities).

The logic compares the magnitudes of phase input current I*nn*FIM to a pickup setting 50P*nn*P. If the current magnitude exceeds the pickup level, Relay Word bit 50P*nn* asserts and the timer starts timing. After the time specified by the delay

setting 50P*nn*D expires, a second Relay Word bit, 50P*nn*T, asserts. Relay Word bit 50P*nn*T only asserts if Relay Word bit 50P*nn* remains asserted for the duration of the 50P*nn*D time setting. When Relay Word bit 50P*nn* deasserts, the timer resets without delay, along with 50P*nn*T if it has asserted.

Figure 5.22 Phase Instantaneous and Time-Delayed Overcurrent Elements

The definite-time overcurrent elements are not enabled in the default settings. Enable the elements by setting E50 := *nn* (*nn* = 01–21). After enabling the elements, the definite-time overcurrent elements of all 21 terminals are available but are still set to OFF. For example, assume we want definite-time overcurrent protection for Terminal 05. Set E50 := 5, making the definite-time overcurrent elements of Terminal 01–Terminal 05 available. Because the default settings for the definite-time overcurrent elements are OFF, the elements are not active. Only enter settings at the definite-time overcurrent protection prompt of Terminal 05. Terminal 05 is the only terminal with definite-time overcurrent protection; the definite-time overcurrent protection for Terminal 01–Terminal 04 remains switched OFF.

Selectable Time-Overcurrent Elements (51)

NOTE: If the relay is using TiDL (EtherCAT), the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay.

Instead of having dedicated inverse-time overcurrent elements for each current channel, the relay offers the flexibility of an unassigned time-overcurrent element, each with the choice of five US and five IEC operating curves. Unassigned means that the 51 element operating quantities are available for assignment, as the application requires (see *Table 5.6*).

The inverse-time overcurrent elements are not enabled in the default settings. Enable the desired number of elements by setting E51 := *nn* (*nn* = 01–21). Choose from any filtered instantaneous phase current quantity magnitudes (I01FIM–I21FIM) to set as the operate quantity, 51Onn.

Table 5.4 shows the five US characteristics, and *Table 5.5* shows the five IEC characteristics. Each table shows the five operating time equations, together with the five electromechanical reset characteristic equations.

Table 5.4 U.S. Time-Overcurrent Equations[a] (Sheet 1 of 2)

Curve Type	Operating Time	Reset Time
U1 (Moderately Inverse)	$Tp = TD \bullet \left(0.0226 + \frac{0.0104}{M^{0.02} - 1}\right)$	$T_R = TD \bullet \left(\frac{1.08}{1 - M^2}\right)$
U2 (Inverse)	$Tp = TD \bullet \left(0.180 + \frac{5.95}{M^2 - 1}\right)$	$T_R = TD \bullet \left(\frac{5.95}{1 - M^2}\right)$
U3 (Very Inverse)	$Tp = TD \bullet \left(0.0963 + \frac{3.88}{M^2 - 1}\right)$	$T_R = TD \bullet \left(\frac{3.88}{1 - M^2}\right)$

Table 5.4 U.S. Time-Overcurrent Equations[a] (Sheet 2 of 2)

Curve Type	Operating Time	Reset Time
U4 (Extremely Inverse)	$Tp = TD \bullet \left(0.02434 + \frac{5.64}{M^2 - 1}\right)$	$T_R = TD \bullet \left(\frac{5.64}{1 - M^2}\right)$
U5 (Short-Time Inverse)	$Tp = TD \bullet \left(0.00262 + \frac{0.00342}{M^{0.02} - 1}\right)$	$T_R = TD \bullet \left(\frac{0.323}{1 - M^2}\right)$

[a] T_P = Operating Time
T_R = Reset Time
TD = Time-Delay Setting
M = Measured Current / Pickup Current

Table 5.5 IEC Time-Overcurrent Equations

Curve Type	Operating Time	Reset Time
C1 (Standard Inverse)	$Tp = TD \bullet \left(\frac{0.14}{M^{0.02} - 1}\right)$	$T_R = TD \bullet \left(\frac{13.5}{1 - M^2}\right)$
C2 (Very Inverse)	$Tp = TD \bullet \left(\frac{13.5}{M - 1}\right)$	$T_R = TD \bullet \left(\frac{47.3}{1 - M^2}\right)$
C3 (Extremely Inverse)	$Tp = TD \bullet \left(\frac{80}{M^2 - 1}\right)$	$T_R = TD \bullet \left(\frac{80}{1 - M^2}\right)$
C4 (Long-Time Inverse)	$Tp = TD \bullet \left(\frac{120}{M - 1}\right)$	$T_R = TD \bullet \left(\frac{120}{1 - M}\right)$
C5 (Short-Time Inverse)	$Tp = TD \bullet \left(\frac{0.05}{M^{0.04} - 1}\right)$	$T_R = TD \bullet \left(\frac{4.85}{1 - M^2}\right)$

Figure 5.23 U.S. Curves U1, U2, U3, and U4

Figure 5.24 U.S. Curve U5 and IEC Curves C1, C2, and C3

Figure 5.25 IEC Curves C4 and C5

The 51 overcurrent elements of the relay have dynamic pickup (51P*xx*) and time-delay (51TD*xx*) values. Because these settings can be programmed by means of protection math variables (PMVs), their actual value cannot be checked at setting time. To ensure that the pickup and time-delay values are within their predefined limits, the relay uses a limit check to verify the validity of setting values. Relay Word bits 51TM*xx* (time-dial limit check) and 51MM*xx* (pickup-limit check) are used to indicate a setting that is outside of the limit check thresholds. If the maximum limit thresholds are exceeded, the relay uses the maximum limit value. If the minimum limit thresholds are exceeded, the relay uses the minimum limit value (see *Figure 5.26*).

Example 5.1

The Terminal 01 current channel input is 5 A nominal …. From relay part number

51O01 := I01FIM

Therefore 51B101 := 0.25 (lower limit)

And 51B201 := 16.0 (upper limit)

5 A Current Terminal: (Determined by Relay part number and the operating quantity)

B_1 := 0.25 and B_2 := 16.0

Example 5.1 (Continued)

The Terminal 01 current channel input is 1 A nominal …. From relay part number

51O01 := I01FIM

Therefore 51B101 := 0.05 (lower limit)

And 51B201 := 3.2 (upper limit)

1 A Current Terminal: (Determined by relay part number and the operating quantity)

B_1 := 0.05 and B_2 := 3.2

If the calculated pickup value is greater than 3.2, the relay logic clamps the pickup value at 3.2. Similarly, if the value is less than 0.05, the relay logic clamps the pickup value at 0.05. At the same time that it clamps the values to these limits, the logic sets a limit bit (51MM*xx*) to indicate to the user that the read-in value is outside the specified limits.

Logic

Figure 5.26 Time-Overcurrent Logic

Settings Description

Operating Quantity

The 51 elements are unassigned, so you can select the operating quantity from *Table 5.6*.

Table 5.6 Time-Overcurrent Operating Quantity List

Analog Quantity	Description
I*nn*FIM[a]	Filtered Instantaneous Terminal *nn* Current Magnitude

[a] Where nn = 01–21.

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**

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 5.2

For example, you want a 1 A relay to pick up at 1.5 A when IN201 asserts and to pick up at 2 A when IN202 asserts (IN201 deasserted). Program the following:

51P01 := IN201 • 1.5 + IN202 • 2

With IN201 asserted (logical 1), and IN202 deasserted (logical 0), the 51P01 setting is:

(1 • 1.5) + (0 • 2) = 1.5 + 0 = 1.5

When IN202 asserts (IN201 deasserted), the 51P01 setting is:

(0 • 1.5) + (1 • 2) = 0 + 2 = 2

If, however, IN202 asserts while IN201 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 5.26* closes, and the relay evaluates input 51O01. For example, if the element should only measure when the circuit breaker is closed, enter the following:

51TC01 := **IN201** (Breaker auxiliary "A" contact connected to IN201)

With this setting, switch S1 closes only when IN201 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 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 5.4* or *Table 5.5*). If you set 51RS01 = N, then the relay resets after one power system cycle when current drops below pickup.

Over- and Undervoltage Elements

NOTE: If the relay is using TiDL (EtherCAT), the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay.

The SEL-487B offers as many as six undervoltage and six overvoltage elements. Each of these 12 elements has two levels, for a total of 24 over- and undervoltage elements. *Figure 5.27* shows the over- and undervoltage element logic.

Use the E27 and E59 settings to enable as many over- and undervoltage elements as you need.

Select any operating quantity shown in *Table 5.7* for the 27O*k* settings, and any value from *Table 5.8* for the 59O*k* settings as an input quantity (27O*k* and 59O*k* settings). You can select the same quantity for an undervoltage element as for an overvoltage element.

Figure 5.27 Over- and Undervoltage Logic

Settings Descriptions

E27 Enable Undervoltage Elements

Use the E27 setting to enable the number of undervoltage elements you want the relay to use. Each undervoltage element provides two pickup settings levels.

27Ok Undervoltage Element Operating Quantity

Select the operating quantity 27O*k* (*k* = 1–6) you want for each voltage element from *Table 5.7*.

Table 5.7 Undervoltage Operating Quantity List

Label	Description
V01FIM	Voltage Element 01 fundamental filtered voltage
V02FIM	Voltage Element 02 fundamental filtered voltage
V03FIM	Voltage Element 03 fundamental filtered voltage
V1FIM	Positive-sequence fundamental filtered voltage

27PkP1 Undervoltage Element Level 1 Pickup

The 27P*k*P1 (*k* = 1–6) undervoltage element Level 1 pickup setting is typically used for alarm level indication of undervoltage conditions. The setting is in secondary voltage. The Level 1 pickup has a definite-time delay (27P*k*D1) that can be used to provide a time delay on the assertion of the undervoltage element.

27PkP2 Undervoltage Element Level 2 Pickup

The 27P*k*P2 (*k* = 1–6) undervoltage element Level 2 pickup setting is typically used for undervoltage tripping conditions. The setting is in secondary voltage. The Level 2 pickup has no definite-time delay.

27TCk Undervoltage Element Torque Control

The 27TC*k* (*k* = 1–6) undervoltage element torque control uses a SELOGIC control equation to provide torque control of the undervoltage elements. All undervoltage elements are blocked from operation when the 27TC*k* input evaluates to a zero. The default setting of 1 allows the undervoltage elements to always operate.

27PkD1 Undervoltage Element Level 1 Delay

When the system voltage falls below the undervoltage setting value, the undervoltage timer starts timing. Set the delay (in cycles) for which the timer must run before the 27P*k*D1 (*k* = 1–6) setting asserts the output.

E59 Enable Overvoltage Elements

Use the E59 setting to enable the number of overvoltage elements you want to use in the relay. Each overvoltage element provides two pickup setting levels.

59Ok Overvoltage Element Operating Quantity

Select the operating quantity 59O*k* (*k* = 1–6) you want for each voltage terminal from *Table 5.8*.

Table 5.8 Overvoltage Operating Quantity List

Label	Description
V01FIM	Voltage Element 01 fundamental filtered voltage
V02FIM	Voltage Element 02 fundamental filtered voltage
V03FIM	Voltage Element 03 fundamental filtered voltage
V1FIM	Positive-sequence fundamental filtered voltage
3V2FIM	Negative-sequence fundamental filtered voltage
3V0FIM	Zero-sequence fundamental filtered voltage

59PkP1 Overvoltage Element Level 1 Pickup

Set pickup thresholds for the voltage values above which you want the Level 1 overvoltage elements to assert. The Level 1 pickup has a definite-time delay (59P*k*D1) that can be used to provide a time delay on the assertion of the overvoltage element.

59PkP2 Overvoltage Element Level 2 Pickup

Set pickup thresholds for the voltage values above which you want the Level 2 overvoltage elements to assert.

The 59P*k*P2 (*k* = 1–6) overvoltage element Level 2 pickup setting is typically used for overvoltage tripping conditions. The setting is in secondary voltage. The Level 2 pickup has no definite-time delay.

59TCk Overvoltage Element Torque Control

The 59TC*k* (*k* = 1–6) overvoltage element torque control uses a SELOGIC control equation to provide torque control of the overvoltage elements. All overvoltage elements are blocked from operation when the 59TC*k* input evaluates to a zero. The default setting of 1 allows the overvoltage elements to always operate.

59PkD1 Overvoltage Element Level 1 Delay

When the system voltage exceeds the overvoltage setting value, the overvoltage timer starts timing. Set the delay (in cycles) for which the timer must run before the 59P*k*D1 (*k* = 1–6) setting asserts the output.

Certain protection philosophies require voltage supervision for a trip. Each SEL-487B provides two levels of negative-sequence voltage and two levels of zero-sequence voltage elements to satisfy this requirement. In addition, the relay also provides two levels of phase undervoltage (27) and overvoltage (59) elements for each of the three phases.

Open-Phase Detection Logic

NOTE: Zero Crossing Detection is only enabled when the current is greater than advanced Global setting OPHDO.

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 5.28* shows open-phase logic that asserts SEL-487B open-phase detection elements OPH*nn* (*nn* = 01, 02, …21) in less than one cycle, even during subsidence current conditions.

① See Figure 5.51.

Figure 5.28 Open-Phase Detection

The relay declares an open phase when the logic does not detect a zero crossing or current value within 7/12 of a power system cycle since the previous measurement. The bottom path in *Figure 5.28* is used to detect when the nominal current

input for any channel is nearing the point of clipping at the analog to digital converter. If current channel clipping is imminent, current is above subsidence levels and the open-phase logic is forced to a false condition.

Open CT Detection Logic

When a CT opens, there is an incremental increase in operating current and a corresponding incremental decrease in restraint current. The two increments should result in a summation equal to zero.

Figure 5.29 shows the open current transformer detection logic. The change in operating current (ΔIOP*n*R), the change in restraint current (ΔIRT*n*R), and operating current (IOP*n*) are the analog inputs to the logic.

The AND gate output asserts when the following conditions are true:

- ΔIOP*n*R is a positive value (greater than or equal to 0.05 pu)
- ΔIRT*n*R is a negative value (less than –0.05 pu)
- The sum of ΔIOP*n*R and ΔIRT*n*R is very small (less than 0.05 pu)
- The filtered operating current (IOP*n*) is greater than or equal to Group Setting S87P

When the AND gate output is asserted, Relay Word bit OCTZ*n* asserts and is latched. SELOGIC control equation ROCTZ*n* resets the latch and Relay Word bit OCTZ*n* clears. Reset has priority over set.

The lower portion of the logic asserts Relay Word bit RSTOCT*n*, the default value for SELOGIC control equation ROCTZ*n*. RSTOCT*n* asserts when any of the following conditions are true:

- IOP*n* is less than 90 percent of group setting S87P
- IOP*n* is less than 0.05

Figure 5.29 Zone n Open CT Detector

Table 5.9 shows the Relay Word bits available in the check zone selection logic with their descriptions.

Table 5.9 Relay Word Bits in the Open CT Detection Logic

Quantity	Description
OCTZ*n*	Zone *n* Open CT detected
ROCTZ*n*	Reset Zone *n* Open CT detector (SELOGIC control equation)
RSTOCT*n*	Zone *n* Open CT detection reset

Circuit Breaker Failure Protection

The SEL-487B has complete breaker failure protection that includes retrip for each of the 21 terminals. This protection uses open-phase detection logic, provided with subcycle current reset, to reduce breaker failure coordination times. Two options are available for application of breaker failure protection:

- Schemes equipped with external breaker failure relays. These schemes send a bus trip (output from the breaker failure relay on the terminal panel) command to the bus protection relay (SEL-487B) that requires only the zone selection and output contacts to operate the appropriate breakers.
- Schemes using the internal breaker failure protection of the SEL-487B. These schemes send a breaker failure initiate (normally a trip output) command to the bus protection relay. The SEL-487B includes breaker failure logic, as well as zone selection and output contacts, to operate the appropriate breakers.

Apply either option exclusively, or use a combination of the two options at the same station. For example, use the breaker failure relays on the feeder panels for protection philosophies requiring discrete breaker failure relays, but use the built-in breaker failure protection in the SEL-487B for all other terminals at the station. Connect breaker failure initiate signals from these terminals to any one of six independent optoisolated inputs. These inputs are available on each INT4 interface board. *Figure 5.30* shows logic for Terminal 01; similar logic is available for all 21 terminals.

Figure 5.30 Breaker Failure Logic

Schemes Using Internal Breaker Failure Relays

The basic breaker failure logic does not include logic to seal-in the breaker failure initiate signals. For applications where BFI seal-in and extension are required, alternate BFI logic is provided. Set EXBF01 := N to enable the internal breaker failure logic for Terminal 01. Refer to *Figure 5.30*.

Breaker Failure Logic

The breaker failure logic requires the trip signal to be continuously present for the duration of the breaker failure timer because the BFI signal is not sealed in. If an external BFI signal falls away for one processing interval longer than the debounce dropout time setting of the input, the breaker failure timers reset. Wire breaker failure initiate circuitry, typically a trip output contact from a protection relay, to one of the six independent optoisolated inputs and assign the input to BFI01.

When the trip contact from the protection relay closes to assert BFI01, timers BFPU01 (Terminal I01 circuit breaker failure timer) and RTPU01 (Terminal I01 retrip timer) start timing. If BF101 remains asserted when the retrip timer expires, Relay Word bit RT01 asserts. Use this Relay Word bit as an output to attempt another trip pulse to the circuit breaker before the relay issues a bus trip command. When timer BFPU01 expires, Relay Word bit FBF01 asserts if 50F01 is asserted. Use this Relay Word bit in the circuit breaker tripping logic to cause a circuit breaker failure trip.

If the circuit breaker opens successfully before timer BFPU01 or timer RTPU01 expires, the cessation of current flow on the circuit will cause the fast breaker open detector element OPH01 to assert, dropping out element 50F01. This will block the assertion of the breaker failure Relay Word bit FBF01. If the trip contact from the protection relay opens before timer RTP01 expires, the BFPU01 timer and RTPU01 timers will drop out and neither RT01 nor FBF01 will assert.

This logic is suitable for applications where two breakers must open to interrupt fault current, such as in breaker-and-a-half and ring-bus configurations. For these applications, breaker failure logic that requires both BFI and 50F to be asserted before the timer starts is often not suitable. The problem occurs because the 50F element may not assert until the first of the two breakers opens and the current redistributes so that all of it goes through the failed breaker. This situation results in a delay of the Breaker 2 breaker failure time equal to the time for Breaker 1 to interrupt the current. The 50 breaker failure logic does not have this problem.

Alternate Breaker Failure Initiating Input With Extension and/or Seal In Logic

The alternate BFI logic lets you choose to either extend the breaker failure initiate signal or seal in the breaker failure initiate signal. *Figure 5.31* shows the combined logic for both breaker failure initiating input extension (AND Gate 1) and seal-in (AND Gates 1 and 2) functions. This logic can also be used for applications where it is required to have 50F01 asserted before the breaker failure timer can start.

Figure 5.31 Circuit Breaker Failure Initiation Extension and Seal In

Breaker Failure Initiating Input Seal In

Use the seal-in option if the breaker failure initiation signal is not continuous and fault current is immediately available (single-breaker applications). Referring to *Figure 5.31*, set EXBF01 := N to enable the internal breaker failure logic. Set EBFIS01 := Y to set the top input of AND Gate 2 to a logical 1. Wire the breaker failure initiate signal to the SEL-487B, and assign the input to ATBFI01. Then assign Relay Word bit ABFIT01 to BFI01 (*Figure 5.30*). On receipt of the breaker failure initiate signal, AND Gate 1 turns on. The output from AND Gate 1 starts the breaker failure timers (*Figure 5.30*) and turns AND Gate 2 on. If the initiate signal is present for longer than the Timer BFISP01 setting, the output from Gate 1 seals in for as long as the current exceeds the 50FP01 threshold. Set the Timer BFISP01 setting longer than a quarter cycle to prevent seal-in for spurious signals, but set it shorter than the initiate signal to ensure seal-in.

NOTE: Coordinate Timer BFISP01 setting with the contact debounce settings.

Breaker Failure Initiating Input Extension

Use the extension option in conjunction with the seal in option if the breaker failure initiation signal is not continuous, but fault current is not immediately available to start the breaker failure timers (double-breaker applications).

The logic still requires the current to be above the 50FP01 threshold after timer BFIDO01 times out to keep Gate 1 turned on. Set EXBF01 := N to enable the internal breaker failure logic. Referring to *Figure 5.31*, wire the breaker failure initiate signal to the SEL-487B, and assign the input to ATBFI01. Then assign Relay Word bit ABFIT01 to BFI01 (*Figure 5.30*). In the absence of fault current, and on receipt of the rising edge of the breaker failure initiate signal at input ATBFI01, AND Gate 1 turns on. When AND Gate 1 turns on, Relay Word bit ABFIT01 asserts, causing timers BFPU01 and RTP01 to start timing (*Figure 5.30*).

When Breaker 1 opens, enough current flows through Breaker 2 to assert the 50F01 Relay Word bit. Refer to *Figure 5.31* and note that the current flowing through Breaker 2 replaces the output from timer BFIDO01 and keeps Gate 1 turned on, sustaining the input to the breaker failure timers. Set Timer BFIDO01 longer than the time Breaker 1 takes to interrupt the current, but shorter than the Timer BFPU01setting. This setting ensures that, after Breaker 1 opens, Timer BFPU01 will continue to run while current greater than 50FP01 is present.

Supervising Breaker Failure Initiate With the Fault Detector

NOTE: Although BFIDO01 is set to 0.0, the timer picks up for one processing interval after assertion.

Use the alternate BFI logic if the breaker failure initiation signal must be supervised by current before the BFPU01 timer can start. Set EXBF01 := N to enable the internal breaker failure logic. Referring to *Figure 5.31*, wire the breaker failure initiate signal to the SEL-487B and assign the input to ATBFI01. Then assign

Relay Word bit ABFIT01 to BFI01 (*Figure 5.30*). Set BFIDO01 to 0.0 CYC. In this configuration, the upper input to AND Gate 1 is controlled by 50F01 and the lower input to AND Gate 1 is controlled by ATBFI01. Thus, ABFIT01 will not assert and start the BFPU01 and RTP01 timers (*Figure 5.30*) unless both ATBFI01 and 50F01 are asserted.

Schemes Equipped With External Breaker Failure Relays

Set EXBF01 := Y to enable the external breaker failure logic. This setting effectively reduces the logic to that shown in *Figure 5.32*.

Figure 5.32 Breaker Failure Logic for External Breaker Failure

Wire breaker failure initiate circuitry to one of the SEL-487B inputs, and assign the input to XBF01. Relay Word bit FBF01 immediately asserts upon assertion of the input signal.

Retrip

Some circuit breakers have two separate trip coils. If one trip coil fails, local protection can attempt to energize the second trip coil (often connected to a separate battery) to prevent an impending circuit breaker failure operation. Configure your protection system to always attempt a local retrip using the second trip coil before the circuit breaker failure pickup timer expires. RTPU01 (Retrip Time Delay on Pickup Timer) begins timing when BFI01 asserts. Relay Word bit RT01 (Breaker 1 Retrip) asserts immediately after RTPU01 times out. Assign a control output to trip the circuit breaker when Relay Word bit RT01 asserts.

Breaker Failure Clearing Times

Figure 5.33 is based on actual test data at room temperature using various settings. Relay element specifications given in *Section 1: Introduction and Specifications* include the entire temperature range of the relay. Output contact times are not included.

Figure 5.33 Breaker Failure Clearing Times

Circuit Breaker Failure Trip Logic

Following a breaker failure relay operation, the SEL-487B breaker failure trip logic sends trip signals to all of the breakers the logic identifies as being in the same bus-zone as the faulted breaker. The logic uses breaker failure trip information from the internal breaker failure logic and zone selection information to determine which breakers to trip. *Figure 5.34* shows the processing sequence for tripping the breakers according to the breaker failure operation FBF01.

Figure 5.34 Station Breaker Failure Trip Logic

For example, assume Terminals I01, I02, I03, and I04 are in Bus-Zone 1, with Terminal 01 failing for an external fault. The logic determines that Terminal 01 is in Bus-Zone 1, just as Terminals 02, 03, and 04 are also in Bus-Zone 1. The relay asserts Relay Word bits SBFTR01, SBFTR02, SBFTR03, and SBFTR04. With the assumption that there are four breakers, assign these four Relay Word bits to the corresponding TR01, TR02, TR03, and TR04 trip equations.

The breaker failure trip logic asserts the breaker failure trips as shown in *Table 5.10*.

Table 5.10 Station Breaker Failure Trips (Sheet 1 of 2)

Terminal Within a Zone	Station Breaker Failure Trip Bit
I01	SBFTR01
I02	SBFTR02
I03	SBFTR03
104	SBFTR04
105	SBFTR05
106	SBFTR06
107	SBFTR07
108	SBFTR08
109	SBFTR09
110	SBFTR10

Table 5.10 Station Breaker Failure Trips (Sheet 2 of 2)

Terminal Within a Zone	Station Breaker Failure Trip Bit
I11	SBFTR11
I12	SBFTR12
I13	SBFTR13
I14	SBFTR14
I15	SBFTR15
I16	SBFTR16
I17	SBFTR17
I18	SBFTR18
I19	SBFTR19
I20	SBFTR20
I21	SBFTR21

SBFTR is the OR combination of SBFTR01 to SBFTR21.

Bus Coupler/Bus Sectionalizer Configurations

With the flexibility of SELOGIC control equations, you can configure any one of the bus sectionalizer (tie breaker) configurations in *Figure 5.35–Figure 5.37* without additional wiring; it is simply a software configuration change.

CT Either Side of the Breaker With Overlap

Figure 5.35 shows a bus sectionalizer with a CT on either side of the circuit breaker with the protection arranged in overlap. For an overlap application, connect the CTs so that each zone of protection (B1 and B2) includes the tie-breaker circuit breaker. For example, for Fault 1, only the differential element of Busbar B2 operates; the differential element of Busbar B1 is stable. However, because of the overlap connections, both differential elements operate for Fault F2.

Figure 5.35 Two CTs With the Busbar Protection Configured in Overlap

CT Either Side of the Breaker With Breaker Differential

Figure 5.36 also shows a bus sectionalizer with a CT on either side of the circuit breaker with the protection arranged in a breaker differential application. For a breaker differential application, connect the CTs so that each zone of protection (B1 and B2) excludes the tie-breaker circuit breaker. For example, for Fault F1, the differential element of Busbar B2 operates; the differential element of Busbar

B1 is stable. The differential element of both Busbar B1 and Busbar B2 is stable for Fault F2. To provide protection for Fault F2, configure an additional differential zone of protection across the tie-breaker circuit breaker.

Figure 5.36 Two CTs With the Busbar Protection Configured as Breaker Differential

Single CT, Single or Two Cores With Overlap

Figure 5.37 shows a bus sectionalizer with a single CT on one side of the circuit breaker with the protection arranged in overlap.

Figure 5.37 Single CT With the Busbar Protection Configured in Overlap

Refer to the application examples in *Section 6: Protection Application Examples* for more information.

Coupler Security Logic

A fault between bus coupler circuit breaker and CT usually results in the loss of multiple zones as well as in delayed fault clearance, except for where the bus coupler has overlapping zones of protection where both zones are tripped instantaneously. For bus coupler configurations such as breaker differential and single CT applications, fault clearance time usually equals the bus coupler breaker failure time for faults between the CT and the breaker. The coupler security logic includes logic to shorten this time so that it equals the operating time of the bus coupler circuit breaker. Coupler security logic also includes logic to prevent tripping of multiple bus-zones instead of just the faulted bus-zone. Although identifying the faulted bus-zone introduces a trip delay, this delay is still shorter than the bus coupler breaker failure time.

Preventing the loss of multiple bus-zones requires two steps. First, the coupler security logic allows the differential elements to trip only the bus coupler circuit breaker, thereby interrupting the fault current from the unfaulted bus-zone. Then, this logic removes the bus coupler CTs from all differential calculations. Removing the bus coupler CTs from the differential calculations of the unfaulted bus-zone has no effect on the stability of this bus-zone because it no longer contributes to the fault current. However, removing the bus coupler CTs from the differential calculations of the faulted bus-zone causes the differential elements of the

faulted bus-zone to operate. This application trips only the faulted bus-zone, thereby preventing the indiscriminate loss of multiple zones, irrespective of the fault position or CT location.

In most cases, breaker auxiliary contacts provide circuit breaker status information. However, circuit breaker auxiliary contact failure or misalignment can result in relay misoperation instead of accelerated tripping. The following discussion describes network operating conditions that may result in relay misoperation and shows how the coupler security logic in the SEL-487B prevents these possible misoperations. Two examples of accelerated tripping show how to apply the coupler security logic to breaker differential and single CT applications. In all cases, assume circuit breaker operating times to be two cycles.

Network Operating Condition 1

Figure 5.38 depicts a subset of a substation showing Bus Sectionalizer Breaker Z, and two terminals labeled Feeder 1 and Feeder 2. Zone 1 and Zone 2 are the two bus sections at the station, with the bus sectionalizer busbar protection arranged in overlap. Because both sectionalizer disconnects (Z891 and Z892) are closed, the currents from the sectionalizer CTs are considered in the differential calculations. In this example, the bus sectionalizer circuit breaker is open, and both feeder circuit breakers are closed. *Table 5.11* summarizes the prevailing network operating conditions.

Figure 5.38 Fault F1 Between Bus Sectionalizer and CT With the Bus Sectionalizer Circuit Breaker Open

Table 5.11 Summary of the Network Conditions Shown in Figure 5.38

Station Conditions	Fault Description
Bus sectionalizer Circuit Breaker Z open Both bus sectionalizer disconnects (Z891 and Z892) closed All other breakers and disconnects closed	Fault F1 develops between the sectionalizer circuit breaker and CT

Assume now that Fault F1 occurs as indicated in *Figure 5.38*. Because the currents from the sectionalizer CTs are considered in the differential calculations, and because the bus sectionalizer busbar protection is arranged in overlap, both zones trip. *Table 5.12* summarizes the event.

Table 5.12 Summary of the Event for Fault F1 Shown in Figure 5.38

Tripping for Fault F1	Clearing Time	Zones Lost	Comment
All breakers in both zones trip without time delay	2 cycles	2	Zone 2 tripped unnecessarily

One solution for overcoming this problem is to include the bus sectionalizer circuit breaker auxiliary contact together with the disconnect auxiliary contact as a condition for CT consideration in the differential calculations. With the bus sectionalizer circuit breaker auxiliary contact included in the conditions, the current inputs from the bus sectionalizer CTs are not considered in the differential calculations when the bus sectionalizer circuit breaker is open. In this case, only Zone 1 trips for Fault F1 in *Figure 5.38*.

Including the bus sectionalizer circuit breaker auxiliary contact solves the problem in Network Operating Condition 1. However, Network Operating Condition 2 shows that the busbar protection is still not completely secure, although the conditions for CT consideration in the differential calculations now include the bus sectionalizer circuit breaker auxiliary contact.

Network Operating Condition 2

Figure 5.39 shows the same substation under different operating conditions. The bus sectionalizer circuit breaker auxiliary contact 52A forms part of the conditions for CT consideration in the differential calculations. Although the disconnects are closed, the bus sectionalizer circuit breaker is open and the differential calculations do not consider the bus sectionalizer CT inputs in the differential calculation. Fault F2 in *Figure 5.39* represents grounding straps that were inadvertently left on the busbars in Zone 1. The Feeder 1 circuit breaker is open, and the bus sectionalizing circuit breaker is about to close. *Table 5.13* summarizes the prevailing network operating conditions.

Figure 5.39 Closing the Bus Sectionalizing Circuit Breaker Onto a Faulted Busbar

Table 5.13 Summary of the Events for Fault F2 Shown in Figure 5.39

Station Conditions	Fault Description
Bus sectionalizer Breaker Z closing Both bus sectionalizer disconnects (Z891 and Z892) are closed All Zone 2 feeder breakers and disconnects (892) are closed All Zone 1 feeder disconnects (891) are open	Sectionalizer breaker closes onto Fault F2

If the bus sectionalizing circuit breaker auxiliary contacts are misaligned or fail in such a way that the CTs from the sectionalizer are not considered in the differential calculation at fault inception, the Zone 2 differential elements misoperate. *Table 5.14* summarizes the event.

Table 5.14 Summary of the Event for Fault F2 Shown in Figure 5.39

Tripping for F2	Clearing Time	Zones Lost	Comment
All breakers in Zone 2 trip without time delay (Feeder 2 and Circuit Breaker Z)	2 cycles	1	Incorrect tripping for terminals connected to Zone 2; only terminals connected to Zone 1 (Breaker Z) should have tripped.

Use the coupler security logic (see *Figure 5.40*) in the SEL-487B to prevent relay misoperation for network conditions 1 and 2.

Coupler Security Logic

Inserting the bus sectionalizer CTs into the differential calculations before fault inception prevents relay misoperation for Network Operating Condition 2. *Figure 5.40* shows one of the four coupler security logics available in the relay. Wire a bus sectionalizer auxiliary contact to input CB52A1, and wire the bus sectionalizer circuit breaker closing signal to input CBCLS1. Inputs CB52A1 and CBCLS1 coordinate the bus sectionalizer CT insertion into and removal from the differential calculation. For breaker differential applications, enter **CSL1**, the output from the coupler security logic, instead of the bus sectionalizer circuit breaker auxiliary contact, as a condition for CT consideration in the differential calculations.

As shown in *Figure 5.40*, the breaker auxiliary contact (CB52A1) and the close signal (CBCLS1) are in parallel. Issuing the close signal to the bus sectionalizer circuit breaker close coil also asserts Relay Word bit CSL1. Timer CBCLD01 maintains the close signal for five cycles (default setting), allowing ample time for the bus sectionalizer circuit breaker auxiliary contact to change state. When Relay Word bit CSL1 asserts, the CTs are immediately considered in the differential calculation. Because the bus sectionalizer CTs are considered in the differential calculation before fault inception, Zone 2 is stable for Network Operating Condition 2.

Figure 5.40 Coupler Security Logic for Accelerated Tripping and Busbar Protection Security for Circuit Breaker Auxiliary Contact Misalignment

When the bus sectionalizer circuit breaker trips, misaligned circuit breaker auxiliary contacts can remove the bus sectionalizer CTs from the differential calculation while current still flows through the bus sectionalizer circuit breaker. Timer CB52D01 maintains the status of the bus sectionalizer circuit breaker auxiliary contact as closed for four cycles (default setting) after the contact changes state. During this four-cycle time delay, the bus sectionalizer CTs are still considered in the differential calculation, allowing the bus sectionalizer circuit breaker ample time to interrupt the current.

ACTRP1, the third input into the coupler security logic provides an input to accelerate tripping of the bus sectionalizer circuit breaker for faults between bus sectionalizer circuit breaker and CT. Accelerated tripping operating time is the time period greater than the bus sectionalizer circuit breaker operating time (typically 2 cycles) but shorter than the breaker failure time (typically 6–10 cycles).

Breaker Differential

Figure 5.41 shows an application of breaker differential protection. There are CTs on either side of the bus sectionalizing circuit breaker, and we configure a differential zone of protection across the bus sectionalizing circuit breaker. This is in addition to Zone 1 and Zone 2 of the busbar protection. Any of the six zones may be used for breaker differential protection. Breaker differential protection is a good choice for stations where preservation of supply is more important than a very fast clearing time.

Figure 5.41 CTs on Either Side of the Sectionalizer Circuit Breaker With Breaker Differential Across Breaker Z

We use the coupler security logic (initially without an ACTRP1 input) and consider the relay operation for Fault F3 in *Figure 5.41*. Circuit Breaker Z opens after two cycles, deasserting the input to CB52A1. When Circuit Breaker Z trips, fault current no longer flows from Zone 2, but Zone 1 still contributes to the fault. Four cycles after Circuit Breaker Z trips (CB52D01 default time), Relay Word bit CSL1 deasserts, removing both bus sectionalizing CTs from all three differential elements (breaker differential, Zone 1, and Zone 2). Zone 2 is stable after removing the CTs from the Zone 2 differential calculations because Zone 2 no longer contributes to the fault. However, Zone 1 still contributes to the fault, and removing the CTs from the Zone 1 differential calculations causes the Zone 1 differential elements to operate, clearing the fault. Only one zone is lost, although this loss occurs after a time delay. *Table 5.15* summarizes the events.

Table 5.15 Summary of the Event for Fault F3 Shown in Figure 5.41

Relay and Circuit Breaker Operation for F3	Time Delay	Zones Lost	Comment
Breaker differential (87R3) asserts	1 cycle	0	Typical operating time is 0.75 cycles
Bus sectionalizer trips	2 cycles	0	Correct tripping
Timer CB52A1 expires	4 cycles	0	Relay Word bit CSL1 deasserts, unbalancing Zone 1
SEL-487B operating time	1 cycle	0	Typical operating time is 0.75 cycles
All circuit breakers in Zone 1 trip	2 cycles	1	Total clearing time is 10 cycles

Because Fault F3 is external to Zone 1 and Zone 2, both of these zones are stable for as long as the sectionalizing breaker CTs are considered in the differential calculations. If the sectionalizing breaker fails, both Zone 1 and Zone 2 trip only after breaker failure time.

Function ACTRP1 provides an input for removing the bus sectionalizing CTs sooner. One solution is to assign 87R3, the output from the sectionalizer breaker differential element to input ACTRP1. Relay Word bit 87R3 asserts when there is a fault within the sectionalizer zone. With ACTPPU1 set to 4 cycles, Relay Word bit CSL1 deasserts about 2 cycles after the sectionalizing circuit breaker interrupts the fault current. *Table 5.16* summarizes the events.

Table 5.16 Summary of the Event for Fault F3 Using the Accelerated Trip Function

Relay and Circuit Breaker Operation for F3	Time Delay	Zones Lost	Comment
Breaker differential (87R3) asserts	1 cycle	0	Typical operating time is 0.75 cycles. Timer ACTPPU1 starts timing
Bus sectionalizer trips	2 cycles	0	Correct tripping
Timer ACTPPU1 expires	2 cycles	0	Reduce this setting for faster clearance
SEL-487B operating time	1 cycle	0	Typical operating time is 0.75 cycles
All circuit breakers in Zone 1 trip	2 cycles	1	Total clearing time is 8 cycles

Single CT Application

Figure 5.42 shows the same substation, now with only one CT installed on the bus sectionalizer. The busbar protection is connected in overlap. The challenge for the busbar protection is to distinguish between faults F4 and F5. When Fault F5 occurs, Zone 1 is stable and the Zone 2 protection immediately trips Feeder 2 and the bus sectionalizer circuit breaker. Tripping Feeder 2 and the bus sectionalizer circuit breaker clears Fault F5.

Figure 5.42 Single CT Application With Fault F4 Between the Bus Sectionalizer Circuit Breaker and CT

When Fault F4 occurs, Zone 1 is stable, and, as before, the Zone 2 protection immediately trips Feeder 2 and the bus sectionalizer circuit breaker. Tripping Feeder 2 and the bus sectionalizer circuit breaker, however, does not clear Fault F4, and fault current still flows through the bus sectionalizer CT. At the same time, the busbar protection also initiates breaker failure protection on Feeder 2 and the bus sectionalizer. This fault current causes the breaker failure protection

of the bus sectionalizer to continue timing, although the bus sectionalizer circuit breaker tripped. After the bus sectionalizer breaker failure timer times out, all circuit breakers in Zone 1 trip. Both Zone 1 and Zone 2 trip to clear this fault.

If delayed tripping time for Zone 2 busbar faults is in order, use a combination of the zone supervision and coupler security logic to prevent losing both zones. Assign 87R2, the output from the Zone 2 differential element, to ACTRP1, the accelerated trip input of the coupler security logic. Assign the negated output from the coupler security logic (NOT CSL1) to supervise the Zone 2 differential element output (Z2S := NOT CSL1). For single CT applications, enter **CB52A1**, the bus sectionalizer circuit breaker auxiliary contact, as a condition for CT consideration in the differential calculations for the zone supervised by CSL1 (Zone 2 in this case). Then, enter **CB52T1**, the coupler status timed-out bit, as a condition for CT consideration in the differential calculations for the unsupervised zone (Zone 1 in this case).

For faults in Zone 2, trip only the bus sectionalizer circuit breaker. After the bus sectionalizer opens, remove the bus sectionalizer CT from the differential calculations of Zone 2. After a set delay of at least 2 cycles (to allow the 87R2 element to reset), remove the Zone 2 supervision and the bus sectionalizer CT from the differential calculations of Zone 1. The operation of the logic is as follows:

> When either Fault F4 or Fault F5 occurs, the Zone 2 differential element operates to clear the fault. The Zone 2 zone supervision prevents Relay Word bit 87Z2 from asserting and only the bus sectionalizer circuit breaker receives a trip signal. The circuit breaker trips two cycles later, removing CT cores C1 and eventually C2 from the differential calculations for Zone 1 and Zone 2.
>
> For Fault F4, the bus sectionalizer circuit breaker is open, but fault current still flows through CT Cores C1 and C2. Removing the bus sectionalizer CTs from all differential calculations prevents Zone 2 from operating (current from CT Core C1 removed) but causes Zone 1 to operate (balancing current from CT Core C2 removed).
>
> For Fault F5, tripping the bus sectionalizer circuit breaker interrupts the fault current contribution from Zone 1, and the Zone 1 differential element is stable. The Zone 2 zone supervision prevents tripping of terminals in Zone 2, until Accelerate Trip Timer ACTRP1 times out. When ACTRP1 times out, coupler security logic output CSL1 deasserts. When Relay Word bit CSL1 deasserts, Relay Word bit Z2S asserts, allowing the Zone 2 differential element (87Z2) to operate and issuing a trip signal to all circuit breakers in Zone 2. See *Application 7: Double and Transfer Bus (Outboard CTs) on page 6.181* for an example.

Disconnect Monitor

Disconnect auxiliary contacts provide the zone selection logic with the information required to dynamically assign current inputs to the appropriate differential elements. *Figure 5.43* depicts the logic for Disconnect Logic Circuit 01 in the relay, one of 60 disconnect logic circuits available in the relay. This logic requires both normally open (89A) and/or normally closed (89B) disconnect auxiliary contacts.

Table 5.17 shows the four possible disconnect auxiliary contact combinations, and the way in which the relay interprets these combinations. Applying the principle of (disconnect) NOT OPEN = (disconnect) CLOSED, the relay properly coordinates the primary current flow and the CT current assignment to the appropriate differential element.

Table 5.17 Disconnect 89A and 89B Auxiliary Contact Status Interpretation

Case	89A01	89B01	Disconnect Status (89CL01)
1	0	0	Closed (1)
2	0	1	Open (0)
3	1	0	Closed (1)
4	1	1	Closed (1)

The following description of the contact combinations assumes the disconnect auxiliary contacts are the only conditions declared in the terminal-to-bus-zone variable settings.

Figure 5.43 Disconnecting Switch Status Logic

Case 1 occurs when disconnect auxiliary contact 89A and auxiliary contacts 89B are open simultaneously. This case is the intermediate position in an open-to-close or close-to-open operation. Timer 89ALP01 times for this condition and asserts Relay Word bit 89AL01 when the disconnect auxiliary contacts remain in the intermediate position for a period exceeding the 89ALP01 timer setting. Relay Word bit 89OIP01 also asserts during this period, indicating a disconnect operation in progress condition. The relay considers the disconnect main contact closed during this period, and the CTs are considered in the differential calculations.

Case 2 is the only combination of disconnect auxiliary contacts for which the relay considers the disconnect main contact to be open. This is also the only combination for which the CTs are not considered in the differential calculations.

NOTE: Use Relay Word bit 89CL01 in SELOGIC control equations when entering the conditions in the terminal-to-bus-zone settings.

Case 3 is the only combination of disconnect auxiliary contacts for which the relay confirms the disconnect main contacts to be closed. Relay Word bit 89CL01 asserts to indicate the main contact close position. The CTs are considered in the differential calculations.

Case 4 is an illegitimate condition, with the disconnect auxiliary contacts showing the disconnect main contact to be open and closed simultaneously. Timer 89ALP01 times for this condition and asserts Relay Word bit 89AL01 when the disconnect auxiliary contacts remain in this condition for a period exceeding the timer setting. The relay considers the disconnect main contact closed during this period, and the CTs are considered in the differential calculations.

The relay includes 60 alarm timers that provide individual time settings for 60 disconnect logic circuits. These individual timers are useful in installations where the disconnect travel times differ substantially. In particular, sequentially operated devices (pantographs, for example) have travel times much longer than normal disconnects.

Relay Word bit 89OIP represents the OR combination of Relay Word bits 89OIP01–89OIP60, and Relay Word bit 89AL (not shown) is respectively the OR combination of Relay Word bits 89AL01–89AL60.

To ensure correct differential element operation, the contacts must comply with the requirements listed in *Table 5.18*.

Table 5.18 Disconnect Auxiliary Contact Requirements to Ensure Correct Differential Element Operation

Operation	Requirement
From disconnect open to disconnect close operation	Assign the currents to the applicable differential element before the disconnect reaches the arcing point (the point where primary current starts to flow).
From disconnect close to disconnect open operation	Remove the current from the applicable differential element only once the disconnect has passed the arcing point (the point where primary current has stopped flowing).

Figure 5.44 shows the disconnect auxiliary contact requirements with respect to the arcing point.

Figure 5.44 Disconnecting Switch Main Contact, 89a, and 89b Status for Open-to-Close and Close-to-Open Conditions

Zone-Switching Supervision Logic

Because the disconnect monitoring logic requires both 89A and 89B disconnect auxiliary contacts, installations with only an 89A (or 89B) contact available cannot use the disconnect monitoring logic. In these installations, there is always uncertainty whether the disconnect auxiliary contact actually changed status.

This is important information because busbar protection will misoperate if input currents are assigned to the incorrect differential elements. Zone-switching supervision logic uses the ZSWOP Relay Word bit (see *Dynamic Zone Selection Logic on page 5.14*) that asserts for any terminal-to-bus-zone or bus-zone-to-bus-zone change. In other words, the ZSWOP Relay Word bit provides an acknowledgment that the relay has recognized a change in disconnect auxiliary contact status. *Figure 5.45* shows the logic.

Figure 5.45 Zone-Switching Supervision Logic

Asserting Relay Word bit ZSWO activates the logic (i.e., the rising edge of ZSWO starts Timer ZSWOPU) and asserts the ZSWOIP bit for the period when the timer is timing. When the zone selection logic acknowledges a change in disconnect status, the ZSWOP Relay Word bit asserts and resets the timer. If the Zone Selection does not acknowledge the switching operation within the ZSWOPU time setting, the logic asserts the switching operation alarm ZSWOAL. SELOGIC control equation RZSWOAL provides the input to reset the alarm.

There is only one zone-switching supervision logic in the relay; disconnect open and close commands must be combined externally to the relay for electrically operated disconnects, as shown in *Figure 5.46*.

Figure 5.46 External Wiring and Initiation Input for Zone-Switching Supervision

For manually operated disconnects, configure one of the SEL-487B front-panel pushbuttons as an input to assert the ZSWO Relay Word bit. Timer ZSWOPU has a range of more than 27 minutes, allowing ample time for the operating procedures.

Differential Trip Logic

This is the final stage of the differential trip output. *Figure 5.47* is the Bus-Zone portion of *Figure 5.20* from the zone supervision logic. At this point, the differential element has operated (87R1), and all supervising criteria are met (Z1S). The differential trip logic now acquires all Zone 1 terminals and generates a trip output to the appropriate breakers.

① See Figure 5.11.

Figure 5.47 Differential Element Zone Supervision for Zone 1

Figure 5.48 shows the processing sequence for tripping the breakers as a function of the differential element operation, 87Z*n*, where *n* = 1–6.

Figure 5.48 Bus Differential Trip Logic

The differential trip logic asserts differential trips as shown in *Table 5.19*.

Table 5.19 Differential Trips (Sheet 1 of 2)

Terminal Within a Zone	Differential Trip Bit
I01	87BTR01
I02	87BTR02
I03	87BTR03
104	87BTR04
105	87BTR05
106	87BTR06
107	87BTR07
108	87BTR08

Table 5.19 Differential Trips (Sheet 2 of 2)

Terminal Within a Zone	Differential Trip Bit
109	87BTR09
110	87BTR10
I11	87BTR11
I12	87BTR12
I13	87BTR13
I14	87BTR14
I15	87BTR15
I16	87BTR16
I17	87BTR17
I18	87BTR18
I19	87BTR19
I20	87BTR20
I21	87BTR21

This is the final stage of the check zone differential trip output. *Figure 5.49* is the check zone portion of *Figure 5.20* from the zone supervision logic. At this point, the Check Zone Differential Element has operated (87RCZ1), and all supervising criteria are met (CZ1S). The supervised trip output is then asserted (87CZ1). The check zone output is independent of the bus zones and is not processed by the differential trip logic shown in *Figure 5.48*.

Figure 5.49 Differential Element Zone Supervision for Check Zone

Breaker Trip Logic

Figure 5.50 shows the tripping logic for Terminal 01 in the SEL-487B. The remaining logic for Terminal 02–Terminal 21 is identical and uses variables TR02–TR21 and ULTR02–ULTR21, and TRIP02–TRIP21, respectively.

NOTE: In the trip logic, the set or latch function (TRkk) has priority over the reset or unlatch (ULTRkk) function (kk = 1–21).

Figure 5.50 Trip Logic for Breaker 1

Enable the trip logic settings by setting the Global setting NUMBK = *kk*, where *kk* is the number of breakers at the station. For example, if you have 12 terminals installed at a substation, set NUMBK = 12.

Asserting TR01 directly asserts TRIP01 via input OR Gate 1 and starts the Minimum Trip Duration Timer (TDURD). TRIP01 asserts for a minimum of TDURD cycles, even if TR01 is asserted for as little as one processing interval, or if the unlatch portion of the logic is asserted before TDURD expires. The default setting of TDURD is twelve cycles.

TRIP01 also seals itself in via AND Gate 1. This AND gate receives the negated inputs from the unlatching functions. As long as ULTR01 or TRGTR are not asserted, TRIP01 remains sealed in. TRIP01 is used to drive an output contact to initiate tripping of the breaker.

You can use one of four methods to unlatch the trip logic. One method is to assert either one of SELOGIC control equation setting ULTR01 or SELOGIC control equation setting RSTTRGT. You can also push the **TARGET RESET** pushbutton on the front panel or send the **TAR R** serial port command to assert Relay Word bit TRGTR for one processing interval. Relay Word bit TRGTR also resets the LED targets on the front panel. In the trip logic, assertion of ULTR01, RSTTRGT, or TRGTR places a zero input on AND Gate 1 and, thereby, breaks the TRIP01 seal-in loop.

Note that TRIP01 is always asserted when TR01 is asserted, regardless of the action of ULTR01 or the **TARGET RESET** commands, and that TRIP01 will be asserted for a minimum of TDURD cycles no matter how short the length of time TR01 has been asserted.

Circuit Breaker Status Logic

Figure 5.51 shows the circuit breaker status logic, which uses the combination of breaker 52A (normally open) auxiliary contact and the open-phase detection function, OPH. Because 52B (normally closed) contacts are not always available and as a means to reduce the number of I/O required, the 52B contacts are not required in the logic. However, for applications where the protection philosophy requires a 52B (normally closed) contact, wire the 52B contact into the relay, but use the negated form of the 52B contact in the logic, i.e., NOT 52B (52A01 := NOT IN301).

Relay Word bits 52CL01–52CL21 assert when the breaker is closed. Open-phase detection logic (OPH*nn*) Relay Word bits are included in the circuit breaker status logic to guard against delayed breaker status declaration resulting from possible breaker auxiliary contact misalignment. If a discrepancy between the open-phase detection logic and the breaker auxiliary contact exists for as long as five cycles, the logic generates an alarm that indicates one of the following:

- Possible auxiliary contact supply voltage failure
- Possible failure in an auxiliary contact connection circuit
- Possible failure of auxiliary contact mechanism

The logic in *Figure 5.51* is generic for three-pole or single-pole breaker mechanisms.

① See Figure 5.28.

Figure 5.51 Breaker Status and Alarm Logic

Note that OPH*nn* Relay Word bits assert when no current flows through the circuit breaker and that set has priority over reset in the circuit breaker status logic. *Table 5.20* shows the output states for all possible breaker conditions.

Table 5.20 Conditions and Results for the Circuit Breaker Status Logic

Breaker Status	52A01 or NOT 52B01	OPH01	52CL01	52AL01
Open	0	1 (no current)	0	0
Closed	1	1 (no current)	1	0
Open	0	0 (current flow)	1	1 (after 5 cyc)
Closed	1	0 (current flow)	1	0

SECTION 6

Protection Application Examples

Configuring the system is the most challenging of the many activities associated with using the SEL-487B relay. System configuration includes renaming (aliasing) terminals and bus-zones, assigning input contacts to selected relay logics, declaring terminal-to-bus-zone connections, declaring bus-zone-to-bus-zone connections, configuring bus couplers and check zones, and assigning logics to relay outputs. System configuration requires careful consideration of the following items because they both influence the number of SEL-487B relays and ordering options needed:

- primary layout of the substation
- choice of protection elements

For example, substations with seven or fewer terminals require only one relay. To monitor both 89A and 89B contacts, however, you must equip this relay with the correct number of interface boards to ensure an adequate number of input contacts.

The following discussion provides general guidelines and outlines general factors that should be considered when using ASCII commands to configure your relay. The section also provides application examples for some of the more common busbar layouts. Included in this section are the following topics:

- *Input, Logic, and Output Assigning Process on page 6.2*
- *Relay Differential Element Composition on page 6.3*
- *CT Requirements on page 6.12*
- *Disconnect Requirements on page 6.15*
- *Alias Names on page 6.18*
- *Bus-Zone Configurations on page 6.18*
- *Bus-Zone-to-Bus-Zone Connections on page 6.33*
- *Zone Supervision on page 6.36*
- *Trip Logic on page 6.36*
- *Output Assignments on page 6.37*
- *Summary on page 6.37*
- *Application 1: Single Bus and Tie Breaker (Three Relays) on page 6.39*
- *Application 2: Single Bus and Tie Breaker (Single Relay) on page 6.60*
- *Application 3: Breaker-and-a-Half on page 6.84*
- *Application 4: Single Bus and Transfer Bus With Bus Coupler on page 6.112*
- *Application 5: Double Bus With Bus Coupler on page 6.134*
- *Application 6: Double and Transfer Bus With Two Busbars on page 6.157*

➤ *Application 7: Double and Transfer Bus (Outboard CTs) on page 6.181*

➤ *Application 8: Double and Transfer Bus (Inboard CTs) on page 6.207*

Input, Logic, and Output Assigning Process

Figure 6.1 shows a block diagram of the SEL-487B input, logic, and output assigning process for system configuration and protection element settings. Digital input sources include disconnect and breaker auxiliary contacts, breaker failure initiate signals, and breaker close signals. Current and potential transformers provide analog inputs. Use alias settings to assign more meaningful names to primitive Relay Word bits and/or analog names, or use the primitive names of the input quantities to configure and set the relay. The relay has many ready-made logic functions available; however, assign these functions before they become operative. System configuration includes terminal-to-bus-zone and bus-zone-to-bus-zone assignments, zone supervision, and zone-switching supervision settings. Scheme settings include enable settings, differential and sensitive differential element settings, directional element settings, selected relay logic settings, and output assignment.

Figure 6.1 Block Diagram of the Input, Logic, and Output Assigning Process for System Configuration Protection Element Settings

Relay Differential Element Composition

Each SEL-487B accepts as many as 21 current inputs (I01–I21) and then assigns these inputs to any of six differential elements (BZ1–BZ6). *Figure 6.2* shows a block diagram of the arrangement.

Figure 6.2 Block Diagram Showing Nine Current Inputs and Six Differential Elements

Single-Relay Application

Because differential calculations occur on a per-phase basis, each phase of a three-phase system must bear a unique identification. *Figure 6.3* shows a typical single-line diagram of a station consisting of two busbars (NORTH and SOUTH), a tie breaker (Z), and four terminals.

Figure 6.3 Single-Line Diagram of a Station With Two Busbars and a Tie Breaker

Because the station has no more than seven terminals, a single SEL-487B suffices. *Figure 6.4* shows the SEL-487B and a three-phase representation of TD, one of the terminals at the station.

Figure 6.4 Three-Phase Diagram of Terminal TD, the NORTH Busbar, and the SEL-487B

Because differential calculations for each protection zone require an individual differential element, assign an individual differential element to each phase. This assignment uses three of the available six differential elements in the relay for Busbar NORTH. In this example, assign the phases and differential elements as shown in *Figure 6.5*. Each assignment is a software assignment, as indicated by the dotted lines; no electrical wires are required.

Assign the A-phase differential element of Busbar NORTH to differential element BZ1

Assign the B-phase differential element of Busbar NORTH to differential element BZ2

Assign the C-phase differential element of Busbar NORTH to differential element BZ3

Figure 6.5 A Three-Phase Zone Requires Three Differential Elements

To make the bus-zone labels more substation specific, assign the following alias names to the bus-zones, as shown in *Figure 6.6*:

For the A-phase differential element BZ1, assign NORTH_A

For the B-phase differential element BZ2, assign NORTH_B

For the C-phase differential element BZ3, assign NORTH_C

Figure 6.6 Three Differential Elements With Alias Names for a Three-Phase Bus-Zone in a Single Relay Application

For the current inputs in a single-relay application, wire A-phase, B-phase, and C-phase to adjacent terminal connections such as I01, I02, and I03, as shown in *Figure 6.7*. These connections are copper wires connecting the CTs to the relay.

Figure 6.7 Three Differential Elements and Three CT Inputs in a Single-Relay Application

Reference *Figure 6.3* and continue CT connections by wiring the CT inputs from TE (I04–I06) and Z1 (tie breaker configured in overlap) to I07–I09. Connect the CTs from Z2, TF, and TG, following the same procedure to complete protection for both bus-zones.

Digital inputs control the dynamic assignment of input currents to differential elements. If you need dynamic zone selection, wire into the relay the auxiliary contacts from the disconnect (89), the circuit breaker (52), or any other conditions that must ultimately be considered in the zone selection logic. *Figure 6.8* shows the disconnect and circuit breaker wiring for Terminal TD.

Only the differential elements are enabled for this example. If you need other functions such as breaker failure protection, wire those inputs to the relay. You need all six zones and all 21 current channels to configure the remaining terminals in the same way. *Figure 6.9* shows the complete station analog channel configuration.

Figure 6.8 Disconnect and Circuit Breaker Wiring for Terminal TD

Figure 6.9 Complete Station Configuration, Using Two Three-Phase Bus-Zones and All 21 Current Inputs in a Single-Relay Application

Three-Relay Application

Consider now the same station, configured with three relays instead of one. In the three-relay application, a total of 21 current inputs are available. As before, the label NORTH in the single-line diagram consists of A-phase, B-phase, and C-phase, and each of the three phases is assigned to a differential element. NORTH still requires three differential elements, but the application uses one differential element from each of the three relays, as shown in *Figure 6.10*, instead of three elements in the same relay.

Figure 6.10 One Differential Element From Each of the Three Relays in a Three-Relay Application

Instead of wiring A-phase, B-phase, and C-phase to adjacent terminal connections on the same relay, as with the single-relay application shown in *Figure 6.7*, wire each phase to a separate relay. For example, wire A-phase to the A-Phase SEL-487B Terminal **I01**, B-phase to the B-Phase SEL-487B Terminal **I01**, and C-phase to the C-Phase SEL-487B Terminal **I01**, as shown in *Figure 6.11*.

Figure 6.11 CT Wiring in a Three-Relay Application Showing One CT Input to Each of the Three Relays

Figure 6.12 shows the CT wiring for one of the three relays with all A-phase inputs of the station and two bus-zones assigned. B-phase and C-phase relays have similar arrangements.

Figure 6.12 CT Wiring for A-Phase Relay, With All A-Phase Inputs of the Station and Two Bus-Zones Assigned

Because the differential elements are in three different relays, each of these relays must receive the same information from the digital inputs. *Figure 6.13* shows jumpers between relays for the case where only one 89 contact and one 52 auxiliary contact are available.

Figure 6.13 Jumpers Between Relays From Digital Inputs 52 and 89

CT Requirements

CT Connections

Connect all CTs to the relay in wye configuration. The SEL-487B does not account for delta-connected CTs.

CT Sizing

Sizing a CT to avoid saturation for maximum asymmetrical fault current is ideal but not always possible. Such sizing requires CTs with C voltage ratings greater than (1 + X/R) times the burden voltage for the maximum symmetrical fault current, where X/R is the reactance-to-resistance ratio of the primary system.

As a rule of thumb, CT performance will be satisfactory if the CT secondary maximum symmetrical external fault current multiplied by the total secondary burden in ohms is less than half the C voltage rating of the CT.

For correct operation, the relay algorithm requires that the CTs not saturate for 2 ms following an external fault inception. The IEEE Document *C37.110 Guide for the Application of Current Transformers Used for Protective Relaying Purposes* contains guidelines that will provide a conservative recommendation of the proper CT characteristics needed for low impedance bus differential protection using the SEL-487B. SEL also offers an executable CT saturation program called SEL Two_CTs to assist in determining the CT performance.

CT Ratio Selection

For installations with different CT ratios, be sure that the highest/lowest CT ratio does not exceed 10. The SEL-487B selects the highest CT ratio and calculates settings TAP01–TAP21, provided that the ratio TAP_{MAX}/TAP_{MIN} is less than or equal to 10. If the ratio TAP_{MAX}/TAP_{MIN} is greater than 10, select a different CT ratio.

CT Grounding

Because each of the 21 current channels is independent, be sure to apply a ground to each set of three CTs forming the current input from each terminal. Such grounding connections are usually in the form of short jumpers on the rear of the relay that together create a common connection among terminals. For example, in a three-relay application that uses all 21 terminals, apply 20 jumpers to create a common ground connection point (a single-relay that uses all 21 terminals requires 6 jumpers). Then connect this common point at one location to the station ground mat. Be sure to make ground connections in accordance with ANSI/IEEE C57.13.3-1983.

Polarity

IEEE Std C37.110-1996 provides the following definition of polarity:

> The designation of the relative instantaneous directions of the currents entering the primary terminals and leaving the secondary terminals during most of each half cycle. Primary and secondary terminals are said to have the same polarity when, at a given instant during most of each cycle, the current enters the identified, similarly marked primary lead and leaves the identified, similarly marked secondary terminals in the same direction, as though the two terminals formed a continuous circuit.

Figure 6.14 shows some of the common polarity marks used to indicate CT polarity.

Figure 6.14 Polarity Marks

Polarity marks are also declared on the relay analog input terminals as dots above the relay terminal, as shown in *Figure 6.15*.

Figure 6.15 Polarity Marks Above the Odd-Numbered CT Terminals at the Rear of the Relay

Guideline for Establishing CT Polarity

Configure a CT to have a positive polarity when the primary current entering the zone of protection is in phase with the secondary current entering the polarity marked terminal on the relay. Because CTs are commonly positioned to point toward the zone of protection, secondary connections are generally polarity-to-polarity or "dot-to-dot." If a CT points away from the zone of protection, apply a polarity-to-nonpolarity connection to continue a positive convention. This results in positive polarity declarations for all CTs in software.

If a single CT has two zone boundaries or is shared by an adjacent zone, you cannot use a positive convention for both zones. In this case, configure the CT polarity to be negative for the non-conforming zone.

Figure 6.16 and *Figure 6.17* show examples for determining polarity.

Figure 6.16 Declare Positive Polarity in Software (Preferred)

Figure 6.17 Declare Negative Polarity in Software

For simplicity, all application examples in this manual assume polarity-to-polarity connections between the CTs and relay.

Disconnect Requirements

Disconnect auxiliary contacts provide Zone Selection Logic with the information required to dynamically assign the appropriate current inputs to the correct differential elements. To ensure correct differential element operation, the contacts must comply with the requirements listed in *Table 6.1*.

Table 6.1 Disconnect Auxiliary Contact Requirements to Ensure Correct Differential Element Operation

Operation	Requirement
From disconnect open to disconnect close operation	Assign the currents to the applicable differential element before the disconnect reaches the "arcing" point, the point where primary current starts to flow.
From disconnect close to disconnect open operation	Remove the current from the applicable differential element only once the disconnect has passed the "arcing" point, the point where primary current has stopped flowing.

Figure 6.18 shows the disconnect auxiliary contact requirements with respect to the arcing point. The position of 0% travel in *Figure 6.18* indicates the position when the main contacts are fully open, and the 100% position indicates when the main contacts are fully closed.

Figure 6.18 Disconnect Auxiliary Contact Requirements With Respect to the Arcing Point for an Open-to-Close Disconnect Operation

When both 89A and 89B contacts are available, use the disconnect monitoring logic in the SEL-487B to establish the principle of

(disconnect) NOT OPEN = (disconnect) CLOSED

Applying this principle, the relay properly coordinates the primary current flow and the CT current assignment to the appropriate differential element. When both 89A and 89B disconnect auxiliary contacts are available, use the disconnect monitoring logic to monitor the disconnect operating time and disconnect status. *Table 6.2* shows the four possible disconnect auxiliary contact combinations and the way the relay interprets these combinations.

Table 6.2 Disconnect A and B Auxiliary Contact Status Interpretation

Case	89A01	89B01	Disconnect Status (89 CLnn)
1	0	0	Closed (1)
2	0	1	Open (0)
3	1	0	Closed (1)
4	1	1	Closed (1)

Table 6.2 (Disconnect Status column) shows that the output from the disconnect monitor logic interprets the disconnect as always closed, except for Case 2. With this interpretation, the relay assigns the input currents to the applicable differential elements for Case 1, Case 3, and Case 4. The following discussion considers the four cases in more detail.

Disconnect Open to Close Operation

Figure 6.19 shows the disconnect main contact starting to travel in an open-to-close operation. Auxiliary contact B is still closed, and auxiliary contact A is open. *Table 6.2* shows this as Case 2; the disconnect is considered open, and the current is removed from all differential elements. This is the only combination of auxiliary contacts for which the relay considers the disconnect main contacts to be open.

Figure 6.19 Disconnect Main Contacts and Auxiliary Contact A Open, Auxiliary Contact B Closed; Disconnect Is Considered Open

Intermediate Position

Figure 6.20 shows the intermediate position (Case 1 in *Table 6.2*) in a disconnect open-to-close operation, with both A and B auxiliary contacts open for a period of time. Enter this time duration as the disconnect switch alarm timer setting value (89ALP*nn*). By choosing the auxiliary contacts that will change status as soon as disconnect travel starts and close only near the end of travel, the intermediate position time duration can be accurately measured. Should the disconnect remain in the intermediate position for longer than the 89ALP*nn* (*nn* = 1–60) time setting, the disconnect switch alarm timer expires and asserts 89AL*nn*, the disconnect monitor alarm.

NOTE: The relay includes 60 alarm timers that provide individual time settings for 60 disconnect logic circuits. These individual timers are useful in installations where the disconnect travel times differ substantially. In particular, sequentially operated devices (pantographs, for example) have travel times much longer than normal disconnects. Relay Word bit 89OIP represents the OR combination of Relay Word bits 89OIP01–89OIP60, and Relay Word bit 89AL is respectively the OR combination of Relay Word bits 89AL01–89AL60.

Figure 6.20 Intermediate Position With Both Auxiliary Contacts Open; the Disconnect Is Considered Closed

When auxiliary contact B opens, the disconnect is considered closed (Case 1 in *Table 6.2*). When the disconnect is considered closed, the CT currents are assigned to applicable differential elements, and the disconnect switch alarm timer starts to time. Because disconnect auxiliary contact B opens well in advance of the arcing point, the CT currents are assigned to applicable differential elements before primary current flows.

Auxiliary Contact A Closes

Figure 6.21 shows contact status after auxiliary contact A closes, with the main contact past the arcing point and approaching the end of the close operation.

Figure 6.21 The Main Contact Has Completed 95% of Travel; Contact A Is Closed, Contact B Is Open, and the Disconnect Is Considered Closed

When the A contact closes, the disconnect switch alarm timer stops and the Disconnect Monitoring Logic considers the disconnect main contact to be closed.

Disconnect Open and Closed Simultaneously

Case 4 is an illegitimate condition, with the disconnect auxiliary contacts showing the disconnect main contact to be open and closed simultaneously. Timer 89ALP*nn* times for this condition and asserts Relay Word bit 89AL*nn* when the disconnect auxiliary contacts remain in this condition for a period exceeding the timer setting. The relay considers the disconnect main contact closed during this period, and the CTs are considered in the differential calculations.

Close-to-Open Operation

For the close-to-open operation, CT currents must remain assigned to the differential elements for as long as primary current flows. When the auxiliary contact A opens (Case 1), we again enter the intermediate position, as depicted in *Figure 6.20*. In the intermediate position, the CT currents are still assigned to the differential elements, and the disconnect switch alarm timer (89AL*nn*) starts to time. Only when auxiliary contact B closes (*Figure 6.19*) are the CT currents removed from the differential elements, which are safely past the arcing point.

Many disconnect switches provide only auxiliary contact B. *Table 6.3* shows the two possible disconnect auxiliary contact positions and status interpretations.

Table 6.3 Disconnect Auxiliary Contact Status Interpretation When Only Auxiliary Contact B Is Available

89B01	Disconnect Position
0	Closed
1	Open

Alias Names

Any Relay Word bit, analog quantity, or default terminal name can be renamed with more meaningful names to improve the readability of fault analysis and customized programming. See the description in *Alias Settings on page 12.25 in the SEL-400 Series Relays Instruction Manual* for more details.

Bus-Zone Configurations

Dynamic zone selection is the process the relay uses to assign or remove CT currents from the differential elements as a function of the Boolean value (logical 0 or logical 1) of a particular SELOGIC control equation. The SELOGIC control equation is a setting in the form of I*nn*BZ*k*C and I*nn*BZ*k*V (*nn* = 01–21, and *k* = 1–6). When setting SELOGIC control equations, use a separate SELOGIC control equation for each busbar to which the terminal can connect.

NOTE: In Quickset, the Terminal-to-Bus-Zone connection setting, InnBZkC, is broken down into two setting: CTnnBZk and TBZPx (x = 1–126). CTnnBZk enables Terminal nn to be connected to Bus-Zone k. TBZPx sets the polarity of the Terminal nn to Bus-Zone k connection.

In general, a terminal can be identified as either a normal terminal (feeders, lines, transformers, etc.) or as a tie breaker (bus coupler). For terminals, typical inputs are disconnect auxiliary contacts and, in some cases, circuit breaker auxiliary contacts. Bus couplers have specific logic and configuration options that require inputs in addition to disconnect and circuit breaker auxiliary contacts to ensure security and dependability.

When configuring bus-zone protection, the goal is to accomplish the following:

- Protect the busbars for all operating conditions
- Eliminate all dead zones
- Open the minimum number of breakers when tripping
- Implement the check zone without disconnect supervision, if a check zone is required

When the terminal-to-bus-zone SELOGIC control equation (I*nn*BZ*k*V Terminal to Bus Connection Logic) is logical 0, differential calculations do not consider the CT inputs from that specific terminal, and no trip outputs from the differential elements are issued to that terminal. Of particular concern are instances when more than one disconnect for any particular terminal are closed at the same time. When this happens, parallel paths form, possibly resulting in the unbalance of multiple zones, as shown in *Figure 6.22* and *Figure 6.23*. Under balanced conditions, the current toward the busbars equals the current away from the busbars, and the differential current in any differential element is practically zero.

In practice, the most popular implementation for preventing misoperation when parallel paths form is to combine the parallel paths into a single zone and route the CTs to a single differential element. Another option is to use a check zone by combining all terminals at a specific voltage level into a single zone independent of the terminal-to-bus-zone SELOGIC control equations. Using the check zone as a second trip criterion prevents relay misoperation in the case of parallel paths.

In general, apply the following rules when setting terminal-to-bus-zone SELOGIC control equations:

- Observe the correct CT polarity
- Avoid parallel operating conditions
- When parallel paths are unavoidable, take necessary precautions

Two situations exist where parallel paths are unavoidable: when two disconnects are closed simultaneously and when using inboard (bushing) CTs.

Two Disconnects Closed Simultaneously

Figure 6.22 shows a double busbar layout in which two disconnects can be closed simultaneously. With the tie breaker (TZ) connected in overlap, CT1 and CT2 form Differential Element 1, and CT3 and CT4 form Differential Element 2. There are no parallel paths in *Figure 6.22*, and both differential elements are balanced. Calculate the differential currents with the following expression:

$$I_{DIFF1} = \sum_{1}^{n} I_n$$

Equation 6.1

where:

I_{DIFF1} = The differential current calculated in Differential Element 1

I_n = CT currents from the *n* terminals assigned to Differential Element 1

Figure 6.22 Both Differential Elements Balanced

Closing 891_TA in *Figure 6.23* forms a parallel path between the two busbars, and both differential elements are unbalanced.

Figure 6.23 Both Differential Elements Unbalanced

To prevent misoperation, combine the two bus-zones by stating the conditions governing the combinations during setting of bus-zones-to-bus-zones connections. When using bushing (inboard) CTs, combining bus-zones involves including a circuit breaker as part of the connection. You can include a circuit breaker provided that the circuit breaker auxiliary contact is wired to the relay and included in the bus-zones-to-bus-zones settings.

Inboard (Bushing) CTs

Figure 6.24 shows an outboard CT, and *Figure 6.25* shows an inboard CT. Defining a CT as inboard or outboard only has meaning when a terminal is on transfer. To define the terms, refer to the area between the circuit breaker and the CT, and determine the connection to the transfer bus.

- Outboard CT: the connection to the transfer bus is between the circuit breaker and the CT (*Figure 6.24*).
- Inboard CT: the connection to the transfer bus is not between the circuit breaker and the CT (*Figure 6.25*).

Figure 6.24 Outboard CT

Figure 6.25 Inboard CT

Bushing CTs (typically the source of inboard CTs) present two difficulties to bus protection when a terminal is on transfer:

- A transfer differential zone cannot be formed because of a lack of CT inputs.
- The check zone is unbalanced.

Not having a transfer differential zone is not a major problem if it is understood that the transfer busbar becomes part of the line and forms part of the line protection when a terminal is on transfer. However, the unbalanced check zone usually necessitates blocking busbar protection when a terminal is on transfer.

Example of Check Zone With In-Board (Bushing) CTs

Instead of blocking the check zone protection when a terminal is on transfer, you can use the Advance Check Zone function to include a terminal from the bus coupler in the check zone differential element calculations. Although this approach deviates from the practice of having the check zone CTs independent of disconnect auxiliary contacts, it provides an opportunity to still have a check zone for in-board CT applications. *Figure 6.26* shows an example of an application with in-board CTs that includes a check zone. In *Figure 6.26*, Feeder 1 connects to Bus 1 (i.e., not on transfer). Under these conditions, Zone 1 (formed by I01 and I03), Zone 2 (formed by I02 and I04), and the check zone (formed by I01 and I04) are all balanced.

Figure 6.26 Normal Operating Conditions

In *Figure 6.27*, Feeder 1 connects to the Transfer busbar. When Feeder 1 connects to the Transfer busbar, note the following conditions:

1. Line CT I01 of Feeder 1 is no longer in the circuit.
2. Without I01, the current to balance I03 is missing, resulting in an unbalanced Zone 1.
3. Without I01, the current to balance I04 is missing, resulting in an unbalanced check zone.
4. I02 and I04 are still available so that Zone 2 is balanced.

Figure 6.27 Feeder With Inboard CTs

To balance Zone 1, we need to remove I03 from the Zone 1 differential element calculations. You can remove I03 with existing settings; either by means of the Terminal-to-Bus-Zone settings, or by means of the Zone Supervision settings (see *Application 6: Double and Transfer Bus With Two Busbars on page 6.157*).

To balance the Check Zone, we need to add I02 to the Check Zone differential element calculations by means of the Advanced Check Zone settings. The steps are as follows:

1. Include I02 in the Terminal to Check Zone Connection settings.
2. Use the Advanced Check Zone settings to remove I02 from the Check Zone differential element calculations, except when Feeder 1 is on transfer.

Following is an example of how to use the Advance Check Zone function to balance the Check Zone for this application.

NOTE: In Quickset, these settings are made in **Group > Zone Configuration > Check Zone Configuration > Terminal nn to Check Zone Connections**.

```
Check Zone Configuration

Enable Check Zones at Station (Y,N)                ECHKZN  := N      ?Y <Enter>

Check Zone Configuration: Terminal to Check Zone Connections


Terminal, Check-Zone, Polarity (P,N)
?  IO1 CZ1 P <Enter>
Terminal, Check-Zone, Polarity (P,N)
?  IO2 CZ1 P <Enter>
Terminal, Check-Zone, Polarity (P,N)
?  IO4 CZ1 P <Enter>
Terminal, Check-Zone, Polarity (P,N)
?  <Enter>
Enable Advance Check Zone Settings (Y,N)           EADVCZ  := N      ? Y <Enter>
Include coupler 1 in check zone 1 (SELogic Eq.)
CZ11R := NA
?  89CL04 <Enter>
Terminal associated with coupler 1 in CZ1 (Inn)    CZ11M   :=        ?IO2 <Enter>
Include coupler 2 in check zone 1 (SELogic Eq.)
CZ12R := NA
?END <Enter>
```

Table 6.4 discusses the settings mentioned above. Please pay close attention to the comments mentioned in Step 4.

Table 6.4 Discussion of the Advanced Check Zone Settings

Step Number	Setting	Comment
Step 1	`ECHKZN := Y`	Enable the three Check Zones.
Step 2	`Terminal, Check-Zone, Polarity (P,N) ? I02 CZ1 P <Enter>`	This is the non-conventional setting. Here we add the bus coupler CT to the Check Zone. This is the first part of the solution. Under normal operating conditions (when no terminal is on transfer) the bus coupler CTs must be EXCLUDED from the Check Zone differential element calculations. You MUST complete the second part of this setting under the Advance Check Zone Settings.
Step 3	`EADVCZ := Y`	Enable the Advance Check Zone Settings.
Step 4	`Include coupler 1 in check zone 1 (SELogic Eq.)` `CZ11R := NA ? 89CL04 <Enter>`	This is the second part of the solution. CZ11R is similar to the Terminal to Bus-Zone Connections (i.e., here is where you enter the conditions when the bus coupler CT must be included in the Check Zone differential element calculations). Assuming you assigned Disconnect Logic 89CL04 to the Transfer Disconnect for I02, enter **89CL04**. CZ11R defeats the Check zone setting of Step 2. This means that, although the list of Check Zone terminals (Step 2) includes I02, I02 is only included in the Check Zone differential element calculations when CZ11R evaluates to logical 1.
Step 5	`CZ11M := I02`	Enter the bus coupler terminal (I02 in this example) you want to include in the Check Zone differential element calculations when CZ11R evaluates to logical 1.

Table 6.5 shows the settings for the Advance Check Zone.

Table 6.5 Advance Check Zone Settings

Label	Prompt	Default Value
EADVCZ	Enable Advance Check Zone Settings (Y, N)	N
CZ*pq*R	Include Coupler *q* in Check Zone *p* (SELOGIC Eq.)	NA
CZ*pq*M	Terminal associated with Coupler *q* in CZ*p* (I*nn*)	

Terminal Configurations

In essence, busbar protection is assigning the correct CT currents to the appropriate differential elements. Disconnect auxiliary contacts provide the information necessary for busbar protection, and breaker auxiliary contacts provide the breaker status for refining the protection. SELOGIC control equations provide the mechanism for declaring the conditions when the currents are assigned to the appropriate differential elements. Entering data in the relay requires two steps. The first identifies the terminal and attributes, and the second involves creation of the SELOGIC control equation stating the conditions for the CTs to be considered in the differential calculation. Bus couplers (tie breakers) require more condition information when two or more bus-zones are combined.

Step 1. Identify the terminal, the bus-zone to which the terminal can connect, and the CT polarity when this connection is made.

The following is the relay prompt for the Step 1 entry:

```
Terminal, Bus-Zone, Polarity (P,N)
?
```

Step 2. State the conditions when **Terminal** will be connected to the **Bus-Zone**:

I01BZ2V :=

Think of **Terminal** as the CT of that particular terminal and **Bus-Zone** as the busbar to which the CT will be connected for differential and restraint current calculations. In other words, assign the CT (**Terminal**) to busbar (**Bus-Zone**) under the following conditions: **I01BZ2V := <conditions>**.

Figure 6.28 shows Terminal NEW_YRK. The differential calculations consider the CT when disconnect NEW891 closes to complete the connection to Bus-Zone NORTH.

Figure 6.28 Terminal NEW_YRK Disconnects NEW892 and NEW891 and Bus-Zone NORTH

Step 3. Enter the data as follows:

```
Terminal, Bus-Zone, Polarity (P,N)
?NEW_YRK,NORTH,P <Enter>
```

Entering incorrect information may result in relay misoperation. To reduce potential entry of incorrect information, the relay provides a double check to verify that terminal and bus-zone connections are indeed as intended. The next prompt has two parts:

- The relay states terminal and bus-zone alias names just entered.
- The relay generates a prompt with the primitive terminal and bus-zone names.

Thus, the prompt now appears as follows:

```
NEW_YRK to NORTH Connection (SELogic Equation)
IO1BZ1V :=
```

Step 4. Enter the conditions under which Terminal NEW_YRK is to be assigned to Busbar NORTH by specifying the particular disconnect (89) auxiliary contact that will connect the terminal to the busbar.

For example, when Disconnect NEW891 is closed, Terminal NEW_YRK is connected to Busbar NORTH. A Terminal, Bus-Zone, Polarity (P, N), and I01BZ1V setting is required for each 89 contact that results in a terminal-to-busbar connection. Consider a terminal that can be connected to Busbar 1, Busbar 2, and the transfer bus. Because the terminal connects to three busbars, provide terminal-to-bus-zone (Terminal, Bus-Zone, Polarity) and conditions for consideration in the differential calculations [I01BZ*n*V (*n* = 3)] for each of the three busbars.

Step 5. Enter the following settings for Terminal NEW_YRK:

```
NEW_YRK to NORTH Connection (SELogic Equation)
I01BZ1V := NEW891 <Enter>
```

Entries here assign CT currents to differential elements. Take care to first investigate the position of the CT for each entry. For example, refer to *Figure 6.24*, and observe that regardless of which disconnect closes (A891, A892 or A898), current always flows through the CT. This is not the case with inboard CTs; closing B898 in *Figure 6.25* bypasses the CT, and no current flows in the inboard CT.

Step 6. Determine the CT polarity, assuming a polarity-to-polarity connection. *Figure 6.29* shows that the CT polarity is positive.

Figure 6.29 Positive CT Polarity for Terminal NEW_YRK

Step 7. Omit the final argument if the CT polarity is positive. For example,

```
Terminal, Bus-Zone, Polarity (P,N)
?NEW_YRK,NORTH,P <Enter>
```

has the same meaning as

```
Terminal, Bus-Zone, Polarity (P,N)
?NEW_YRK,NORTH <Enter>
```

In Quickset, go to **Group 1 > Zone Configuration 1 > Terminal Bus-Zone Connections > Terminal 1 To Bus-Zone Connections**. Set CT01BZ1 = Y, TBZP1 = P, and I01BZ1V = NEW891. NEW_YRK and NORTH are automatically populated into the TBZT1 and TBZB1 fields as the alias names for I01 and BZ1.

Figure 6.30 Terminal to Bus-Zone Connections Screen

Bus Coupler (Tie Breaker) Configurations

In general, bus couplers are usually configured according to one of the three cases shown in *Figure 6.31*:

- Case 1: Single CT, single or two cores (two cores shown) with overlap
- Case 2: CT either side of the breaker, configured in overlap
- Case 3: CT either side of the breaker with breaker differential

Figure 6.31 Three Typical Cases of Bus Coupler Configurations

A discussion on how to set the three configurations follows.

Label all CTs as indicated in *Figure 6.32* (i.e., CPL1 and CPL2) with the understanding that CPL1 is wired to Terminal I01, and CPL2 to Terminal I02 of the SEL-487B.

Figure 6.32 General Information Regarding the Three Typical Bus Coupler Configurations

Case 1: Single CT, Single or Two Cores (Two Cores Shown) With Overlap

Step 1. For an overlap, establish the following relationships:

- ➢ CPL1 and SOUTH when CPL891 is closed
- ➢ CPL2 and NORTH when CPL892 is closed

Step 2. Determine the polarity of Terminal CPL1, assuming a polarity-to-polarity connection. *Figure 6.33* shows that the polarity of Terminal CPL1 is negative.

Figure 6.33 Negative CT Polarity for Terminal CPL1

Step 3. Determine the polarity of Terminal CPL2, assuming a polarity-to-polarity connection. *Figure 6.34* shows that the polarity of Terminal CPL2 is positive.

Figure 6.34 Positive CT Polarity for Terminal CPL2

Step 4. *Figure 6.35* shows an extract from the **SET Z 1** ASCII command in determining the terminal-to-bus-zone settings in the relay.

```
Terminal, Bus-Zone, Polarity (P,N)
? CPL1,SOUTH,N <Enter>
CPL1 to SOUTH Connection (SELogic Equation)
IO1BZ2V := CPL891 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
? CPL2,NORTH,P <Enter>
CPL2 to NORTH Connection (SELogic Equation)
IO2BZ1V := CPL892 <Enter>
```

Figure 6.35 Using the SET Z 1 Command to Determine Terminal-to-Bus-Zone Settings

This concludes the Case 1 configuration.

Case 2: CT Either Side of the Breaker, Configured in Overlap

Step 1. As we did before for an overlap, establish the following relationships:

- ➢ CPL1 and SOUTH when CPL891 is closed
- ➢ CPL2 and NORTH when CPL892 is closed

Step 2. Determine the polarity of Terminals CPL1 and CPL2, assuming polarity-to-polarity connections. *Figure 6.36* shows that the polarities of Terminals CPL1 and CPL2 are positive.

Figure 6.36 Positive CT Polarity for Both Terminals CPL1 and CPL2

Figure 6.37 shows an extract from use of the **SET Z 1** ASCII command to set the terminal-to-bus-zone settings in the relay.

```
Terminal, Bus-Zone, Polarity (P,N)
? CPL1,SOUTH,P <Enter>
CPL1 to SOUTH Connection (SELogic Equation)
IO1BZ2V := CPL891 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
? CPL2,NORTH,P <Enter>
CPL21 to NORTH Connection (SELogic Equation)
IO2BZ1V := CPL892 <Enter>
```

Figure 6.37 Using the SET Z 1 Command to Set the Terminal-to-Bus-Zone Settings

This concludes the configuration for Case 2.

Case 3: CT Either Side of the Breaker With Breaker Differential

Step 1. Use one of the six available differential elements to configure the breaker differential.

For the bus coupler in the example, three differential elements are required; the third differential element covers only the common area between the two CTs.

In addition to the breaker differential, configure the same CTs (CPL1 and CPL2) to balance SOUTH and NORTH. For the breaker differential, establish the following relationships:

For balancing SOUTH and NORTH:

- CPL1 and NORTH when CPL892 is closed
- CPL2 and SOUTH when CPL891 is closed

For the breaker differential:

- CPL1 and ZONE3 when CPL891 or CPL892 is closed
- CPL2 and ZONE3 when CPL891 or CPL892 is closed

Considering both Terminals CPL1 and CPL2, we determine that both polarities are negative, when we balance SOUTH and NORTH, as shown in *Figure 6.38*.

Figure 6.38 Negative CT Polarities for Both Terminals CPL1 and CPL2 When Balancing SOUTH and NORTH

Step 2. Determine the polarity of Terminals CPL1 and CPL2 for the breaker differential (ZONE3), assuming polarity-to-polarity connections. *Figure 6.39* shows that the polarities of Terminals CPL1 and CPL2 for the breaker differential are positive.

Figure 6.39 Positive CT Polarities for Both Terminals CPL1 and CPL2 for the Breaker Differential

Figure 6.40 shows the entries for Terminals CPL1 and CPL2.

```
Terminal, Bus-Zone, Polarity (P,N)
? CPL1,NORTH,N <Enter>
CPL1 to NORTH Connection (SELogic Equation)
IO1BZ1V := CPL892 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
? CPL1,ZONE3,P <Enter>
CPL1 to ZONE3 Connection (SELogic Equation)
IO1BZ3V := CPL891 OR CPL892 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
? CPL2,SOUTH,N <Enter>
CPL2 to SOUTH Connection (SELogic Equation)
IO2BZ2V := CPL891 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
? CPL2,ZONE3,P <Enter>
CPL2 to ZONE3 Connection (SELogic Equation)
IO2BZ3V := CPL891 OR CPL892 <Enter>
```

Figure 6.40 Entries for Terminals CPL1 and CPL2

Bus-Zone-to-Bus-Zone Connections

Bus-zone-to-bus-zone settings are used only when bus-zone-to-bus-zone connections are formed between two or more busbars, particularly when the connection is formed without a circuit breaker between the busbars. For example, closing disconnects D891 and D892 in *Figure 6.41* forms a solid connection between NORTH and SOUTH, and there is no circuit breaker between the busbars.

Figure 6.41 Forming Bus-Zone-to-Bus-Zone Connections With and Without a Circuit Breaker

By contrast, closing E892 and E898 or E891, E892, and E898 also forms a connection between Busbar 1 and Busbar 2, but now there exists a circuit breaker between the busbars, namely the Terminal E circuit breaker. The significance of the bus-zone-to-bus-zone connection is twofold.

- Both differential zones (SOUTH and NORTH) must operate when a fault develops on either zone during the time when the two differential zones are connected via disconnects D891 and D892 (or similar connections).
- Parallel paths are formed, and both differential zones may be unbalanced (see *Figure 6.23*).

When two bus-zones are combined, bus coupler CTs are redundant and are removed from the differential calculations.

One protection philosophy requires the tripping of only those circuit breakers that can contribute fault current to optimize breaker maintenance. However, there is also the protection philosophy that requires all breakers in the faulted differential zone to be tripped. To satisfy both protection philosophies, the SEL-487B offers the choice of leaving the bus coupler closed or issuing a trip signal. The first prompt in this group asks you for the two busbars that will be combined.

Step 1. From *Figure 6.41*, we see that we would enter SOUTH and NORTH at the prompt (without spaces between the differential zone names or the comma).

```
Bus-Zone,Bus-Zone?
SOUTH,NORTH <Enter>
```

Step 2. Next, the SELOGIC control equation that declares the digital input conditions which must be a logical 1 for the relay to recognize the combination of SOUTH and NORTH. Again, the relay states the names you enter and then generates a prompt with the primitive names as a double check.

List all of the several possible combinations, separating each combination with the OR function. From *Figure 6.41*, NORTH and SOUTH are combined when D891 and D892 are closed, or when E891 and E892 are closed:

```
SOUTH to NORTH Connection (SELogic Equation)
BZ1BZ2V := (D891 AND D892) OR (E891 AND E892) <Enter>
```

NOTE: When the bus-zone-to-bus-zone SELOGIC control equation includes the circuit breaker, be sure to also include the breaker auxiliary contact status (not only the disconnect status) to ensure separate bus-zones when the circuit breaker is open.

This setting identifies the particular differential zones that can be combined and the conditions under which this combination can take place.

Step 3. The next setting allows you to select a subset of the conditions stated in the previous setting. In the present example, there is no subset, and the setting is a repeat of the previous setting.

```
Remove Terminals when NORTH and SOUTH Bus-Zones merge (SELogic Equation)
BZ1BZ2R := NA
?  (D891 AND D892) OR (E891 AND E892) <Enter>
```

Step 4. Next, state the terminals to be removed when the two differential zones are combined. In most cases, these terminals are the bus coupler CTs, as is the case in *Figure 6.41*. You would, therefore, enter the bus coupler terminal names at the prompt.

```
Terminals Removed when NORTH and SOUTH Bus-Zone merge (Ter k,...,Ter n)
BZ1BZ2M :=

?CPL1,CPL2 <Enter>
```

Step 5. To end this group, select whether the bus coupler must be tripped (Y) when a fault occurs in the combined protection zone during the time when the two bus-zones are merged, or whether the bus coupler must not be issued a trip signal (N). Again, as a double check, the relay states the primitive names of the terminals that must be removed:

```
Trip Terminals CPL1, CPL2 (Y,N)
BZ1BZ2T := N

?  Y <Enter>
```

In Quickset, go to **Group 1 > Zone Configuration 1 > Bus-Zone to Bus-Zone Connections > Bus-Zone to Bus-Zone Connections Blocks 1–5**. Set CBZ1BZ2 = Y, BZ1BZ2V = (D891 AND D892) OR (E891 AND E892), BZ1BZ2V = (D891 AND D892) OR (E891 AND E892), CPT11 = CPL1, CPT21 = CPL2, and BZBZT1 = Y. NORTH and SOUTH are automatically populated into the BZBZ11 and BZBZ21 fields as the alias names for BZ1 and BZ2.

Figure 6.42 Bus-Zone to Bus-Zone Blocks 1-5

Zone Supervision

This is the final check before a bus-zone trip (87Z1) is issued for each of the six differential zones. *Figure 6.43* shows the relay logic for this function, where the output from the differential calculations (87R1) is ANDed with the zone supervision conditions. See *Section 5: Protection Functions* for more information.

Figure 6.43 Zone Supervision Logic

This is a good place to include the overall check zone differential element output, if one was configured.

Assume Check Zone 1 was configured. Enter the following to include the check zone.

```
Z1S:= 87CZ1 <Enter>
```

Trip Logic

Figure 6.44 shows the steps necessary for assigning protection functions to the trip logic.

Make sure all selected protection functions appear in the trip equation.

For example, having selected the breaker failure protection, assign the output from this logic to the output contact, or the contact will not assert when the breaker failure protection operates. For Terminal I06 wired to OUT201, the following includes differential protection, internal breaker failure protection, and time-overcurrent protection.

```
=>>SET TRO6 <Enter>
Group 1
Trip Logic
Trip O6 (SELogic Equation)
TRO6 := NA
?  87BTRO6 OR SBFTRO6 OR 51PO1T <Enter>
Unlatch Trip O6 (SELogic Equation)
ULTRO6 := NA
?  END <Enter>
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.44 Assign the Protection Functions to the Trip Logic

Output Assignments

Figure 6.45 shows the steps necessary for assigning the output from the trip logic (TRIP06) to output contact OUT201.

```
=>>SET O OUT201 <Enter>
Output
Interface Board #1
OUT201 := NA
?  TRIP06 <Enter>
OUT202 := NA
?  END <Enter>
Output
Main Board
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.45 Assigning the Output From the Trip Logic to an Output Contact

Summary

In general, system configuration can be summarized in the four-step approach shown in *Figure 6.46*.

Figure 6.46 Information Flow Diagram

Step 1. Assess your station and select appropriate protection functions.

Inspect the substation layout to make the appropriate selection in terms of number of bus-zones, number of terminals, CT ratio mismatch, I/O count, etc.

As for protection functions, decide whether to use internal or external breaker failure protection, breaker differential, or an overlap coupler CT application (if two sets of CTs are available), etc.

Step 2. Assign alias names.

Because configuration settings use terminal names, assign alias names at this point.

Step 3. Configure your system.

Entries here determine the CT/differential element assignment with the terminal-to-bus-zone and bus-zone-to-bus-zone settings, while zone supervision and zone-switching supervision provide for additional control and information.

Step 4. Assign outputs.

For each terminal, select the relay functions for which the terminal will be issued a trip signal.

Use *Table 6.6–Table 6.11* to assist with Step 1 of the configuration process.

Table 6.6 Primary Plant Data

Items	Requirement for Your Plant
Number of terminals (maximum 21)	
Number of busbars (maximum 6)	
Number of main zones (maximum 6)	
Number of check zones (maximum 3)	
Number of bus couplers or tie breakers (maximum 4)[a]	
Inboard CTs (Y,N)	
Maximum/minimum CT ratio	

[a] Mutually exclusive; sum of bus couplers and bus sections cannot exceed four.

Table 6.7 Data for Bus Coupler 1 and Bus Coupler 2

Bus Coupler 1 Data		Bus Coupler 2 Data	
Number of CTs		Number of CTs	
Overlap or differential		Overlap or differential	
Coupler security logic? Y, N[a]		Coupler security logic? Y, N[a]	
Breaker status logic? Y, N[b]		Breaker status logic? Y, N[b]	

[a] Allocate independent optoisolated inputs to the selected logic.
[b] Allocate one grouped optoisolated input to the selected logic for each logic.

Table 6.8 Data for Bus Coupler 3 and Bus Coupler 4

Bus Coupler 3 Data		Bus Coupler 4 Data	
Number of CTs		Number of CTs	
Overlap or differential		Overlap or differential	
Coupler security logic? Y, N[a]		Coupler security logic? Y, N[a]	
Breaker status logic? Y, N[b]		Breaker status logic? Y, N[b]	

[a] Allocate independent optoisolated inputs to the selected logic.
[b] Allocate one grouped optoisolated input to the selected logic for each logic.

Table 6.9 Disconnect, Breaker, and Input Data

Items	Requirement for Your Plant
Number of 89A (N/O) contacts?[a]	
Number of 89B (N/C) contacts?[a]	
Disconnect Monitoring Logic? (maximum 60)	
Zone-Switching Supervision Logic?	
Number of 52A contacts	

[a] Allocate independent optoisolated inputs to the selected logic.

Table 6.10 Breaker Failure Data

Items	Requirement for Your Plant
Number of internal breaker failure circuits	
Number of external breaker failure circuits	
Additional security?[a]	

[a] Allocate independent optoisolated inputs to the selected logic.

Table 6.11 End-Zone Protection

Items	Requirement for Your Plant
Number of 52A (N/O) contacts?[a]	
Number of communication outputs required?[b]	

[a] Allocate this number of common optoisolated input contacts.
[b] Allocate this number of independent output contacts.

Application 1: Single Bus and Tie Breaker (Three Relays)

This application describes the busbar arrangement shown in *Figure 6.47*, a single bus with bus sectionalizer (tie breaker), three-relay application. The busbar arrangement consists of two busbar sections, four feeders, and a tie breaker. Consider the following to set and configure the relay:

- Busbar classification
- Protection philosophy
- Protection functions selection
- Number of SEL-487B Relays and I/O boards
- Input, logic, and output allocation and alias name assignment
- Station layout update
- Relay setting and configuration

Figure 6.47 Single Bus With Bus Sectionalizer (Tie Breaker)

Busbar Classification

The busbar classification provides general busbar layout and CT positioning (inboard or outboard) information and declares the tie-breaker (bus coupler or sectionalizing breaker) configuration. The classification for this application is:

- Description
  - Single bus with tie breaker
- Current Transformers

- Outboard (free standing)
- Disconnects
  - Both 89A and 89B disconnect auxiliary contacts are available
- Sectionalizing breaker (tie-breaker) configuration
  - Overlap
- Future expansion
  - Four feeders

Protection Philosophy

Although the SEL-487B offers a variety of protection and control functions, not all of these functions are applied at every substation. Carefully consider each application before stating the functional requirements. The protection philosophy for this application is as follows:

1. Use the 89 disconnect auxiliary contacts to dynamically configure the station.
2. Use the Disconnect Monitoring Logic.
3. Block the busbar protection for an open-circuit CT.
4. Configure check-zone protection.

Protection Functions Selection

We select the protection functions early in the relay setting and configuration process because the choice of protection functions determines the number of relay digital inputs and outputs required for the application. Study the protection philosophy to determine which protection and/or control functions to apply to any particular substation. For example, in this application the protection philosophy calls for a check zone, but not for breaker failure protection.

The SEL-487B offers a number of protection functions as standard features, but also includes the capability through SELOGIC control equations to create user-configurable functions. To properly identify and categorize the protection philosophy requirements, group the protection functions as follows:

- standard protection functions (available in the relay)
- user-defined protection functions (created using SELOGIC control equations)

Standard Functions

Refer to *Protection Philosophy on page 6.61* and select the standard functions required for the application. *Table 6.12* shows the selection of the standard functions.

Table 6.12 Selection of the Standard Protection Functions

Protection Function	Selection	Comment
CT ratio mismatch ≤ 10:1	Yes	10:1 mismatch is the maximum allowable mismatch
Circuit breaker status logic	No	Not required
Disconnect monitor logic	Yes	89A and 89B disconnect contacts available

Table 6.12 Selection of the Standard Protection Functions

Protection Function	Selection	Comment
Differential protection	Yes	Busbar protection, zone specific Check-zone protection
Dynamic zone selection logic	Yes	Use the zone selection to reconfigure the differential protection according to the disconnect positions
Sensitive differential protection	Yes	CT open circuit detection
Zone supervision logic	Yes	Enter the check zone and zone-specific conditions to supervise the zone-specific differential elements
Zone-switching supervision logic	No	89A and 89B disconnect contacts available; therefore, this logic is not required
Coupler security logic	No	Two CTs with overlap configuration do not require the coupler security logic
Circuit breaker failure protection	No	Not required
Instantaneous overcurrent protection	No	Not required
Time-overcurrent protection	No	Not required
Phase voltage elements	No	Not required
Zero- or negative-sequence voltage elements	No	Not required

User-Defined Functions

Because the SEL-487B includes all protection functions necessary for this application as standard protection functions, we do not need any user-defined functions.

Check-Zone Protection

Figure 6.48 shows a station with check-zone protection. Check-zone protection stems from the philosophy of providing an additional trip criterion before issuing a busbar protection trip signal. This philosophy encompasses additional trip criteria such as directional elements and overcurrent elements.

When using check-zone protection as an additional criterion, the practice is to provide a measurement from a second differential element that is independent of the disconnect auxiliary contact status. Using a measurement independent of the disconnect auxiliary contact status prevents differential element misoperation resulting from disconnect auxiliary contact failure.

Figure 6.48 Station With Two Zone-Specific Bus-Zones and an Overall Check Zone

Both the Check Zone and either Zone 1 or Zone 2 differential elements must assert before a busbar protection trip output asserts. Use the Differential Element Zone Supervision setting to comply with the requirement for both check zone and zone-specific differential elements to assert. *Figure 6.49* shows the zone supervision logic. Relay Word bit 87R1 is the output from the Zone 1 differential element and Z1S is the SELOGIC control equation where we enter conditions for supervising the Zone 1 differential element. (See *Zone Configuration Group Settings on page 6.54* for more detail.)

Figure 6.49 Zone Supervision Logic

Create the check-zone protection by configuring a check zone when entering the zone configuration settings (ECHKZN := Y).

Number of Relays and I/O Boards

Selecting the relay has two parts:

- the number of relays (single-relay application or three-relay application)
- the number of interface boards (as many as four interface boards per relay)

The number of analog (CT) inputs determines the number of relays, and the number of digital inputs and outputs determines the number of interface boards.

Number of Relays

Each SEL-487B has 21 current channels and three voltage channels. For stations with as many as 7 three-phase terminals (21 CTs), we can install a single SEL-487B. For stations with more than 21 and as many as 63 CTs, we install 3 SEL-487B Relays. Use *Equation 6.2* to calculate the number of current channels at the station, and use *Equation 6.3* to calculate the number of zones at the station.

$$\text{\# of current channels required} = \text{\# of per-phase station CTs}$$

Equation 6.2

$$\text{\# of bus-zones required} = \text{\# of per-phase station bus sections}$$

Equation 6.3

The number of per-phase CTs at the station is 18 and the number of bus-zones required is 2 (Zone 1 and Zone 2). The number of check zones required is 1 (Check Zone 1). One SEL-487B suffices for these requirements, but the requirement for 4 future feeders increases the number of per-phase CTs to 30. Because each SEL-487B has 21 analog input channels, we need 3 relays. This is known as a three-relay application.

In a three-relay application, each relay provides six zones and three check zones of protection for one of the three phases of the power system. For example, wire all the A-phase CTs to Relay 1, the B-phase CTs to Relay 2, and the C-phase CTs to Relay 3. Settings for the three relays are identical; all three relays require the same information. Wire input and output contacts (from the circuit breaker or disconnects, for example) to one of the three relays, then jumper (hard wiring) the input and output contacts to the other two relays. This example shows the setting and configuration for the A-phase relay, so identified with an appended letter A (LOND_A). For the other two relays, the settings and configuration are the same as for the A-phase relay, but the appended letter changes according to the letter designation of the relay. For example, the corresponding LOND_A setting is LOND_B in the B-phase relay and LOND_C in the C-phase relay.

Number of Relay Inputs

The protection philosophy and protection function selection determine the number of digital relay inputs and outputs required for each application.

The number of disconnect logics (NUMDS) required is the number of disconnects for which the protection philosophy requires disconnect monitoring logic. In this example, each of the four feeders requires one disconnect monitoring logic and the tie breaker requires two; therefore, the number of disconnect logics required is six. Each disconnect monitoring logic requires two disconnect auxiliary contact inputs: an 89A and an 89B contact. Use *Equation 6.4* to calculate the number of relay inputs required for the disconnect auxiliary contacts.

$$\text{\# relay inputs required} = 2 \bullet \text{\# disconnect monitoring logics}$$

Equation 6.4

Table 6.13 summarizes the input contact required for this application.

Table 6.13 Number of Relay Input Contacts Required

Input Description	Inputs
Number of relay inputs required for the disconnect contacts	6 • 2 = 12
Total number of inputs	12

The relay main board has seven input contacts, which are not enough input contacts for our application. Each interface board provides two sets of nine grouped input contacts and six independent input contacts. Use the grouped input contacts for the disconnect auxiliary contact inputs. From the input contact perspective, we need one interface board. It is not necessary to include I/O for future expansion with the initial order; install additional I/O if and when required.

Number of Relay Output Contacts

Our example station has five circuit breakers, all of which are part of the busbar differential protection. Because all breakers are part of the busbar differential protection, we want to trip each breaker upon differential protection operation. *Table 6.14* shows the breakdown and the total number of relay output contacts required.

Table 6.14 Breakdown and the Total Number of Relay Outputs Required

Output Description	Outputs
Number of relay output contacts required for tripping	5
Total number of relay output contacts	5

The relay main board has eight standard output contacts (Output Contact 7 is used to assert when the **RELAY TEST MODE** pushbutton on the front panel is selected, and Output Contact 8 is used for alarming purposes in the default settings). However, the main board contacts are all standard output contacts.

The interface boards may have high-speed, high-interrupting output contacts that provide faster contact closure. Each interface board can be ordered with an option that provides six high-speed, high-interrupting output contacts and two standard output contacts. For fast busbar fault clearance, assign each circuit breaker trip output to a high-speed, high-interrupting output contact for each of the circuit breakers at the station. From the output contact perspective, we need one interface board.

The conclusion from the preceding analysis is that we need three SEL-487B Relays, each relay equipped with a single interface board.

Input, Logic, and Output Allocation and Alias Name Assignment

At this point we have determined the following:

- the number of SEL-487B Relays required for the application
- the number of input contacts
- the number of output contacts
- the selected functions

For example, we have matched the number of CTs at the station with the number of available analog channels in the relay. However, we still need to do the following:

- link specific CT inputs to specific relay analog channels
- link specific disconnect and circuit breaker inputs to specific relay input contacts
- link relay element/logic outputs to specific relay output contacts
- assign alias names where appropriate

Assign a valid seven-character alias name to any of the following:

- Relay Word bit
- Analog quantity
- Terminal name
- Bus-Zone name
- Check-Zone name

Alias names are valid when they consist of a maximum of seven characters and they are constructed with characters 0–9, uppercase A–Z, or the underscore (_).

CT-to-Analog Channel Allocation and CT Alias Assignment

Table 6.15 shows CT-to-relay analog channel allocations and alias assignments. For example, allocate the A-phase tie-breaker CT1 to relay channel I01, and assign to this CT the alias name SEC1_A. The choice of CT-to-analog channel allocation is arbitrary; you can assign the CTs randomly to relay analog channels. *Table 6.15* shows the assignment for the A-phase relay starting with the tie-breaker CTs, followed by the four terminals, taken left to right from *Figure 6.47*.

Table 6.15 CTs-to-Analog Channel Allocations and Alias Assignments

CTs	Analog Channel	Alias
TIE-BREAKER CT1, A-phase	I01	SEC1_A
TIE-BREAKER CT2, A-Phase	I02	SEC2_A
LONDON, A-phase	I03	LOND_A
BERLIN, A-phase	I04	BERL_A
NEW YORK, A-phase	I05	NEWY_A
CANBERRA, A-phase	I06	CANB_A

Bus-Zone Alias Assignment

Each SEL-487B provides six zones of protection. For the A-phase relay, we use two bus-zones with alias names as shown in *Table 6.16*.

Table 6.16 Alias Names for the Two Bus-Zones

Bus-Zone Name	Description	Alias
BZ1	Bus-Zone 1	WEST_A
BZ2	Bus-Zone 2	EAST_A

Check-Zone Alias Assignment

Each SEL-487B provides three check zones. For the A-phase relay, we use the check zone with the alias name as shown in *Table 6.17*.

Table 6.17 Alias Name for the Check Zone

Check-Zone Name	Description	Alias
CZ1	Check Zone	CHECK_A

Input to Logic Allocation and Alias Assignment

Table 6.13 shows that we require 12 digital inputs. We now assign the 12 digital input contacts to the selected logic and assign alias names to the input contacts and logic elements. Because of the functional requirement of this application, we do not need to use any digital inputs on the main board.

Input Contact to Logic Allocation and Alias Assignment, Interface Board 1 (200)

Table 6.18 shows the disconnect auxiliary contact input allocations and the alias names. Inputs IN201, IN202, IN203, IN213, IN214, and IN215 are independent inputs for breaker failure initiate inputs; these inputs are not used in the present application.

Table 6.18 Alias Names for the Breaker Status Logic Output Relay Word Bits

Input	Description	Alias
IN204	TIE-BREAKER disconnect (WEST) NO contact	ISE891A
IN205	TIE-BREAKER disconnect (WEST) NC contact	ISE891B
IN206	TIE-BREAKER disconnect (EAST) NO contact	ISE892A
IN207	TIE-BREAKER disconnect (EAST) NC contact	ISE892B
IN208	LONDON disconnect N/O contact	ILON89A
IN209	LONDON disconnect N/C contact	ILON89B
IN210	BERLIN disconnect N/O contact	IBER89A
IN211	BERLIN disconnect N/C contact	IBER89B
IN212	NEW YORK disconnect NO contact	INEW89A
IN216	NEW YORK disconnect NC contact	INEW89B
IN217	CANBERRA disconnect NO contact	ICAN89A
IN218	CANBERRA disconnect NC contact	ICAN89B

Assign Alias Names to the Selected Standard Logic

Referring to *Table 6.12*, the following is a discussion on each selected function. Alias name assignments are also included.

Disconnect Monitoring Logic and Disconnect Alias Assignment

Figure 6.50 shows one of the 60 disconnect monitor logic circuits available in the relay. (See *Disconnect Requirements on page 6.15* for more information on the disconnect auxiliary contact requirements).

Figure 6.50 One of the Disconnect Monitoring Logic Circuits Available in the Relay

Table 6.19 shows the alias names for the disconnect auxiliary contact Relay Word bits.

Table 6.19 Alias Names for the Disconnect Auxiliary Contact Relay Word Bits

Input	Description	Alias
89A01	TIE-BREAKER disconnect (WEST) NO contact	SEC891A
89B01	TIE-BREAKER disconnect (WEST) NC contact	SEC891B
89A02	TIE-BREAKER disconnect (EAST) NO contact	SEC892A
89B02	TIE-BREAKER disconnect (EAST) NC contact	SEC892B
89A03	LONDON disconnect NO contact	LON89A
89B03	LONDON disconnect NC contact	LON89B
89A04	BERLIN disconnect NO contact	BER89A
89B04	BERLIN disconnect NC contact	BER89B
89A05	NEW YORK disconnect NO contact	NEW89A
89B05	NEW YORK disconnect NC contact	NEW89B
89A06	CANBERRA disconnect NO contact	CAN89A
89B06	CANBERRA disconnect NC contact	CAN89B

Wire a normally open disconnect auxiliary contact (89A) and a normally closed disconnect auxiliary contact (89B) from each disconnect to individual relay inputs on the A-phase relay. Jumper (hardwire) the disconnect input contacts to the other two relays. Relay Word bits 89CL*nn* assert when the disconnect monitoring logic interprets that the disconnect main contacts as closed. Use Relay Word bits 89CL*nn* as conditions in the terminal-to-bus-zone SELOGIC control equations. We also assign alias names to the alarm Relay Word bits (89AL*nn*). *Table 6.20* shows the alias names.

Table 6.20 Alias Names for the Disconnect Monitor Logic Output Relay Word Bits (Sheet 1 of 2)

Primitive Name	Description	Alias
89CL01	TIE-BREAKER disconnect (WEST) is closed	SEC189C
89CL02	TIE-BREAKER disconnect (EAST) is closed	SEC289C
89CL03	LONDON disconnect is closed	LOND89C
89CL04	BERLIN disconnect is closed	BERL89C
89CL05	NEW YORK disconnect is closed	NEWY89C
89CL06	CANBERRA disconnect is closed	CANB89C

Table 6.20 Alias Names for the Disconnect Monitor Logic Output Relay Word Bits (Sheet 2 of 2)

Primitive Name	Description	Alias
89AL01	TIE-BREAKER disconnect (WEST) alarm	SEC189A
89AL02	TIE-BREAKER disconnect (EAST) alarm	SEC289A
89AL03	LONDON disconnect alarm	LOND89A
89AL04	BERLIN disconnect alarm	BERL89A
89AL05	NEW YORK disconnect alarm	NEWY89A
89AL06	CANBERRA disconnect alarm	CANB89A

Differential Trip Logic and Differential Element Alias Assignment

Figure 6.51 shows the differential trip logic for Differential Element 1. Relay Word bit 87Z1 asserts only if the zone supervision conditions permit an output from the AND gate. (See *Section 5: Protection Functions* for more information). *Table 6.21* shows the Relay Word bits and the alias names for the zone differential protection outputs.

Table 6.21 Alias Names for the Zone Differential Protection Output Relay Word Bits

Primitive Name	Description	Alias
87Z1	Zone 1 differential element trip	WESTA_T
87Z2	Zone 2 differential element trip	EASTA_T
87CZ1	Check Zone differential element trip	CHECA_T

Differential trip bits 87BTR01–87BTR06 assert to trip the circuit breakers of the terminals in the faulted bus-zone. (See *Section 5: Protection Functions* for more information).

Figure 6.51 Differential Trip Logic for Differential Element 1

Be sure to include the differential trip bits in the trip equations of all the terminals you want to trip when the differential elements operate (see *Global Settings on page 6.53* for more information). *Table 6.22* shows the primitive differential trip bit names, the alias names for the differential trip bits, and the terminal with which the relay associates each differential trip bit.

Table 6.22 Primitive Differential Trip Bit Names, Alias Names for the Differential Trip Bits, and Associated Terminals

Differential Trip Bit	Alias	Comments
87BTR01	87SEC1A	Associated with Terminal 01
87BTR02	87SEC2A	Associated with Terminal 02
87BTR03	87LON_A	Associated with Terminal 03
87BTR04	87BER_A	Associated with Terminal 04
87BTR05	87NEW_A	Associated with Terminal 05
87BTR06	87CAN_A	Associated with Terminal 06

Breaker Trip Logic and Trip Alias Assignment

Figure 6.52 shows the general tripping logic in the SEL-487B. (See *Section 5: Protection Functions* for more information.)

Figure 6.52 Breaker Trip Logic

There exists a direct relationship between the number of circuit breakers setting (NUMBK) and the number of trip equations, i.e., the number of trip equations (TR*kk*) equals the number of circuit breakers (NUMBK) setting. *Table 6.23* shows the five primitive and alias names for the trip logic of each terminal.

Table 6.23 Primitive and Alias Names for the Trip Logic of Each Terminal

Primitive Name	Description	Alias Name
TRIP01	Trip output of the sectionalizing breaker asserted	TRSEC_A
TRIP02	Trip output of the LONDON Terminal asserted	TRLON_A
TRIP03	Trip output of the BERLIN Terminal asserted	TRBER_A
TRIP04	Trip output of the NEW YORK Terminal asserted	TRNEW_A
TRIP05	Trip output of the CANBERRA Terminal asserted	TRCAN_A

Assign Alias Names to the User-Defined Logic

This application requires no user-defined logic.

Relay Logic-to-Output Contact Allocation and Output Contact Alias Assignments

At this point, we have assigned alias names to all relay functions. *Table 6.14* shows the breakdown of the five relay outputs we need for this application. We now link the appropriate relay logic outputs to specific relay output contacts and assign alias names to the relay output contacts. *Table 6.24* shows TEST and ALARM protection logic assigned to the output contacts of the main board output contacts. *Table 6.25* shows the linking of the trip logic outputs to the relay output contacts of Interface Board 1 and the alias names of the of the interface board output contacts.

Output Alias Assignment, Main Board

This application requires no output contacts from the main board.

Table 6.24 Alias Names for the Main Board Output Contacts

Output Contact Assignment	Description	Output Contact Alias
OUT107	Relay in test mode	TEST
OUT108	Relay alarm	ALARM

Output Alias Assignment, Interface Board 1 (200)

Each interface board of the SEL-487B can be ordered to include six high-speed, high-interrupting output contacts. *Table 6.25* shows the alias assignment for the five terminals of the A-phase relay.

Table 6.25 Alias Assignment for the Five Terminals in Our Example

Output Contact Assignment	Description	Output Contact Alias
OUT201[a]	TIE-BREAKER trip logic output	SECTR_A
OUT202[a]	LONDON trip logic output	LONTR_A
OUT203[a]	BERLIN trip logic output	BERTR_A
OUT204[a]	NEW YORK trip logic output	NEWTR_A
OUT205[a]	CANBERRA trip logic output	CANTR_A

[a] High-speed, high-interrupting outputs.

Station Layout Update (A-Phase)

We are now ready to set and configure the relay. Write all the relevant information on the station diagram, as shown in *Figure 6.53*.

1. Write down the bus-zone, terminal, and disconnect names.
2. Draw in the overlapping zone on the bus section to clearly identify the terminal/zone allocation.
3. Allocate the terminal CTs to the relay input current channels.
4. Allocate the auxiliary terminal contacts to the relay digital inputs.
5. Allocate the digital outputs from the relay to the terminals

Figure 6.53 Substation Layout With Specific Terminal Information

Setting the Relay

The following describes the settings for this application. We set the following settings classes:

- Alias Settings
- Global Settings
- Zone Configuration Group Settings
- Protection Group Settings
- Control Output Settings

Alias Settings

We have identified and allocated the alias names to the analog channels and Relay Word bits. We now enter the alias names in the relay. Type **SET T <Enter>** to enter the alias settings class. Many default Relay Word bits have useful alias names ready for use. Type **LIST <Enter>** to see a list of default primitive names and associated alias names, as shown in *Figure 6.54*.

After inspecting the list, we decide the only useful alias names are those of the 16 LEDs, TEST, and ALARM.

```
=>>SET T <Enter>
Alias
Relay Aliases
(RW Bit,Analog Qty.,Terminal,Bus-Zone, or Check Zone, 7 Char. Alias [0-9 A-Z _])
1: IO1,"FDR_1"
?  LIST <Enter>
1: IO1,"FDR_1"
2: IO2,"FDR_2"
3: IO3,"FDR_3"
4: IO4,"TRFR_1"
5: IO5,"TB_1"
6: IO6,"TB_2"
7: BZ1,"BUS_1"
8: BZ2,"BUS_2"
.
.
.
68: TLED_23,"52_ALRM"
69: TLED_24,"IRIGLED"
1: IO1,"FDR_1"
?
```

Figure 6.54 List of Default Primitive Names and Associated Alias Names

Type **DELETE 43 <Enter>** at the first action prompt to delete the first 43 default alias names, as shown in *Figure 6.55*.

```
1: IO1,"FDR_1"
?  DELETE 43 <Enter>
```

Figure 6.55 Deletion of the First 43 Alias Names

Type **> <Enter>** to advance to the next available line in the setting list. Enter the alias names for the six analog channels and Relay Word bits, as shown in *Figure 6.56*.

```
1: OUT107,"TEST"
?  > <Enter>
19:
?  IO1,SEC1_A <Enter>
20:
?  IO2,SEC2_A <Enter>
21:
?  IO3,LOND_A <Enter>
22:
?  IO4,BERL_A <Enter>
23:
?  IO5,NEWY_A <Enter>
24:
?  IO6,CANB_A <Enter>
25:
?  BZ1,WEST_A <Enter>
26:
?  BZ2,EAST_A <Enter>
27:
?  CZ1,CHECK_A <Enter>
28:
?  IN204,ISE891A <Enter>
29:
?  IN205,ISE891B <Enter>
30:
.
.
.
?  OUT204,NEWTR_A <Enter>
92:
?  OUT205,CANTR_A <Enter>
93:
?  END <Enter>
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.56 Analog Quantities and Relay Word Bit Alias Names

This concludes the alias settings. The next settings class is the global settings.

Global Settings

Global settings comprise settings that apply to all protection settings groups. For example, when changing from protection setting Group 1 to protection setting Group 2, Global settings such as station name and relay name still apply. *Figure 6.57* shows the setting changes we need for our example. Because we declared the alias names in the alias settings class, use either alias names or primitive names when entering settings.

NOTE: The relay interprets the number of circuit breakers (NUMBK) as the number of circuit breaker poles, not as the number of circuit breakers.

Setting NUMBK equal to five makes five corresponding circuit breaker auxiliary input equations (52A01–52A05) and five corresponding trip equations (TR01–TR05) available for setting. Because we do not need circuit breaker auxiliary contacts for this application, set 52A01–52A05 to NA.

Setting NUMDS declares the number of disconnect logics we need, not the number of disconnect inputs. In our example, we need six disconnect logics. You can set each disconnect travel time individually with the 89ALP*pp* setting (*pp* = 01–06). Travel time is the time period when both disconnect auxiliary contacts are in the open position (see *Figure 6.20* for more information). Measure the travel time during commissioning and adjust the settings appropriately. Based on previous experience with similar equipment, we set the tie-breaker disconnect travel time to 400 cycles in this example.

```
=>>SET G <Enter>
Global
General Global Settings


Station Identifier (40 characters)
SID := "Station A"
?  <Enter>
Relay Identifier (40 characters)
RID := "Relay 1"
?  <Enter>
Number of Breakers (N,1-21)                          NUMBK   := 5      ? <Enter>
Number of Disconnects (N,1-60)                       NUMDS   := N      ?6<Enter>
Nominal System Frequency (50,60 Hz)                  NFREQ   := 60     ? <Enter>


Global Enables

Station DC Battery Monitor (Y,N)                     EDCMON  := N      ? <Enter>
Independent Control Input Settings (Y,N)             EICIS   := N      ? <Enter>
Data Reset Control (Y,N)                             EDRSTC  := N      ? <Enter>

Control Inputs (Global)

Input Pickup Delay (0.0-30 ms)                       GINPU   := 2.0    ?> <Enter>


Settings Group Selection

Select Setting Group 1 (SELogic Equation)
SS1 := NA
?  ><Enter>

Time and Date Management


Date Format (MDY,YMD,DMY)                            DATE_F  := MDY    ?> <Enter>

Breaker Inputs

N/O Contact Input -BK01 (SELogic Equation)
52A01 := NA
?  ><Enter>
```

Figure 6.57 Global Settings for Application 1

```
Disconnect Inputs and Timers

N/O Contact Input -DS01 (SELogic Equation)
89A01 := NA
?  ISE891A<Enter>
N/C Contact Input -DS01 (SELogic Equation)
89B01 := NA
?  ISE891B<Enter>
DS01 Alarm Pickup Delay (0-99999 cyc)                89ALP01 := 300    ?400<Enter>
N/O Contact Input -DS02 (SELogic Equation)

89A02 := NA
?  ISE892A<Enter>
N/C Contact Input -DS02 (SELogic Equation)
89B02 := NA
?  ISE892B<Enter>
DS02 Alarm Pickup Delay (0-99999 cyc)                89ALP02 := 300    ?400<Enter>
N/O Contact Input -DS03 (SELogic Equation)
89A03 := NA
?  ILON89A<Enter>

.
.
.

DS06 Alarm Pickup Delay (0-99999 cyc)                89ALP06 := 300    ?400<Enter>

DNP

Event Summary Lock Period (0-1000 s)                 EVELOCK := 0      ? <Enter>
DNP Session Time Base (LOCAL, UTC)                   DNPSRC  := UTC    ? <Enter>

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

=>>
```

Figure 6.57 Global Settings for Application 1 (Continued)

This concludes the global settings. The next settings class is the zone configuration group settings.

Zone Configuration Group Settings

The terminal-to-bus-zone SELOGIC control equations identify an analog channel, a differential element, and the conditions for which the relay assigns the analog channel to the differential element. Dynamic zone selection provides a mechanism to automatically reconfigure the zone of protection, without any wiring changes (See *Dynamic Zone Selection Logic on page 5.14* for more information). In this example, the dynamic zone selection logic uses the disconnect auxiliary contacts status to determine the station configuration and assign the input currents from the CTs to the appropriate differential elements. For each terminal, wire an 89A and an 89B disconnect auxiliary contact to the relay.

Because the disconnect simultaneously operates all three phases of the terminal, we state the disconnect status in the terminal-to-bus-zone SELOGIC control equations of all three relays. Because we wire disconnect auxiliary contacts to only one relay, jumper (hardwire) the contact to the two other relays. For example, when we close the busbar disconnect on the LONDON feeder, all three phases (LOND_A, LOND_B, and LOND_C) operate together. Because the relay measures the three phases in three separate relays (phase LOND_A in the A-phase relay, phase LOND_B in B-phase relay, etc.), we need to convey the disconnect status to all three relays.

The check zone performs supervision, so you must first determine zone configuration settings for the check zone before determining settings for Zone 1 and Zone 2. Configure the check zone by declaring all terminals but the tie-breaker (bus sectionalizer) CTs in the terminal-to-check-zone SELOGIC control equations. Never include the tie-breaker CTs in the check zone. *Figure 6.61* shows the zone configuration group settings.

Use the Differential Element Zone Supervision setting to comply with the requirement for both check zone and zone-specific differential elements to assert before a busbar protection trip output asserts. For this application, we allocated BZ1 for Zone 1, BZ2 for Zone 2, and CZ1 for the overall check zone (see *Table 6.16*). Because the check zone is independent from any other zone, the relay does not follow the differential trip logic shown in *Figure 6.58* when the check zone asserts.

Figure 6.58 Bus Differential Trip Logic

The implication of this independence is that the Check Zone Supervision Logic can be left to its default value of 1 as seen in *Figure 6.59*. The same effect is achieved by setting E87CZSP = N.

Figure 6.59 Check-Zone Supervision Logic

For the zone-specific elements, enter the Check Zone differential element trip output 87CZ1 as a supervisory condition for each zone, as shown in *Figure 6.60*.

Figure 6.60 Zone Supervision for Zone 1 (a) and Zone 2 (b)

Be sure to include Relay Word bit 87CZ1 as the supervisory condition for all zones encompassed by the Check Zone. Set E87ZSUP = Y to enable the Differential Element Zone Supervision settings, then enter the supervision settings.

For the ease of setting the zone configuration settings for the new substation, delete the existing zone configuration group default settings. With the zone configuration group default settings deleted, the setting prompts no longer reference the default settings. The zone configuration group default settings are for a specific substation with arbitrarily selected alias names, serving only as an example.

```
=>>SET Z TE<Enter>
Zone Config Group 1
Potential Transformer Ratio


Potential Transformer Ratio -VO1 (1-10000)          PTR1    := 2000   ?> <Enter>


Current Transformer Ratio

Current Transformer Ratio -IO1 (1-50000)            CTR01   := 600    ?400<Enter>
Current Transformer Ratio -IO2 (1-50000)            CTR02   := 600    ?400<Enter>
Current Transformer Ratio -IO3 (1-50000)            CTR03   := 600    ?40<Enter>
Current Transformer Ratio -IO4 (1-50000)            CTR04   := 600    ?400<Enter>
Current Transformer Ratio -IO5 (1-50000)            CTR05   := 600    ?400<Enter>
Current Transformer Ratio -IO6 (1-50000)            CTR06   := 600    ?400<Enter>
Current Transformer Ratio -IO7 (1-50000)            CTR07   := 600    ?> <Enter>

Zone Configuration: Terminal to Bus-Zone Connections

Terminal, Bus-Zone, Polarity (P,N)
IO1BZ1C := SEC1_A, WEAT_A, P
?  DELETE 100<Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO1 BZ2 P<Enter>
SEC1_A to EAST_A Connection (SELogic Equation)
IO1BZ2V := NA
?  SEC189C AND SEC289C<Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO2 BZ1 P<Enter>
SEC2_A to WEAT_A Connection (SELogic Equation)
IO2BZ1V := NA
?  SEC189C AND SEC289C<Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO3 BZ1 P<Enter>
LOND_A to WEAT_A Connection (SELogic Equation)
IO3BZ1V := NA
?  LOND89C<Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO4 BZ1 P<Enter>
BERL_A to WEAT_A Connection (SELogic Equation)
IO4BZ1V := NA
?  BERL89C<Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO5 BZ2 P<Enter>
NEWY_A to EAST_A Connection (SELogic Equation)
IO5BZ2V := NA
?  NEWY89C<Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO6 BZ2 P<Enter>
CANB_A to EAST_A Connection (SELogic Equation)
IO6BZ2V := NA
?  CANB89C<Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  <Enter>


Zone Configuration: Bus-Zone to Bus-Zone Connections

Bus-Zone, Bus-Zone
?  <Enter>

Zone Supervision

Differential Element Zone Supervision (Y,N)         E87ZSUP := N      ?Y<Enter>
Zone 1 Supervision (SELogic Equation)
Z1S := 1
?  87CZ1<Enter>
Zone 2 Supervision (SELogic Equation)
Z2S := 1
?  87CZ1<Enter>
```

Figure 6.61 Zone Configuration Group Settings for Application 1

```
Zone Switching Supervision

Zone Switching Supervision (Y,N)                    EZSWSUP := N      ? <Enter>


Zone Open CT Detector

Reset Zone 1 Open CT Detector (SELogic Equation)
ROCTZ1 := RSTOCT1
?  <Enter>
Reset Zone 2 Open CT Detector (SELogic Equation)
ROCTZ2 := RSTOCT2
?  <Enter>
Check Zone Configuration
Enable Check Zones at Station (Y,N)                 ECHKZN  := N      ?Y<Enter>

Check Zone Configuration: Terminal to Check Zone Connections

Terminal, Check-Zone, Polarity (P,N)
?  IO3 CZ1 P<Enter>
Terminal, Check-Zone, Polarity (P,N)
?  IO4 CZ1 P<Enter>
Terminal, Check-Zone, Polarity (P,N)
?  IO5 CZ1 P<Enter>
Terminal, Check-Zone, Polarity (P,N)
?  IO6 CZ1 P<Enter>
Terminal, Check-Zone, Polarity (P,N)
?
Enable Advance Check Zone Settings (Y,N)            EADVCZ  := N      ? <Enter>


Check Zone Supervision

Differential Element Check Zone Supervision (Y,N)   E87CZSP := N      ? <Enter>

Current Normalization Factor

Normalization Factor -IO1                           TAP01   := 5.00   ?
Normalization Factor -IO2                           TAP02   := 5.00   ?
Normalization Factor -IO3                           TAP03   := 50.00  ?
Normalization Factor -IO4                           TAP04   := 5.00   ?
Normalization Factor -IO5                           TAP05   := 5.00   ?
Normalization Factor -IO6                           TAP06   := 5.00   ?
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
=>>
```

Figure 6.61 Zone Configuration Group Settings for Application 1 (Continued)

This concludes the zone configuration group settings. The next settings class is the protection group settings.

Protection Group Settings

Settings of this class comprise the protection functions, starting with the function enable settings. Default settings for the differential elements are 60 percent for Slope 1 and 80 percent for Slope 2. To change the slope settings, first enable the advanced settings by setting EADVS := Y.

With EADVS := Y, the slope settings and incremental restrained and operating current settings become available.

The protection philosophy calls for the blocking of the busbar protection for an open CT condition. Use the sensitive differential element by setting E87SSUP := Y (see *Figure 5.11* and *Figure 5.18* for more information). Set ECSL := N, ETOS := N, EBFL := N, E50 := N, E51 := N, and EVOLT := N because we do not use the coupler security logic, terminal out of service, breaker failure protection, overcurrent elements, or voltage elements in this application.

Setting NUMBK equal to five makes five corresponding circuit breaker auxiliary input equations (52A01–52A05) and five corresponding trip equations (TR01–TR05) available for setting. There are five trip equations available, but there are six analog channels (I01–I06) at the station. Each of the six analog channels has a corresponding differential trip bit that asserts (*Table 6.22*) when the differential

element asserts. Be sure to include these differential trip bits in the trip equations of all circuit breakers you want to trip. Because the tie breaker has two analog channels but only one circuit breaker, include both differential trip bits (87SEC1A and 87SEC2A) in trip equation TR01.

The trip logic latches the trip outputs TRIP*kk* after TR*kk* assertion. One way to deassert the trip outputs is to press the **TARGET RESET** pushbutton on the front panel. An alternative method is to enter specific reset conditions at the ULTR*kk* settings.

Although each SEL-487B includes 21 trip logics, there is only one Minimum Trip Duration Time Delay (TDURD) setting. Set the timer TDURD longer than the clearing time of the slowest circuit breaker at the station. For this application, we use the default values for the Sensitive Differential Element, the Restrained Differential Element, the Directional Element, and the Trip Duration Timer. *Figure 6.62* shows the group settings.

```
=>>SET <Enter>

Group 1
Relay Configuration

Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y      ? <Enter>
Coupler Security Logic (N,1-4)                       ECSL    := N      ? <Enter>
Terminal Out of Service (N,1-21)                     ETOS    := 5      ?N <Enter>
Breaker Failure Logic (N,1-21)                       EBFL    := 6      ?N <Enter>
Definite Time Overcurrent Elements (N,1-21)          E50     := N      ? <Enter>
Inverse Time Overcurrent Elements (N,1-21)           E51     := N      ? <Enter>
Enable Under Voltage Elements (N,1-6)                E27     := N      ? <Enter>
Enable Over Voltage Elements (N,1-6)                 E59     := N      ? <Enter>
Advanced Settings (Y,N)                              EADVS   := N      ? <Enter>


Sensitive Differential Element

Sensitive Differential Element Pickup (0.05-1 pu)    S87P    := 0.10   ?> <Enter>

Check Zone Sensitive Differential Element

CZ Sensitive Diff. Element Pickup (0.05-1 pu)        CZS87P  := 0.10   ?> <Enter>

Restrained Differential Element

Restrained Diff Element Pickup (0.10-4 pu)           O87P    := 1.00   ?> <Enter>

Check Zone Restrained Differential Element

CZ Restrained Diff Element Pickup (0.10-4 pu)        CZO87P  := 1.00   ?> <Enter>


Directional Element

Dir Element O/C Supervision Pickup (0.05-3 pu)       50DSP   := 0.05   ?> <Enter>


Trip Logic

Trip 01 (SELogic Equation)
TR01 := SBFTR01 OR 87SEC1A
?  87SEC1A OR 87SEC2A <Enter>
Unlatch Trip 01 (SELogic Equation)
ULTR01 := NA
?

Trip 02 (SELogic Equation)
TR02 := SBFTR02 OR 87SEC2A
?  87LON_A <Enter>
Unlatch Trip 02 (SELogic Equation)
ULTR02 := NA
?

Trip 03 (SELogic Equation)
TR03 := SBFTR03 OR 87LON_A
?  87BER_A <Enter>
Unlatch Trip 03 (SELogic Equation)
ULTR03 := NA
?
```

Figure 6.62 Protection Group Settings for Application 1

```
Trip 04 (SELogic Equation)
TR04 := SBFTR04 OR 87BER_A
?  87NEW_A<Enter>
Unlatch Trip 04 (SELogic Equation)
ULTR04 := NA
?

Trip 05 (SELogic Equation)
TR05 := SBFTR05 OR 87NEW_A OR SBFTR06 OR 87CAN_A
?  87CAN_A<Enter>
Unlatch Trip 05 (SELogic Equation)
ULTR05 := NA
?

Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000 ?> <Enter>
Group 1
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
=>>
```

Figure 6.62 Protection Group Settings for Application 1 (Continued)

This concludes the protection group settings. The next settings class is the control output settings.

Control Output Settings

In this settings class, we assign the logic or Relay Word bits in the relay to output contacts. We need five output contacts for our example. Although not specifically called for in the protection philosophy, it is good practice to also include the default TEST and ALARM outputs in the relay settings.

Because each relay protects only one phase of the power system, combine the trip outputs from the three relays in a single output to the circuit breaker. Jumper (hardwire) the trip output from each relay, and connect the cable to the circuit breaker trip coil to any one of the three relays.

We include Protection Latch Bit PLT03 in the output equation. With PLT03 included in every output equation, the RELAY TEST MODE pushbutton disables all output contacts. Because we do not use any output contacts from the main board for protection functions (OUT107 and OUT108 are used for alarming purposes), set OUT101–OUT106 = NA. *Figure 6.63* shows the control output settings.

```
=>>SET O <Enter>

Output
Main Board
OUT101 := TRSEC_A AND NOT PLT03
?  NA <Enter>

OUT102 := TRLON_A AND NOT PLT03
?  NA <Enter>
OUT103 := TRBER_A AND NOT PLT03
?  NA <Enter>

OUT104 := TRNEW_A AND NOT PLT03
?  NA <Enter>
OUT105 := TRCAN_A AND NOT PLT03
?  NA <Enter>

OUT106 := NA
? > <Enter>

Interface Board #1
OUT201 := NA
?  TRSEC_A AND NOT PLT03 <Enter>
OUT202 := NA
?  TRLON_A AND NOT PLT03 <Enter>
```

Figure 6.63 Control Output Settings for Application 1

```
OUT203 := NA
?  TRBER_A AND NOT PLTO3 <Enter>
OUT204 := NA
?  TRNEW_A AND NOT PLTO3 <Enter>

OUT205 := NA
?  TRCAN_A AND NOT PLTO3 <Enter>
OUT206 := NA
?  END <Enter>

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

=>>
```

Figure 6.63 Control Output Settings for Application 1 (Continued)

This concludes the settings for Application 1.

Application 2: Single Bus and Tie Breaker (Single Relay)

This application describes the busbar arrangement shown in *Figure 6.64*, a single bus with bus sectionalizer (tie breaker), single-relay application. The busbar arrangement consists of two busbar sections, four feeders, and a tie breaker. Consider the following to set and configure the relay:

- Busbar classification
- Protection philosophy
- Protection functions selection
- Number of SEL-487B Relays and I/O boards
- Input, logic, and output allocation and alias name assignment
- Station layout update
- Relay setting and configuration

Figure 6.64 Single Bus With Bus Sectionalizer (Tie Breaker)

Busbar Classification

The busbar classification provides general busbar layout and CT positioning (inboard or outboard) information, and declares the tie breaker (bus coupler or sectionalizing breaker) configuration.

- Description:
  - Single bus with tie breaker
- Current Transformers:
  - Outboard
- Disconnect:
  - Both 89A and 89B disconnect auxiliary contacts are available
- Sectionalizing breaker (tie-breaker) configuration:
  - Overlap

Protection Philosophy

Although the SEL-487B offers a variety of protection and control functions, not all of these functions are applied at every substation. Carefully consider each application before stating the functional requirements. The protection philosophy for this application is as follows:

1. Use the 89 disconnect auxiliary contacts to dynamically configure the station.
2. Block the busbar protection for an open-circuit CT.
3. Use the Disconnect Monitoring Logic.
4. Include end-zone protection with direct transfer tripping for the four feeders.

Protection Functions Selection

We select the protection functions early in the relay setting and configuration process because the choice of protection functions determines the number of relay digital inputs and outputs required for the application. Study the protection philosophy to determine which protection and/or control functions to apply to any particular substation. For example, in this application the protection philosophy calls for end-zone protection, but not for breaker failure protection.

The SEL-487B offers a number of protection functions as standard features, but also includes the capability through SELOGIC control equations to create user-configurable functions. Breaker failure protection is a standard function but end-zone protection is not. To properly identify and categorize the protection philosophy requirements, group the protection functions as follows:

- standard protection functions (available in the relay)
- user-defined protection functions (created using SELOGIC control equations)

Standard Functions

Refer to *Protection Philosophy on page 6.86* and select the standard functions required for the application. *Table 6.26* shows the selection of the standard functions.

Table 6.26 Selection of the Standard Protection Functions

Protection Function	Selection	Comment
CT ratio mismatch ≤ 10:1	Yes	10:1 mismatch is the maximum allowable mismatch.
Circuit breaker status logic	No	Not required
Disconnect monitor logic	Yes	89A and 89B disconnect contacts available.
Differential protection	Yes	Busbar protection (zone specific and check zone)
Dynamic zone selection logic	Yes	Use the zone selection to reconfigure the differential protection according to the disconnect positions
Sensitive differential protection	Yes	CT open circuit detection.
Zone supervision logic	No	Not required
Zone-switching supervision logic	No	89A and 89B disconnect contacts available, so this logic is not required.
Coupler security logic	No	Two CTs configured in overlap configuration do not require the coupler security logic.
Circuit breaker failure protection	No	Not required
Instantaneous overcurrent protection	No	Not required
Time-overcurrent protection	No	Not required
Phase voltage elements	No	Not required
Zero- or negative-sequence voltage elements	No	Not required

User-Defined Functions

Identify logic functions we need for the application that are not part of the standard logic in the relay. For this application, end-zone protection for the four feeders is not a standard function; we use SELOGIC control equations to create this logic.

End-Zone Protection

Figure 6.65 shows end-zone fault F1, which is a fault between the feeder CT and circuit breaker. The busbar protection at Busbar S operates for this fault and trips Circuit Breaker 1, but the line still feeds the fault from the source at Busbar R.

Figure 6.65 Fault Between Circuit Breaker 1 and the CT at Busbar S

Fault F1 is only cleared when Circuit Breaker 2 at Busbar R trips. In step-distance protection schemes, Circuit Breaker 2 trips after a time delay, typically on the order of 400 ms. Using end-zone protection, we can shorten this time by sending a direct transfer trip (DTT) from Station S to Circuit Breaker 2 at Station R to trip Circuit Breaker 2.

This logic detects faults under the following three conditions:

- The differential protection has issued a trip signal to the circuit breaker.
- There is still current flowing in the feeder CT after Circuit Breaker 1 has been open for 5 cycles.
- The busbar disconnect of the feeder is closed.

Create the above-mentioned end-zone logic by programming four protection SELOGIC control variables (PSV01–PSV04) when setting the protection logic, and assign the alias names as described in Assign Alias Names to the User-Defined Logic.

Number of Relays and I/O Boards

Selecting the relay has two parts:

- the number of relays (single-relay application or three-relay application)
- the number of interface boards (as many as four interface boards per relay)

The number of analog (CT) inputs determines the number of relays, and the number of digital inputs and outputs determines the number of interface boards.

Number of Relays

Each SEL-487B has 21 current channels and 3 voltage channels. For stations with as many as 21 CTs (per phase), we can install a single SEL-487B. For stations with more than 21 and as many as 63 CTs, we install 3 SEL-487B Relays. Use *Equation 6.5* to calculate the number of current channels at the station, and use *Equation 6.6* to calculate the number of zones at the station.

$$\text{\# of current channels required} = \text{\# of per-phase station CTs}$$

Equation 6.5

$$\text{\# of bus-zones required} = \text{\# of per-phase station bus sections}$$

Equation 6.6

The number of per-phase CTs at the station is 18 and the number of bus-zones required is 6. Because each SEL-487B has 21 analog input channels and 6 zones, we need only one SEL-487B. This is known as a single-relay application.

Number of Relay Inputs

The protection philosophy and protection function selection determine the number of digital relay inputs and outputs required for each application.

The number of disconnect logics (NUMDS) required is the number of disconnects for which the protection philosophy requires disconnect monitoring logic. In this example, each of the four feeders requires one disconnect monitoring logic and the tie breaker requires two; the number of disconnect logics required is therefore six. Each disconnect monitoring logic requires two disconnect auxiliary contact inputs: an 89A and an 89B contact. Use *Equation 6.7* to calculate the number of relay inputs required for the disconnect auxiliary contacts.

$$\text{\# relay inputs required} = 2 \bullet \text{\# disconnect monitoring logics}$$

Equation 6.7

The protection philosophy calls for end-zone protection. Because there are four feeder circuit breakers at the station the number of circuit breaker auxiliary inputs we need is four. *Table 6.27* summarizes the input contact required for this application.

Table 6.27 Number of Relay Input Contacts Required

Input Description	Inputs
Number of relay inputs required for the disconnect contacts	2 • 6 = 12
Number of relay inputs required for end-zone protection	4
Total number of inputs	16

The relay main board has seven input contacts, which are not enough input contacts for our application. Each interface board provides two sets of nine grouped input contacts and six independent input contacts. Use the grouped input contacts for the disconnect auxiliary contact inputs; the six independent input contacts are available for breaker failure initiate inputs. Because this application has no circuit breaker failure protection, the independent input contacts are available for circuit breaker auxiliary contact inputs. However, in anticipation of future circuit breaker failure protection installation, instead use the grouped input contacts on the interface board for the circuit breaker auxiliary contact inputs and disconnect contact inputs. From the input contact perspective, we need one interface board.

Number of Relay Output Contacts

Our example station has five circuit breakers, all of which are part of the busbar differential protection. Because all breakers are part of the busbar differential protection, we want to trip each breaker upon differential protection operation. We also need direct transfer trip output contacts for the end-zone protection for each of the four feeders. *Table 6.28* shows the breakdown and the total number of relay output contacts required.

Table 6.28 Breakdown and the Total Number of Relay Outputs Required

Output Description	Outputs
Number of relay output contacts required for tripping	5
Number of relay output contacts required for direct transfer tripping	4
Total number of relay output contacts	9

The relay main board has eight standard output contacts (Output Contact 7 is used to assert when the RELAY TEST MODE pushbutton on the front panel is selected, and Output Contact 8 is used for alarming purposes in the default settings). *Table 6.28* shows that we need nine output contacts; the eight main board output contacts are insufficient for our application. Also, the main board contacts are all standard output contacts.

The interface boards can have high-speed, high-interrupting output contacts that provide faster contact closure. Each interface board provides six high-speed, high-interrupting output contacts and two standard output contacts. For fast busbar fault clearance, assign the circuit breaker trip outputs to a high-speed, high-interrupting output contact for each of the circuit breakers at the station. Although the standard output contacts are slightly slower (6 ms for resistive loads) than the high-speed, high-interrupting output contacts, we use the main board output contact for direct transfer tripping. From the output contact perspective, we need one interface board. If you require fast output contacts for direct transfer tripping, add another interface board to the relay.

The conclusion from the preceding analysis is that we need one SEL-487B, equipped with a single interface board, for this application.

Input, Logic, and Output Allocation and Alias Name Assignment

At this point we have determined the following:

- the number of SEL-487B Relays required for the application
- the number of input contacts
- the number of output contacts
- the selected protection functions

For example, we have matched the number of CTs at the station with the number of available analog channels in the relay. However, we still need to do the following:

NOTE: Alias names cannot exceed seven characters.

- link specific CT inputs to specific relay analog channels
- link specific disconnect and circuit breaker inputs to specific relay input contacts
- link relay element/logic outputs to specific relay output contacts
- assign alias names where appropriate

Assign a valid seven-character alias name to any of the following:

- Relay Word bit
- Analog quantity
- Terminal name
- Bus-Zone name

Alias names are valid when they consist of a maximum of seven characters and they are constructed with characters 0–9, uppercase A–Z, or the underscore (_).

CT-to-Analog Channel Allocation and CT Alias Assignment

Table 6.29 shows CT-to-relay analog channel allocations and alias assignments. For example, allocate the A-phase tie breaker CT1 to relay channel I01, and assign to this CT the alias name SEC1_A. The choice of CT-to-analog channel allocation is arbitrary; you can assign the CTs randomly to relay analog channels. *Table 6.29* shows the assignment taken from *Figure 6.64*.

Table 6.29 CTs to Analog Channel Allocations and Alias Assignments (Sheet 1 of 2)

CTs	Analog Channel	Alias
LONDON, A-phase	I01	LOND_A
LONDON, B-phase	I02	LOND_B
LONDON, C-phase	I03	LOND_C
BERLIN, A-phase	I04	BERL_A
BERLIN, B-phase	I05	BERL_B
BERLIN, C-phase	I06	BERL_C
NEW YORK, A-phase	I07	NEWY_A
NEW YORK, B-phase	I08	NEWY_B
NEW YORK, C-phase	I09	NEWY_C

Table 6.29 CTs to Analog Channel Allocations and Alias Assignments (Sheet 2 of 2)

CTs	Analog Channel	Alias
CANBERRA, A-phase	I10	CANB_A
CANBERRA, B-phase	I11	CANB_B
CANBERRA, C-phase	I12	CANB_C
TIE-BREAKER CT1, A-phase	I13	SEC1_A
TIE-BREAKER CT1, B-phase	I14	SEC1_B
TIE-BREAKER CT1, C-phase	I15	SEC1_C
TIE-BREAKER CT2, A-phase	I16	SEC2_A
TIE-BREAKER CT2, B-phase	I17	SEC2_B
TIE-BREAKER CT2, C-phase	I18	SEC2_C

Bus-Zone Alias Assignment

Each SEL-487B provides six zones of protection. In this application, we use all six zones with alias names as shown in *Table 6.30*.

Table 6.30 Alias Names for the Six Bus-Zones

Bus-Zone Name	Description	Alias
BZ1	Bus-Zone 1	WEST_A
BZ2	Bus-Zone 2	WEST_B
BZ3	Bus-Zone 3	WEST_C
BZ4	Bus-Zone 4	EAST_A
BZ5	Bus-Zone 5	EAST_B
BZ6	Bus-Zone 6	EAST_C

Input-to-Logic Allocation and Alias Assignment

Table 6.27 shows that we require 16 digital inputs. We now assign the digital inputs to the selected logic, and apply alias names to the inputs and logic elements. Because of the functional requirement of this application, we do not need to use any digital inputs on the main board.

Input-to-Logic-Allocation and Alias Assignment, Interface Board 1 (200)

Table 6.31 shows the circuit breaker auxiliary contact input allocations, the disconnect auxiliary contact input allocations, and the alias names. Inputs IN201, IN202, IN203, IN213, IN214, and IN215 are independent inputs for breaker failure initiate inputs; these inputs are not used in this application.

Table 6.31 Alias Names and Assignment for the Digital Inputs (Sheet 1 of 2)

Input	Description	Alias
IN204	LONDON circuit breaker	ILON52A
IN205	BERLIN circuit breaker	IBER52A
IN206	NEW YORK circuit breaker	INEW52A
IN207	CANBERRA circuit breaker	ICAN52A

Table 6.31 Alias Names and Assignment for the Digital Inputs (Sheet 2 of 2)

Input	Description	Alias
IN208	LONDON disconnect NO contact	ILON89A
IN209	LONDON disconnect NC contact	ILON89B
IN210	BERLIN disconnect NO contact	IBER89A
IN211	BERLIN disconnect NC contact	IBER89B
IN212	NEW YORK disconnect NO contact	INEW89A
IN216	NEW YORK disconnect NC contact	INEW89B
IN217	CANBERRA disconnect NO contact	ICAN89A
IN218	CANBERRA disconnect NC contact	ICAN89B
IN219	TIE-BREAKER disconnect (WEST) NO contact	ISE891A
IN220	TIE-BREAKER disconnect (WEST) NC contact	ISE891B
IN221	TIE-BREAKER disconnect (EAST) NO contact	ISE892A
IN222	TIE-BREAKER disconnect (EAST) NC contact	ISE892B

Assign Alias Names to the Selected Standard Logic

Referring to *Table 6.26*, the following is a discussion on each selected function. Alias name assignments are also included.

Disconnect Monitoring Logic and Disconnect Alias Assignment

Figure 6.66 shows one of the 60 disconnect monitor logic circuits available in the relay. (See *Disconnect Requirements on page 6.15* for more information on the disconnect auxiliary contact requirements.)

Figure 6.66 One of the Disconnect Monitoring Logic Circuits Available in the Relay

Table 6.32 shows the alias names for the disconnect auxiliary contact Relay Word bits.

Table 6.32 Alias Names for the Disconnect Auxiliary Contact Relay Word Bits (Sheet 1 of 2)

Input	Description	Alias
89A01	LONDON disconnect NO contact	LON89A
89B01	LONDON disconnect NC contact	LON89B
89A02	BERLIN disconnect NO contact	BER89A
89B02	BERLIN disconnect NC contact	BER89B
89A03	NEW YORK disconnect NO contact	NEW89A

Table 6.32 Alias Names for the Disconnect Auxiliary Contact Relay Word Bits (Sheet 2 of 2)

Input	Description	Alias
89B03	NEW YORK disconnect NC contact	NEW89B
89A04	CANBERRA disconnect NO contact	CAN89A
89B04	CANBERRA disconnect NC contact	CAN89B
89A05	TIE-BREAKER disconnect (WEST) NO contact	SEC891A
89B05	TIE-BREAKER disconnect (WEST) NC contact	SEC891B
89A06	TIE-BREAKER disconnect (EAST) NO contact	SEC892A
89B06	TIE-BREAKER disconnect (EAST) NC contact	SEC892B

Wire a normally open disconnect auxiliary contact (89A) and a normally closed disconnect auxiliary contact (89B) from each disconnect to individual relay inputs. Relay Word bits 89CL*nn* assert when the disconnect monitoring logic interprets the disconnect main contacts as closed. Use Relay Word bits 89CL*nn* as conditions in the terminal-to-bus-zone SELOGIC control equations. We also assign alias names to the alarm Relay Word bits (89AL*nn*). *Table 6.33* shows the alias names.

Table 6.33 Alias Names for the Disconnect Monitor Logic Output Relay Word Bits

Primitive Name	Description	Alias
89CL01	LONDON disconnect is closed	LOND89C
89CL02	BERLIN disconnect is closed	BERL89C
89CL03	NEW YORK disconnect is closed	NEWY89C
89CL04	CANBERRA disconnect is closed	CANB89C
89CL05	TIE-BREAKER disconnect (WEST) is closed	SEC189C
89CL06	TIE-BREAKER disconnect (EAST) is closed	SEC289C
89AL01	LONDON disconnect alarm	LON89AL
89AL02	BERLIN disconnect alarm	BER89AL
89AL03	NEW YORK disconnect alarm	NEW89AL
89AL04	CANBERRA disconnect alarm	CAN89AL
89AL05	TIE-BREAKER disconnect (WEST) alarm	SE189AL
89AL06	TIE-BREAKER disconnect (EAST) alarm	SE289AL

Breaker Status Logic

Figure 6.67 shows the breaker status logic circuit associated with current channel I01. This logic includes an OPH01 input from the open-phase detection logic. Open-phase detection logic asserts the OPH01 Relay Word bit when the logic measures no current in that specific phase. Alarm output 52AL01 asserts when the 52A01 and OPH01 inputs are both deasserted for longer than 5 cycles. For example, when the circuit breaker is open (52A01 is logical 0), Relay Word bit OPH01 asserts (changes to logical 1) when current stops flowing. AND Gate 2 in *Figure 6.67* outputs a logical 0 and the timer does not run. However, if current still flows through the CT when the circuit breaker is open (end-zone fault, for example), Relay Word bit OPH01 does not assert (remains at logical 0) and the timer starts.

Figure 6.67 Breaker Status Logic

Wire a single, normally open circuit breaker auxiliary contact from each of the four feeder circuit breakers to an individual relay input (IN204, IN205, IN206, and IN207). In this example, we do not assign alias names to the Relay Word bits; we use the primitive names instead. Because this is a single-relay application, the three phases of each terminal are in the same relay. *Table 6.34* shows the breaker status logic input and output Relay Word bits.

Table 6.34 Breaker Status Logic Input and Output Relay Word Bits

Primitive Name	Description
52A01	LONDON A-phase NO contact
52AL01	LONDON A-phase discrepancy alarm
52A02	LONDON B-phase NO contact
52AL02	LONDON B-phase discrepancy alarm
52A03	LONDON C-phase NO contact
52AL03	LONDON C-phase discrepancy alarm
52A04	BERLIN A-phase NO contact
52AL04	BERLIN A-phase discrepancy alarm
52A05	BERLIN B-phase NO contact
52AL05	BERLIN B-phase discrepancy alarm
52A06	BERLIN C-phase NO contact
52AL06	BERLIN C-phase discrepancy alarm
52A07	NEW YORK A-phase NO contact
52AL07	NEW YORK A-phase discrepancy alarm
52A08	NEW YORK B-phase NO contact
52AL08	NEW YORK B-phase discrepancy alarm
52A09	NEW YORK C-phase NO contact
52AL09	NEW YORK C-phase discrepancy alarm
52A10	CANBERRA A-phase NO contact
52AL10	CANBERRA A-phase discrepancy alarm
52A11	CANBERRA B-phase NO contact
52AL11	CANBERRA B-phase discrepancy alarm
52A12	CANBERRA C-phase NO contact
52AL12	CANBERRA C-phase discrepancy alarm

Differential Trip Logic and Differential Element Alias Assignment

Figure 6.68 shows the differential trip logic for Differential Element 1. Relay Word bit 87Z1 asserts only if the zone supervision conditions permit an output from the AND gate. (See *Section 5: Protection Functions* for more information). *Table 6.35* shows the Relay Word bits and the alias names for the zone differential protection outputs.

Table 6.35 Alias Names for the Zone Differential Protection Output Relay Word Bits

Primitive Name	Description	Alias
87Z1	Zone 1 differential element trip	WESTA_T
87Z2	Zone 2 differential element trip	WESTB_T
87Z3	Zone 3 differential element trip	WESTC_T
87Z4	Zone 4 differential element trip	EASTA_T
87Z5	Zone 5 differential element trip	EASTB_T
87Z6	Zone 6 differential element trip	EASTC_T

Differential trip bits 87BTR01–87BTR21 assert to trip the circuit breakers of the terminals in the faulted bus-zone. (See *Section 5: Protection Functions* for more information.)

Figure 6.68 Differential Trip Logic for Differential Element 1

Be sure to include the differential trip bits in the trip equations of all the terminals you want to trip when the differential elements operate. In our example, we will use 18 of the 87BTR*mm* (*mm* = 01–21) Relay Word bits. *Table 6.36* shows the primitive differential trip bit names and the alias names for the differential trip bits.

Table 6.36 Primitive Terminal and Differential Trip Bit Names and the Alias Names for the Differential Trip Bits (Sheet 1 of 2)

Differential Trip Bit	Alias	Comments
87BTR01	87LON_A	Associated with Terminal 01
87BTR02	87LON_B	Associated with Terminal 02
87BTR03	87LON_C	Associated with Terminal 03
87BTR04	87BER_A	Associated with Terminal 04
87BTR05	87BER_B	Associated with Terminal 05
87BTR06	87BER_C	Associated with Terminal 06
87BTR07	87NEW_A	Associated with Terminal 07
87BTR08	87NEW_B	Associated with Terminal 08
87BTR09	87NEW_C	Associated with Terminal 09
87BTR10	87CAN_A	Associated with Terminal 10
87BTR11	87CAN_B	Associated with Terminal 11
87BTR12	87CAN_C	Associated with Terminal 12

Table 6.36 Primitive Terminal and Differential Trip Bit Names and the Alias Names for the Differential Trip Bits (Sheet 2 of 2)

Differential Trip Bit	Alias	Comments
87BTR13	87SEC1A	Associated with Terminal 13
87BTR14	87SEC1B	Associated with Terminal 14
87BTR15	87SEC1C	Associated with Terminal 15
87BTR16	87SEC2A	Associated with Terminal 16
87BTR17	87SEC2B	Associated with Terminal 17
87BTR18	87SEC2C	Associated with Terminal 18

Breaker Trip Logic and Trip Alias Assignment

Figure 6.69 shows the general tripping logic for the 15 trip outputs used in this application. (See *Section 5: Protection Functions* for more information).

Figure 6.69 Breaker Trip Logic

There exists a direct relationship between the number of circuit breakers and the number of trip equations, i.e., the number of trip equations (TR*kk*) equals the number of circuit breakers (NUMBK). Because the relay interprets the number of circuit breakers (NUMBK) as the number of circuit breaker poles, the setting of NUMBK in this application equals 15.

After setting the TR*nn* trip equations, the relay associates each TR*nn* trip equation with a particular circuit breaker pole; we must combine the trip equations in the output settings to form a single output for the tie breaker (see the *Protection Group Settings on page 6.80*). For example, after setting TR01 := 87BTR01 and TR02 := 87BTR02, the relay associates Trip Equation TR01 with Terminal 01 (LOND_A), Trip Equation TR02 with Terminal 02 (LOND_B), and so on. *Table 6.37* shows the 15 primitive and alias names for the trip logic of each terminal.

Table 6.37 Primitive and Alias Names for the Trip Logic of Each Terminal (Sheet 1 of 2)

Primitive Name	Description	Alias
TRIP01	Trip output of the LONDON terminal A-Phase asserted	TRLON_A
TRIP02	Trip output of the LONDON terminal B-Phase asserted	TRLON_B
TRIP03	Trip output of the LONDON terminal C-Phase asserted	TRLON_C
TRIP04	Trip output of the BERLIN terminal A-Phase asserted	TRBER_A
TRIP05	Trip output of the BERLIN terminal B-Phase asserted	TRBER_B
TRIP06	Trip output of the BERLIN terminal C-Phase asserted	TRBER_C
TRIP07	Trip output of the NEW YORK terminal A-Phase asserted	TRNEW_A

Table 6.37 Primitive and Alias Names for the Trip Logic of Each Terminal (Sheet 2 of 2)

Primitive Name	Description	Alias
TRIP08	Trip output of the NEW YORK terminal B-Phase asserted	TRNEW_B
TRIP09	Trip output of the NEW YORK terminal C-Phase asserted	TRNEW_C
TRIP10	Trip output of the CANBERRA terminal A-Phase asserted	TRCAN_A
TRIP11	Trip output of the CANBERRA terminal B-Phase asserted	TRCAN_B
TRIP12	Trip output of the CANBERRA terminal C-Phase asserted	TRCAN_C
TRIP13	Trip output of the sectionalizing breaker A-Phase asserted	TRSEC_A
TRIP14	Trip output of the sectionalizing breaker B-Phase asserted	TRSEC_B
TRIP15	Trip output of the sectionalizing breaker C-Phase asserted	TRSEC_C

Assign Alias Names to the User-Defined Logic

We created the general end-zone protection logic under *User-Defined Functions on page 6.62*. We now assign the application-specific alias names to all the appropriate Relay Word bits in the end-zone protection logic.

End-Zone Protection

Table 6.38 shows the alias names for the four protection SELOGIC control equation variables (PSV01–PSV04).

Table 6.38 Alias Names for the End-Zone Protection Logic

Primitive Name	Description	Alias
PSV01	End-zone element for LONDON terminal	LOND_EZ
PSV02	End-zone element for BERLIN terminal	BERL_EZ
PSV03	End-zone element for NEW YORK terminal	NEWY_EZ
PSV04	End-zone element for CANBERRA terminal	CANB_EZ

Figure 6.70 shows the end-zone logic with the alias names instead of the primitive names. The logic declares an end-zone fault when the following three conditions are met:

- A differential trip signal has been issued to the circuit breaker
- Current continues to flow through the feeder CT after a 5-cycle delay
- The busbar disconnect of the feeder is closed.

Note that the second condition is met by using the built-in 5-cycle delay of 52AL*nn*, which is the alarm timer output of the circuit breaker status logic. Create similar logic for the other three feeders with the protection logic settings.

Figure 6.70 End-Zone Logic With the Alias Names for the London Feeder

Relay Logic-to-Output Contact Allocation and Output Contact Alias Assignments

At this point, we have assigned alias names to all relay functions. *Table 6.28* shows the breakdown of the nine relay outputs we need for this application. We now link the appropriate relay logic outputs to specific relay output contacts and assign alias names to the relay output contacts. *Table 6.39* shows the linking of the end-zone protection logic to the output contacts of the main board and the alias names of the relay main board output contacts. *Table 6.40* shows the linking of the trip logic outputs to the relay output contacts of Interface Board 1 and the alias names of the of the interface board output contacts.

Output Alias Assignment–Main Board

We assign the outputs from the end-zone protection logics as direct transfer trip (DTT) functions to the output contacts of the main board. Wire the direct transfer trip outputs to the communications equipment or terminal panel to transmit the signal to the remote busbar.

Table 6.39 Alias Names for the Main Board Output Contacts

Output Contact Assignment	Description	Output Contact Alias
OUT101	DTT for an end zone fault on LONDON Feeder	LON_DTT
OUT102	DTT for an end zone fault on BERLIN Feeder	BER_DTT
OUT103	DTT for an end zone fault on NEW YORK Feeder	NEW_DTT
OUT104	DTT for an end zone fault on CANBERRA Feeder	CAN_DTT
OUT105	NA	NA
OUT106	NA	NA
OUT107	Relay in test mode	TEST
OUT108	Relay alarm	ALARM

Output Alias Assignment–Interface Board 1 (200)

Each interface board of the SEL-487B can include six high-speed, high-interrupting output contacts. *Table 6.40* shows the alias assignment for the five terminals in our example.

Table 6.40 Alias Assignment for the Five Terminals in Our Example

Output Contact Assignment	Description	Output Contact Alias
OUT201[a]	LONDON trip logic output	LON_TRP
OUT202[a]	BERLIN trip logic output	BER_TRP
OUT203[a]	NEW YORK trip logic output	NEW_TRP
OUT204[a]	CANBERRA trip logic output	CAN_TRP
OUT205[a]	TIE-BREAKER trip logic output	SEC_TRP

[a] High-speed, high-interrupting outputs.

Station Layout Update

We are now ready to set and configure the relay. Write all the relevant information on the station diagram, as shown in *Figure 6.71*.

1. Write down the bus-zone, terminal, and disconnect names.
2. Draw in the overlapping zone on the bus section to clearly identify the terminal/zone allocation.
3. Allocate the terminals CTs to the relay input current channels.
4. Allocate the auxiliary contacts to the relay digital inputs.
5. Allocate the digital outputs from the relay to the terminals.

Figure 6.71 Substation Layout With Specific Terminal Information

Setting the Relay

The following describes the settings for this application. For this application, we set the following settings classes:

- Alias Settings
- Global Settings
- Zone Configuration Group Settings
- Protection Group Settings
- Protection Logic Settings
- Control Output Settings

Alias Settings

We have identified and allocated the alias names to the analog channels and Relay Word bits. We now enter the alias names in the relay. Type **SET T <Enter>** to enter the alias setting class. Many default Relay Word bits have useful alias names ready for use. Type **LIST <Enter>** to see a list of default primitive names and associated alias names, as shown in *Figure 6.72*.

After inspecting the list, we decide that the only useful alias names are those of the 16 LEDs, TEST, and ALARM.

```
=>>SET T <Enter>
Alias
Relay Aliases
(RW Bit or Analog Qty. or Terminal or Bus-Zone, 7 Character Alias [0-9 A-Z _])
1: IO1,"FDR_1"
?  LIST <Enter>
1: IO1,"FDR_1"
2: IO2,"FDR_2"
3: IO3,"FDR_3"
4: IO4,"TRFR_1"
5: IO5,"TB_1"
6: IO6,"TB_2"
7: BZ1,"BUS_1"
8: BZ2,"BUS_2"
.
.
.
60: TLED_15,"89_ALRM"
61: TLED_16,"PT_ALRM"
1: IO1,"FDR_1"
?
```

Figure 6.72 List of Default Primitive Names and Associated Alias Names

Type **DELETE 43 <Enter>** at the first action prompt to delete the first 43 default alias names, as shown in *Figure 6.73*.

```
1: IO1,"FDR_1"
?  DELETE 43 <Enter>
```

Figure 6.73 Deletion of the First 43 Alias Names

Type **> <Enter>** to advance to the next available line in the settings list. Enter the alias names for the 18 analog channels and Relay Word bits, as shown in *Figure 6.74*.

```
1:OUT107,"TEST"
?  <Enter>
19:
?  IO1,LOND_A <Enter>
20:
?  IO2,LOND_B <Enter>

21:
?  IO3,LOND_C <Enter>
22:
?  IO4,BERL_A <Enter>
23:
?  IO5,BERL_B <Enter>

24:
?  IO6,BERL_C <Enter>
.
.
.
133:
?  OUT204,CAN_TRP <Enter>

134:
?  OUT205,SEC_TRP <Enter>
135:
?  END <Enter>
Alias
.
.
.

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

=>>
```

Figure 6.74 Analog Quantities and Relay Word Bit Alias Names for Application 2

This concludes the alias settings. The next settings class is the global settings.

Global Settings

Global settings comprise settings that apply to all protection setting groups. For example, when changing from Protection Settings Group 1 to Protection Settings Group 2, global settings such as station name and relay name still apply. *Figure 6.75* shows the setting changes we need for our example. Because we declared the alias names in the alias setting class, use either alias names or primitive names when entering settings.

Carefully consider circuit breaker related settings when applying the relay in a single-relay application. The relay considers all applications to be three-relay applications; there is no setting distinguishing a single-relay application from a three-relay application. In particular, the relay interprets the number of circuit breakers (NUMBK) as the number of circuit breaker poles, not as the number of circuit breakers.

In this single-relay application example, there are 15 circuit breaker poles at the substation, and the value of NUMBK is 15. However, wire only one circuit breaker auxiliary contact from each circuit breaker to the relay; see the TR*kk*, TRIP*kk*, and the output settings for information on how to set the relay for this application.

There exists a direct relationship between the number of circuit breakers and the number of breaker status logics, i.e., the number of breaker input equations (52A*kk*) equals the number of circuit breakers (NUMBK). Enter the number of poles at the station for the NUMBK setting. Because the relay interprets the number of circuit breakers (NUMBK) as the number of circuit breaker poles, the setting of NUMBK in this application equals 15.

Setting NUMBK equal to 15 makes 15 corresponding circuit breaker auxiliary input equations (52A01–52A15), and 15 corresponding trip equations (TR01–TR15) available for setting. Although 15 circuit breaker auxiliary input equations are available, there are only four circuit breaker auxiliary contacts wired to the relay, one contact from each of the four feeder circuit breakers at the station. Group three circuit breaker auxiliary input equations to form an association with a circuit breaker, and enter the same contact name for the three circuit breaker auxiliary input equations. For example, group circuit breaker auxiliary input equations 52A01, 52A02, and 52A03 to form an association with the LONDON circuit breaker.

Table 6.31 shows the allocation of ILON52A, the circuit breaker auxiliary contact to relay input IN204. We use relay input IN204 to monitor the status of the LONDON circuit breaker. All three circuit breaker auxiliary input equations (52A01, 52A02, and 52A03) must assert when ILON52A asserts, so ILON52A must appear in all three circuit breaker auxiliary input equations. Because we do not need a circuit breaker auxiliary contact from the tie breaker, set 52A13–52A15 to NA.

Setting NUMDS declares the number of disconnect logics we need, not the number of disconnect inputs. In our example, we need six disconnect logics although there are 12 disconnect inputs. You can set each disconnect travel time individually with the 89ALP*nn* setting (*nn* = 01–06). Travel time is the time period when both disconnect auxiliary contacts are in the open position (see *Figure 6.20* for more information). Measure the travel time during commissioning and adjust the settings appropriately. Based on previous experience with similar equipment, we set the tie-breaker disconnect travel time to 400 cycles in this example.

```
=>>SET G <Enter>
Global
General Global Settings
Station Identifier (40 characters)
SID := "Station A"
?<Enter>

Relay Identifier (40 characters)
RID := "Relay 1"
?<Enter>
Number of Breakers (N,1-21)                          NUMBK   := 5      ?15 <Enter>
Number of Disconnects (N,1-60)                       NUMDS   := N      ?6 <Enter>
Nominal System Frequency (50,60 Hz)                  NFREQ   := 60     ?<Enter>
Date Format (MDY,YMD,DMY)                            DATE_F  := MDY    ?> <Enter>


Global Enables

Station DC Battery Monitor (Y,N)                     EDCMON  := N      ?> <Enter>

Time and Date Management

Date Format (MDY,YMD,DMY)                            DATE_F  := MDY    ?> <Enter>

Control Inputs (Global)


Input Pickup Delay (0.00-30 ms)                      GINPU   := 2.0    ?> <Enter>
Settings Group Selection
Select Setting Group 1 (SELogic Equation)
SS1 := NA
?  > <Enter>


Breaker Inputs

N/O Contact Input -BK01 (SELogic Equation)
52A01 := NA
?  ILON52A <Enter>
N/O Contact Input -BK02 (SELogic Equation)
52A02 := NA
?  ILON52A <Enter>
N/O Contact Input -BK03 (SELogic Equation)
52A03 := NA
?  ILON52A <Enter>
N/O Contact Input -BK04 (SELogic Equation)
52A04 := NA
?  IBER52A <Enter>

N/O Contact Input -BK05 (SELogic Equation)
52A05 := NA
?  IBER52A <Enter>
N/O Contact Input -BK06 (SELogic Equation)
52A06 := NA
?  IBER52A <Enter>
N/O Contact Input -BK07 (SELogic Equation)

.
.
.

52A13 := NA
?  <Enter>
N/O Contact Input -BK13 (SELogic Equation)
52A14 := NA
?  <Enter>
N/O Contact Input -BK14 (SELogic Equation)
52A15 := NA
?  <Enter>

N/O Contact Input -BK15 (SELogic Equation)
Disconnect Inputs and Timers
N/O Contact Input -DS01 (SELogic Equation)
89A01 := NA
?  ILON89A <Enter>
N/C Contact Input -DS01 (SELogic Equation)
89B01 := NA
?  ILON89B <Enter>
```

Figure 6.75 Global Settings for Application 2

```
DS01 Alarm Pickup Delay (0-99999 cyc)                89ALP01 := 300    ? <Enter>
N/O Contact Input -DS02 (SELogic Equation)
89A02 := NA
?  IBER89A <Enter>
N/C Contact Input -DS02 (SELogic Equation)
89B02 := NA
?  IBER89B <Enter>
DS02 Alarm Pickup Delay (0-99999 cyc)                89ALP02 := 300    ? <Enter>

.
.
.

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

Figure 6.75 Global Settings for Application 2 (Continued)

This concludes the global settings. The next settings class is the zone configuration group settings.

Zone Configuration Group Settings

The terminal-to-bus-zone SELOGIC control equations identify an analog channel, a differential element, and the conditions for which the relay assigns the analog channel to the differential element. Dynamic zone selection provides a mechanism to automatically reconfigure the zone of protection, without any wiring changes (See *Dynamic Zone Selection Logic on page 5.14* for more information).

In this example, the dynamic zone selection logic uses the disconnect auxiliary contacts status to determine the station configuration and to assign the input currents from the CTs to the appropriate differential elements. For each terminal, wire an 89A and an 89B disconnect auxiliary contact to the relay.

Because the disconnect simultaneously operates all three phases of the terminal, we state the disconnect status in the terminal-to-bus-zone SELOGIC control equations of all three phases. For example, when we close the busbar disconnect on the LONDON feeder, all three phases (LOND_A, LOND_B, and LOND_C) operate together. Because the relay measures the three phases in three separate differential elements (phase LOND_A in differential element WEST_A, phase LOND_B in differential element WEST_B, etc.), we need to convey the disconnect status to all three differential elements. *Table 6.33* shows the alias names of the disconnect status Relay Word bits; *Figure 6.76* shows the zone configuration group settings.

The zone configuration group default settings are for a specific substation with arbitrarily selected alias names, serving only as an example. For the ease of setting the zone configuration group settings for the new substation, delete the existing zone configuration default settings. With the zone configuration group default settings deleted, the setting prompts no longer reference the default settings.

```
=>>SET Z <Enter>

Zone Config Group 1
Potential Transformer Ratio
Potential Transformer Ratio -V01 (1-10000)          PTR1    := 2000   ?> <Enter>

Current Transformer Ratio
Current Transformer Ratio -I01 (1-50000)            CTR01   := 600    ?40 <Enter>
Current Transformer Ratio -I02 (1-50000)            CTR02   := 600    ?40 <Enter>
Current Transformer Ratio -I03 (1-50000)            CTR03   := 600    ?40 <Enter>
Current Transformer Ratio -I04 (1-50000)            CTR04   := 600    ?400 <Enter>
Current Transformer Ratio -I05 (1-50000)            CTR05   := 600    ?400 <Enter>
Current Transformer Ratio -I06 (1-50000)            CTR06   := 600    ?400 <Enter>
Current Transformer Ratio -I07 (1-50000)            CTR07   := 600    ?400 <Enter>
Current Transformer Ratio -I08 (1-50000)            CTR08   := 600    ?400 <Enter>
Current Transformer Ratio -I09 (1-50000)            CTR09   := 600    ?400 <Enter>
Current Transformer Ratio -I10 (1-50000)            CTR10   := 600    ?400 <Enter>
Current Transformer Ratio -I11 (1-50000)            CTR11   := 600    ?400 <Enter>

.
.
.

Current Transformer Ratio -I18 (1-50000)            CTR18   := 600    ?400 <Enter>
Zone Configuration: Terminal to Bus-Zone Connections
Terminal, Bus-Zone, Polarity (P,N)
IO1BZ1C := SEC1_A, WEST_A, P
?  DELETE 2OO <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO1,BZ1,P <Enter>

LOND_A to WEST_A Connection (SELogic Equation)
IO1BZ1V := NA
?  LOND89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO2,BZ2,P <Enter>
LOND_B to WEST_B Connection (SELogic Equation)
IO2BZ2V := NA
?  LOND89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO3,BZ3,P <Enter>

LOND_C to WEST_C Connection (SELogic Equation)
IO3BZ3V := NA
?  LOND89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO4,BZ1,P <Enter>
BERL_A to WEST_A Connection (SELogic Equation)
IO4BZ1V := NA
?  BERL89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO5,BZ2,P <Enter>

BERL_B to WEST_B Connection (SELogic Equation)
IO5BZ2V := NA
?  BERL89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO6,BZ3,P <Enter>
BERL_C to WEST_C Connection (SELogic Equation)
IO6BZ3V := NA
?  BERL89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO7,BZ4,P <Enter>

NEWY_A to EAST_A Connection (SELogic Equation)
IO7BZ4V := NA
?  NEWY89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO8,BZ5,P <Enter>
NEWY_B to EAST_B Connection (SELogic Equation)
IO8BZ5V := NA
?  NEWY89C <Enter>

Terminal, Bus-Zone, Polarity (P,N)
?  IO9,BZ6,P <Enter>
NEWY_C to EAST_C Connection (SELogic Equation)
IO9BZ6V := NA
?  NEWY89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I10,BZ4,P <Enter>

CANB_A to EAST_A Connection (SELogic Equation)
I10BZ4V := NA
?  CANB89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I11,BZ5,P <Enter>
CANB_B to EAST_B Connection (SELogic Equation)
I11BZ5V := NA
?  CANB89C <Enter>
```

Figure 6.76 Zone Configuration Group Settings for Application 2

```
Terminal, Bus-Zone, Polarity (P,N)
?  I12,BZ6,P <Enter>
CANB_C to EAST_C Connection (SELogic Equation)
I12BZ6V := NA
?  CANB89C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I13,BZ4,P <Enter>

SEC1_A to EAST_A Connection (SELogic Equation)
I13BZ4V := NA
?  SEC189C AND SEC298C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I14,BZ5,P <Enter>
SEC1_B to EAST_B Connection (SELogic Equation)
I14BZ5V := NA
?  SEC189C AND SEC298C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I15,BZ6,P <Enter>

SEC1_C to EAST_C Connection (SELogic Equation)
I15BZ6V := NA
?  SEC189C AND SEC298C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I16,BZ1,P <Enter>
SEC2_A to WEST_A Connection (SELogic Equation)
I16BZ1V := NA
?  SEC189C AND SEC298C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I17,BZ2,P <Enter>
SEC2_B to WEST_B Connection (SELogic Equation)
I17BZ2V := NA
?  SEC189C AND SEC298C <Enter>

Terminal, Bus-Zone, Polarity (P,N)
?  I18,BZ3,P <Enter>
SEC2_C to WEST_C Connection (SELogic Equation)
I18BZ3V := NA
?  SEC189C AND SEC298C <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?<Enter>
Zone Configuration: Bus-Zone to Bus-Zone Connections


Bus-Zone, Bus-Zone
?<Enter>
Zone Supervision
Differential Element Zone Supervision (Y,N)          E87ZSUP := N      ?<Enter>
Zone Switching Supervision
Zone Switching Supervision (Y,N)                     EZSWSUP := N      ?<Enter>

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

=>>
```

Figure 6.76 Zone Configuration Group Settings for Application 2 (Continued)

This concludes the zone configuration group settings. The next settings class is the protection group settings.

Protection Group Settings

Settings of this class comprise the protection functions, starting with the function enable settings. Default settings for the differential elements are 60 percent for Slope 1 and 80 percent for Slope 2. To change the slope settings, first enable the advanced settings by setting EADVS := Y. With EADVS := Y, the slope settings and incremental restrained and operating current settings become available.

The protection philosophy calls for the blocking of the busbar protection for an open CT condition. Set E87SSUP := Y (see *Figure 5.11* and *Figure 5.18* for more information) to use the sensitive differential element for this requirement. Set ECSL := N, ETOS := N, EBFL := N, E50 := N, E51 := N, E27 := N, and E59 := N because we do not use the Coupler Security Logic, terminal out of service, breaker failure protection, overcurrent elements, or voltage elements in this application. Pay close attention to the trip logic (TR01–TR15) settings.

Because we use one SEL-487B, CTs from the three phases (A-phase, B-phase, and C-phase) from each terminal are assigned to three different differential elements (see *Single-Relay Application on page 6.3*).

Setting NUMBK (Global Settings) equal to 15 also makes 15 corresponding trip equations (TR01–TR15) available for setting. *Table 6.36* shows the 18 differential trip bits that assert when the differential protection operates. Setting the trip equations involves assigning the 18 differential trip bits to the correct 15 trip equations. There are six differential elements in the relay, and because there are six bus-zones at the station, we use all six differential elements.

For the per-phase differential calculations, the relay assigns the individual phases of each terminal to three separate differential elements. (Strictly speaking, the relay assigns the phases according to the zone configuration group settings. However, correct zone configuration group settings cause the relay to assign the individual phases of each terminal to three separate differential elements.) The tie breaker has six CTs; one CT assigned to each of the six differential elements. Because the tie breaker has only one circuit breaker, operation of any one of the six differential elements must trip the tie-breaker circuit breaker. For this reason, we include the two A-phase differential trip bits (87SEC1A and 87SEC2A) in the same trip equation, the two B-phase differential trip bits (87SEC1B and 87SEC2B) in the same trip equation, and so on.

The trip logic latches the trip outputs TRIP*kk* after TR*kk* assertion. Press the **TARGET RESET** pushbutton on the front panel to deassert the trip outputs. Alternatively, enter specific reset conditions at the ULTR*kk* settings.

Although the SEL-487B includes 21 trip logics, there is only one Minimum Trip Duration Time Delay (TDURD) setting. Set the timer TDURD longer than the clearing time of the slowest circuit breaker at the station.

For this application, we use the default values for the Sensitive Differential Element, the Restrained Differential Element, the Directional Element, and the Trip Duration Timer. *Figure 6.77* shows the group settings.

```
=>>SET <Enter>

Group 1
Relay Configuration
Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y      ?<Enter>
Coupler Security Logic (N,1-4)                       ECSL    := N      ?<Enter>
Terminal Out of Service (N,1-21)                     ETOS    := 5      ?N <Enter>
Breaker Failure Logic (N,1-21)                       EBFL    := 6      ?N <Enter>
Definite Time Overcurrent Elements (N,1-21)          E50     := N      ?<Enter>
Inverse Time Overcurrent Elements (N,1-21)           E51     := N      ?<Enter>
Enable Under Voltage Elements (N,1-6)                E27     := N      ?<Enter>
Enable Over Voltage Elements (N,1-6)                 E59     := N      ?<Enter>
Advanced Settings (Y,N)                              EADVS   := N      ?<Enter>

Sensitive Differential Element
Sensitive Differential Element Pickup (0.05-1 pu)    S87P    := 0.10   ?> <Enter>
Restrained Differential Element
Restrained Diff Element Pickup (0.10-4 pu)           O87P    := 1.00   ?> <Enter>
Directional Element
Dir Element O/C Supervision Pickup (0.05-3 pu)       50DSP   := 0.05   ?> <Enter>

Trip 01 (SELogic Equation)
TR01 := SBFTR01 OR 87LON_A
?  87LON_A <Enter>
Unlatch Trip 01 (SELogic Equation)
ULTR01 := NA
?<Enter>

Trip 02 (SELogic Equation)
TR02 := SBFTR02 OR 87LON_B
?  87LON_B <Enter>
Unlatch Trip 02 (SELogic Equation)
ULTR02 := NA
?<Enter>
```

Figure 6.77 Protection Group Settings for Application 2

```
Trip 03 (SELogic Equation)
TR03 := SBFTR03 OR 87LON_C
?  87LON_C <Enter>
Unlatch Trip 03 (SELogic Equation)
ULTR03 := NA
?<Enter>

.
.
.
Trip 12 (SELogic Equation)
TR12 := NA
?  87CAN_C <Enter>
Unlatch Trip 12 (SELogic Equation)
ULTR12 := NA
?<Enter>

Trip 13 (SELogic Equation)
TR13 := NA
?  87SEC1A OR 87SEC2A <Enter>
Unlatch Trip 13 (SELogic Equation)
ULTR13 := NA
?<Enter>

Trip 14 (SELogic Equation)
TR14 := NA
?  87SEC1B OR 87SEC2B <Enter>
Unlatch Trip 14 (SELogic Equation)
ULTR14 := NA
?<Enter>

Trip 15 (SELogic Equation)
TR15 := NA
?  87SEC1C AND 87SEC2C <Enter>
Unlatch Trip 15 (SELogic Equation)
ULTR15 := NA
?  <Enter>

Trip Logic
Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000 ?> <Enter>
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.77 Protection Group Settings for Application 2 (Continued)

This concludes the protection group settings. The next settings class is the protection logic settings.

Protection Logic Settings

Use the protection logic settings to create logics in the relay. *Figure 6.78* shows the settings in our example. Protection Latch Bit PLT01 constitutes the differential enable function on the front-panel pushbutton labeled **87(DIFF) ENABLED**. Lines 22–27 show the programming for the end-zone protection. *Figure 6.78* shows the protection logic settings.

```
=>>SET L <Enter>

Protection 1

1: PLT01S := NOT PLT01 AND PLT04 # DIFFERENTIAL ENABLED
?  ><Enter>
21:
?  # END-ZONE PROTECTION FOR THE LONDON FEEDER <Enter>
22:
? LOND_EZ:=(TRLON_A OR TRLON_B OR TRLON_C) AND (52AL01 OR 52AL02 OR 52AL03) AND
   LOND89C <Enter>

7:
? # END-ZONE PROTECTION FOR THE BERLIN FEEDER <Enter>
23:
? BERL_EZ:=(TRBER_A OR TRBER_B OR TRBER_C) AND (52AL04 OR 52AL05 or 52AL06) AND
   BERL89C <Enter>
24:
? # END-ZONE PROTECTION FOR THE NEW YORK FEEDER <Enter>
25:
? NEWY_EZ:=(TRNEW_A OR TRNEW_B OR TRNEW_C) AND (52AL07 or 52AL08 or 52AL09) \ AND
   NEWY89C <Enter>
26:
? # END-ZONE PROTECTION FOR THE CANBERRA FEEDER <Enter>

27:
? CANB_EZ:=(TRCAN_A OR TRCAN_B OR TRCAN_C) AND (52AL10 OR 52AL11 OR 52AL12) \ AND
   CANB89C <Enter>
28:
? END <Enter>

Protection 1
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.78 Protection Logic Settings for Application 2

This concludes the protection logic settings. The next settings class is the control output settings.

Control Output Settings

In this settings class, we assign the logic or Relay Word bits in the relay to output contacts. We need nine output contacts for our example:

- four for the direct transfer trip outputs
- five for the bus-bar protection trip outputs

Although not specifically called for in the protection philosophy, it is good practice to also include the TEST and ALARM outputs in the relay settings.

Because the relay interprets the NUMBK setting as the number of poles, there are 15 trip equations for this application. There is, of course, only one circuit breaker for each terminal. We, therefore, combine the appropriate trip outputs from the breaker trip logic (TRIP01–TRIP15, see *Figure 6.69*) to provide a single trip output for each circuit breaker. For example, we set the trip equations (Protection Group Settings) for the London terminal to TR01 := 87LON_A, TR02 := 87LON_B, and TR03 := 87LON_C, with the corresponding breaker trip logic output alias names of TRLON_A, TRLON_B, and TRLON_C. Because Terminal LONDON has only one circuit breaker, we assign only one trip output contact (OUT201) to trip the circuit breaker. Therefore, assertion of any one of the three breaker trip logic outputs (TRLON_A, TRLON_B, or TRLON_C) must trip the circuit breaker of the London terminal. To achieve this tripping, set Output OUT201 equal to the OR combination of the three breaker trip logic outputs.

NOTE: The tie-breaker trip equations (TR13–TR15) already include the combination of two differential elements (87SEC1A OR 87SEC2A, etc.).

Figure 6.79 shows the settings. We include Protection Latch Bit PLT03 in the output equation. With PLT03 included in every output equation, the **RELAY TEST MODE** pushbutton disables all output contacts. We assign the direct transfer trip outputs to the main board contacts and the bus-zone protection to the trip outputs of the interface board. *Figure 6.79* shows the output settings.

```
=>>SET O <Enter>
Output
Main Board
OUT101 := TRSEC_A AND NOT PLT03
?  LOND_EZ AND NOT PLT03 <Enter>
OUT102 := TRSEC_B AND NOT PLT03
?  BERL_EZ AND NOT PLT03 <Enter>
OUT103 := TRSEC_C AND NOT PLT03
?  NEWY_EZ AND NOT PLT03 <Enter>
OUT104 := TRLON_A AND NOT PLT03
?  CANB_EZ AND NOT PLT03 <Enter>
OUT105 := TRLON_B AND NOT PLT03
?  NA <Enter>
OUT106 := NA
?  > <Enter>
Interface Board #1
OUT201 := NA
?  (TRLON_A OR TRLON_B OR TRLON_C) AND NOT PLT03 <Enter>
OUT202 := NA
?  (TRBER_A OR TRBER_B OR TRBER_C) AND NOT PLT03 <Enter>
OUT203 := NA
?  (TRNEW_A OR TRNEW_B OR TRNEW_C) AND NOT PLT03 <Enter>
OUT204 := NA
?  (TRCAN_A OR TRCAN_B OR TRCAN_C) AND NOT PLT03 <Enter>
OUT205 := NA
?  (TRSEC_A OR TRSEC_B OR TRSEC_C) AND NOT PLT03 <Enter>
OUT206 := NA
?  END <Enter>
Output
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
=>>
```

Figure 6.79 Control Output Settings for Application 2

This concludes the settings for Application 2.

Application 3: Breaker-and-a-Half

This application describes the breaker-and-a-half busbar arrangement shown in *Figure 6.80*. Consider the following to set and configure the relay:

- Busbar classification
- Protection philosophy
- Protection functions selection
- Number of SEL-487B Relays and I/O boards
- Input, logic, and output allocation and alias name assignment
- Station layout update
- Relay setting and configuration

Figure 6.80 Breaker-and-a-Half Busbar Layout

Busbar Classification

The busbar classification provides general busbar layout and CT positioning (inboard or outboard) information.

- Description:
  - Breaker-and-a-half
- Current Transformers:
  - Outboard (free standing)
- Disconnects:
  - No disconnect auxiliary contacts are available
- Future expansion:
  - One feeder

Protection Philosophy

Although the SEL-487B offers a variety of protection and control functions, not every substation uses all of these functions. Carefully consider each application before stating the functional requirements. The protection philosophy for this application is as follows:

1. Use the terminal out-of-service function.
2. Use the voltage elements as an additional trip criterion, and generate an event report when the voltage elements assert.
3. Block the busbar protection for an open-circuit CT.
4. Use the internal breaker failure protection in the relay for Terminals TD, TE, and TF and include retrip for each terminal.
5. Protect the two busbars with separate relays.

Protection Functions Selection

We select the protection functions early in the relay setting and configuration process because the choice of protection functions determines the number of relay digital inputs and outputs necessary for the application. Study the protection philosophy to determine which protection and/or control functions to apply to any particular substation. The SEL-487B offers a number of protection functions as standard features, but it also includes the capability through SELOGIC control equations to create user-configurable functions. To properly identify and categorize the protection philosophy requirements, group the protection functions as follows:

- standard protection functions (available in the relay)
- user-defined protection functions (created with SELOGIC control equations)

Standard Functions

Refer to the protection philosophy and select the standard functions necessary for the application. *Table 6.41* shows the selection of the standard functions.

Table 6.41 Section of Standard Protection Functions (Sheet 1 of 2)

Protection Function	Selection	Comment
CT ratio mismatch ≤ 10:1	Yes	10:1 mismatch is the maximum allowable mismatch
Circuit breaker status logic	No	Not required
Disconnect monitor logic	No	No disconnect auxiliary contacts available
Differential protection	Yes	Busbar protection (zone specific and check zone)
Dynamic zone selection logic	No	No disconnect auxiliary contacts available
Sensitive differential protection	Yes	CT open circuit detection
Zone supervision logic	Yes	Supervise tripping with the undervoltage elements as well as the negative- and zero-sequence overvoltage elements
Zone-switching supervision logic	No	No disconnect auxiliary contacts available
Coupler security logic	No	Breaker-and-a-half busbar layout does not require this function

Table 6.41 Section of Standard Protection Functions (Sheet 2 of 2)

Protection Function	Selection	Comment
Circuit breaker failure protection	Yes	Use the internal circuit breaker failure protection
Instantaneous overcurrent protection	No	Not required
Time-overcurrent protection	No	Not required
Phase voltage elements	Yes	Use these elements as an additional trip criterion
Zero- or negative-sequence voltage elements	Yes	Use these elements as an additional trip criterion

User-Defined Functions

Because the SEL-487B includes all protection functions necessary for this application as standard protection functions, we do not need any user-defined functions.

Number of Relays and I/O Boards

Selecting the relay has two parts:

- the number of relays (single-relay application or three-relay application)
- the number of interface boards (as many as four interface boards per relay)

The number of analog (CT) inputs determines the number of relays, and the number of digital inputs and outputs determines the number of interface boards.

Number of Relays

Each SEL-487B has 21 current channels and three voltage channels. For stations with as many as 21 CTs (per phase), we can install a single SEL-487B. For stations with more than 21 and as many as 63 CTs, we install 3 SEL-487B Relays. Use *Equation 6.8* to calculate the number of current channels at the station, and use *Equation 6.9* to calculate the number of zones at the station.

$$\text{\# of current channels required} = \text{\# of per-phase station CTs}$$

Equation 6.8

$$\text{\# of bus-zones required} = \text{\# of per-phase station bus sections}$$

Equation 6.9

The protection philosophy calls for a separate relay for each busbar. There are three terminals in each zone, for a total of nine analog channels. Because of future expansion, however, add 3 more channels for a total of 12. Each SEL-487B has 21 analog channels, so that one relay has enough analog inputs to protect one of the busbars; we need 2 relays to protect both busbars.

Therefore, an SEL-487B protects busbar NORTH, and a separate SEL-487B protects the SOUTH busbar. This is known as a single-relay application. The following discussion describes setting the relay that protects the NORTH busbar. Configuration settings for the relay protecting the SOUTH busbar are the same, except for the alias names. System settings such as CT ratios may be different.

Number of Relay Inputs

The protection philosophy and protection function selection determine the number of digital relay inputs and outputs required for each application. The protection philosophy calls for breaker failure protection. We, therefore, need a breaker failure initiate input contact for each of the three terminals. *Table 6.42* summarizes the input contact requirement for this application.

Table 6.42 Number of Relay Input Contacts Required

Input Description	Inputs
Number of relay inputs required for circuit breaker failure protection	3
Total number of inputs	3

The relay main board has seven input contacts, sufficient for our application. From the input contact perspective, we only need the main board; we do not need an interface board.

Number of Relay Output Contacts

Circuit breakers TD, TE, and TF each need a trip output contact as well as a direct transfer trip (DTT). *Table 6.43* shows the breakdown and the total number of relay output contacts required.

Table 6.43 Breakdown and the Total Number of Relay Outputs Required

Output Description	Outputs
Number of relay output contacts required for differential, breaker failure tripping, and direct transfer trip	3
Number of relay output contacts required for direct transfer tripping	3
Total number of relay output contacts	6

The relay main board has eight standard output contacts (Output Contact 7 is used to assert when the RELAY TEST MODE pushbutton on the front panel is selected, and Output Contact 8 is used for alarming purposes in the default settings). There are enough output contacts on the main board, but these contacts are all standard output contacts. The interface boards can have high-speed, high-interrupting output contacts that provide faster contact closure. Each interface board provides six high-speed, high-interrupting output contacts and two standard output contacts. For fast busbar fault clearance, assign each circuit breaker trip output to a high-speed, high-interrupting output contact. From the output contact perspective, we need one interface board.

The conclusion from the preceding analysis is that we need one SEL-487B per busbar, each relay equipped with a single interface board.

Input, Logic, and Output Allocation and Alias Name Assignment

At this point, we have determined the following:

- the number of SEL-487B Relays necessary for the application
- the number of input contacts
- the number of output contacts
- the selected functions

For example, we have matched the number of CTs at the station with the number of available analog channels in the relay. However, we still need to do the following:

- link specific CT inputs to specific relay analog channels
- link relay element/logic outputs to specific relay output contacts
- assign alias names where appropriate

Assign a valid seven-character alias name to any of the following:

- Relay Word bit
- Analog quantity
- Terminal name
- Bus-zone name

Alias names are valid when they consist of a maximum of seven characters, and they are constructed using characters 0–9, uppercase A–Z, or the underscore (_).

CT-to-Analog Channel Allocation and CT Alias Assignment

Table 6.44 shows CT-to-relay analog channel allocations and alias assignments. For example, allocate the A-phase CT from Terminal TD to relay channel I01, and assign to this CT the alias name TD_A. The choice of CT-to-analog channel allocation is arbitrary; you can assign the CTs randomly to relay analog channels. *Table 6.44* shows the assignment starting with Terminal TD, followed by Terminal TE, and Terminal TF, taken left-to-right from *Figure 6.80*.

Table 6.44 CTs-to-Analog Channel Allocations and Alias Assignments

CTs	Analog Channel	Alias
Terminal TD, A-phase	I01	TD_A
Terminal TD, B-phase	I02	TD_B
Terminal TD, C-phase	I03	TD_C
Terminal TE, A-phase	I04	TE_A
Terminal TE, B-phase	I05	TE_B
Terminal TE, C-phase	I06	TE_C
Terminal TF, A-phase	I07	TF_A
Terminal TF, B-phase	I08	TF_B
Terminal TF, C-phase	I09	TF_C

Bus-Zone Alias Assignment

Each SEL-487B provides six zones of protection. In this application, we use three of the six zones with alias names as shown in *Table 6.45*.

Table 6.45 Alias Names for Three of the Six Bus-Zones

Bus-Zone Name	Description	Alias
BZ1	Bus-Zone 1	NORTH_A
BZ2	Bus-Zone 2	NORTH_B
BZ3	Bus-Zone 3	NORTH_C

Input-to-Logic Allocation and Alias Assignment

Table 6.42 shows that we require three digital inputs. We now assign the digital inputs to the selected logic and apply alias names to the inputs and logic elements. Because we installed an interface board, we use the independent inputs on the interface board for the breaker failure initiate inputs, instead of the inputs on the main board.

Input-to-Logic Allocation and Alias Assignment, Interface Board 1 (200)

Table 6.46 shows the breaker failure initiate input allocations.

Table 6.46 Alias Names for the Breaker Failure Input Contacts

Input	Description	Alias
IN201	Terminal TD breaker failure initiate	ITD_BFI
IN202	Terminal TE breaker failure initiate	ITE_BFI
IN203	Terminal TF breaker failure initiate	ITF_BFI

Assign Alias Names to the Selected Standard Logic

The following explains each selected function in reference to *Table 6.41*. Alias name assignments are also included.

Breaker Failure

This application is a breaker-and-a-half busbar layout. For such busbar layouts, two circuit breakers must operate to clear a fault. *Figure 6.81* shows fault F1, for which both Circuit Breaker TD and Circuit Breaker TG must operate to clear the fault. For certain faults, the current distribution may be such that Circuit Breaker TD carries the bulk of the fault current, as shown in *Figure 6.81*.

Figure 6.81 Current Distribution for Fault F1 With Circuit Breaker TD and Circuit Breaker TG Closed

Because of the current distribution, Terminal TG may only have enough current to assert the breaker failure current element threshold (50F*nn*) when Circuit Breaker TD opens, as shown in *Figure 6.82*.

Figure 6.82 Current Flow for Fault F1 After Circuit Breaker TD Opened

This situation delays initiation of the breaker failure protection of Terminal TG until Circuit Breaker TD interrupts the current. However, both circuit breakers receive the trip signal at the same time and are expected to operate at the same time. Use breaker failure protection Scheme 2 to prevent this delay. See *Circuit Breaker Failure Protection on page 5.30* for more information.

Because the protection philosophy calls for use of the internal breaker failure protection, wire a breaker failure initiate contact from each feeder panel to an independent relay input contact. *Table 6.47* shows the primitive names and the alias names of the breaker failure initiate Relay Word bits (see the *Protection Group Settings on page 6.101* for more information).

Table 6.47 Alias Names for the Breaker Failure Initiate Relay Word Bits

Logic Name	Description	Alias
ATBFI01	Terminal TD A-phase breaker failure protection initiate input	TDA_BFI
ATBFI02	Terminal TD B-phase breaker failure protection initiate input	TDB_BFI
ATBFI03	Terminal TD C-phase breaker failure protection initiate input	TDC_BFI
ATBFI04	Terminal TE A-phase breaker failure protection initiate input	TEA_BFI
ATBFI05	Terminal TE B-phase breaker failure protection initiate input	TEB_BFI
ATBFI06	Terminal TE C-phase breaker failure protection initiate input	TEC_BFI
ATBFI07	Terminal TF A-phase breaker failure protection initiate input	TFA_BFI
ATBFI08	Terminal TF B-phase breaker failure protection initiate input	TFB_BFI
ATBFI09	Terminal TF C-phase breaker failure protection initiate input	TFC_BFI

We also assign alias names to breaker failure logic output Relay Word bits. *Table 6.48* shows the primitive names and the alias names.

Table 6.48 Alias Names for the Breaker Failure Logic Output Relay Word Bits

Logic Name	Description	Alias
FBF01	Terminal TD A-phase breaker failure protection asserted	TDA_BF
FBF02	Terminal TD B-phase breaker failure protection asserted	TDB_BF
FBF03	Terminal TD C-phase breaker failure protection asserted	TDC_BF
FBF04	Terminal TE A-phase breaker failure protection asserted	TEA_BF
FBF05	Terminal TE B-phase breaker failure protection asserted	TEB_BF
FBF06	Terminal TE C-phase breaker failure protection asserted	TEC_BF
FBF07	Terminal TF A-phase breaker failure protection asserted	TFA_BF
FBF08	Terminal TF B-phase breaker failure protection asserted	TFB_BF
FBF09	Terminal TF C-phase breaker failure protection asserted	TFC_BF

Breaker Failure Trip Logic and Station Breaker Failure Logic Output Alias Assignment

Figure 6.83 shows the station breaker failure trip logic. Relay Word bits FBF01–FBF09 are the inputs to the station breaker failure trip logic; Relay Word bits SBFTR01–SBFTR09 are the outputs from the station breaker failure trip logic. Relay Breaker failure trip bits SBFTR01–SBFTR09 assert to trip the circuit breakers of the terminals in the bus-zone with the failed circuit breaker. (See *Section 5: Protection Functions* for more information.)

Figure 6.83 Station Breaker Failure Trip Logic

Table 6.49 shows the station breaker failure Relay Word bits and the alias names for the breaker failure protection outputs.

Table 6.49 Primitive Terminal and Station Breaker Failure Trip Relay Word Bit Names and the Alias Names for the Breaker Failure Trip Bits

Primitive Name	Description	Alias Names
SBFTR01	Terminal TD A-phase station breaker failure protection asserted	TDA_SBF
SBFTR02	Terminal TD B-phase station breaker failure protection asserted	TDB_SBF
SBFTR03	Terminal TD C-phase station breaker failure protection asserted	TDC_SBF
SBFTR04	Terminal TE A-phase station breaker failure protection asserted	TEA_SBF
SBFTR05	Terminal TE B-phase station breaker failure protection asserted	TEB_SBF
SBFTR06	Terminal TE C-phase station breaker failure protection asserted	TEC_SBF
SBFTR07	Terminal TF A-phase station breaker failure protection asserted	TFA_SBF
SBFTR08	Terminal TF B-phase station breaker failure protection asserted	TFB_SBF
SBFTR09	Terminal TF C-phase station breaker failure protection asserted	TFC_SBF

Be sure to include the station breaker failure trip bits in the trip equations of all the terminals you want to trip for breaker failure protection (see the *Control Output Settings on page 6.111* for more information).

Differential Trip Logic and Differential Element Alias Assignment

Figure 6.84 shows the differential trip logic for Differential Element 1. Relay Word bit 87Z1 asserts only if the zone supervision conditions permit an output from the AND gate. (See *Section 5: Protection Functions* for more information.)

Differential trip bits 87BTR01–87BTR09 assert to trip the circuit breakers of the terminals in the faulted bus-zone. (See *Section 5: Protection Functions* for more information.)

Figure 6.84 Differential Trip Logic for Differential Element 1

Table 6.50 shows the Relay Word bits and the alias names for the zone differential protection outputs.

Table 6.50 Alias Names for the Zone Differential Protection Output Relay Word Bits

Primitive Name	Description	Alias
87Z1	Zone 1 differential element trip	NORTA_T
87Z2	Zone 2 differential element trip	NORTB_T
87Z3	Zone 3 differential element trip	NORTC_T

Be sure to include the differential trip bits in the trip equations of all the terminals you want to trip when the differential elements operate. In our example, we want to trip three terminals. *Table 6.51* shows the primitive terminal names, the differential trip bit names, and the alias names for the differential trip bits.

Table 6.51 Primitive Terminal and Differential Trip Bit Names and the Alias Names for the Differential Trip Bits

Primitive Name	Description	Alias
87BTR01	Terminal TD A-phase differential protection trip asserted	TD_TA
87BTR02	Terminal TD B-phase differential protection trip asserted	TD_TB
87BTR03	Terminal TD C-phase differential protection trip asserted	TD_TC
87BTR04	Terminal TE A-phase differential protection trip asserted	TE_TA
87BTR05	Terminal TE B-phase differential protection trip asserted	TE_TB
87BTR06	Terminal TE C-phase differential protection trip asserted	TE_TC
87BTR07	Terminal TF A-phase differential protection trip asserted	TF_TA
87BTR08	Terminal TF B-phase differential protection trip asserted	TF_TB
87BTR09	Terminal TF C-phase differential protection trip asserted	TF_TC

Breaker Trip Logic and Trip Alias Assignment

Figure 6.85 shows the general tripping logic in the SEL-487B. (See *Section 5: Protection Functions* for more information.)

Figure 6.85 Breaker Trip Logic

There exists a direct relationship between the number of circuit breakers and the number of trip equations, i.e., the number of trip equations (TR*kk*) equals the number of circuit breakers (NUMBK). Because the relay interprets the number of circuit breakers (NUMBK) as the number of circuit breaker poles, the setting of NUMBK in this application equals nine. After setting the TR*kk* trip equations, the relay associates each TR*kk* trip equation with a particular circuit breaker pole; we must combine the trip equations in the output settings to form a single output

for the circuit breaker (see *Control Output Settings on page 6.111* for more information). For example, after setting TR01 := 87BTR01 OR SBFTR01 and TR02 := 87BTR02 OR SBFTR02, the relay associates Trip Equation TR01 with Terminal 01 (TD_A), Trip Equation TR02 with Terminal 02 (TD_B), and so on. *Table 6.52* shows the primitive and alias names for the trip logic of each terminal.

Table 6.52 Primitive and Alias Names for the Trip Logic of Each Terminal

Primitive Name	Description	Alias Name
TRIP01	Terminal TD A-phase trip output asserted	TRTD_A
TRIP02	Terminal TD B-phase trip output asserted	TRTD_B
TRIP03	Terminal TD C-phase trip output asserted	TRTD_C
TRIP04	Terminal TE A-phase trip output asserted	TRTE_A
TRIP05	Terminal TE B-phase trip output asserted	TRTE_B
TRIP06	Terminal TE C-phase trip output asserted	TRTE_C
TRIP07	Terminal TF A-phase trip output asserted	TRTF_A
TRIP08	Terminal TF B-phase trip output asserted	TRTF_B
TRIP09	Terminal TF C-phase trip output asserted	TRTF_C

Assign Alias Names to the User-Defined Logic

This application requires no user-defined logic.

Relay Logic-to-Output Contact Allocation and Output Contact Alias Assignments

At this point, we have assigned alias names to all relay functions. *Table 6.43* shows the breakdown of the relay outputs that we need for this application. We now assign specific relay output contacts to the relay functions and assign alias names to the relay output contacts. *Table 6.53* shows the main board assignments and alias names.

Output Alias Assignment, Main Board

This application requires no main board output contacts.

Table 6.53 Alias Assignment for the Trip Output Contacts

Output Contact Assignment	Description	Output Contact Alias
OUT107	Relay in test mode	TEST
OUT108	Relay alarm	ALARM

Output Alias Assignment, Interface Board 1 (200)

Each interface board of the SEL-487B can include six high-speed, high-interrupting output contacts. *Table 6.54* shows the assignments and alias names for Interface Board 1.

Table 6.54 Alias Assignments for the Output Contacts of Interface Board 1

Output Contact Assignment	Description	Output Contact Alias
OUT201[a]	Terminal TD trip output	TD_TRIP
OUT202[a]	Terminal TE trip output	TE_TRIP
OUT203[a]	Terminal TF trip output	TF_TRIP
OUT204[a]	Terminal TD direct transfer trip output	TD_DTT
OUT205[a]	Terminal TE direct transfer trip output	TE_DTT
OUT206[a]	Terminal TF direct transfer trip output	TF_DTT

[a] High-speed, high-interrupting outputs.

Station Layout Update

We are now ready to set and configure the relay. Write down all the relevant information onto the station diagram, as shown in *Figure 6.86*. *Figure 6.86* shows the updated station layout for both relays.

1. Write down the bus-zone, terminal, and disconnect names.
2. Allocate the terminals CTs to the relay input current channels.
3. Allocate the auxiliary contacts to the relay digital inputs.
4. Allocate the digital outputs from the relay to the station terminals.

Figure 6.86 Substation Layout With Specific Terminal Information

Setting the Relay

The following describes the settings for this application. For this application, we set the following settings classes:

- Alias Settings
- Global Settings
- Zone Configuration Group Settings
- Protection Group Settings
- Front Panel Settings
- Control Output Settings

Alias Settings

We have identified and allocated the alias names to the analog channels and Relay Word bits. Type **SET T <Enter>** to enter the alias setting class. Many default Relay Word bits have useful alias names ready for use. Type **LIST <Enter>** to see a list of default primitive names and associated alias names, as shown in *Figure 6.87*.

After inspecting the list, we decide the only useful alias names are those of the 16 LEDs, TEST, and ALARM.

```
=>>SET T <Enter>

Alias
Relay Aliases
(RW Bit or Analog Qty. or Terminal or Bus-Zone, 7 Character Alias [0-9 A-Z _])
1: IO1,"FDR_1"
?  LIST <Enter>
1: IO1,"FDR_1"
2: IO2,"FDR_2"
3: IO3,"FDR_3"
4: IO4,"TRFR_1"
5: IO5,"TB_1"
6: IO6,"TB_2"
7: BZ1,"BUS_1"
8: BZ2,"BUS_2"
.
.
.
60: TLED_15,"89_ALRM"
61: TLED_16,"PT_ALRM"
1: IO1,"FDR_1"
?
```

Figure 6.87 List of Default Primitive Names and Associated Alias Names

Type **DELETE 43 <Enter>** at the first action prompt to delete the first 43 default alias names, as shown in *Figure 6.88*.

```
1: IO1,"FDR_1"

?  DELETE 43 <Enter>
```

Figure 6.88 Deletion of the First 43 Alias Names

Type **> <Enter>** to advance to the next available line in the settings list. Enter the alias names for the analog channels and Relay Word bits, as shown in *Figure 6.89*.

We include the alias names for the three protection latch bits (PLT01, PLT02, and PLT03). We use these protection latch bits for local control of the differential elements (PLT01), the breaker fail protection (PLT02), and the relay test mode (PLT03). Because the protection logic default settings include these three protection latch bits as default settings, we did not select these protection latch bits as user-defined logic.

```
1: OUT107,"TEST"
?  > <Enter>
19:
?  IO1,TD_A <Enter>
20:
?  IO2,TD_B <Enter>
21:
?  IO3,TD_C <Enter>
22:
?  IO4,TE_A <Enter>
23:
?  IO5,TE_B <Enter>
24:
?  IO6,TE_C <Enter>
.
.
.
136:
?  PLT01,DIFF_EN <Enter>
137:
?  PLT02,BF_EN <Enter>
138:
?  PLT03,TNS_SW <Enter>
139:
?  END <Enter>
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.89 Analog Quantities and Relay Word Bits Alias Names

This concludes the alias settings. The next settings class is the Global settings.

Global Settings

Global settings comprise settings that apply to all protection settings groups. For example, when changing from Protection Setting Group 1 to Protection Setting Group 2, Global settings such as station name and relay name still apply. *Figure 6.90* shows the setting changes we need for our example. Because we declared the alias names in the alias settings class, use either the alias names or the primitive names when entering settings.

Enter the number of poles at the station for the NUMBK settings. There are three terminals in the differential equation, each with three poles. The total number of poles, therefore, equals nine poles, and we set NUMBK to 9.

Setting NUMBK to 9 makes 9 corresponding circuit breaker auxiliary input equations (52A01–52A09) and nine corresponding trip equations (TR01–TR09) available for setting. Because we do not need circuit breaker auxiliary inputs for this example, we need not enter values for the circuit breaker auxiliary input equations. For this example, the only Global setting change is the number of circuit breakers; all other settings remain at default settings.

```
=>>SET G <Enter>
Global
General Global Settings
Station Identifier (40 characters)
SID := "Station A"
?<Enter>
Relay Identifier (40 characters)
RID := "Relay 1"
?<Enter>
Number of Breakers (N,1-21)                          NUMBK   := 5      ?9 <Enter>
Number of Disconnects (N,1-60)                       NUMDS   := N      ?END <Enter>
Global
.
.
.
52A08 := NA
52A09 := NA
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.90 Global Settings for Application 3

This concludes the global settings. The next settings class is the zone configuration group settings.

Zone Configuration Group Settings

The terminal-to-bus-zone SELOGIC control equations identify an analog channel, a differential element, and the conditions for which the relay assigns the analog channel to the differential element. In this application, there are no disconnect auxiliary contacts available, and we permanently assign analog channels to the appropriate differential elements. All 21 channels are available for setting, but only the first 9 are part of the differential protection. We, therefore, assign only the first nine analog channels to the differential elements. The protection philosophy calls for the use of the voltage elements as an additional trip criterion.

Calculate the ratio settings as follows:

$$\begin{aligned} \text{PTR} &= \frac{\text{Primary Nominal Voltage}}{\text{Secondary Nominal Voltage}} \\ &= \frac{115000}{115} \\ &= 1000 \end{aligned}$$

Equation 6.10

Figure 6.91 shows the zone configuration settings.

Because there are no disconnects available at this station, we cannot use the dynamic zone selection logic. Because we cannot use the dynamic zone selection logic, the CTs are always considered in the differential equations.

When we consider only the disconnect auxiliary contacts as conditions in the terminal-to-bus-zone connection settings, we would have entered a 1 for each of the terminal-to-bus-zone connection settings.

This example, however, also includes two other conditions that must be a logical 1 before the relay considers the CTs in the differential equations. The two conditions are

- the differential enable switch (Alias DIFF_EN)
- and the terminal-out-of-service switch (TOS*nn*, where *nn* is the terminal number)

Front-panel pushbutton **PB1** controls DIFF_EN. The function of DIFF_EN is to remove all the terminals from the differential equations with a single command. Enter **DIFF_EN** at every terminal-to-bus-zone variable.

The terminal out-of-service switch, which removes individual terminals from the differential calculations, is part of the front-panel local controls. Include an individual terminal out-of-service (TOS*nn*) for each terminal.

The zone configuration default settings are for a specific substation with arbitrarily selected alias names, serving only as an example. Delete the terminal-to-bus-zone default settings for ease of setting zone configuration settings for the new substation. With the terminal-to-bus-zone default settings deleted, the setting prompts no longer reference the default settings.

You can use a combination of primitive and alias names when entering the terminal-to-bus-zone and bus-zone-to-bus-zone settings. *Figure 6.91* shows the Zone configuration settings for this application. Instead of entering **1 AND DIFF_EN AND NOT TOS*nn***, we omit the 1, and enter only **DIFF_EN AND NOT TOS*nn*** for each setting.

```
=>>SET Z <Enter>

Zone Config Group 1
Potential Transformer Ratio
Potential Transformer Ratio -V01 (1-10000)          PTR1    := 2000   ?1000 <Enter>
Potential Transformer Ratio -V02 (1-10000)          PTR2    := 2000   ?1000 <Enter>
Potential Transformer Ratio -V03 (1-10000)          PTR3    := 2000   ?1000 <Enter>
Current Transformer Ratio
Current Transformer Ratio -I01 (1-50000)            CTR01   := 600    ?400 <Enter>
Current Transformer Ratio -I02 (1-50000)            CTR02   := 600    ?400 <Enter>

.
.
.
Current Transformer Ratio -I09 (1-50000)            CTR09   := 600    ?400 <Enter>
Current Transformer Ratio -I10 (1-50000)            CTR10   := 600    ?> <Enter>
```

Figure 6.91 Zone Configuration Group Settings for Application 3

```
Zone Configuration: Terminal to Bus-Zone Connections
Terminal, Bus-Zone, Polarity (P,N)
IO1BZ1C := TD_A, NORTH_A, P
?  DELETE 100 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO1,BZ1,P <Enter>
TD_A to NORTH_A Connection (SELogic Equation)
IO1BZ1V := NA
?  PLTO1 AND NOT TOSO1 <Enter>

Terminal, Bus-Zone, Polarity (P,N)
?  IO2,BZ2,P <Enter>
TD_B to NORTH_B Connection (SELogic Equation)
IO2BZ2V := NA
?  PLTO1 AND NOT TOSO1 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO3,BZ3,P <Enter>
TD_C to NORTH_C Connection (SELogic Equation)
IO3BZ3V := NA
?  PLTO1 AND NOT TOSO1 <Enter>

Terminal, Bus-Zone, Polarity (P,N)
?  IO4,BZ1,P <Enter>
TE_A to NORTH_A Connection (SELogic Equation)
IO4BZ1V := NA
?  PLTO1 AND NOT TOSO2 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO5,BZ2,P <Enter>

TE_B to NORTH_B Connection (SELogic Equation)
IO5BZ2V := NA
?  PLTO1 AND NOT TOSO2 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO6,BZ3,P <Enter>
TE_C to NORTH_C Connection (SELogic Equation)
IO6BZ3V := NA
?  PLTO1 AND NOT TOSO2 <Enter>

Terminal, Bus-Zone, Polarity (P,N)
?  IO7,BZ1,P <Enter>
TF_A to NORTH_A Connection (SELogic Equation)
IO7BZ1V := NA
?  PLTO1 AND NOT TOSO3 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO8,BZ2,P <Enter>

TF_B to NORTH_B Connection (SELogic Equation)
IO8BZ2V := NA
?  PLTO1 AND NOT TOSO3 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO9,BZ3,P <Enter>
TF_C to NORTH_C Connection (SELogic Equation)
IO9BZ3V := NA
?  PLTO1 AND NOT TOSO3 <Enter>

Terminal, Bus-Zone, Polarity (P,N)
?<Enter>
Zone Configuration: Bus-Zone to Bus-Zone Connections
Bus-Zone, Bus-Zone
? DELETE 100 <Enter>
Bus-Zone, Bus-Zone
?<Enter>

Zone Supervision
Differential Element Zone Supervision (Y,N)          E87ZSUP := N      ?Y <Enter>
Zone 1 Supervision (SELogic Equation)
Z1S := 1
?  591P1 OR 592P1 OR 271P1 <Enter>
Zone 2 Supervision (SELogic Equation)
Z2S := 1
?  592P1 OR 592P1 OR 271P1 <Enter>
Zone 3 Supervision (SELogic Equation)
Z3S := 1
?  591P1 OR 592P1 OR 271P1 <Enter>

Zone Switching Supervision
Zone Switching Supervision (Y,N)                     EZSWSUP := N      ?<Enter>
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.91 Zone Configuration Group Settings for Application 3 (Continued)

This concludes the zone configuration group settings. The next settings class is the protection group settings.

Protection Group Settings

Settings of this class comprise the protection functions, beginning with the function enable settings.

The protection philosophy calls for the blocking of the busbar protection for an open CT condition. Set E87SSUP := Y (see *Figure 5.11* and *Figure 5.18* for more information) to use the sensitive differential element for this requirement. Set ECSL := N because we do not use the Coupler Security Logic.

Terminal out of service is a local bit (local bits provide programming capabilities for functions available on the front-panel screen under `LOCAL CONTROL`). Include the terminal out of service in the trip equations to disable the outputs from individual terminals.

This local control selectively takes a terminal out of service, whereas the **87(DIFF) ENABLED** pushbutton disables all the trip outputs. Set ETOS := 3 because there are three breakers in the bus-zone differential protection.

There are nine breaker poles (NUMBK := 9), all of which need relay breaker failure protection. Set EBFL := 9 to enable nine breaker failure logics. Set E50 := N and E51 := N because we do not need overcurrent protection for this application.

The protection philosophy calls for undervoltage as an additional trip criterion. Because the voltage elements are enabled in the default settings, leave EVOLT := Y.

Default settings for the differential elements are 60 percent for Slope 1 and 80 percent for Slope 2. Enable the advanced settings by setting EADVS := Y to change the slope setting.

With EADVS := Y, the slope settings and incremental restrained and operating current settings become available. For this application, we use the default values for the sensitive differential element, the restrained differential element, and the directional element.

The protection philosophy calls for breaker failure protection. This application shows an example of how to calculate breaker failure settings for the Terminal TD circuit breaker. In this example, we apply the settings calculated for Terminal TD to all the terminals at the station. Because network parameters are different, be sure to calculate values for the other terminals; do not assume that settings for one terminal apply to all other terminals at the same station.

EBFL, Enable Breaker Fail Setting

Enter the number of per-pole breaker fail logics you want to enable.

In this single-relay application, we need nine per-pole breaker fail logics, because we must provide breaker failure protection for three breakers.

EBFL := **9** Enable breaker fail

Figure 6.92 shows the components of breaker failure protection for line protection. Do not consider remote terminal information when considering breaker failure protection for equipment such as capacitor banks, transformers, etc.

Figure 6.92 Breaker Failure Timing Diagram

Use the SEL-487B to provide circuit breaker failure protection for Circuit Breaker TD in *Figure 6.93*.

Figure 6.93 shows the power system for this example. Line 1 and Line 2 connect Station S and Station R. We set the breaker failure protection in the SEL-487B to detect circuit breaker failures for Terminal TD at Station S. This example uses a line with three-pole tripping, but the relay provides the flexibility to also apply circuit breaker failure for single-pole trip circuit breakers. This flexibility is possible because the current measurement and timers are available on a per-phase basis.

Figure 6.93 Power System for Circuit Breaker Failure Scheme 2

50FP01, Phase Current Level Detector Setting

NOTE: This is one method for calculating setting 50FP01. Use your company's practices and policies for determining the pickup setting for your particular application.

Set the current pickup (50FP01) greater than maximum load and less than the fault current that flows through Terminal TD. Assume that the total load current (I_S) is 3.25 A secondary, supplied from Substation S. Calculate setting 50FP01 with all the load current I_S through Terminal TD.

$$\begin{aligned} 50FP01 &= 120\%(\text{Percent Current} \bullet I_S) \\ &= 120\%(100\%\ \text{Current} \bullet 3.25\ \text{A}) \\ &= 3.91\ \text{A secondary} \end{aligned}$$

Equation 6.11

A fault study shows that the minimum ground fault current, $I_{fault\ minimum}$, is 4.2 A secondary when the parallel line is in service at minimum generation. Calculate the 50FP01 setting for dependability at half the minimum fault current.

$$\begin{aligned} 50FP01 &= 0.5(\text{Percent Current} \bullet I_{fault\ minimum}) \\ &= 0.5(100\%\ \text{Current} \bullet 4.20\text{A}) \\ &= 2.10\ \text{A secondary} \end{aligned}$$

Equation 6.12

Although the result of this setting calculation is less than maximum load, obtain greater dependability by using this calculation to set the 50FP01 element to 2.10 A.

BFPU01, Circuit Breaker Failure Time Delay Setting

BFPU01 (Breaker Failure Time Delay-Terminal TD) is the time for which the input (BFI01) to Timer BFPU01 must be continuously present to result in a circuit breaker failure trip operation. The recommended setting for BFPU1 is the sum of the following:

- Maximum circuit breaker operating time
- OPH01 maximum dropout time
- Safety margin

Figure 6.94 shows the timing diagram for setting Timer BFPU01.

Figure 6.94 Timing Diagram for Setting BFPU01–Scheme 2

NOTE: If the relay is using TiDL (EtherCAT), the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay.

To maintain system stability, you must clear the fault within the total clearing time, assumed to be 17 cycles for this example. Use the maximum operating time of the local and remote circuit breakers. The maximum circuit breaker operating time, t_{bk}, is 3 cycles for this example.

Use 0.75 cycle for tOPH, the maximum assertion time of the open-phase detector, OPH01. You must also include the communications channel time, t_{ch}, for remote circuit breaker tripping. To determine setting BFPU1, you must find the safety margin, t_s. Use *Equation 6.13* to calculate the safety margin:

$$\begin{aligned} t_s &= tt - (t_{lr} + t_{lbk} + t_{OPH} + t_{86} + t_{ch} + t_{rbk}) \\ &= 17 - (2 + 3 + 0.75 + 1 + 1 + 3) \\ &= 5.75 \text{ cycles} \end{aligned}$$

Equation 6.13

where:

t_s = safety margin
t_t = total clearing time (17 cycles)
t_{lr} = line protection maximum operating time (2 cycles)
t_{lbk} = local circuit breaker maximum operating time (3 cycles)
t_{OPH} = open-phase detection OPH01 maximum assertion time (0.75 cycle)
t_{86} = auxiliary breaker failure relay operating time (1 cycle)
t_{ch} = communications channel maximum operating time (1 cycle)
t_{rbk} = remote circuit breaker maximum operating time (3 cycles)

Use the safety margin result from *Equation 6.13* to calculate BFPU01:

$$\begin{aligned} \text{BFPU01} &= t_{lbk} + t_{OPH} + t_s \\ &= 3 + 0.75 + 5.75 \\ &= 9.5 \text{ cycles} \end{aligned}$$

Equation 6.14

BFPU01 := **9.50** cycles Breaker Failure Time Delay

RTPU01, Retrip Time Delay Setting

If the circuit breaker is equipped with two trip coils, the relay should attempt to retrip the protected circuit breaker before a circuit breaker failure trip asserts. In this example, local circuit breaker maximum operating time is 3 cycles, and the open-phase detection assertion is 0.75 cycle. Wait 4 cycles for the retrip.

RTPU01 := **4.00** Retrip Time Delay

BFI01 and ABFI01, Circuit Breaker Initiation Settings

Figure 6.95 shows the breaker failure initiate contact for Terminal TD. Wire similar contacts for Terminal TE and Terminal TF into the SEL-487B.

Figure 6.95 Breaker Failure Protection Wiring for Terminal TD

For this example, assume the breaker failure initiate signal is continuous. Because this is a breaker-and-a-half busbar layout, use the input extension option of *Alternate Breaker Failure Initiating Input With Extension and/or Seal In Logic on page 5.31* (see *Circuit Breaker Failure Protection on page 5.30* for more information).

Figure 6.96 shows the circuit breaker failure initiation extension and seal-in logic, and *Figure 6.97* shows the circuit breaker failure logic.

Figure 6.96 Circuit Breaker Failure Initiation Extension and Seal-In Logic

Scheme 2 uses a combination of the logic in *Figure 6.96* and *Figure 6.97* by setting the output from the circuit breaker failure initiation extension and seal-in logic (ABFIT01, *Figure 6.96*) as the breaker failure initiate input of the breaker failure logic (BFI01, *Figure 6.97*).

Figure 6.97 Circuit Breaker Failure Logic

Because this is an example of a three-pole circuit breaker, enter the same breaker failure initiate input (IN201) for all three phases (ATBFI01–ATBFI03) for Terminal TD.

Table 6.55 shows the breaker failure initiate input (IN201) and the assignment and setting to combine the logic for Terminal TD, stating the alias names where applicable. Settings for the remaining terminals are similar.

Table 6.55 Input and Relay Word Bit Assignments and Settings for the Combined Logic

Assignment	Setting to Achieve the Assignment
IN201 to ATBFI01	TDA_BFI := ITD_BFI
IN201 to ATBFI02	TDB_BFI := ITD_BFI
IN201 to ATBFI03	TDC_BFI := ITD_BFI
ABFIT01 to BFI01	BFI01 := ABFIT01
ABFIT02 to BFI02	BFI02 := ABFIT02
ABFIT03 to BFI03	BFI03 := ABFIT03

BFIDO01, Circuit Breaker Failure Protection Initiation Dropout Delay Setting

Setting EBFIS01 applies to the case where the breaker failure initiate signal is not continuous. Because the breaker failure initiate signal is continuous in this example, leave EBFIS01 at the default value of N. Consider the case where the entire fault current initially flows through Terminal TG, and no current flows through Terminal TD. Timer BFIDO01 replaces the current input 50FI01 (*Figure 6.96*) for the period when the entire fault current flows through Circuit Breaker TG. During this period, not enough current is available to assert Relay Word bit 50FI01 to turn AND Gate 1 on (*Figure 6.96*). Timer BFIDO01 extends the breaker failure initiate signal, waiting for Terminal TD to interrupt the fault current. The maximum circuit breaker operating time for Terminal TG is 3 cycles; allow a short safety margin and set Timer BFIDO01 to 4 cycles.

BFID01 := **4.00** Breaker Failure Initiate Dropout Delay-BK1

Negative- and Zero-Sequence Overvoltage, Thresholds and Phase Undervoltage Settings

Conduct fault studies to obtain appropriate settings for the negative-sequence and zero-sequence overvoltage elements.

For this example, assume a setting of 15 V for both negative-sequence and zero-sequence overvoltage elements and 45 V for the undervoltage elements.

59P1P1 := **15** Overvoltage Element 1 pickup setting. Use 59O1 = 3V2FIM for the negative-sequence operating quantity.

59P2P1 := **15** Overvoltage Element 2 pickup setting. Use 59O2 = 3V0FIM for the zero-sequence operating quantity.

27P1P1 := **45** Undervoltage Element 1 pickup setting. Use V0*n*FIM (*n* = 1–3) for the undervoltage operating quantity.

TR01–TR09, Trip Equations Settings

Pay close attention to the trip logic (TR01–TR09) settings. Because this is a single-relay application, CTs from the three phases (A-phase, B-phase, and C-phase) from each terminal are assigned to three different differential elements (see *Single-Relay Application on page 6.3*). Setting NUMBK (Global settings) to 9 also makes 9 corresponding trip equations (TR01–TR09) available for setting. All nine channels are part of the breaker failure protection, as well as part of the bus-zone protection. Therefore, we include the differential trip outputs as well as the station breaker fail trip outputs in the trip equation of each terminal. Setting the trip equations involves assigning the nine differential trip bits to the correct nine trip equations, and assigning the nine station breaker failure trip bits to the correct nine trip equations.

TDURD, Minimum Trip Duration Time Delay Setting

Although the SEL-487B includes nine trip logics, there is only one Minimum Trip Duration Time Delay setting. Set the timer TDURD longer than the operating time of the slowest circuit breaker at the station, using the default value of 12 cycles.

The trip logic latches the trip outputs TRIP*kk* after TR*kk* assertion. Press the **TARGET RESET** pushbutton on the front panel to deassert the trip outputs. Alternatively, enter specific reset conditions at the ULTR*kk* settings.

The SEL-487B triggers an event report when any one of the following Relay Word bits asserts:

- 87BTR (any one of the differential trip bits)
- SBFTR (any one of the station breaker failure trip bits)
- TRIP (any one of the nine trip logic outputs)
- ER (user-defined functions)
- **TRI** (ASCII command)

The protection philosophy calls for the relay to generate an event report when the negative-sequence and zero-sequence overvoltage elements assert. To achieve this, enter Relay Word bit 591P1 and 592P1 at the ER prompt.

ER := **591P1 OR 592P1 OR 87S1 OR 87S2 OR 87S3**

Protection Latch bit PLT02 enables/disables the breaker failure protection in the default settings. Include PLT02 in each breaker failure initiate setting for the **BKR FAIL ENABLE** pushbutton to control the breaker failure protection. *Figure 6.98* shows the group settings.

```
=>>SET <Enter>

Group 1
Relay Configuration
Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y      ?<Enter>
Coupler Security Logic (N,1-4)                       ECSL    := N      ?<Enter>
Terminal Out of Service (N,1-21)                     ETOS    := 5      ?3 <Enter>
Breaker Failure Logic (N,1-21)                       EBFL    := 6      ?9 <Enter>
Definite Time Overcurrent Elements (N,1-21)          E50     := N      ?> <Enter>

Sensitive Differential Element
Sensitive Differential Element Pickup (0.05-1 pu)    S87P    := 0.10   ?> <Enter>
Restrained Differential Element
Restrained Diff Element Pickup (0.10-4 pu)           O87P    := 1.00   ?> <Enter>

Directional Element
Dir Element O/C Supervision Pickup (0.05-3 pu)       50DSP   := 0.05   ?> <Enter>
Terminal Out-of-Service
Terminal 01 Out-of-Service (SELogic Equation)
TOS01 := LB01
?  > <Enter>
Breaker 01 Failure Logic
External Breaker Fail -BK01 (Y,N)                    EXBF01  := N      ?<Enter>
Fault Current Pickup -BK01 (0.50-50 amps,sec)        50FP01  := 3.00   ?2.1 <Enter>
Brkr Fail Init Pickup Delay -BK01 (0.00-6000 cyc)    BFPU01  := 6.00   ?9.5 <Enter>
Retrip Delay -BK01 (0.00-6000 cyc)                   RTPU01  := 3.00   ?4 <Enter>

Breaker Fail Initiate -BK01 (SELogic Equation)
BFI01 := IN101 AND BF_EN
?  ABFITO1 <Enter>
Alt Breaker Fail Initiate -BK01 (SELogic Equation)
ATBFI01 := NA
?  IN201 AND PLTO2 <Enter>
Breaker Fail Initiate Seal-In -BK01 (Y,N)            EBFIS01 := N      ?<Enter>
Brkr Fail Init Dropout Delay -BK01 (0.00-1000 cyc)   BFIDO01 := 1.50   ?4 <Enter>

Breaker 02 Failure Logic
External Breaker Fail -BK02 (Y,N)                    EXBF02  := N      ?<Enter>
Fault Current Pickup -BK02 (0.50-50 amps,sec)        50FP02  := 3.00   ?2.1 <Enter>
Brkr Fail Init Pickup Delay -BK02 (0.00-6000 cyc)    BFPU02  := 6.00   ?9.5 <Enter>
Retrip Delay -BK02 (0.00-6000 cyc)                   RTPU02  := 3.00   ?4 <Enter>
Breaker Fail Initiate -BK02 (SELogic Equation)
BFI02 := IN102 AND BF_EN
?  ABFITO2 <Enter>

Alt Breaker Fail Initiate -BK02 (SELogic Equation)
ATBFI02 := NA
?  IN201 AND PLTO2 <Enter>
Breaker Fail Initiate Seal-In -BK02 (Y,N)            EBFIS02 := N      ?<Enter>
Brkr Fail Init Dropout Delay -BK02 (0.00-1000 cyc)   BFIDO02 := 1.50   ?4 <Enter>
.
.
.

Trip Logic
Trip 01 (SELogic Equation)
TR01 := TDA_SBF OR TD_TA
?<Enter>
Unlatch Trip 01 (SELogic Equation)
ULTR01 := NA
?<Enter>

Trip 02 (SELogic Equation)
TR02 := TDB_SBF OR TD_TB
?<Enter>
Unlatch Trip 02 (SELogic Equation)
ULTR02 := NA
?<Enter>
Trip 03 (SELogic Equation)
TR03 := TDC_SBF OR TD_TC
?<Enter>
Unlatch Trip 03 (SELogic Equation)
ULTR03 := NA
?<Enter>

Trip 04 (SELogic Equation)
TR04 := TEA_SBF OR TE_TA
?<Enter>
Unlatch Trip 04 (SELogic Equation)
ULTR04 := NA
?<Enter>
```

Figure 6.98 Protection Group Settings for Application 3

```
Trip 05 (SELogic Equation)
TR05 := TEB_SBF OR TE_TB OR TEC_SBF OR TE_TC
?  TEB_SBF OR TE_TB <Enter>
Unlatch Trip 05 (SELogic Equation)
ULTR05 := NA
?<Enter>

Trip 06 (SELogic Equation)
TR06 := NA
?  TEC_SBF OR TE_TC
Unlatch Trip 06 (SELogic Equation)
ULTR06 := NA
?<Enter>
.
.
.
Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000  ? <Enter>

Event Report Trigger Equation (SELogic Equation)
ER := R_TRIG 87ST
?  591P1 OR 592P1 OR 87S1 OR 87S2 OR 87S3 <Enter>
Group 1
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.98 Protection Group Settings for Application 3 (Continued)

This concludes the protection group settings. The next settings class is the front-panel settings.

Front-Panel Settings

The front-panel settings class is where we set functions visible and accessible from the front panel. Settings include LEDs, pushbuttons, front-panel screen selection, display point, and local control. All of these functions have default settings, except five pushbuttons and the display points.

Because not all functions are required in this application, change the settings according to the protection philosophy. Remove the following LED settings:

- ZONE 4 trip indication (LED 6)
- ZONE 5 trip indication (LED 7)
- ZONE 6 trip indication (LED 8)
- 50 indication (LED 9)
- 51 indication (LED 10)
- 89 IN PROG (LED 14)
- 89 ALARM (LED 15)

Also, change the number of Local bits for the TOS (Terminal Out of Service) function to the correct number, 3. *Figure 6.99* shows the settings.

```
=>>SET F <Enter>
Front Panel
Front Panel Settings
Front Panel Display Time-Out (OFF,1-60 mins)         FP_TO   := 15     ? <Enter>
Enable LED Asserted Color (R,G)                      EN_LEDC := G      ? <Enter>
Trip LED Asserted Color (R,G)                        TR_LEDC := R      ? <Enter>

Pushbutton LED 1 (SELogic Equation)
PB1_LED := PLT01 # DIFFERENTIAL PROTECTION ENABLED
?  <Enter>
PB1_LED Assert & Deassert Color (Enter 2: R,G,A,O)   PB1_COL := AO     ? <Enter>
Pushbutton LED 2 (SELogic Equation)

PB2_LED := PLT02 # BREAKER FAILURE ENABLED
.
.
.
PB12LED Assert & Deassert Color (Enter 2: R,G,A,O)   PB12COL := AO     ? <Enter>

Target LED 1 (SELogic Equation)
T1_LED := 87BTR
?  <Enter>
Target LED 1 Latch (Y,N)                             T1LEDL  := Y      ? <Enter>
T1_LED Assert & Deassert Color (Enter 2: R,G,A,O)    T1LEDC  := RO     ? <Enter>
Target LED 2 (SELogic Equation)
T2_LED := SBFTR
?  <Enter>
.
.
.

Target LED 6 Latch (Y,N)                             T6LEDL  := Y      ?N <Enter>
T6_LED Assert & Deassert Color (Enter 2: R,G,A,O)    T6LEDC  := RO     ? <Enter>
Target LED 7 (SELogic Equation)
T7_LED := 87Z5
?  <Enter>
Target LED 7 Latch (Y,N)                             T7LEDL  := Y      ?N <Enter>
T7_LED Assert & Deassert Color (Enter 2: R,G,A,O)    T7LEDC  := RO     ? <Enter>
Target LED 8 (SELogic Equation)
T8_LED := 87Z6
?  <Enter>
Target LED 8 Latch (Y,N)                             T8LEDL  := Y      ?N <Enter>
T8_LED Assert & Deassert Color (Enter 2: R,G,A,O)    T8LEDC  := RO     ? <Enter>

Target LED 9 (SELogic Equation)
T9_LED  := 50P01T OR 50P02T OR 50P03T OR 50P04T OR 50P05T OR 50P06T OR \
           50P07T OR 50P08T OR 50P09T OR 50P10T OR 50P11T OR 50P12T OR \
           50P13T OR 50P14T OR 50P15T OR 50P16T OR 50P17T OR 50P18T OR \
           50P19T OR 50P20T OR 50P21T
?  <Enter>
Target LED 9 Latch (Y,N)                             T9LEDL  := Y      ?N <Enter>
T9_LED Assert & Deassert Color (Enter 2: R,G,A,O)    T9LEDC  := RO     ? <Enter>
Target LED 10 (SELogic Equation)
T10_LED := 51T01 OR 51T02 OR 51T03 OR 51T04 OR 51T05 OR 51T06 OR \
           51T07 OR 51T08 OR 51T09 OR 51T10 OR 51T11 OR 51T12 OR \
           51T13 OR 51T14 OR 51T15 OR 51T16 OR 51T17 OR 51T18 OR \
           51T19 OR 51T20 OR 51T21
?  <Enter>
Target LED 10 Latch (Y,N)                            T10LEDL := Y      ?N <Enter>
T10LED Assert & Deassert Color (Enter 2: R,G,A,O)    T10LEDC := RO     ? <Enter>

Target LED 11 (SELogic Equation)
T11_LED := 87ST
?  <Enter>
.
.
.
?  <Enter>
Target LED 24 Latch (Y,N)                            T24LEDL := N      ? <Enter>
T24LED Assert & Deassert Color (Enter 2: R,G,A,O)    T24LEDC := RO     ? <Enter>


Selectable Screens for the Front Panel

Front Panel Display Update Rate (OFF,1-15 seconds)   SCROLD  := 5      ? <Enter>
Station Battery Screen (Y,N)                         STA_BAT := N      ? <Enter>
Fundamental Voltage and Current Screen (Y,N)         FUND_VI := Y      ? <Enter>
Differential Metering (Y,N)                          DIFF    := Y      ? <Enter>
Terminals Associated with Zones (Y,N)                ZONECFG := Y      ? <Enter>

Selectable Operator Pushbuttons

Pushbutton 1 HMI Screen (OFF,AP,DP,EVE,SER)          PB1_HMI := OFF    ?> <Enter>
```

Figure 6.99 Front-Panel Settings for Application 3

```
Front Panel Event Display

Enable HMI Auto Display of Event Summaries (Y,N)     DISP_ER := Y      ?> <Enter>

Display Points
(Boolean):RWB Name, "Label", "Set String", "Clear String", "Text Size"
(Analog) : Analog Quantity Name, "User Text and Formatting", "Text Size"

1:
?  <Enter>


Local Control
(Local Bit, Local Label, Local Set State, Local Clear State, Pulse Enable)

1: LBO1,"F1 OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N
?  LBO1,"Terminal TD","OUT OF SERVICE","IN SERVICE",N<Enter>
2: LBO2,"F2 OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N
?  LBO2,"Terminal TE","OUT OF SERVICE","IN SERVICE",N<Enter>
3: LBO3,"F3 OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N
?  LBO3,"tERMINAL TF","OUT OF SERVICE","IN SERVICE",N<Enter>
4: LBO4,"T1 OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N
?  DELETE<Enter>
4: LBO5,"TB OUT OF SERVICE","OUT OF SERVICE","IN SERVICE",N
?  END<Enter>

Front Panel

Front Panel Settings

.
.
.

SER Parameters

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

=>>
```

Figure 6.99 Front-Panel Settings for Application 3 (Continued)

This concludes the front-panel settings. The next settings class is the control output settings.

Control Output Settings

In this setting class, we assign the logic or Relay Word bits in the relay to output contacts. We need six output contacts for our example:

- three for the differential and breaker failure trip outputs
- three for direct transfer trip outputs

Although not specifically called for in the protection philosophy, it is good practice to also include the TEST and ALARM outputs in the relay settings.

Because the relay interprets the NUMBK setting as the number of poles, there are nine trip equations for this application. There is, of course, only one circuit breaker for each terminal. We therefore combine the appropriate trip outputs from the breaker trip logic (TRIP01–TRIP09, see *Figure 6.85*) to provide a single trip output for each circuit breaker. For example, we set (Group settings) the trip equations for Terminal TD to TR01 := TDA_SBF OR TD_TA, TR02 := TDB_SBF OR TD_TB, and TR03 := TDC_SBF OR TD_TC, with the corresponding breaker trip logic output alias names of TRTD_A, TRTD_B, and TRTD_C. Because Terminal TD has only one circuit breaker, assertion of any one of the three breaker trip logic outputs (TRTD_A, TRTD_B, or TRTD_C) must trip the circuit breaker of Terminal TD. To achieve this combination, enter all three of the breaker trip logic output Relay Word bits in the output equation of the circuit

breaker of Terminal TD. We assign the output Relay Word bits of the breaker failure logic to output contacts OUT204, OUT205, and OUT206 for direct transfer tripping.

Figure 6.100 shows the output settings. We include Protection Latch Bit PLT03 in the output equation. With PLT03 included in every output equation, the **RELAY TEST MODE** pushbutton disables all output contacts.

```
=>>SET O <Enter>
Output
Main Board
OUT101 := TRTD_A AND NOT TNS_SW
?  NA <Enter>
OUT102 := TRTD_B AND NOT TNS_SW
?  NA <Enter>
OUT103 := TRTD_C AND NOT TNS_SW
?  NA <Enter>

OUT104 := TRTE_A AND NOT TNS_SW
?  NA <Enter>
OUT105 := TRTE_B AND NOT TNS_SW
?  NA <Enter>
OUT106 := NA
?  > <Enter>
Interface Board #1
OUT201 := NA
?  (TRTD_A OR TRTD_B OR TRTD_C) AND NOT PLT03 <Enter>
OUT202 := NA
?  (TRTE_A OR TRTE_B OR TRTE_C) AND NOT PLT03 <Enter>
OUT203 := NA
?  (TRTF_A OR TRTF_B OR TRTF_C) AND NOT PLT03 <Enter>

OUT204 := NA
?  (TDA_SBF OR TDB_SBF OR TDC_SBF) AND NOT PLT03 <Enter>
OUT205 := NA
?  (TEA_SBF OR TEB_SBF OR TEC_SBF) AND NOT PLT03 <Enter>
OUT206 := NA
?  TFA_SBF OR TFB_SBF OR TFC_SBF AND NOT PLT03 <Enter>
OUT207 := NA
?  END <Enter>

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

=>>
```

Figure 6.100 Output Settings for Application 3

This concludes the settings for Application 3.

Application 4: Single Bus and Transfer Bus With Bus Coupler

This application describes the busbar arrangement shown in *Figure 6.101*, single bus and transfer bus with tie breaker (bus coupler). The busbar arrangement consists of two busbars (main busbar and transfer busbar), four feeders and a tie breaker. Consider the following to set and configure the relay:

- Busbar classification
- Protection philosophy
- Protection functions selection
- Number of SEL-487B Relays and I/O boards
- Input, logic, and output allocation and alias name assignment

- Station layout update
- Relay setting and configuration

Figure 6.101 Single Bus and Transfer Bus With Bus Coupler (Tie Breaker)

Busbar Classification

The busbar classification provides general busbar layout and CT positioning (inboard or outboard) information, and declares the tie-breaker (bus coupler) configuration.

- Description:
  - Single bus and transfer bus with tie breaker
- Current transformers:
  - Outboard (free standing)
- Disconnects:
  - Only 89A disconnect auxiliary contacts are available
- Bus coupler (tie breaker):
  - Single CT with one CT core for busbar protection
- Future expansion:
  - Five feeders

Protection Philosophy

Although the SEL-487B offers a variety of protection and control functions, not every substation uses all of these functions. Carefully consider each application before stating the functional requirements. The protection philosophy for this application is as follows:

1. Rename only the terminals and bus-zones with alias names.
2. Block the busbar protection for an open-circuit CT.
3. Use the 89B disconnect auxiliary contacts to dynamically configure the station.
4. Use the zone-switching supervision logic.
5. Prevent the loss of Busbar 1 for a fault between the tie breaker and tie-breaker CT.
6. Ensure bus-zone protection stability for all operating conditions.

Protection Functions Selection

We select the protection functions early in the relay setting and configuration process because the choice of protection functions determines the number of relay digital inputs and outputs necessary for the application. Study the protection philosophy to determine which protection and/or control functions to apply to any particular substation. For example, in this application the protection philosophy calls for the use of the zone-switching supervision, but not for breaker failure protection. The SEL-487B offers a number of protection functions as standard features, but it also includes the capability through SELOGIC control equations to create user-configurable functions.

To prevent tripping of Busbar 1 when there is a fault between the tie breaker and tie-breaker CT, we can delay tripping of Busbar 1 and trip the tie breaker first (see *Protection Group Settings on page 6.128*). We then remove the tie-breaker currents from the differential calculations. To remove the tie-breaker currents from the differential calculations, we use the breaker auxiliary contact from the tie breaker and a combination of the coupler security logic and zone supervision.

To properly identify and categorize the protection philosophy requirements, group the protection functions as follows:

- standard protection functions (available in the relay)
- user-defined protection functions (created with SELOGIC control equations)

Standard Functions

Refer to the protection philosophy and select the standard functions required for the application. *Table 6.56* shows the selection of the standard functions.

Table 6.56 Selection of the Standard Protection Functions (Sheet 1 of 2)

Protection Function	Selection	Comment
CT ratio mismatch ≤ 10:1	Yes	10:1 mismatch is the maximum allowable mismatch
Circuit breaker status logic	No	Not required
Disconnect monitor logic	No	We need both 89A and 89B disconnect; only the 89A contact is available.
Differential protection	Yes	Busbar protection (zone specific and check zone)
Dynamic zone selection logic	Yes	Use the zone selection to reconfigure the differential protection according to the disconnect positions.
Sensitive differential protection	Yes	CT open circuit detection

Table 6.56 Selection of the Standard Protection Functions (Sheet 2 of 2)

Protection Function	Selection	Comment
Zone supervision logic	Yes	Use the zone supervision logic as part of preventing the loss of Busbar 1 for a fault between the tie breaker and the tie-breaker CT.
Zone-switching supervision logic	Yes	Use this logic when only one (either 89A or 89B) disconnect contact is available.
Coupler security logic	Yes	Use the coupler security logic in a single CT application for enhanced protection for faults between the tie-breaker CT and circuit breaker.
Circuit breaker failure protection	No	Not required
Instantaneous overcurrent protection	No	Not required
Time-overcurrent protection	No	Not required
Phase voltage elements	No	Not required
Zero- or negative-sequence voltage elements	No	Not required

User-Defined Functions

This application requires no user-defined functions.

Number of Relays and I/O Boards

Selecting the relay has two parts:

- the number of relays (single-relay application or three-relay application)
- and the number of interface boards (as many as four interface boards per relay)

The number of analog (CT) inputs determines the number of relays, and the number of digital inputs and outputs determines the number of interface boards.

Number of Relays

Each SEL-487B has 21 current channels and three voltage channels. For stations with as many as 21 CTs (per phase), we can install a single SEL-487B. For stations with more than 21 and as many as 63 CTs, we install 3 SEL-487B Relays. Use *Equation 6.15* to calculate the number of current channels at the station, and use *Equation 6.16* to calculate the number of zones at the station.

$$\text{\# of current channels required} = \text{\# of per-phase station CTs}$$

Equation 6.15

$$\text{\# of bus-zones required} = \text{\# of per-phase station bus sections}$$

Equation 6.16

The number of per-phase CTs at the station is 15 (the tie breaker has three CT cores), and one SEL-487B suffices. However, the requirement for five future feeders increases the number of per-phase CTs to 30. Because each SEL-487B has 21 analog input channels, we need three relays. This is known as a three-relay application.

In a three-relay application, each relay provides six zones of protection for one of the three phases of the power system. For example, wire all the A-phase CTs to Relay 1, the B-phase CTs to Relay 2, and the C-phase CTs to Relay 3. Settings for the three relays are identical; all three relays require the same information. Wire input and output contacts (from the circuit breaker or disconnects, for example) to one of the three relays, then jumper (hardwire) the input and output contacts to the other two relays.

This example shows the setting and configuration for the A-phase relay, identified with an appended letter A (MEXCO_A). For the other two relays, the settings and configuration are the same as for the A-phase relay, but the appended letter changes according to the letter designation of the relay. For example, the corresponding MEXCO_A setting is MEXCO_B in the B-phase relay, and MEXCO_C in the C-phase relay.

Number of Relay Inputs

The protection philosophy and protection function selection determine the number of digital relay inputs and outputs required for each application.

The protection philosophy calls for disconnect auxiliary contacts to dynamically configure the station. Because each terminal provides only one disconnect auxiliary contact, we cannot use the disconnect monitoring logic. Each feeder has two busbar disconnects (891 and 892), and the tie breaker also has two disconnects (891 and 892). Each feeder therefore requires two inputs, and the tie breaker requires two inputs, for a total number of ten disconnect logics.

The protection philosophy also calls for zone-switching supervision logic, and we will use the coupler security logic to prevent tripping of Busbar 1 when there is a fault between the tie breaker and tie-breaker CT. For the zone-switching supervision logic, connect the close and open signals from each disconnect in parallel, and wire the parallel combination as a single input into the relay (see *Zone Configuration Group Settings on page 6.124*).

The coupler security logic requires three inputs:

- a close signal
- a circuit breaker 52A auxiliary contact
- an input for the accelerated tripping function (see *Figure 6.110* for more information)

We need one input for the circuit breaker 52A auxiliary contact and one input for the closing signal. For the accelerated tripping input (ACTRP1), we use the output from the BZ1 differential element (87R1). *Table 6.57* summarizes the input contacts necessary for this application.

Table 6.57 Number of Required Relay Inputs

Input Description	Inputs
Number of relay inputs required for the disconnect contacts	(4 • 2) + 2 = 10
Number of relay inputs required for disconnect open/close signal	1
Number of relay inputs required for the coupler security logic on the tie breaker	2 (one closing signal and one circuit breaker auxiliary contact)
Total number of inputs	13

The relay main board has seven inputs, insufficient inputs for our application. Each interface board provides two sets of nine grouped inputs and six independent inputs. Use the grouped inputs for the disconnect auxiliary contact inputs; the six independent inputs are available for breaker failure initiate inputs. Because this application has no circuit breaker failure protection, and the circuit breaker closing signals are best suited for independent inputs, use the independent inputs on the interface board for the circuit breaker closing signal. From the input perspective, we need one interface board. It is not necessary to include I/O for future expansion with the initial order; install additional I/O if and when required.

Number of Relay Output Contacts

Our example station has five circuit breakers, all of which are part of the busbar differential protection. Because all circuit breakers are part of the busbar differential protection, we want to trip each breaker when the differential protection operates. *Table 6.58* shows the breakdown and the total number of relay output contacts required for tripping.

Table 6.58 Breakdown and the Total Number of Relay Outputs Required

Output Description	Outputs
Number of relay output contacts required for tripping the circuit breakers	5
Total number of relay output contacts	5

The relay main board has eight standard output contacts (Output Contact 7 is used to assert when the **RELAY TEST MODE** pushbutton on the front panel is selected, and Output Contact 8 is used for alarming purposes in the default settings). However, the main board contacts are all standard output contacts. The interface boards can have high-speed, high-interrupting output contacts that provide faster contact closure. Each interface board provides six high-speed, high-interrupting output contacts and two standard output contacts. For fast busbar fault clearance, assign each circuit breaker trip output to a high-speed, high-interrupting output contact for each of the circuit breakers at the station. From the output contact perspective, we need one interface board.

The conclusion from the preceding analysis is that we need three SEL-487B Relays, each relay equipped with a single interface board.

Input, Logic, and Output Allocation and Alias Name Assignment

At this point, we have determined the following:

- The number of SEL-487B Relays necessary for the application
- The number of inputs
- The number of output contacts
- The selected protection functions

For example, we have matched the number of CTs at the station with the number of available analog channels in the relay. However, we still need to do the following:

- Link specific CT inputs to specific relay analog channels
- Link specific disconnect and circuit breaker inputs to specific relay input contacts
- Link relay element/logic outputs to specific relay output contacts
- Assign alias names where appropriate

Assign a valid seven-character alias name to any of the following:

- Relay Word bit
- Analog quantity
- Terminal name
- Bus-Zone name

Alias names are valid when they consist of a maximum of seven characters, and they are constructed using characters 0–9, uppercase A–Z, or the underscore (_).

CT-to-Analog Channel Allocation, and CT Alias Assignment

The protection philosophy specifies that only the terminals and bus-zones need alias names. *Table 6.59* shows CT-to-relay analog channel allocations and alias assignments. For example, allocate the A-phase tie-breaker CT to relay Channel I01, and assign to this CT the alias name TIE_A. The choice of CT-to-analog channel allocation is arbitrary; you can assign the CTs randomly to relay analog channels. *Table 6.59* shows the assignment for the A-phase relay starting with the tie-breaker CTs, followed by the four terminals, taken left-to-right from *Figure 6.101*.

Table 6.59 CTs-to-Analog Channel Allocations and Alias Assignments

CTs	Analog Channel	Alias
TIE-BREAKER CT, A-phase	I01	TIE_A
MEXICO terminal, A-phase	I02	MEXCO_A
RIO DE JANEIRO terminal, A-phase	I03	RIODJ_A
BOGOTA terminal, A-phase	I04	BOGOT_A
PANAMA terminal, A-phase	I05	PANAM_A

Bus-Zone Alias Assignment

Each SEL-487B provides six zones of protection. For the A-phase relay, we use two bus-zones with alias names as shown in *Table 6.60*.

Table 6.60 Alias Names for the Two Bus-Zones

Bus-Zone Name	Description	Alias
BZ1	Bus-Zone 1	BUS_A
BZ2	Bus-Zone 2	TRANS_A

Input-to-Logic Allocation

Table 6.57 shows that we require 13 digital inputs. We now assign the 13 digital input contacts to the selected logic. There are 18 grouped and 6 independent input contacts on the interface board. We assign the 10 disconnect inputs to the grouped terminals and the remaining 3 inputs to the independent relay inputs on the interface board.

Input Contact to Logic Allocation, Main Board

This application requires no main board inputs.

Input Contact-to-Logic Allocation, Interface Board 1 (200)

Table 6.61 shows the disconnect and circuit breaker auxiliary contact input allocations. Because inputs IN201–IN203 and IN213–IN215 are independent inputs, assign the inputs for the coupler security logic and the open/closing signals to these relay inputs.

Table 6.61 Relay Input-to-Relay Logic Assignment

Input	Description
IN201	TIE-BREAKER circuit breaker 52A auxiliary contact
IN202	TIE-BREAKER circuit breaker closing signal
IN203	Disconnect open/closing signal
IN204	TIE-BREAKER disconnect (BUS_A) NO contact
IN205	TIE-BREAKER disconnect (TRANS_A) NO contact
IN206	MEXICO terminal disconnect (BUS_A) NO contact
IN207	MEXICO terminal disconnect (TRANS_A) NO contact
IN208	RIO DE JANEIRO terminal disconnect (BUS_A) NO contact
IN209	RIO DE JANEIRO terminal disconnect (TRANS_A) NO contact
IN210	BOGOTA terminal disconnect (BUS_A) NO contact
IN211	BOGOTA terminal disconnect (TRANS_A) NO contact
IN212	PANAMA terminal disconnect (BUS_A) NO contact
IN216	PANAMA terminal disconnect (TRANS_A) NO contact

Identification of the Selected Standard Logic

The following explains each selected function in reference to *Table 6.56*. Alias name assignments are also included.

Differential Trip Logic Identification

Figure 6.102 shows the differential trip logic for Differential Element 1. Relay Word bit 87Z1 asserts only if zone supervision conditions permit an output from the AND gate. (See *Section 5: Protection Functions* for more information.) *Table 6.62* shows the Relay Word bits and description for the zone differential protection outputs.

Table 6.62 Zone Differential Protection Output Relay Word Bits

Primitive Name	Description
87Z1	Zone 1 differential element trip
87Z2	Zone 2 differential element trip

Differential trip bits 87BTR01–87BTR05 assert to trip the circuit breakers of the terminals in the faulted bus-zone. (See *Section 5: Protection Functions* for more information.)

Figure 6.102 Differential Trip Logic for Differential Element 1

Be sure to include the differential trip bits in the trip equations of all the terminals you want to trip when the differential elements operate (see *Global Settings on page 6.123* for more information). *Table 6.63* shows the differential trip bit and the associated terminals.

Table 6.63 Differential Trip Bit and Associated Terminals

Differential Trip Bit	Description
87BTR01	Associated with Terminal 01
87BTR02	Associated with Terminal 02
87BTR03	Associated with Terminal 03
87BTR04	Associated with Terminal 04
87BTR05	Associated with Terminal 05

Relay Logic-to-Output Contact Allocation

Table 6.58 shows the breakdown of the five relay outputs we need for this application. We now link the appropriate relay logic outputs to specific relay output contacts. *Table 6.64* shows TEST and ALARM protection logic assigned to the output contacts of the main board output contacts. *Table 6.65* shows the linking of the trip logic outputs to the relay output contacts of Interface Board 1.

Output Contact Allocation, Main Board

This application requires only the TEST and ALARM output contacts from the main board.

Table 6.64 Alias Names and Contact Allocation of the Main Board Output Contacts

Output Contact Assignment	Description	Output Contact Alias
OUT107	Relay in test mode	TEST
OUT108	Relay alarm	ALARM

Output Contact Allocation, Interface Board 1 (200)

Each interface board of the SEL-487B can include six high-speed, high-interrupting output contacts. *Table 6.65* shows the assignment for the five terminals of the A-phase relay.

Table 6.65 Allocation of the Interface Board Output Contacts

Output Contact Assignment	Description
OUT201[a]	Tie-breaker trip logic output
OUT202[a]	MEXICO trip logic output
OUT203[a]	RIO DE JANERO trip logic output
OUT204[a]	BOGOTA trip logic output
OUT205[a]	PANAMA trip logic output

[a] High-speed, high-interrupting outputs.

Station Layout Update (A-Phase)

We are now ready to set and configure the relay. Write all the relevant information on the station diagram, as shown in *Figure 6.103*.

1. Write down the bus-zone, terminal, and disconnect names.
2. Draw in the overlapping zone on the bus section to clearly identify the terminal/zone allocation.
3. Allocate the terminal CTs to the relay input current channels.
4. Allocate the terminal digital inputs to the relay digital inputs.
5. Allocate the digital outputs from the relay to the terminals.

Figure 6.103 Substation Layout With Specific Information

Setting the Relay

The following describes the settings for this application. For this application example, we set the following setting classes:

- Alias Settings
- Global Settings
- Zone Configuration Group Settings
- Protection Group Settings
- Control Output Settings

Alias Settings

We have identified and allocated the alias names to the analog channels and Relay Word bits. We now enter the alias names in the relay.

Type **SET T <Enter>** to enter the alias setting class. Many default Relay Word bits have useful alias names ready for use. Type **LIST <Enter>** to see a list of default primitive names and associated alias names, as shown in *Figure 6.104*.

After inspecting the list, we decide the only useful alias names are those of the 24 LEDs, TEST, and ALARM.

```
=>>SET T <Enter>
Alias
Relay Aliases
(RW Bit or Analog Qty. or Terminal or Bus-Zone, 7 Character Alias [0-9 A-Z _])
1: IO1,"FDR_1"
?  LIST <Enter>


1: IO1,"FDR_1"
2: IO2,"FDR_2"
3: IO3,"FDR_3"
4: IO4,"TRFR_1"
5: IO5,"TB_1"
6: IO6,"TB_2"
7: BZ1,"BUS_1"
8: BZ2,"BUS_2"
.
.
.
68: TLED_23,"52_ALRM"
69: TLED_24,"IRIGLED"
1: IO1,"FDR_1"
?
```

Figure 6.104 List of Default Primitive Names and Associated Alias Names

Type **DELETE 43 <Enter>** at the first action prompt to delete the first 43 default alias names, as shown in *Figure 6.105*.

```
1: IO1,"FDR_1"
?  DELETE 43 <Enter>
```

Figure 6.105 Deletion of the First 43 Alias Names

Type **> <Enter>** to advance to the next available line in the setting list. Enter the alias names for the six analog channels and Relay Word bits, as shown in *Figure 6.106*.

```
v1: OUT107,"TEST"
?  > <Enter>
27:
?  IO1,TIE_A <Enter>

28:
?  IO2,MEXCO_A <Enter>
29:
?  IO3,RIODJ_A <Enter>
30:
?  IO4,BOGOT_A <Enter>

31:
?  IO5,PANAM_A <Enter>
32:
?  BZ1,BUS_A <Enter>
33:
?  BZ2,TRANS_A <Enter>

34:
?  PLTO1,DIFF_EN <Enter>
35:
? PLTO3,TNS_SW <Enter>
36:
? END <Enter>
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.106 Analog Quantities and Relay Word Bits Alias Names

This concludes the alias settings. The next settings class is global settings.

Global Settings

Global settings comprise settings that apply to all protection setting groups. For example, when changing from Protection Setting Group 1 to Protection Setting Group 2, Global settings such as station name and relay name still apply. *Figure 6.107* shows the setting changes we need for our example.

Because there are five circuit breakers at the station, set NUMBK to 5. Setting NUMBK to 5 makes five corresponding circuit breaker auxiliary input equations (52A01–52A05), and five corresponding trip equations (TR01–TR05) available for setting.

Declare here the input contact for the tie-breaker auxiliary contact (52A01 := IN201). Set the remaining four circuit breaker auxiliary input equations (52A02–52A05) to NA.

```
=>>SET G <Enter>
Global
General Global Settings
Station Identifier (40 characters)
SID := "Station A"
?  <Enter>

Relay Identifier (40 characters)
RID := "Relay 1"
?  <Enter>
Number of Breakers (N,1-21)                          NUMBK   := 5      ?> <Enter>


Global Enables

Station DC Battery Monitor (Y,N)                     EDCMON  := N      ?> <Enter>

Control Inputs (Global)

Input Pickup Delay (0.0-30 ms)                       GINPU   := 2.0    ?> <Enter>


Settings Group Selection

Select Setting Group 1 (SELogic Equation)
SS1 := NA
?  ><Enter>

Time and Date Management

Date Format (MDY,YMD,DMY)                            DATE_F  := MDY    ?> <Enter>


Breaker Inputs

N/O Contact Input -BK01 (SELogic Equation)
52A01 := NA
?  IN201<Enter>
N/O Contact Input -BK02 (SELogic Equation)
52A02 := NA
? <Enter>
N/O Contact Input -BK03 (SELogic Equation)
52A03 := NA
?  > <Enter>


DNP

Event Summary Lock Period (0-1000 s)                 EVELOCK := 0      ?> <Enter>
Global
.
.
.
EVELOCK := 0        DNPSRC  := UTC
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.107 Global Settings for Application 4

This concludes the global settings. The next settings class is the zone configuration group settings.

Zone Configuration Group Settings

The terminal-to-bus-zone SELOGIC control equations identify an analog channel, a differential element, and the conditions for which the relay assigns the analog channel to the differential element. Dynamic zone selection provides a mechanism to automatically reconfigure the zone of protection, without any wiring changes (See *Dynamic Zone Selection Logic on page 5.14* for more information).

In this example, the dynamic zone selection logic uses the disconnect auxiliary contact status to determine the station configuration and assign the input currents from the CTs to the appropriate differential elements. For each terminal, wire an 89B disconnect auxiliary contact to the relay.

Because the disconnect simultaneously operates all three phases of the terminal, we state the disconnect status in the terminal-to-bus-zone SELOGIC control equations of all three relays. Because we wire a disconnect auxiliary contacts to only one relay, jumper (hardwire) the contact to the two other relays. For example, when we close the busbar disconnect on the Mexico feeder, all three phases (MEXCO_A, MEXCO_B, and MEXCO_C) operate together. Because the relay measures the three phases in three separate relays (phase MEXCO_A in the A-phase relay, phase MEXCO_B in B-phase relay, etc.), we must convey the disconnect status to all three relays.

For this discussion, we define the following terms:

- Source busbar: the busbar to which all terminals are connected, except the terminal on transfer
- Transfer busbar: the busbar to which the terminal on transfer is connected
- Transfer disconnect: the disconnect that connects the terminal to the transfer busbar (disconnect G892 on the Panama Feeder)

Although the relay is flexible enough to accept settings for many disconnect combinations, we will configure the relay according to the following operating conditions:

- Only one feeder will be on transfer at any given time, i.e., the tie-breaker disconnects and the feeder transfer disconnect (*n*892, *n* = D, E, F, G) of only one of the four feeders can be closed simultaneously.
- Only Busbar 1 can be the source busbar.
- The operating sequence to put a feeder on transfer is fixed.

Because the operating sequence defines a set of operating rules, settings engineers can decide on appropriate terminal-to-bus-zone and bus-zone-to-bus-zone settings for each step.

Table 6.66 shows the operating sequence for the settings in this application; many other operating sequences are possible and in use.

Refer to *Figure 6.103* and consider a case in which we put the PANAMA Feeder on transfer.

Assume the tie breaker is open and both tie-breaker disconnects are open.

Table 6.66 Fixed Operating Sequence to Put a Feeder on Transfer

Step Number	Description	Comment
1	Close tie-breaker disconnects Z892 and Z891. Close the tie-breaker circuit breaker.	Feeder Disconnects D891, E891, F891, and G891 as well as D893, E893, F893, and G893 are now closed. Feeder Disconnects D892, E892, F892, and G892 are open. Closing the tie breaker brings both busbars to the same potential.
2	Close the Panama G892 disconnect.	Closing Disconnect G892 forms a bus-zone-to-bus-zone connection, resulting in a parallel path between the tie breaker and the Panama Feeder. Merge the two zones to prevent possible relay misoperation.
3	Open the Panama circuit breaker.	Although the current distribution is known at this point, the feeder is still considered in the intermediate position and the two zones are still merged.
4	Open the line disconnect (G893) of the Panama feeder. Open the Busbar 1 (G891) disconnect.	Opening G891 removes the bus-zone-to-bus-zone connection, forming two independent zones. The Panama feeder is now on transfer.

Because the operating sequence prevents connections that could result in relay misoperation, we must merge the zones during the intermediate position (Step 2 in *Table 6.66*). We define this intermediate position as the time when disconnects *n*891 and *n*892 of any feeder are closed simultaneously.

Enter this state to merge the zones in the bus-zone-to-bus-zone connections:

BZ1BZ2V := **(IN206 AND IN207) OR (IN208 AND IN209) OR (IN210 AND IN211) OR (IN212 AND IN216)**

We use a combination of the zone supervision and coupler security logics to prevent tripping Busbar 1 for a fault between the tie-breaker circuit breaker and CT. For the zone supervision setting, we supervise the BZ1 differential element output by the negated coupler security output (ZS1 := NOT CSL1) (see *Protection Group Settings on page 6.128* for more information).

I01BZ1V and I01BZ2V, the tie-breaker terminal-to-bus-zone settings, comprise the disconnect auxiliary contacts (IN204 and IN205), the circuit breaker auxiliary contact (CB52A1), the circuit breaker closing signal (CBCLST1), and the coupler status timed out bit (CB52T1). (See *Figure 6.110* and *Protection Group Settings on page 6.128* for more detail.)

In this application, the disconnect provides only one (89B) disconnect auxiliary contact. We cannot use the disconnect monitoring logic because the disconnect monitoring logic requires two disconnect auxiliary contacts. For installations with only one disconnect auxiliary contact, use the zone-switching supervision logic. (See *Section 5: Protection Functions* for more information.) Enable the zone switching supervision by setting EZSWSUP := Y. Connect the open and close signals from the disconnects in parallel (see *Figure 6.108*).

In this application, we assign this parallel connection to relay input IN203. Set ZSWO := IN203.

Alarm ZSWOAL stays asserted indefinitely in the event of the disconnect auxiliary contact failing to change status. Use pushbutton PB5 to reset Alarm ZSWOAL when a disconnect auxiliary contact fails to change status. Set RZSWOAL := PB5.

Figure 6.108 External Wiring and Initiation Input for Zone-Switching Supervision

Measure each disconnect travel time.

Set the zone-switching operation pickup delay (ZSWOPU) to a value longer than the time necessary for the slowest disconnect to complete an open-to-close, or close-to-open operation. Based on previous experience with similar equipment, we set the ZSWOPU to 3600 cycles in this example. *Figure 6.109* shows the zone configuration settings for this application.

The zone configuration default settings are for a specific substation with arbitrarily selected alias names, serving only as an example.

For ease of setting zone configuration settings for the new substation, delete the terminal-to-bus-zone connections default settings. With the terminal-to-bus-zone connections default settings deleted, the setting prompts no longer reference the default settings.

You can use a combination of primitive and alias names when entering the terminal-to-bus-zone and bus-zone-to-bus-zone connection settings. *Figure 6.109* shows the zone configuration settings for this application.

```
=>>SET Z <Enter>
Zone Config Group 1
Potential Transformer Ratio
Potential Transformer Ratio -V01 (1-10000)          PTR1    := 2000   ?> <Enter>
Current Transformer Ratio
Current Transformer Ratio -IO1 (1-50000)            CTR01   := 600    ?800 <Enter>
Current Transformer Ratio -IO2 (1-50000)            CTR02   := 600    ?600 <Enter>
Current Transformer Ratio -IO3 (1-50000)            CTR03   := 600    ?> <Enter>

Zone Configuration: Terminal to Bus-Zone Connections
Terminal, Bus-Zone, Polarity (P,N)
IO1BZ1C := TIE_A, BUS_A, P
?  DELETE 100 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO1,BZ1,P <Enter>
TIE_A to BUS_A Connection (SELogic Equation)
IO1BZ1V := NA
?  IN204 AND IN205 AND (CB52A1 OR CBCLST1) <Enter>

Terminal, Bus-Zone, Polarity (P,N)
?  IO1,BZ2,N <Enter>
TIE_A to TRANS_A Connection (SELogic Equation)
IO1BZ2V := NA
?  IN204 AND IN205 AND (CB52T1 OR CBCLST1) <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO2,BZ1,P <Enter>
MEXCO_A to BUS_A Connection (SELogic Equation)
IO2BZ1V := NA
?  IN206 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO2,BZ2,P <Enter>
```

Figure 6.109 Zone Configuration Group Settings for Application 4

```
MEXCO_A to TRANS_A Connection (SELogic Equation)
IO2BZ2V := NA
?  IN207 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO3,BZ1,P <Enter>
RIODJ_A to BUS_A Connection (SELogic Equation)
IO3BZ1V := NA
?  IN208 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO3,BZ2,P <Enter>

RIODJ_A to TRANS_A Connection (SELogic Equation)
IO3BZ2V := NA
?  IN209 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO4,BZ1,P <Enter>
BOGOT_A to BUS_A Connection (SELogic Equation)
IO4BZ1V := NA
?  IN210 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO4,BZ2,P <Enter>

BOGOT_A to TRANS_A Connection (SELogic Equation)
IO4BZ2V := NA
?  IN211 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO5,BZ1,P <Enter>
PANAM_A to BUS_A Connection (SELogic Equation)
IO5BZ1V := NA
?  IN212 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO5,BZ2,P <Enter>

PANAM_A to TRANS_A Connection (SELogic Equation)
IO5BZ2V := NA
?  IN216 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?
Zone Configuration: Bus-Zone to Bus-Zone Connections
Bus-Zone, Bus-Zone
?  BZ1,BZ2 <Enter>

BUS_A to TRANS_A Connection (SELogic Equation)
BZ1BZ2V := NA
?  (IN206 AND IN207) OR (IN208 AND IN209) OR (IN210 AND IN211) OR (IN212 AND IN\
216) <Enter>
Connection to Remove Terminals when BUS_A and TRANS_A merge (SELogic Equation)
BZ1BZ2R := NA
?  (IN206 AND IN207) OR (IN208 AND IN209) OR (IN210 AND IN211) OR (IN212 AND IN\
216) <Enter>

Terminals Removed when BUS_A and TRANS_A Bus-Zones merge (Ter k,...,Ter n)
BZ1BZ2M :=
?  IO1 <Enter>
Trip Terminals TIE_A (Y,N)
BZ1BZ2T := N
?  Y <Enter>
Bus-Zone, Bus-Zone
?

Zone Supervision
Differential Element Zone Supervision (Y,N)         E87ZSUP := N      ?Y <Enter>
Zone 1 Supervision (SELogic Equation)
Z1S := 1
?  NOT CSL1 <Enter>
Zone 2 Supervision (SELogic Equation)
Z2S := 1
?  > <Enter>

Zone Switching Supervision (Y,N)                    EZSWSUP := N      ?Y <Enter>
Zone Switching Operation (SELogic Equation)
ZSWO := NA
?  IN203 <Enter>
Reset Zone Switching Op Alarm (SELogic Equation)
RZSWOAL := NA
?  PB5 <Enter>
Zone Switching Op Pickup Delay (0-99999 cyc)        ZSWOPU  := 1800   ?3600 <Enter>

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

=>>
```

Figure 6.109 Zone Configuration Group Settings for Application 4 (Continued)

This concludes the zone configuration group settings. The next settings class is the protection group settings.

Protection Group Settings

Settings of this class comprise the protection functions, beginning with the function enable settings. Default settings for the differential elements are 60 percent for Slope 1 and 80 percent for Slope 2. To change the slope settings, first enable the advanced settings by setting EADVS := Y. With EADVS := Y, the slope settings and incremental restrained and operating current settings become available. For this application, we use the default values for the sensitive differential element, the restrained differential element and the directional element.

The protection philosophy calls for the blocking of the busbar protection for an open CT condition. Use the sensitive differential element for this requirement by setting E87SSUP := Y (see *Figure 5.11* and *Figure 5.18* for more information).

We need one coupler security logic for this application. Set ECSL := 1. Set ETOS := N, EBFL := N, E50 := N, E51 := N, E27 := N, E59 := N, and EADVS := N because we do not use the terminal out of service function, breaker failure protection, overcurrent elements, voltage elements, or advanced settings in this application.

Setting NUMBK to 5 (Global settings) makes five corresponding circuit breaker auxiliary input equations (52A01–52A05), and five corresponding trip equations (TR01–TR05) available for setting. Each of the five analog channels has a corresponding differential trip bit that asserts (*Table 6.63*) when the differential element asserts.

Be sure to include these differential trip bits in the trip equations of all circuit breakers you want to trip. When applying the coupler security logic as in this example, include the differential element trip output (87R1) and the 87BTR01 differential trip bit in the tie-breaker trip logic.

The trip logic latches the trip outputs TRIP*kk* after TR*kk* assertion. One way to deassert the trip outputs is to press the **TARGET RESET** pushbutton on the front panel. An alternative method is to enter specific reset conditions at the ULTR*kk* settings.

Figure 6.110 shows the combination of the coupler security logic and the zone supervision with the input settings applied. Notice that Gate 1 and Gate 2 represent the tie-breaker terminal-to-bus-zone connection settings; they are not part of the fixed logic.

Figure 6.110 Coupler Security Logic With Applied Input Settings

The protection philosophy calls for the loss of only one zone when a fault between the tie-breaker CT and circuit breaker occurs. Use the coupler security logic to prevent the loss of Busbar 1 for a fault between the tie-breaker CT and circuit breaker. Be aware, however, that using this logic delays relay operation for all busbar faults on Busbar 1.

Assume for this application that the maximum circuit breaker tripping time is two cycles and that the maximum closing time is four cycles. Refer to *Figure 6.110*, and notice the difference in the CB52A1 and CBCLS1 inputs from the regular coupler security application. Input CBCLS1 provides the closing signal information to the relay. For an open-to-close operation, Input CBCLS1 asserts when the operator issues a closing signal to the circuit breaker, asserting Relay Word bits I01BZ1V and I01BZ2V. When Relay Word bits I01BZ1V and I01BZ2V assert, the relay considers the CT in the differential equations. Inserting the CTs in the differential equations before primary current flows emulates the early make, late break timing requirement for the disconnect auxiliary contacts. Set the timer dropout time (CBCLDO1) to a value longer than the maximum breaker closing time. In this example, allow a short safety margin and set CBCLDO1 to 5 cycles (default value). A setting of five cycles allows the circuit breaker ample time to change state, during which time Relay Word bit CB52A1 asserts.

When opening the circuit breaker, the inverse applies. For a close-to-open circuit breaker operation, we must guard against prematurely removing the CTs from the differential equations due to circuit breaker auxiliary contact misalignment. We use CB52T1 in the tie-breaker terminal-to-bus-zone connection settings to accomplish this for Zone 2. However, because we supervise all Zone 1 faults, premature removal of the CTs does not adversely affect Zone 1 differential elements.

Figure 6.111 shows just the tie breaker and two terminals of the application. The single CT on the tie breaker has one core, providing CT information to both differential elements. The challenge to the coupler security logic is to trip BZ2 and not BZ1 for Fault F1. This requirement contradicts the existing configuration, for

it calls for the coupler security logic to prevent BZ1 from operating for an in-zone fault (fault on Busbar 1) and for BZ2 to operate for an out-of-zone fault (fault on Busbar 1).

Figure 6.111 Single CT Application With Faults Between the Circuit Breaker and Tie-Breaker CT

Consider the operation when Fault F1 occurs without the coupler security logic. Differential protection BZ2 is stable, and differential protection BZ1 immediately trips the Mexico circuit breaker and the tie-breaker circuit breaker. However, tripping the Mexico circuit breaker and the tie-breaker circuit breaker does not clear Fault F1. Fault current still flows from the Rio de Janeiro Feeder, through the transfer bus, and into the fault. Although breaker failure protection will operate to trip the Rio de Janeiro circuit breaker, this operation takes place after the breaker failure time delay. After the tie-breaker breaker failure timer times out, all circuit breakers in BZ2 zone trip, resulting in both BZ1 and BZ2 tripping to clear Fault F1.

If a delay in bus-zone protection operation is in order, implement the coupler security logic in such a way that tripping of the BZ1 bus-zone is only permitted when the tie-breaker circuit breaker is open. To prevent tripping BZ1, configure the relay to achieve the following:

- Check if the tie-breaker circuit breaker is closed.
- If the tie-breaker circuit breaker is closed, trip only the tie breaker to interrupt the fault current from BZ1; trip no other circuit breakers.
- If the tie breaker is open, allow normal busbar protection tripping.
- When the tie breaker is open, remove the tie-breaker CT from the differential calculations of BZ1 and eventually BZ2.

To check the tie-breaker status and remove the CT from the supervised zone when the tie breaker is open, use the tie-breaker auxiliary contact in the tie-breaker terminal-to-bus-zone connection settings. To remove the CT from the unsupervised zone, use the coupler status timed-out bit (CB52T1) in the tie-breaker terminal-to-bus-zone connection settings. To trip only the tie breaker for a fault on Busbar 1 requires the following two settings:

- Supervising the BZ1 differential element
- Issuing a trip signal to the tie breaker first

Supervise the BZ1 differential element output with the negated output from the coupler security logic (Z1S := NOT CSL1). We assign 87R1, the unsupervised output from the BZ1 differential element, to ACTRP1, the accelerated trip input of the coupler security logic. When accelerated trip timer output (ACTRPT1) asserts, Gate 4 in *Figure 6.110* turns off and Relay Word bit CSL1 deasserts. When Relay Word bit CSL1 deasserts, Relay Word bit Z1S asserts, removing the supervision from the BZ1 differential element.

Supervising the BZ1 differential element in this way prevents the tripping of all terminals in BZ1, including the tie breaker. To trip the tie breaker, include 87R1, the unsupervised output from Differential Element 1 in the trip equation of the tie breaker.

After the tie breaker opens (two cycles), we remove the tie-breaker CT from the differential calculations of BZ1, but not the BZ1 supervision. Maintain the BZ1 supervision for at least another 1.25 cycles (add a safety margin of 0.75 cycle) to allow the differential element to reset. Achieve this delay by setting ACTPPU1 to at least 4 cycles.

For Fault F1, BZ1 operates, asserting Relay Word bit 87R1. When Relay Word bit 87R1 asserts, the accelerated trip timer starts timing. Because of the BZ1 zone supervision (NOT CSL1), 87Z1 cannot assert, and only the bus tie breaker receives a trip signal.

Two cycles later, the tie-breaker trips, interrupting the fault current contribution from BZ1. Assume the circuit breaker auxiliary contact changes state at the same time. When the auxiliary contact changes state, Relay Word bit CB52A1 deasserts, causing Relay Word bits I01BZ1V and eventually I01BZ2V to also deassert. When Relay Word bits I01BZ1V and I01BZ2V deassert, the relay removes the CTs from the differential calculations for BZ1 and BZ2. For Fault F1, the tie breaker is open, but fault current still flows through the CT. Removing the tie-breaker CTs from all differential calculations does not trip BZ1 (no fault current contribution from BZ1) but causes BZ2 to operate (BZ2 balancing tie-breaker CT removed), tripping all circuit breakers on the transfer bus. Removing the bus sectionalizer CTs also deasserts Relay Word bit 87R1, causing the accelerated trip timer to stop timing. Fault F1 is now cleared, although there is a time delay.

For Fault F2, the initial tripping is the same as for Fault F1: BZ1 operates, asserting Relay Word bit 87R1. When Relay Word bit 87R1 asserts, the accelerated trip timer starts timing. Because of the BZ1 zone supervision (NOT CSL1), 87Z1 cannot assert, and only the bus coupler circuit breaker receives a trip signal.

Two cycles later, the tie-breaker circuit breaker trips, and the auxiliary contact changes state at the same time. When the auxiliary contact changes state, Relay Word bit CB52A1 deasserts, causing Relay Word bits I01BZ1V and eventually I01BZ2V to also deassert. When Relay Word bits I01BZ1V and I01BZ2V deassert, the relay removes the CTs from the differential calculations for BZ1 and BZ2. Because the circuit breaker is open, terminals from BZ2 no longer contribute to the fault, and BZ2 is stable. However, the BZ1 zone supervision (NOT CSL1) still supervises the BZ1 trip output for another two cycles. Two cycles

later, Accelerate Trip Timer ACTRP1 times out, causing CSL1 to deassert. When Relay Word bit CSL1 deasserts, Relay Word bit Z1S asserts, removing the zone supervision from BZ1, issuing a trip signal to all circuit breakers on Busbar 1.

Although each SEL-487B includes 21 trip logics, there is only one Minimum Trip Duration Time Delay (TDURD) setting.

Because the default setting is longer than the slowest tripping time, use the default setting of 12 cycles. *Figure 6.112* shows the group settings.

```
=>>SET <Enter>

Group 1
Relay Configuration
Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y      ?<Enter>
Coupler Security Logic (N,1-4)                       ECSL    := N      ?1 <Enter>
Terminal Out of Service (N,1-21)                     ETOS    := 5      ?N <Enter>
Breaker Failure Logic (N,1-21)                       EBFL    := 6      ?N <Enter>
Definite Time Overcurrent Elements (N,1-21)          E50     := N      ?<Enter>
Inverse Time Overcurrent Elements (N,1-21)           E51     := N      ?<Enter>
Enable Under Voltage Elements (N,1-6)                E27     := N      ?<Enter>
Enable Over Voltage Elements (N,1-6)                 E59     := N      ?<Enter>
Advanced Settings (Y,N)                              EADVS   := N      ?<Enter>

Sensitive Differential Element
Sensitive Differential Element Pickup (0.05-1 pu)    S87P    := 0.10   ?> <Enter>
Restrained Differential Element
Restrained Diff Element Pickup (0.10-4 pu)           O87P    := 1.00   ?> <Enter>
Directional Element
Dir Element O/C Supervision Pickup (0.05-3 pu)       50DSP   := 0.05   ?> <Enter>
Coupler 1 Security Logic
Coupler 1 Status (SELogic Equation)
CB52A1 := NA
?  IN201 <Enter>

Coupler 1 Status Dropout Delay (0.00-1000 cyc)       CB52DO1 := 4.00   ?<Enter>
Coupler 1 Close Command (SELogic Equation)
CBCLS1 := NA
?  IN202 <Enter>
Coupler 1 Close Command D/O Delay (0.00-1000 cyc)    CBCLDO1 := 5.00   ?<Enter>
Coupler 1 Acc Trip (SELogic Equation)
ACTRP1 := NA
?  87R1 <Enter>

Coupler 1 Acc Trip Pickup Delay (0.00-1000 cyc)      ACTPPU1 := 4.00   ?<Enter>
Trip Logic
Trip 01 (SELogic Equation)
TR01 := SBFTR01 OR 87BTR01
?  87R1 OR 87BTR01 <Enter>
Unlatch Trip 01 (SELogic Equation)
ULTR01 := NA
?<Enter>

Trip 02 (SELogic Equation)
TR02 := SBFTR02 OR 87BTR02
?  87BTR02 <Enter>
Unlatch Trip 02 (SELogic Equation)
ULTR02 := NA
?<Enter>

Trip 03 (SELogic Equation)
TR03 := SBFTR03 OR 87BTR03
?  87BTR03 <Enter>
Unlatch Trip 03 (SELogic Equation)
ULTR03 := NA
?<Enter>

Trip 04 (SELogic Equation)
TR04 := SBFTR04 OR 87BTR04
?  87BTR04 <Enter>
Unlatch Trip 04 (SELogic Equation)
ULTR04 := NA
?<Enter>

Trip 05 (SELogic Equation)
TR05 := SBFTR05 OR 87BTR05 OR SBFTR06 OR 87BTR06
?  87BTR05 <Enter>
Unlatch Trip 05 (SELogic Equation)
ULTR05 := NA
?<Enter>
```

Figure 6.112 Protection Group Settings for Application 4

```
Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000 ?<Enter>
Event Report Trigger Equation (SELogic Equation)
.
.
.

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


=>>
```

Figure 6.112 Protection Group Settings for Application 4 (Continued)

This concludes the protection group settings. The next settings class is the control output settings.

Control Output Settings

In this settings class, we assign the logic or Relay Word bits in the relay to output contacts. We need five output contacts for our example. Although not specifically called for in the protection philosophy, it is good practice to also include the default TEST and ALARM outputs in the relay settings. Because each relay protects only one phase of the power system, combine the trip outputs from the three relays in a single output to the circuit breaker. Jumper (hardwire) the trip output from each relay. Connect the cable to the circuit breaker trip coil to any one of the three relays.

We include Protection Latch Bit PLT03 in the output equation. With PLT03 included in every output equation, the RELAY TEST MODE pushbutton disables all output contacts.

Because we do not use any output contacts from the main board for protection functions (OUT107 and OUT108 are used for alarming purposes), set OUT101–OUT106 = NA. *Figure 6.113* shows the control output settings.

```
=>>SET O <Enter>
Output
Main Board
OUT101 := TRIP01 AND NOT TNS_SW
?  > <Enter>

.
.
.
Interface Board #1
OUT201 := NA
?  TRIP01 AND NOT PLT03 <Enter>
OUT202 := NA
?  TRIP02 AND NOT PLT03 <Enter>
OUT203 := NA
?  TRIP03 AND NOT PLT03 <Enter>
OUT204 := NA
?  TRIP04 AND NOT PLT03 <Enter>
OUT205 := NA
?  TRIP05 AND NOT PLT03 <Enter>
OUT206 := NA
?  END <Enter>

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

=>>
```

Figure 6.113 Control Output Settings for Application

This concludes the settings for Application 4.

Application 5: Double Bus With Bus Coupler

This application describes the busbar arrangement shown in *Figure 6.114*, double bus with tie breaker (bus coupler). The busbar arrangement consists of two busbars (main busbar and transfer busbar), four terminals and a tie breaker. Consider the following to set and configure the relay:

- Busbar classification
- Protection philosophy
- Protection functions selection
- Number of SEL-487B Relays and I/O boards
- Input, logic, and output allocation and alias name assignment
- Station layout update
- Relay setting and configuration

Figure 6.114 Double Bus With Bus Coupler (Tie Breaker)

Busbar Classification

The busbar classification provides general busbar layout and CT positioning (inboard or outboard) information, and declares the tie-breaker (bus coupler) configuration.

- Description:
  - Double bus with tie breaker
- Current Transformers:
  - Inboard

- Disconnects:
  - 89A and 89B disconnect auxiliary contacts are available
- Bus coupler (tie breaker):
  - Two CTs, configured in overlap
- Future expansion:
  - Four feeders

Protection Philosophy

Although the SEL-487B offers a variety of protection and control functions, not all of these functions are applied at every substation. Carefully consider each application before stating the functional requirements. The protection philosophy for this application is as follows:

1. Rename only the terminals and bus-zones with alias names.
2. Block the busbar protection for an open circuit CT.
3. Use the disconnect auxiliary contacts to dynamically configure the differential protection.
4. Use the disconnect monitor logic
5. Use external breaker failure protection.
6. Ensure stable differential protection for all operating conditions.

Protection Functions Selection

We select the protection functions early in the relay setting and configuration process because the choice of protection functions determines the number of relay digital inputs and outputs required for the application. Study the protection philosophy to determine which protection and/or control functions to apply to any particular substation. Requirement 6 of the protection philosophy calls for stable differential protection for all operating conditions. There are two network conditions when the differential protection can become unstable:

- When disconnects *n*891 and *n*892 (*n* = D, E, F, G) of any feeder are closed at the same time
- When the transfer disconnect of any feeder is closed

By declaring the appropriate conditions in the bus-zone-to-bus-zone connection settings of the zone selection logic, the relay is stable when disconnects *n*891 and *n*892 are closed simultaneously. We use the zone supervision logic to ensure stable differential protection during the time when one of the transfer disconnects is closed.

Standard Functions

Refer to the protection philosophy and select the standard functions required for the application. *Table 6.67* shows the selection of the standard functions.

Table 6.67 Selection of the Standard Protection Functions (Sheet 1 of 2)

Protection Function	Selection	Comment
CT ratio mismatch ≤ 10:1	Yes	10:1 mismatch is the maximum allowable mismatch
Circuit breaker status logic	No	Not required
Disconnect monitor logic	Yes	89A and 89B disconnect contacts available

Table 6.67 Selection of the Standard Protection Functions (Sheet 2 of 2)

Protection Function	Selection	Comment
Differential protection	Yes	Busbar protection (zone specific and check zone)
Dynamic zone selection logic	Yes	Use the zone selection to reconfigure the differential protection according to the disconnect positions
Sensitive differential protection	Yes	Use the sensitive differential element as CT open circuit detection
Zone supervision logic	Yes	Use the zone supervision logic to ensure stable differential protection for all operating conditions
Zone-switching supervision logic	No	89A and 89B disconnect contacts available so this logic is not required
Coupler security logic	No	Two CTs in overlap configuration do not require the coupler security logic
Circuit breaker failure protection	Yes	External breaker failure
Instantaneous overcurrent protection	No	Not required
Time-overcurrent protection	No	Not required
Phase voltage elements	No	Not required
Zero- or negative-sequence voltage elements	No	Not required

User-Defined Functions

Identify logic functions we need for the application that is not part of the standard logic in the relay. We comply with the protection philosophy using the standard functions in the relay.

Number of Relays and I/O Boards

Selecting the relay has two parts:

- the number of relays (single-relay application or three-relay application)
- the number of interface boards (as many as four interface boards per relay)

The number of analog (CT) inputs determines the number of relays, and the number of digital inputs and outputs determines the number of interface boards.

Number of Relays

Each SEL-487B has 21 current channels and 3 voltage channels. For stations with as many as 21 CTs (per phase), we can install a single SEL-487B. For stations with more than 21 and as many as 63 CTs we install 3 SEL-487B Relays. Use *Equation 6.17* to calculate the number of current channels at the station, and use *Equation 6.18* to calculate the number of zones at the station.

$$\text{\# of current channels required} = \text{\# of per-phase station CTs}$$

Equation 6.17

$$\text{\# of bus-zones required} = \text{\# of per-phase station bus sections}$$

Equation 6.18

The number of per-phase CTs at the station is 18 (tie breaker has 6 CT cores), and one SEL-487B suffices. However, the requirement for 4 future feeders increases the number of per-phase CTs to 30. Because each SEL-487B has 21 analog input channels, we need 3 relays. This is known as a three-relay application.

In a three-relay application, each relay provides six zones of protection for one of the three phases of the power system. For example, wire all the A-phase CTs to Relay 1, the B-phase CTs to Relay 2, and the C-phase CTs to Relay 3. Settings for the three relays are identical; all three relays require the same information. Wire input and output contacts (from the circuit breaker or disconnects, for example) to one of the three relays, then jumper (hardwire) the input and output contacts to the other two relays. This example shows the setting and configuration for the A-phase relay, so identified with an appended letter A (MADRI_A). For the other two relays, the settings and configuration are the same as for the A-phase relay, but the appended letter changes according to the letter designation of the relay. For example, the corresponding MADRI_A setting is MADRI_B in the B-phase relay, and MADRI_C in the C-phase relay.

Number of Relay Inputs

The protection philosophy and protection function selection determine the number of digital relay inputs and outputs required for each application.

The number of disconnect logics (NUMDS) required is the number of disconnects for which the protection philosophy requires disconnect monitoring logic. In this example, each of the four feeders requires three disconnect monitoring logic and the tie breaker requires two; the number of disconnect logics required is therefore six. Each disconnect monitoring logic requires two disconnect auxiliary contact inputs: an 89A and an 89B contact. Use *Equation 6.19* to calculate the number of relay inputs required for the disconnect auxiliary contacts.

$$\text{\# relay inputs required} = 2 \bullet \text{\# disconnect monitoring logics}$$

Equation 6.19

The protection philosophy calls for external breaker failure as well as dynamic zone selection. Use the external breaker failure logic when the breaker failure relays are integrated in the terminal protection. The zone selection dynamically reconfigures the station according to the disconnect positions and records the terminals in each bus-zone. The relay then uses this information to only trip the terminals in the bus-zone with the failed breaker, when a circuit breaker fails. Wire an output from each breaker failure relay on each of the terminals to the SEL-487B. *Table 6.68* summarizes the input contact required for this application.

Table 6.68 Number of Relay Input Contacts Required

Input Description	Inputs
Number of relay inputs required for the disconnect contacts	2 • 14 = 28
Number of relay inputs required for breaker failure protection	5
Total number of inputs	33

The relay main board has seven input contacts, which are not enough input contacts for our application. Each interface board provides two sets of nine grouped input contacts and six independent input contacts. Use the grouped input contacts

for the disconnect auxiliary contact inputs; and five of the six independent input contacts for the breaker failure inputs. From the input contact perspective, we need two interface boards.

Number of Relay Output Contacts

Our example station has five circuit breakers, all of which are part of the busbar differential protection. Because all circuit breakers are part of the busbar differential protection, we want to trip each breaker when the differential protection operates. *Table 6.69* shows the breakdown and the total number of relay output contacts required for tripping.

Table 6.69 Breakdown and Total Number of Relay Outputs Required

Output Description	Outputs
Number of relay output contacts required for breaker tripping	5
Total number of relay output contacts	5

The relay main board has eight standard output contacts (Output Contact 7 is used to assert when the **RELAY TEST MODE** pushbutton on the front panel is selected, and Output Contact 8 is used for alarming purposes in the default settings). However, the main board contacts are all standard output contacts; high-speed, high-interrupting output contacts provide for faster contact closure. Each interface board can provide six high-speed, high-interrupting output contacts, and two standard output contacts. For fast busbar fault clearance, assign each circuit breaker trip output to a high-speed, high-interrupting output contact for each of the circuit breakers at the station. From the output contact perspective, we need one interface board.

The conclusion from the preceding analysis is that we need three SEL-487B Relays, each relay equipped with two interface boards.

Input, Logic, and Output Allocation and Alias Name Assignment

At this point we have determined the number of the following:

- the number of SEL-487B Relays required for the application
- the number of input contacts
- the number of output contacts
- selected protection functions

For example, we have matched the number of CTs at the station with the number of available analog channels in the relay. However, we still need to do the following:

- link specific CT inputs to specific relay analog channels
- link specific disconnect and external circuit breaker failure inputs to specific relay input contacts
- link relay element/logic outputs to specific relay output contacts
- assign alias names where appropriate

Assign a valid seven-character alias name to any of the following:

- Relay Word bit
- Analog quantity

- Terminal name
- Bus-Zone name

Alias names are valid when they consist of a maximum of seven characters, and they are constructed using characters 0–9, uppercase A–Z, or the underscore (_).

CT-to-Analog Channel Allocation and CT Alias Assignment

The protection philosophy specifies that only the terminals and bus-zones need alias names. *Table 6.70* shows CT-to-relay analog channel allocations and alias assignments. For example, allocate the A-phase tie-breaker CT to relay channel I01, and assign to this CT the alias name TIE1_A. The choice of CT-to-analog channel allocation is arbitrary; you can assign the CTs randomly to relay analog channels. *Table 6.70* shows the assignment for the A-phase relay starting with the tie-breaker CTs, followed by the four terminals, taken left-to-right from *Figure 6.114*.

Table 6.70 CT-to-Analog Channel Allocations and Alias Assignments

CTs	Analog Channel	Alias
TIE-BREAKER CT1, A-phase	I01	TIE1_A
TIE-BREAKER CT2, A-phase	I02	TIE2_A
MADRID terminal, A-phase	I03	MADRI_A
MILAN terminal, A-phase	I04	MILAN_A
ROME terminal, A-phase	I05	ROME_A
CAIRO terminal, A-phase	I06	CAIRO_A

Bus-Zone Alias Assignment

Each SEL-487B provides six zones of protection. For the A-phase relay, we use two bus-zones with alias names as shown in *Table 6.71*.

Table 6.71 Alias Names for the Six Bus-Zones

Bus-Zone Name	Description	Alias
BZ1	Bus-Zone 1	ZONE1_A
BZ2	Bus-Zone 2	ZONE2_A

Input to Logic Allocation

Table 6.68 shows that we require 33 digital inputs. We now assign the 33 digital input contacts to the selected logic. Because of the functional requirements of this application, we do not need any digital inputs on the main board.

Input Contact to Logic Allocation, Interface Board 1 (200)

Table 6.72 and *Table 6.73* show the disconnect and circuit breaker failure contact input allocations. Because Inputs IN201, IN202, IN203, IN213, IN214, and IN215 are independent inputs, we assign the circuit breaker failure input signals to these relay inputs.

Table 6.72 Disconnect and Circuit Breaker Failure Contact Input Allocation

Input	Description
IN201	TIE-BREAKER breaker failure input
IN202	MADRID breaker failure input
IN203	MILAN breaker failure input
IN204	TIE-BREAKER disconnect (ZONE2_A) NO contact
IN205	TIE-BREAKER disconnect (ZONE2_A) NC contact
IN206	TIE-BREAKER disconnect (ZONE1_A) NO contact
IN207	TIE-BREAKER disconnect (ZONE1_A) NC contact
IN208	MADRID terminal disconnect (ZONE1_A) NO contact
IN209	MADRID terminal disconnect (ZONE1_A) NC contact
IN210	MADRID terminal disconnect (ZONE2_A) NO contact
IN211	MADRID terminal disconnect (ZONE2_A) NC contact
IN212	MADRID terminal disconnect (TRANS _A) NO contact
IN216	MADRID terminal disconnect (TRANS _A) NC contact
IN217	MILAN terminal disconnect (ZONE1_A) NO contact
IN218	MILAN terminal disconnect (ZONE1_A) NC contact
IN219	MILAN terminal disconnect (ZONE2_A) NO contact
IN220	MILAN terminal disconnect (ZONE2_A) NC contact
IN221	MILAN terminal disconnect (TRANS _A) NO contact
IN222	MILAN terminal disconnect (TRANS _A) NC contact

Input Contact to Logic Allocation, Interface Board 2 (300)

Table 6.73 shows the disconnect and circuit breaker auxiliary contact input allocations. Because Inputs IN301, IN302, IN303, IN313, IN314, and IN315 are independent inputs, we assign the circuit breaker failure input signals to these relay inputs.

Table 6.73 Disconnect and Circuit Breaker Failure Contact Input Allocations

Input	Description
IN301	ROME breaker failure input
IN302	CAIRO breaker failure input
IN304	ROME terminal disconnect (ZONE1_A) NO contact
IN305	ROME terminal disconnect (ZONE1_A) NC contact
IN306	ROME terminal disconnect (ZONE2_A) NO contact
IN307	ROME terminal disconnect (ZONE2_A) NC contact
IN308	ROME terminal disconnect (TRANS _A) NO contact
IN309	ROME terminal disconnect (TRANS _A) NC contact
IN310	CAIRO terminal disconnect (ZONE1_A) NO contact
IN311	CAIRO terminal disconnect (ZONE1_A) NC contact
IN312	CAIRO terminal disconnect (ZONE2_A) NO contact
IN316	CAIRO terminal disconnect (ZONE2_A) NC contact
IN317	CAIRO terminal disconnect (TRANS _A) NO contact
IN318	CAIRO terminal disconnect (TRANS _A) NC contact

Assignment of the Selected Standard Logic

Referring to *Table 6.67*, the following is a discussion on each selected function.

Disconnect Monitoring Logic

Figure 6.115 shows one of the 60 disconnect monitor logic circuits available in the relay. (See *Dynamic Zone Selection Logic on page 5.14* for more information on the disconnect auxiliary contact requirements).

Figure 6.115 One of the Disconnect Monitoring Logic Circuits Available in the Relay

Table 6.74 shows the assignment of the disconnect auxiliary contact Relay Word bits.

Table 6.74 Disconnect Auxiliary Contact Relay Word Bits (Sheet 1 of 2)

Input	Description
89A01	TIE-BREAKER disconnect (ZONE1_A) NO contact
89B01	TIE-BREAKER disconnect (ZONE1_A) NC contact
89A02	TIE-BREAKER disconnect (ZONE2_A) NO
89B02	TIE-BREAKER disconnect (ZONE2_A) NC
89A03	MADRI_A disconnect (ZONE1_A) NO contact
89B03	MADRI_A disconnect (ZONE1_A) NC contact
89A04	MADRI_A disconnect (ZONE2_A) NO contact
89B04	MADRI_A disconnect (ZONE2_A) NC contact
89A05	MADRI_A disconnect (TRANS_A) NO contact
89B05	MADRI_A disconnect (TRANS_A) NC contact
89A06	MILAN_A disconnect (ZONE1_A) NO contact
89B06	MILAN _A disconnect (ZONE1_A) NC contact
89A07	MILAN _A disconnect (ZONE2_A) NO contact
89B07	MILAN _A disconnect (ZONE2_A) NC contact
89A08	MILAN _A disconnect (TRANS_A) NO contact
89B08	MILAN _A disconnect (TRANS_A) NC contact
89A09	ROME_A disconnect (ZONE1_A) NO contact
89B09	ROME _A disconnect (ZONE1_A) NC contact
89A10	ROME _A disconnect (ZONE2_A) NO contact
89B10	ROME _A disconnect (ZONE2_A) NC contact
89A11	ROME _A disconnect (TRANS_A) NO contact

Table 6.74 Disconnect Auxiliary Contact Relay Word Bits (Sheet 2 of 2)

Input	Description
89B11	ROME _A disconnect (TRANS_A) NC contact
89A12	CAIRO _A disconnect (ZONE1_A) NO contact
89B12	CAIRO _A disconnect (ZONE1_A) NC contact
89A13	CAIRO _A disconnect (ZONE2_A) NO contact
89B13	CAIRO _A disconnect (ZONE2_A) NC contact
89A14	CAIRO _A disconnect (TRANS_A) NO contact
89B14	CAIRO _A disconnect (TRANS_A) NC contact

Wire a normally open disconnect auxiliary contact (89A) and a normally closed disconnect auxiliary contact (89B) from each disconnect to individual relay inputs on the A-phase relay. Jumper (hardwire) the disconnect input contacts to the other two relays. Relay Word bits 89CL*nn* assert when the disconnect monitoring logic interprets the disconnect main contacts as closed. Use Relay Word bits 89CL*nn* as conditions in the terminal-to-bus-zone SELOGIC control equations.

Differential Trip Logic and Differential Element Assignment

Figure 6.116 shows the differential trip logic for Differential Element 1. Relay Word bit 87Z1 asserts only if the zone supervision conditions permit an output from the AND gate. (See *Section 5: Protection Functions* for more information.) *Table 6.75* shows the Relay Word bits and description for the zone differential protection outputs.

Table 6.75 Zone Differential Protection Output Relay Word Bits

Primitive Name	Description
87Z1	Zone 1 differential element trip
87Z2	Zone 2 differential element trip

Differential trip bits 87BTR01–87BTR06 assert to trip the circuit breakers of the terminals in the faulted bus-zone. (See *Section 5: Protection Functions* for more information.)

Figure 6.116 Differential Trip Logic for Differential Element 1

Be sure to include the differential trip bits in the trip equations of all the terminals you want to trip when the differential elements operate (see *Global Settings on page 6.148* for more information). *Table 6.76* shows the primitive analog channel names and the differential trip bit names for the differential trip bits.

Table 6.76 Differential Trip Bit Names and Associated Terminal Names (Sheet 1 of 2)

Differential Trip Bit	Description
87BTR01	Associated with Terminal 01
87BTR02	Associated with Terminal 02
87BTR03	Associated with Terminal 03
87BTR04	Associated with Terminal 04

Table 6.76 Differential Trip Bit Names and Associated Terminal Names (Sheet 2 of 2)

Differential Trip Bit	Description
87BTR05	Associated with Terminal 05
87BTR06	Associated with Terminal 06

Breaker Failure Trip Logic and Station Breaker Failure Logic Output Assignment

Figure 6.117 shows the station breaker failure trip logic. Relay Word bits FBF01–FBF06 are the inputs to the station breaker failure logic; Relay Word bits SBFTR01–SBFTR06 are the outputs from the station breaker failure logic. Relay Breaker failure trip bits SBFTR01–SBFTR06 assert to trip the circuit breakers of the terminals in the bus-zone with the failed circuit breaker. (See *Section 5: Protection Functions* for more information.)

Figure 6.117 Breaker Failure Trip Logic

Table 6.77 shows the station breaker failure Relay Word bits and the primitive names for the breaker failure protection outputs.

Table 6.77 Station Breaker Failure Trip Bit Names and Associated Terminal Names

Station Breaker Failure Trip Bits	Description
SBFTR01	Associated with Terminal 01
SBFTR02	Associated with Terminal 02
SBFTR03	Associated with Terminal 03
SBFTR04	Associated with Terminal 04
SBFTR05	Associated with Terminal 05
SBFTR06	Associated with Terminal 06

Be sure to include the station breaker failure trip bits in the trip equations of all the terminals you want to trip for breaker failure protection. In this example, we want to trip six terminals.

Breaker Failure Input Assignments

This application uses external breaker failure protection. *Figure 6.118* shows the logic for the external breaker failure function.

Figure 6.118 Breaker Failure Logic for External Breaker Failure

We assign the relay breaker failure inputs shown in *Table 6.72* to the appropriate XBF*nn* (*nn* = 01–06) of the breaker failure protection logic (see *Protection Group Settings on page 6.154*). *Table 6.78* shows the primitive names and assignments.

Table 6.78 Breaker Failure Logic Output Relay Word Bits

Logic Name	Description
IN201	TIE1_A breaker failure protection asserted
IN201	TIE2_A breaker failure protection asserted
IN202	MADRI_A breaker failure protection asserted
IN203	MILAN_A breaker failure protection asserted
IN301	ROME_A breaker failure protection asserted
IN302	CAIRO_A breaker failure protection asserted

Relay Logic-to-Output Contact Allocation and Output Contact Assignments

Table 6.69 shows the breakdown of the five relay outputs we need for Application 5. We now link the appropriate relay logic outputs to specific relay output contacts. *Table 6.79* shows TEST and ALARM protection logic assigned to the output contacts of the main board output contacts. *Table 6.80* shows the linking of the trip logic outputs to the relay output contacts of Interface Board 1.

Output Assignment, Main Board

This application requires no other output contacts from the main board.

Table 6.79 Alias Names for the Main Board Output Contacts

Output Contact Assignment	Description	Output Contact Alias
OUT107	Relay in test mode	TEST
OUT108	Relay alarm	ALARM

Output Assignment, Interface Board 1 (200)

Each interface board of the SEL-487B can include six high-speed, high-interrupting output contacts. *Table 6.80* shows the assignment for the five terminals of the A-phase relay.

Table 6.80 Assignment of the Output Contacts

Output Contact Assignment	Description
OUT201[a]	Tie-Breaker trip logic output
OUT202[a]	MADRID trip logic output
OUT203[a]	MILAN trip logic output
OUT204[a]	ROME trip logic output
OUT205[a]	CAIRO trip logic output

[a] High-speed, high-interrupting outputs.

Station Layout Update (A-Phase)

We are now ready to set and configure the relay. Write all relevant information on the station diagram, as shown in *Figure 6.119*.

1. Write down the bus-zone, terminal and disconnect names.
2. Draw in the overlapping zone on the bus section to clearly identify the terminal zone allocation.
3. Allocate the terminal CTs to the relay input current channels.
4. Allocate the terminal digital inputs to the relay digital inputs.
5. Allocate the digital outputs from the relay to the terminals.

Figure 6.119 Substation Layout With Specific Information

Setting the Relay

The following describes the settings for this application. For this application example, we set the following setting classes:

- Alias Settings
- Global Settings
- Zone Configuration Group Settings
- Protection Group Settings
- Control Output Settings

Alias Settings

We have identified and allocated the alias names to the analog channels and Relay Word bits. We now enter the alias names in the relay. Type **SET T <Enter>** to enter the alias setting class. Many default Relay Word bits have useful alias names ready for use. Type **LIST <Enter>** to see a list of default primitive names and associated alias names, as shown in *Figure 6.120*.

After inspecting the list, we decide the only useful alias names are those of the 16 LEDs, TEST and ALARM.

```
=>>SET T <Enter>
Alias
Relay Aliases
(RW Bit or Analog Qty. or Terminal or Bus-Zone, 7 Character Alias [0-9 A-Z _])
1: IO1,"FDR_1"
?  LIST <Enter>
1: IO1,"FDR_1"
2: IO2,"FDR_2"
3: IO3,"FDR_3"
4: IO4,"TRFR_1"
5: IO5,"TB_1"
6: IO6,"TB_2"
7: BZ1,"BUS_1"
8: BZ2,"BUS_2"
.
.
.
68: TLED_23,"52_ALRM"
69: TLED_24,"IRIGLED"
1: IO1,"FDR_1"
?
```

Figure 6.120 List of Default Primitive Names and Associated Alias Names

Type **DELETE 43 <Enter>** at the first action prompt to delete the first 43 default alias names, as shown in *Figure 6.121*.

```
1: IO1,"FDR_1"
?  DELETE 43 <Enter>
```

Figure 6.121 Deletion of the First 43 Alias Names

Type **> <Enter>** to advance to the next available line in the setting list. Enter the alias names for the six analog channels and Relay Word bits, as shown in *Figure 6.122*.

```
1: OUT107,"TEST"
?  > <Enter>
27:
?  IO1,TIE1_A <Enter>
28:
?  IO2,TIE2_A <Enter>

29:
?  IO3,MADRI_A <Enter>
30:
?  IO4,MILAN_A <Enter>

31:
?  IO5,ROME_A <Enter>
32:
?  IO6,CAIRO_A <Enter>

33:
?  BZ1,ZONE1_A <Enter>
34:
?  BZ2,ZONE2_A <Enter>
35:
?  END <Enter>

Alias
.
.
.

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


=>>
```

Figure 6.122 Analog Quantities and Relay Word Bits Alias Names

This concludes the alias settings. The next settings class is Global settings.

Global Settings

Global settings comprise settings that apply to all protection setting groups. For example, when changing from protection setting Group 1 to protection setting Group 2, Global settings such as station name and relay name still apply. *Figure 6.123* shows the setting changes we need for our example.

Because we declared the alias names in the previous setting class, use either the alias names or the primitive names when entering settings.

Setting NUMDS declares the number of disconnect logics we need, not the number of disconnect inputs. In our example, we need 14 disconnect logics although there are 28 disconnect inputs. You can set each disconnect travel time individually with the 89ALP*pp* setting (*pp* = 01–60). Travel time is the time period when both disconnect auxiliary contacts are in the open position (see *Figure 6.20* for more information). Measure the travel time during commissioning and adjust the settings appropriately. Based on previous experience with similar equipment, we set the tie-breaker disconnect travel time to 400 cycles in this example.

```
=>>SET G <Enter>
Global
General Global Settings
Station Identifier (40 characters)
SID := "Station A"
?<Enter>
Relay Identifier (40 characters)
RID := "Relay 1"
?<Enter>

Number of Breakers (N,1-21)                        NUMBK   := 5      ?<Enter>
Number of Disconnects (N,1-60)                     NUMDS   := N      ?14 <Enter>
Nominal System Frequency (50,60 Hz)                NFREQ   := 60     ?> <Enter>
Global Enables
Station DC Battery Monitor (Y,N)                   EDCMON  := N      ?> <Enter>
Control Inputs (Global)
Input Pickup Delay (0.00-30 ms)                    GINPU   := 2.0   ?> <Enter>

Settings Group Selection
Select Setting Group 1 (SELogic Equation)
SS1 := NA
?  > <Enter>


Time and Date Management

Date Format (MDY,YMD,DMY)                          DATE_F  := MDY    ?> <Enter>
Breaker Inputs
N/O Contact Input -BK01 (SELogic Equation)
52A01 := NA
?  > <Enter>
Disconnect Inputs and Timers
N/O Contact Input -DS01 (SELogic Equation)
89A01 := NA
?  IN204 <Enter>

N/C Contact Input -DS01 (SELogic Equation)
89B01 := NA
?  IN205 <Enter>
DS01 Alarm Pickup Delay (0-99999 cyc)              89ALP01 := 300    ?400 <Enter>
N/O Contact Input -DS02 (SELogic Equation)
89A02 := NA
?  IN206 <Enter>
N/C Contact Input -DS02 (SELogic Equation)
89B02 := NA
?  IN207 <Enter>

DS02 Alarm Pickup Delay (0-99999 cyc)              89ALP02 := 300    ?400 <Enter>
N/O Contact Input -DS03 (SELogic Equation)
89A03 := NA
?  IN208 <Enter>
N/C Contact Input -DS03 (SELogic Equation)
89B03 := NA
?  IN209 <Enter>
DS03 Alarm Pickup Delay (0-99999 cyc)              89ALP03 := 300    ?<Enter>

N/O Contact Input -DS04 (SELogic Equation)
89A04 := NA
?  IN210 <Enter>
N/C Contact Input -DS04 (SELogic Equation)
89B04 := NA
?  IN211 <Enter>
DS04 Alarm Pickup Delay (0-99999 cyc)              89ALP04 := 300    ?<Enter>
N/O Contact Input -DS05 (SELogic Equation)
.
.
.

N/O Contact Input -DS14 (SELogic Equation)
89A14 := NA
?  IN317 <Enter>
N/C Contact Input -DS14 (SELogic Equation)
89B14 := NA
?  IN318 <Enter>
DS14 Alarm Pickup Delay (0-99999 cyc)              89ALP14 := 300    ? <Enter>
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.123 Global Settings for Application 5

This concludes the global settings. The next settings class is the zone configuration group settings.

Zone Configuration Group Settings

The terminal-to-bus-zone SELOGIC control equations identify an analog channel, a differential element, and the conditions for which the relay assigns the analog channel to the differential element. Dynamic zone selection provides a mechanism to automatically reconfigure the zone of protection, without any wiring changes (See *Dynamic Zone Selection Logic on page 5.14* for more information).

In this example, the dynamic zone selection logic uses the disconnect auxiliary contacts status to determine the station configuration and assign the input currents from the CTs to the appropriate differential elements. For each disconnect, wire an 89A and an 89B disconnect auxiliary contact to the relay.

Because the disconnect simultaneously operates all three phases of the terminal, we state the disconnect status in the terminal-to-bus-zone SELOGIC control equations of all three relays. Because we wire a disconnect auxiliary contacts to only one relay, jumper (hardwire) the contact to the two other relays. For example, when we close the busbar disconnect on the London feeder, all three phases (MILAN_A, MILAN_B, and MILAN_C) operate together. Because the relay measures the three phases in three separate relays (phase MILAN_A in the A-phase relay, phase MILAN_B in B-phase relay, etc.), we need to convey the disconnect status to all three relays.

For this discussion we define the following terms:

- Source busbar: the busbar to which all terminals are connected, except the terminal on transfer.
- Transfer busbar: the busbar to which the terminal on transfer is connected.
- Transfer disconnect: the disconnect, when closed, bypasses the circuit breaker (e.g., disconnect G898 on the CAIRO Terminal).

Although the relay is flexible enough to accept settings for the many disconnect combinations, we will configure the relay according to the following operating conditions:

- Only one terminal will be on transfer at any given time, i.e., the tie-breaker transfer disconnect (Z892 or Z891) and the transfer disconnect (*n*898, *n* = D, E, F, and G) of only one of the four feeders can be closed simultaneously.
- Either Busbar B1 or Busbar B2 can be the source busbar.
- When closing the transfer disconnect, the protection of the transfer busbar becomes part of the line protection.
- The operating sequence to put a terminal on transfer is fixed. Because the operating sequence defines a set of operating rules, settings engineers can decide on appropriate terminal-to-bus-zone and bus-zone-to-bus-zone connection settings for each step.

Table 6.81 shows the operating sequence for the settings in this application; many other operating sequences are possible and in use.

Assume that the tie breaker and tie-breaker disconnects are closed. For brevity, we consider only the MADRID and CAIRO Feeders in the following discussion. Consider a case where we put the CAIRO Feeder on transfer, with Busbar B2 selected as the source busbar.

Table 6.81 Fixed Operating Sequence to Put a Feeder on Transfer

Step Number	Description	Comment
1	Switch Terminals TD, TE, and TF to the source busbar (B2).	Assume that all FDRs are connected to B1. Close the disconnects that connect the terminals to Busbar B2 (D892, E892, F892, and G892), and open the disconnects that connect the terminals to Busbar B1 (D891, E891, and F891). After Step 1, CAIRO is the only feeder connected to Busbar B1, see *Figure 6.124*. Both Bus-zone B2 (I03 + I01 = $I_s - I_s$ = 0) and Bus-Zone B1 are balanced (I02 + I06 = $I_s - I_s$ = 0).
2	Close the transfer disconnect (G898) of the terminal going on transfer.	This operation forms a parallel path, with current IS splitting at the G894 and G898 junction; not all current flows through the CAIRO CT. There are still two bus-zones (B1 and B2), but because the current from the CAIRO CT is missing (worst case), Bus-Zone B1 can misoperate. Remove Bus-Zone B1 by removing the CAIRO CT and tie-breaker channel I02 from the differential calculations. (See the ensuing discussion and *Figure 6.125*). The transfer busbar is now part of the line protection.
3	Open the circuit breaker of the terminal going on transfer.	Opening the CAIRO circuit breaker interrupts the current path through the circuit breaker. Tie-breaker channel I01 remains part of the differential calculations to balance the current flow to the CAIRO Feeder.
4	Open the source busbar disconnect (G894) and the line disconnect (G895) to isolate the circuit breaker.	Step 4 is shown here to complete the operating sequence; the operation has no effect on the busbar protection.

Figure 6.124 shows the station after Step 1 in *Table 6.81*. Step 1 is standard operating procedure and requires no special busbar protection settings. With all transfer disconnects open, all the CT secondary currents are available, and both Bus-Zones B1 and B2 are balanced.

Figure 6.124 Bus-Zone B1 and Bus-Zone B2 Are Balanced When Both Transfer Disconnects Are Open

Figure 6.125 shows the current distribution for the condition when disconnect G891 and disconnect G898 are both closed. Current I_S enters the MADRID terminal, flows through the tie breaker, busbar B1, and as far as the junction between disconnect G894 and G898. At this junction, the current splits into i_a and i_b. As a worst-case scenario, assume the entire current, IS, flows through disconnect G898, with no current flowing through the CAIRO CT. To balance the B1 differential element, we need the sum of the currents in the B1 element to equal zero. Without the CAIRO CT current contribution, the differential element is unbalanced and can result in misoperation. To conclude, the current input from the CAIRO CT is uncertain when disconnect G891 and disconnect G898 are both closed, and disappears when the circuit breaker opens. For these reasons, Bus-Zone B1 cannot form a reliable differential zone when disconnect G898 closes. Differential Element B2 remains stable, and the B2 Busbar protection is secure.

Figure 6.125 Current Distribution During Transfer Procedure Using Inboard CTs

By removing the CAIRO CT as well as the tie-breaker I02 channel from the differential calculations, we effectively remove Differential element B1. We can achieve the same result in two ways:

- by using the zone supervision setting (Z*n*S)
- entering values for each of the terminal-to-bus-zone settings

This example uses the first option (i.e., the zone supervision setting).

Consider also that by removing Differential Element B1, the transfer busbar is without protection. One solution is to use the tie-breaker I02 CT for the line protection, thereby including the transfer busbar as part of the line. When using the SEL-421 as line protection, program the selection functions in the relay to select current I02 as an alternate current source.

To configure the correct disconnect combinations, use the following conditions:

1. With no feeder on transfer, manipulate the tie-breaker CTs with the bus-zone-to-bus-zone connections.
2. A feeder is on transfer when any *n*898 AND *n*891, or any *n*898 AND *n*892 (*n* = D, E, F, and G) disconnects are closed simultaneously.
3. When a feeder is on transfer and B2 is the source busbar, remove I02. B2 is the source busbar when *n*891 AND *n*898 (*n* = D, E, F, and G) disconnects are closed.
4. When a feeder is on transfer and B1 is the source busbar, remove I01. B1 is the source busbar when *n*892 AND *n*898 (*n* = D, E, F, and G) disconnects are closed.

Z1S:= **NOT ((89CL03 AND 89CL05) OR (89CL06 AND 89CL08) OR (89CL09 AND 89CL11) OR (89CL12 AND 89CL14))**

Z2S:= **NOT ((89CL04 AND 89CL05) OR (89CL07 AND 89CL08) OR (89CL10 AND 89CL11) OR (89CL13 AND 89CL14))**

The zone configuration default setting are settings for a specific substation with arbitrarily selected alias names, serving only as an example.

For the ease of setting the zone configuration settings for the new substation, delete the existing zone configuration default settings.

With the zone configuration default settings deleted, the setting prompts no longer reference the default settings.

You can use a combination of primitive and alias names when entering the terminal-to-bus-zone and bus-zone-to-bus-zone connection settings. *Figure 6.126* shows the zone configuration settings for this application.

```
=>>SET Z <Enter>
Zone Config Group 1
Potential Transformer Ratio
Potential Transformer Ratio -V01 (1-10000)          PTR1    := 2000   ?> <Enter>

Current Transformer Ratio
Current Transformer Ratio -I01 (1-50000)            CTR01   := 600    ?800 <Enter>
Current Transformer Ratio -I02 (1-50000)            CTR02   := 600    ?800 <Enter>
Current Transformer Ratio -I03 (1-50000)            CTR03   := 600    ?> <Enter>

Zone Configuration: Terminal to Bus-Zone Connections
Terminal, Bus-Zone, Polarity (P,N)
I01BZ1C := TIE1_A, ZONE1_A, P
?  DELETE 200 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I01,ZONE2_A,P <Enter>
TIE1_A to ZONE2_A Connection (SELogic Equation)
I01BZ2V := NA
?  89CL02 <Enter>

Terminal, Bus-Zone, Polarity (P,N)
?  I02,ZONE1_A <Enter>
TIE2_A to ZONE1_A Connection (SELogic Equation)
I02BZ1V := NA
?  89CL01 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I03,ZONE1_A,P <Enter>
MADRI_A to ZONE1_A Connection (SELogic Equation)
I03BZ1V := NA
?  89CL03 <Enter>

Terminal, Bus-Zone, Polarity (P,N)
?  I03,ZONE2_A,P <Enter>
MADRI_A to ZONE2_A Connection (SELogic Equation)
I03BZ2V := NA
?  89CL04 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  I04,ZONE1_A,P <Enter>
MILAN_A to ZONE1_A Connection (SELogic Equation)
I04BZ1V := NA
?  89CL06 <Enter>
```

Figure 6.126 Zone Configuration Group Settings for Application 5

```
Terminal, Bus-Zone, Polarity (P,N)
?  IO4,ZONE2_A,P <Enter>
MILAN_A to ZONE2_A Connection (SELogic Equation)
IO4BZ2V := NA
?  89CLO7 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO5,ZONE1_A,P <Enter>
ROME_A to ZONE1_A Connection (SELogic Equation)
IO5BZ1V := NA
?  89CLO9 <Enter>

Terminal, Bus-Zone, Polarity (P,N)
?  IO5,ZONE2_A,P <Enter>
ROME_A to ZONE2_A Connection (SELogic Equation)
IO5BZ2V := NA
?  89CL10 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO6,ZONE1_A,P <Enter>

CAIRO_A to ZONE1_A Connection (SELogic Equation)
IO6BZ1V := NA
?  89CL12 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO6,ZONE2_A,P <Enter>
CAIRO_A to ZONE2_A Connection (SELogic Equation)
IO6BZ2V := NA
?  89CL13 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?<Enter>

Zone Configuration: Bus-Zone to Bus-Zone Connections
Bus-Zone, Bus-Zone
?  ZONE1_A,ZONE2_A <Enter>
ZONE1_A to ZONE2_A Connection (SELogic Equation)
BZ1BZ2V := NA
?  (89CLO3 AND 89CLO4) OR (89CLO6 AND 89CLO7) OR (89CLO9 AND 89CL10) OR (89CL12\
 AND 89CL13) <Enter>
Connection to Remove Terminals when ZONE1_A and ZONE2_A merge (SELogic Equation)
BZ1BZ2R := NA
?  BZ1BZ2V <Enter>

Terminals Removed when ZONE1_A and ZONE2_A Bus-Zones merge (Ter k,...,Ter n)
BZ1BZ2M :=
?  TIE1_A,TIE2_A <Enter>
Trip Terminals TIE1_A, TIE2_A (Y,N)
BZ1BZ2T := N
?  Y <Enter>
Bus-Zone, Bus-Zone
? <Enter>
Zone Supervision
Differential Element Zone Supervision (Y,N)          E87ZSUP := N      ?Y <Enter>

Zone 1 Supervision (SELogic Equation)
Z1S := 1
?  NOT ((89CLO3 AND 89CLO5) OR (89CLO6 AND 89CLO8) OR (89CLO9 AND 89CL11) OR (8\
9CL12 AND 89CL14)) <Enter>
Zone 2 Supervision (SELogic Equation)
Z2S := 1
?  NOT ((89CLO4 AND 89CLO5) OR (89CLO7 AND 89CLO8) OR (89CL10 AND 89CL11) OR (8\
9CL13 AND 89CL14)) <Enter>

Zone Switching Supervision
Zone Switching Supervision (Y,N)                     EZSWSUP := N      ?<Enter>
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.126 Zone Configuration Group Settings for Application 5 (Continued)

This concludes the zone configuration group settings. The next settings class is the protection group settings.

Protection Group Settings

Settings of this class comprise the protection functions, starting with the function enable settings. Default settings for the differential elements are 60 percent for Slope 1 and 80 percent for Slope 2. To change the slope settings, first enable the advanced settings by setting EADVS := Y. With EADVS := Y, the slope settings

and incremental restrained and operating current settings become available. For this application, we use the default values for the Sensitive Differential Element, the Restrained Differential Element, and the Directional Element.

The protection philosophy calls for the blocking of the busbar protection for an open CT condition. Set E87SSUP := Y (see *Figure 5.11* and *Figure 5.18* for more information) to use the sensitive differential element for this requirement. Set TOS := N, E50 := N, E51 := N, E27 := N, E59 := N, and EADVS := N because we do not use the Coupler Security Logic, overcurrent elements, terminal out of service, or voltage elements in this application.

Because breaker failure protection measures each current channel, select the number of breaker failure logics (EBFL setting) equal to the number of current channels, not the number of circuit breakers.

This application has five circuit breakers, but six current channels (tie breaker has two CTs). Select six as the number of breaker failure logics for this application.

This application assumes a single breaker failure input from the tie-breaker protection. With a single breaker failure input from the tie-breaker protection, set both tie-breaker breaker failure initiate setting (XBF01 and XBF02) equal to IN201. For tie breakers with two breaker failure relays, allocate an additional relay input for the second breaker failure input, and equate each relay input to an XBF*nn* settings. For example, assume the two breaker failure inputs are assigned to relay input IN201 and relay input IN202. With these input assignments, set XBF01 := IN201 and XBF02 := IN202.

Setting NUMBK equal to five makes five corresponding trip equations (TR01–TR05) available for setting. There are five trip equations available, but there are six analog channels (I01–I06) at the station. Each of the six analog channels has a corresponding differential trip bit that asserts (*Table 6.76*) when the differential element asserts. Be sure to include these differential trip bits in the trip equations of all circuit breakers you want to trip.

The trip logic latches the trip outputs TRIP*kk* after TR*kk* assertion. One way to deassert the trip outputs is to press the **TARGET RESET** pushbutton on the front panel. An alternative method is to enter specific reset conditions at the ULTR*kk* settings.

Each of the six analog channels also has a corresponding station breaker failure trip bit that asserts (*Table 6.77*) when the breaker failure element asserts. Be sure to include these station breaker failure trip bits in the trip equations of all circuit breakers you want to trip.

Because the tie breaker has two analog channels, but only one circuit breaker, include both Differential Trip bits (87BTR01 and 87BTR02) as well as both station breaker failure trip bits (SBFTR01 and SBFTR02) in the trip equation of the tie breaker (TR01).

Figure 6.127 shows the protection group settings for this application.

```
=>>SET <Enter>
Group 1
Relay Configuration
Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y      ? <Enter>
Coupler Security Logic (N,1-4)                       ECSL    := N      ? <Enter>
Terminal Out of Service (N,1-21)                     ETOS    := 5      ?N <Enter>
Breaker Failure Logic (N,1-21)                       EBFL    := 6      ? <Enter>

Definite Time Overcurrent Elements (N,1-21)          E50     := N      ? <Enter>
Inverse Time Overcurrent Elements (N,1-21)           E51     := N      ? <Enter>
Enable Under Voltage Elements (N,1-6)                E27     := N      ? <Enter>
Enable Over Voltage Elements (N,1-6)                 E59     := N      ? <Enter>
Advanced Settings (Y,N)                              EADVS   := N      ? <Enter>

Sensitive Differential Element
Sensitive Differential Element Pickup (0.05-1 pu)    S87P    := 0.10   ?> <Enter>
Restrained Differential Element
Restrained Diff Element Pickup (0.10-4 pu)           O87P    := 1.00   ?> <Enter>
Directional Element
Dir Element O/C Supervision Pickup (0.05-3 pu)       50DSP   := 0.05   ?> <Enter>

Breaker 01 Failure Logic
External Breaker Fail -BK01 (Y,N)                    EXBF01  := N      ?Y <Enter>
External Brkr Fail Init -BK01 (SELogic Equation)
XBF01 := NA
?  IN201 <Enter>
Brkr Fail Init Dropout Delay -BK01 (0.00-1000 cyc)   BFID001 := 1.50   ? <Enter>
Breaker 02 Failure Logic
External Breaker Fail -BK02 (Y,N)                    EXBF02  := N      ?Y <Enter>
External Brkr Fail Init -BK02 (SELogic Equation)
XBF02 := NA
?  IN201 <Enter>
Brkr Fail Init Dropout Delay -BK02 (0.00-1000 cyc)   BFID002 := 1.50   ? <Enter>

.
.
.
External Breaker Fail -BK06 (Y,N)                    EXBF06  := N      ?Y <Enter>
External Brkr Fail Init -BK06 (SELogic Equation)
XBF06 := NA
?  IN302 <Enter>
Brkr Fail Init Dropout Delay -BK06 (0.00-1000 cyc)   BFID006 := 1.50   ? <Enter>

Trip Logic
Trip 01 (SELogic Equation)
TR01 := SBFTR01 OR 87BTR01
?  SBFTR01 OR 87BTR01 OR SBFTR02 OR 87BTR02 <Enter>
Unlatch Trip 01 (SELogic Equation)
ULTR01 := NA
?<Enter>
Trip 02 (SELogic Equation)
TR02 := SBFTR02 OR 87BTR02
?  SBFTR03 OR 87BTR03 <Enter>
Unlatch Trip 02 (SELogic Equation)
ULTR02 := NA
?<Enter>

Trip 03 (SELogic Equation)
TR03 := SBFTR03 OR 87BTR03
?  SBFTR04 OR 87BTR04 <Enter>
Unlatch Trip 03 (SELogic Equation)
ULTR03 := NA
?<Enter>
.
.
.

Trip 05 (SELogic Equation)
TR05 := SBFTR05 OR 87BTR05 OR SBFTR06 OR 87BTR06
?  SBFTR06 OR 87BTR06 <Enter>
Unlatch Trip 05 (SELogic Equation)
ULTR05 := NA
?<Enter>
Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000 ? <Enter>

Event Report Trigger Equation (SELogic Equation)
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.127 Protection Group Settings for Application 5

This concludes the protection group settings. The next settings class is the control output settings.

Control Output Settings

In this settings class, we assign the logic or Relay Word bits in the relay to output contacts. We need five output contacts for our example. Although not specifically called for in the protection philosophy, it is good practice to also include the default TEST and ALARM outputs in the relay settings. Because each relay protects only one phase of the power system, combine the trip outputs from the three relays in a single output to the circuit breaker. Jumper (hardwire) the trip output from each relay, and connect the cable to the circuit breaker trip coil to any one of the three relays.

We include Protection Latch Bit PLT03 in the output equation. With PLT03 included in every output equation, the **RELAY TEST MODE** pushbutton disables all output contacts. Because we do not use any output contacts from the main board for protection functions (OUT107 and OUT108 are used for alarming purposes), set OUT101–OUT106 = NA.

Figure 6.128 shows the control output settings.

```
=>>SET O <Enter>
Output
Main Board
OUT101 := TRIP01 AND NOT TNS_SW
?  NA <Enter>
OUT102 := TRIP02 AND NOT TNS_SW
?  NA <Enter>
OUT103 := TRIP03 AND NOT TNS_SW
?  NA <Enter>
OUT104 := TRIP04 AND NOT TNS_SW
?  NA <Enter>

OUT105 := TRIP05 AND NOT TNS_SW
?  NA <Enter>
OUT106 := NA
?  > <Enter>
Interface Board #1
OUT201 := NA
?  TRIP01 AND NOT PLT03 <Enter>
OUT202 := NA
?  TRIP02 AND NOT PLT03 <Enter>
OUT203 := NA
?  TRIP03 AND NOT PLT03 <Enter>

OUT204 := NA
?  TRIP04 AND NOT PLT03 <Enter>
OUT205 := NA
?  TRIP05 AND NOT PLT03 <Enter>
OUT206 := NA
?  END <Enter>
Output
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.128 Control Output Settings for Application 5

This concludes the settings for Application 5.

Application 6: Double and Transfer Bus With Two Busbars

This describes the busbar arrangement shown in *Figure 6.129*. The busbar arrangement consists of two busbars (main busbar and transfer busbar), four terminals and a tie breaker. Consider the following to set and configure the relay:

- Busbar classification
- Protection philosophy

- Protection functions selection
- Number of SEL-487B Relays and I/O boards
- Input, logic, and output allocation and alias name assignment
- Station layout update
- Relay setting and configuration

Figure 6.129 Double Bus and Transfer Bus With Bus Coupler (Tie Breaker)

Busbar Classification

The busbar classification provides general busbar layout and CT positioning (inboard or outboard) information, and declares the tie-breaker (bus coupler) configuration.

- Description:
  - Double bus with tie breaker
- Current Transformers:
  - Inboard
- Disconnects:
  - 89A and 89B disconnect auxiliary contacts are available
- Bus coupler (tie breaker):
  - Two CTs, configured in overlap

- Future expansion:
  - Four feeders

Protection Philosophy

Although the SEL-487B offers a variety of protection and control functions, not all of these functions are applied at every substation. Carefully consider each application before stating the functional requirements. The protection philosophy for this application is as follows:

1. Rename only the terminals and bus-zones with alias names.
2. Block the busbar protection for an open circuit CT.
3. Ensure stable differential protection for all operating conditions.
4. Use the disconnect auxiliary contacts to dynamically configure the station.
5. Use the disconnect monitor logic.
6. Use external breaker failure protection.

Protection Functions Selection

We select the protection functions early in the relay setting and configuration process because the choice of protection functions determines the number of relay digital inputs and outputs required for the application. Study the protection philosophy to determine which protection and/or control functions to apply to any particular substation. Requirement 3 of the protection philosophy calls for stable differential protection for all operating conditions.

There are two network conditions when the differential protection can become unstable: when disconnects *n*891 and *n*892 (*n* = D, E, F, G) of any feeder are closed at the same time, or when the transfer disconnect of any feeder is closed. By declaring the appropriate conditions in the bus-zone-to-bus-zone connection settings of the zone selection logic, the relay is stable when disconnects *n*891 and *n*892 are closed simultaneously. We use the zone supervision logic to ensure stable differential protection during the time when one of the transfer disconnects is closed.

Standard Functions

Refer to the protection philosophy and select the standard functions required for the application. *Table 6.82* shows the selection of the standard functions.

Table 6.82 Selection of the Standard Protection Functions (Sheet 1 of 2)

Protection Functions	Selection	Comment
CT ratio mismatch ≤ 10:1	Yes	10:1 mismatch is the maximum allowable mismatch
Circuit breaker status logic	No	Not required
Disconnect monitor logic	Yes	89A and 89B disconnect contacts available
Differential protection	Yes	Busbar protection (zone specific and check zone)
Dynamic zone selection logic	Yes	Use the zone selection to reconfigure the station according to the disconnect positions.
Sensitive differential protection	Yes	Use the sensitive differential element as CT open circuit detection.
Zone supervision logic	Yes	Use the zone supervision logic to compensate for the inboard CTs during the bypass period, as well as when a feeder is on transfer.

Table 6.82 Selection of the Standard Protection Functions (Sheet 2 of 2)

Protection Functions	Selection	Comment
Zone-switching supervision logic	No	89A and 89B disconnect contacts available, so this logic is not required.
Coupler security logic	No	Not required
Circuit breaker failure protection	Yes	External breaker failure
Instantaneous overcurrent protection	No	Not required
Time-overcurrent protection	No	Not required
Phase voltage elements	No	Not required
Zero- or negative-sequence voltage elements	No	Not required

User-Defined Functions

Identify logic functions we need for the application that is not part of the standard logic in the relay. We comply with the protection philosophy using the standard functions in the relay.

Number of Relays and I/O Boards

Selecting the relay has two parts:

- the number of relays (single-relay application or three-relay application)
- the number of interface boards (as many as four interface boards per relay)

The number of analog (CT) inputs determines the number of relays, and the number of digital inputs and outputs determines the number of interface boards.

Number of Relays

Each SEL-487B has 21 current channels and three voltage channels. For stations with as many as 21 CTs (per phase), we can install a single SEL-487B. For stations with more than 21 and as many as 63 CTs, we install 3 SEL-487B Relays. Use *Equation 6.20* to calculate the number of current channels at the station, and use *Equation 6.21* to calculate the number of zones at the station.

$$\text{\# of current channels required} = \text{\# of per-phase station CTs}$$

Equation 6.20

$$\text{\# of bus-zones required} = \text{\# of per-phase station bus sections}$$

Equation 6.21

The number of per-phase CTs at the station is 18 (tie breaker has 6 CT cores), and one SEL-487B suffices. However, the requirement for 4 future feeders increases the number of per-phase CTs to 30. Because each SEL-487B has 21 analog input channels, we need 3 relays. This is known as a three-relay application.

In a three-relay application, each relay provides six zones of protection for one of the three phases of the power system. For example, wire all the A-phase CTs to Relay 1, the B-phase CTs to Relay 2, and the C-phase CTs to Relay 3. Settings for the three relays are identical; all three relays require the same information.

Wire input and output contacts (from the circuit breaker or disconnects, for example) to one of the three relays, then jumper (hardwire) the input and output contacts to the other two relays.

This example shows the setting and configuration for the A-phase relay, so identified with an appended letter A (MADRI_A). For the other two relays, the settings and configuration are the same as for the A-phase relay, but the appended letter changes according to the letter designation of the relay. For example, the corresponding MADRI_A setting is MADRI_B in the B-phase relay, and MADRI_C in the C-phase relay.

Number of Relay Inputs

The protection philosophy and protection function selection determine the number of digital relay inputs and outputs required for each application.

The number of disconnect logics (NUMDS) required is the number of disconnects for which the protection philosophy requires disconnect monitoring logic. In this example, each of the 4 feeders requires 3 disconnect monitoring logic and the tie breaker requires 2; the number of disconnect logics required is therefore 14. Each disconnect monitoring logic requires two disconnect auxiliary contact inputs: an 89A and an 89B contact. Use *Equation 6.22* to calculate the number of relay inputs required for the disconnect auxiliary contacts.

$$\text{\# relay inputs required} = 2 \bullet \text{\# disconnect monitoring logics}$$

Equation 6.22

The protection philosophy calls for external breaker failure as well as dynamic zone selection. Use the external breaker failure logic when the breaker failure relays are integrated in the terminal protection. The zone selection dynamically reconfigures the station according to the disconnect positions and records the terminals in each bus-zone. The relay then uses this information to only trip the terminals in the bus-zone with the failed breaker, when a circuit breaker fails. Wire an output from each breaker failure relay on each of the terminals to the SEL-487B. *Table 6.83* summarizes the input contact required for this application.

Table 6.83 Number of Relay Input Contacts Required

Input Description	Inputs
Number of relay inputs required for the disconnect contacts	2 • 14 = 28
Number of relay inputs required for breaker failure protection	5
Total number of inputs	33

The relay main board has seven inputs, which are not enough inputs for our application. Each interface board provides two sets of nine grouped inputs and six independent input contacts. Use the grouped inputs for the disconnect auxiliary contact inputs and the six independent inputs for the breaker failure inputs. From the input perspective, we need two interface boards.

Number of Relay Output Contacts

Our example station has five circuit breakers, all of which are part of the busbar differential protection. Because all circuit breakers are part of the busbar differential protection, we want to trip each breaker when the differential protection operates. *Table 6.84* shows the breakdown and the total number of relay output contacts required for tripping.

Table 6.84 Breakdown and Total Number of Relay Outputs Required

Output Description	Outputs
Number of relay output contacts required for breaker tripping	5
Total number of relay output contacts	5

The relay main board has eight standard output contacts (Output Contact 7 is used to assert when the RELAY TEST MODE pushbutton from the front panel is selected, and Output Contact 8 is used for alarming purposes in the default settings). However, the main board contacts are all standard output contacts. The interface boards have high-speed, high-interrupting output contacts that provide faster contact closure. Each interface board can provide six high-speed, high-interrupting output contacts, and two standard output contacts. For fast busbar fault clearance, assign each circuit breaker trip output to a high-speed, high-interrupting output contact for each of the circuit breakers at the station. From the output contact perspective, we need one interface board.

The conclusion from the preceding analysis is that we need three SEL-487B Relays, each relay equipped with two interface boards.

Input, Logic, and Output Allocation and Alias Name Assignment

At this point we have determined the following:

- The number of SEL-487B Relays required for the application
- The number of input contacts
- The number of output contacts
- Selected functions

For example, we have matched the number of CTs at the station with the number of available analog channels in the relay.

However, we still need to do the following:

- Link specific CT inputs to specific relay analog channels
- Link specific disconnect and circuit breaker inputs to specific relay input contacts
- Link relay element/logic outputs to specific relay output contacts
- Assign alias names where appropriate

Assign a valid seven-character alias name to any of the following:

- Relay Word bit
- Analog quantity
- Terminal name
- Bus-Zone name

Alias names are valid when they consist of a maximum of seven characters, and they are constructed using characters 0–9, uppercase A–Z, or the underscore (_).

CT-to-Analog Channel Allocation and CT Alias Assignment

The protection philosophy specifies that only the terminals and bus-zones need alias names. *Table 6.85* shows CT-to-relay analog channel allocations and alias assignments. For example, allocate the A-phase tie-breaker CT to relay Channel I01, and assign to this CT the alias name TIE1_A. The choice of CT-to-analog channel allocation is arbitrary; you can assign the CTs randomly to relay analog

channels. *Table 6.85* shows the assignment for the A-phase relay starting with the tie-breaker CTs, followed by the four terminals, taken left-to-right from *Figure 6.129*.

Table 6.85 CT-to-Analog Channel Allocations and Alias Assignments

CTs	Analog Channel	Alias
TIE-BREAKER CT1, A-phase	I01	TIE1_A
TIE-BREAKER CT2, A-phase	I02	TIE2_A
MADRID terminal, A-phase	I03	MADRI_A
MILAN terminal, A-phase	I04	MILAN_A
ROME terminal, A-phase	I05	ROME_A
CAIRO terminal, A-phase	I06	CAIRO_A

Bus-Zone Alias Assignment

Each SEL-487B provides six zones of protection. For the A-phase relay, we use two bus-zones with alias names as shown in *Table 6.86*.

Table 6.86 Alias Names for the Two Bus-Zones

Bus-Zone Name	Description	Alias
BZ1	Bus-Zone 1	ZONE1_A
BZ2	Bus-Zone 2	ZONE2_A

Input-to-Logic Allocation

Table 6.83 shows that we require 33 digital inputs. We now assign the digital input contacts to the selected logic. Because of the functional requirements of this application, we do not need any digital inputs on the main board.

Input Contact-to-Logic Allocation, Interface Board 1 (200)

Table 6.87 and *Table 6.88* show the disconnect and circuit breaker failure contact input allocations. Because Inputs IN201, IN202, IN203, IN213, IN214, and IN215 are independent inputs, we assign the circuit breaker failure input signals to these relay inputs.

Table 6.87 Disconnect and Circuit Breaker Failure Contact Input Allocations (Sheet 1 of 2)

Input	Description
IN201	TIE-BREAKER breaker failure input
IN202	MADRID breaker failure input
IN203	MILAN breaker failure input
IN204	TIE-BREAKER disconnect (ZONE2_A) NO contact
IN205	TIE-BREAKER disconnect (ZONE2_A) NC contact
IN206	TIE-BREAKER disconnect (ZONE1_A) NO contact
IN207	TIE-BREAKER disconnect (ZONE1_A) NC contact
IN208	MADRID terminal disconnect (ZONE1_A) NO contact
IN209	MADRID terminal disconnect (ZONE1_A) NC contact
IN210	MADRID terminal disconnect (ZONE2_A) NO contact

Table 6.87 Disconnect and Circuit Breaker Failure Contact Input Allocations (Sheet 2 of 2)

Input	Description
IN211	MADRID terminal disconnect (ZONE2_A) NC contact
IN212	MADRID terminal disconnect (TRANS _A) NO contact
IN216	MADRID terminal disconnect (TRANS _A) NC contact
IN217	MILAN terminal disconnect (ZONE1_A) NO contact
IN218	MILAN terminal disconnect (ZONE1_A) NC contact
IN219	MILAN terminal disconnect (ZONE2_A) NO contact
IN220	MILAN terminal disconnect (ZONE2_A) NC contact
IN221	MILAN terminal disconnect (TRANS _A) NO contact
IN222	MILAN terminal disconnect (TRANS _A) NC contact

Input Contact to Logic Allocation, Interface Board 2 (300)

Table 6.88 shows the disconnect and circuit breaker auxiliary contact input allocations. Because Inputs IN301, IN302, IN303, IN313, IN314, and IN315 are independent inputs, we assign the circuit breaker failure input signals to these relay inputs.

Table 6.88 Disconnect and Circuit Breaker Failure Contact Input Allocations

Input	Description
IN301	ROME breaker failure input
IN302	CAIRO breaker failure input
IN304	ROME terminal disconnect (ZONE1_A) NO contact
IN305	ROME terminal disconnect (ZONE1_A) NC contact
IN306	ROME terminal disconnect (ZONE2_A) NO contact
IN307	ROME terminal disconnect (ZONE2_A) NC contact
IN308	ROME terminal disconnect (TRANS _A) NO contact
IN309	ROME terminal disconnect (TRANS _A) NC contact
IN310	CAIRO terminal disconnect (ZONE1_A) NO contact
IN311	CAIRO terminal disconnect (ZONE1_A) NC contact
IN312	CAIRO terminal disconnect (ZONE2_A) NO contact
IN316	CAIRO terminal disconnect (ZONE2_A) NC contact
IN317	CAIRO terminal disconnect (TRANS _A) NO contact
IN318	CAIRO terminal disconnect (TRANS _A) NC contact

Assignment of the Selected Standard Logic

Referring to *Table 6.82*, the following is a discussion on each selected function.

Disconnect Monitoring Logic

Figure 6.130 shows one of the 60 disconnect monitor logic circuits available in the relay (see *Figure 6.20*).

Figure 6.130 One of the Disconnect Monitoring Logic Circuits Available in the Relay

Table 6.89 shows the assignment of the disconnect auxiliary contact Relay Word bits.

Table 6.89 Disconnect Auxiliary Contact Relay Word Bits (Sheet 1 of 2)

Disconnect Input	Description
89A01	TIE-BREAKER disconnect (ZONE1_A) NO contact
89B01	TIE-BREAKER disconnect (ZONE1_A) NC contact
89A02	TIE-BREAKER disconnect (ZONE2_A) NO contact
89B02	TIE-BREAKER disconnect (ZONE2_A) NC contact
89A03	MADRI_A disconnect (ZONE1_A) NO contact
89B03	MADRI_A disconnect (ZONE1_A) NC contact
89A04	MADRI_A disconnect (ZONE2_A) NO contact
89B04	MADRI_A disconnect (ZONE2_A) NC contact
89A05	MADRI_A disconnect (TRANS_A) NO contact
89B05	MADRI_A disconnect (TRANS_A) NC contact
89A06	MILAN_A disconnect (ZONE1_A) NO contact
89B06	MILAN _A disconnect (ZONE1_A) NC contact
89A07	MILAN _A disconnect (ZONE2_A) NO contact
89B07	MILAN _A disconnect (ZONE2_A) NC contact
89A08	MILAN _A disconnect (TRANS_A) NO contact
89B08	MILAN _A disconnect (TRANS_A) NC contact
89A09	ROME_A disconnect (ZONE1_A) NO contact
89B09	ROME _A disconnect (ZONE1_A) NC contact
89A10	ROME _A disconnect (ZONE2_A) NO contact
89B10	ROME _A disconnect (ZONE2_A) NC contact
89A11	ROME _A disconnect (TRANS_A) NO contact
89B11	ROME _A disconnect (TRANS_A) NC contact
89A12	CAIRO _A disconnect (ZONE1_A) NO contact
89B12	CAIRO _A disconnect (ZONE1_A) NC contact
89A13	CAIRO _A disconnect (ZONE2_A) NO contact

Table 6.89 Disconnect Auxiliary Contact Relay Word Bits (Sheet 2 of 2)

Disconnect Input	Description
89B13	CAIRO _A disconnect (ZONE2_A) NC contact
89A14	CAIRO _A disconnect (TRANS_A) NO contact
89B14	CAIRO _A disconnect (TRANS_A) NC contact

Wire a normally open disconnect auxiliary contact (89A) and a normally closed disconnect auxiliary contact (89B) from each disconnect to individual relay inputs on the A-phase relay. Jumper (hardwire) the disconnect input contacts to the other two relays. Relay Word bits 89CL*nn* assert when the disconnect monitoring logic interprets the disconnect main contacts as closed. Use Relay Word bits 89CL*nn* as conditions in the terminal-to-bus-zone SELOGIC control equations.

Differential Trip Logic and Differential Element Assignment

Figure 6.131 shows the differential trip logic for Differential Element 1. Relay Word bit 87Z1 asserts only if the zone supervision conditions permit an output from the AND gate. (See *Section 5: Protection Functions* for more information.) *Table 6.90* shows the Relay Word bits and description for the zone differential protection outputs.

Table 6.90 Zone Differential Protection Output Relay Word Bits

Primitive Name	Description
87Z1	Zone 1 differential element trip
87Z2	Zone 2 differential element trip

Differential trip bits 87BTR01–87BTR06 assert to trip the circuit breakers of the terminals in the faulted bus-zone. (See *Section 5: Protection Functions* for more information.)

Figure 6.131 Differential Trip Logic for Differential Element 1

Be sure to include the differential trip bits in the trip equations of all the terminals you want to trip when the differential elements operate (see *Global Settings on page 6.171* for more information). *Table 6.91* shows the primitive analog channel names and the differential trip bit names for the differential trip bits.

Table 6.91 Differential Trip Bit Names and the Associated Terminals

Differential Trip Bit	Description
87BTR01	Associated with Terminal 01
87BTR02	Associated with Terminal 02
87BTR03	Associated with Terminal 03
87BTR04	Associated with Terminal 04
87BTR05	Associated with Terminal 05
87BTR06	Associated with Terminal 06

Breaker Failure Trip Logic and Station Breaker Failure Logic Output Assignment

Figure 6.132 shows the station breaker failure trip logic. Relay Word bits FBF01–FBF06 are the inputs to the station breaker failure logic; Relay Word bits SBFTR01–SBFTR06 are the outputs from the station breaker failure logic. Relay Breaker failure trip bits SBFTR01–SBFTR06 assert to trip the circuit breakers of the terminals in the bus-zone with the failed circuit breaker. (See *Section 5: Protection Functions* for more information.)

Figure 6.132 Breaker Failure Trip Logic

Table 6.92 shows the station breaker failure Relay Word bits and the primitive names for the breaker failure protection outputs.

Table 6.92 Station Breaker Failure Trip Relay Word Bit Names and Associated Terminals

Station Breaker Failure Trip Bits	Description
SBFTR01	Associated with Terminal 01
SBFTR02	Associated with Terminal 02
SBFTR03	Associated with Terminal 03
SBFTR04	Associated with Terminal 04
SBFTR05	Associated with Terminal 05
SBFTR06	Associated with Terminal 06

Be sure to include the station breaker failure trip bits in the trip equations of all the terminals you want to trip for breaker failure protection. In this example, we want to trip six terminals.

Breaker Failure Input Assignments

This application uses external breaker failure protection. *Figure 6.133* shows the logic for the external breaker failure function.

Figure 6.133 Breaker Failure Logic for External Breaker Failure

Table 6.87 and *Table 6.88* show the appropriate XBF*qq* (*qq* = 1–6) and relay input assignment (see *Protection Group Settings on page 6.178*).

Relay Logic-to-Output Contact Allocation and Output Contact Assignments

Table 6.84 shows the breakdown of the five relay outputs we need for this application. We now link the appropriate relay logic outputs to specific relay output contacts. *Table 6.93* shows TEST and ALARM protection logic assigned to the output contacts of the main board output contacts. *Table 6.94* shows the linking of the trip logic outputs to the relay output contacts of Interface Board 1.

Output Assignment, Main Board

This application requires no other output contacts from the main board.

Table 6.93 Alias Names for the Main Board Output Contacts

Output Contact Assignment	Description	Output Contact Alias
OUT107	Relay in test mode	TEST
OUT108	Relay alarm	ALARM

Output Assignment, Interface Board 1 (200)

Each interface board of the SEL-487B can include six high-speed, high-interrupting output contacts. *Table 6.94* shows the assignment for the five terminals of the A-phase relay.

Table 6.94 Assignment of the Output Contacts

Output Contact Assignment	Description
OUT201[a]	TIE-BREAKER trip logic output
OUT202[a]	MADRID trip logic output
OUT203[a]	MILAN trip logic output
OUT204[a]	ROME trip logic output
OUT205[a]	CAIRO trip logic output

[a] High-speed, high-interrupting outputs.

Station Layout Update (A-Phase)

We are now ready to set and configure the relay. Write all relevant information on the station diagram, as shown in *Figure 6.134*.

1. Write down the bus-zone, terminal and disconnect names.
2. Draw in the overlapping zone on the bus section to clearly identify the terminal/zone allocation.
3. Allocate the terminal CTs to the relay input current channels.
4. Allocate the auxiliary contacts to the relay digital inputs.
5. Allocate the digital outputs from the relay to the terminals.

Figure 6.134 Substation Layout With Specific Terminal Information

Setting the Relay

The following describes the settings for this application. For this application, we set the following setting classes:

- Alias Settings
- Global Settings
- Zone Configuration Group Settings
- Protection Group Settings
- Control Output Settings

Alias Settings

We have identified and allocated the alias names to the analog channels and Relay Word bits. We now enter the alias names in the relay. Type **SET T <Enter>** to enter the alias setting class. Many default Relay Word bits have useful alias names ready for use. Type **LIST <Enter>** to see a list of default primitive names and associated alias names, as shown in *Figure 6.135*.

After inspecting the list, we decide the only useful alias names are those of the 16 LEDs, TEST, and ALARM.

```
=>>SET T <Enter>
Alias
Relay Aliases
(RW Bit or Analog Qty. or Terminal or Bus-Zone, 7 Character Alias [0-9 A-Z _])
1: IO1,"FDR_1"
?  LIST <Enter>
1: IO1,"FDR_1"
2: IO2,"FDR_2"
3: IO3,"FDR_3"
4: IO4,"TRFR_1"
5: IO5,"TB_1"
6: IO6,"TB_2"
7: BZ1,"BUS_1"
8: BZ2,"BUS_2"
.
.
.
68: TLED_23,"52_ALRM"
69: TLED_24,"IRIGLED"
1: IO1,"FDR_1"
?
```

Figure 6.135 List of Default Primitive Names and Associated Alias Names

Type **DELETE 43 <Enter>** at the first action prompt to delete the first 43 default alias names, as shown in *Figure 6.136*.

```
1: IO1,"FDR_1"
?  DELETE 43 <Enter>
```

Figure 6.136 Deletion of the First 43 Alias Names

Type **> <Enter>** to advance to the next available line in the setting list. Enter the alias names for the six analog channels and Relay Word bits, as shown in *Figure 6.137*.

```
1: OUT107,"TEST"
?  > <Enter>
27:
?  IO1,TIE1_A <Enter>
28:
?  IO2,TIE2_A <Enter>
29:
?  IO3,MADRI_A <Enter>
30:
?  IO4,MILAN_A <Enter>
31:
?  IO5,ROME_A <Enter>
32:
?  IO6,CAIRO_A <Enter>
33:
?  BZ1,ZONE1_A <Enter>
```

Figure 6.137 Analog Quantities and Relay Word Bit Alias Names

```
34:
?  BZ2,ZONE2_A <Enter>
35:
?  END <Enter>

Alias
.
.
.

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

=>>
```

Figure 6.137 Analog Quantities and Relay Word Bit Alias Names (Continued)

This concludes the alias settings. The next settings class is global settings.

Global Settings

Global settings comprise settings that apply to all protection setting groups. For example, when changing from Protection Setting Group 1 to Protection Setting Group 2, Global settings such as station name and relay name still apply. *Figure 6.138* shows the setting changes we need for our example. Because we declared the alias names in the previous setting class, use either the alias names or the primitive names when entering settings.

Setting NUMDS declares the number of disconnect logics we need, not the number of disconnect inputs. In our example, we need 14 disconnect logics although there are 28 disconnect inputs. You can set each disconnect travel time individually with the 89ALP*pp* setting (*pp* = 01–14). Travel time is the time period when both disconnect auxiliary contacts are in the open position (see *Figure 6.20* for more information). Measure the travel time during commissioning and adjust the settings appropriately. Based on previous experience with similar equipment, we set the tie-breaker disconnect travel time to 400 cycles in this example.

```
=>>SET G <Enter>
Global
General Global Settings
Station Identifier (40 characters)
SID := "Station A"
?<Enter>

Relay Identifier (40 characters)
RID := "Relay 1"
?<Enter>
Number of Breakers (N,1-21)                          NUMBK   := 5      ?<Enter>
Number of Disconnects (N,1-60)                       NUMDS   := N      ?14 <Enter>
Nominal System Frequency (50,60 Hz)                  NFREQ   := 60     ?> <Enter>

Global Enables
Station DC Battery Monitor (Y,N)                     EDCMON  := N      ?> <Enter>
Control Inputs (Global)
Input Pickup Delay (0.00-30 ms)                      GINPU   := 2.0   ?> <Enter>

Settings Group Selection
Select Setting Group 1 (SELogic Equation)
SS1 := NA
?  > <Enter>
Time and Date Management
Date Format (MDY,YMD,DMY)                            DATE_F  := MDY    ?> <Enter>

Breaker Inputs
N/O Contact Input -BK01 (SELogic Equation)
52A01 := NA
?  > <Enter>
Disconnect Inputs and Timers
N/O Contact Input -DS01 (SELogic Equation)
89A01 := NA
?  IN204 <Enter>
N/C Contact Input -DS01 (SELogic Equation)
89B01 := NA
?  IN205 <Enter>
```

Figure 6.138 Global Settings for Application 6

```
DS01 Alarm Pickup Delay (0-99999 cyc)                89ALP01 := 300    ?400 <Enter>
N/O Contact Input -DS02 (SELogic Equation)
89A02 := NA
?  IN206 <Enter>
N/C Contact Input -DS02 (SELogic Equation)
89B02 := NA
?  IN207 <Enter>
DS02 Alarm Pickup Delay (0-99999 cyc)                89ALP02 := 300    ?400 <Enter>
N/O Contact Input -DS03 (SELogic Equation)
89A03 := NA
?  IN208 <Enter>
N/C Contact Input -DS03 (SELogic Equation)
89B03 := NA
?  IN209 <Enter>

DS03 Alarm Pickup Delay (0-99999 cyc)                89ALP03 := 300    ?<Enter>
N/O Contact Input -DS04 (SELogic Equation)
89A04 := NA
?  IN210 <Enter>
N/C Contact Input -DS04 (SELogic Equation)
89B04 := NA
?  IN211 <Enter>
DS04 Alarm Pickup Delay (0-99999 cyc)                89ALP04 := 300    ?<Enter>
N/O Contact Input -DS05 (SELogic Equation)

.
.
.
N/O Contact Input -DS14 (SELogic Equation)
89A14 := NA
?  IN317 <Enter>
N/C Contact Input -DS14 (SELogic Equation)
89B14 := NA
?  IN318 <Enter>
DS14 Alarm Pickup Delay (0-99999 cyc)                89ALP14 := 300    ?<Enter>

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

=>>
```

Figure 6.138 Global Settings for Application 6 (Continued)

This concludes the global settings. The next settings class is the zone configuration group settings.

Zone Configuration Group Settings

The terminal-to-bus-zone SELOGIC control equations identify an analog channel, a differential element, and the conditions for which the relay assigns the analog channel to the differential element. Dynamic zone selection provides a mechanism to automatically reconfiguring the zone of protection, without any wiring changes (See *Dynamic Zone Selection Logic on page 5.14* for more information). In this example, the dynamic zone selection logic uses the disconnect auxiliary contacts status to determine the station configuration, and assign the input currents from the CTs to the appropriate differential elements. For each disconnect, wire an 89A and an 89B disconnect auxiliary contact to the relay.

Because the disconnect simultaneously operates all three phases of the terminal, we state the disconnect status in the terminal-to-bus-zone SELOGIC control equations of all three relays. Because we wire a disconnect auxiliary contacts to only one relay, jumper (hardwire) the contact to the two other relays. For example, when we close the busbar disconnect on the Milan feeder, all three phases (MILAN_A, MILAN_B, and MILAN_C) operate together. Because the relay measures the three phases in three separate relays (phase MILAN_A in the A-phase relay, phase MILAN_B in B-phase relay, etc.), we need to convey the disconnect status to all three relays.

For this discussion we define the following terms:

- Source busbar: the busbar to which all terminals are connected, except the terminal on transfer.
- Transfer busbar: the busbar to which the terminal on transfer is connected (B1).
- Transfer disconnect: the disconnect, when closed, bypasses the circuit breaker (e.g., Disconnect G898 on the Cairo Terminal).

Although the relay is flexible enough to accept settings for the many disconnect combinations, we will configure the relay according to the following operating conditions:

- Only one terminal will be on transfer at any given time, i.e., the transfer Disconnect (*n*898, *n* = D, E, F, and G) of only one of the four feeders can be closed at a time.
- Only Busbar B2 can be the source busbar.
- The transfer busbar (B1) becomes part of the line protection when a terminal is on transfer.
- The operating sequence to put a terminal on transfer is fixed. Because the operating sequence defines a set of operating rules, settings engineers can decide on appropriate terminal-to-bus-zone and bus-zone-to-bus-zone connection settings for each step.

Table 6.95 shows the operating sequence for the settings in this application; many other operating sequences are possible and in use.

Assume that Disconnects Z891 and Z892 and the tie-breaker circuit breaker are closed. For brevity, we consider only the MADRID and CAIRO terminals in the following discussion. Consider the case where we put Terminal CAIRO on transfer.

Table 6.95 Fixed Operating Sequence to Put a Terminal on Transfer

Step Number	Description	Comment
1	Switch terminals TD, TE, and TF to the source busbar (B2).	Close all disconnects that connect the terminals to busbar B2 (D892, E892, F892, and G892), and open all disconnects that connect the terminals to busbar B1 (D891, E891, F891, and G891). No current flows through the tie breaker, see *Figure 6.139*. Bus-Zone B1 does not operate because no current flows through the tie breaker. Bus-Zone B2 is balanced because I03 + I06 = 0.
2	Close the transfer Disconnect (G898) of the terminal going on transfer.	This operation forms a parallel path, with ($i_a + i_b - i_a - i_b$) current I_s splitting into i_a and i_b at the D892 and Busbar B2 junction, as shown in *Figure 6.140*. To overcome this problem, remove tie-breaker Channel I02 from the B1 differential calculations when G898 closes. (See the ensuing discussion and *Figure 6.140*).
3	Open the circuit breaker of the terminal going on transfer.	Opening the CAIRO circuit breaker interrupts the current path through the circuit breaker. Tie-breaker Channel I01 remains part of the B2 differential calculations to balance the current flow to the CAIRO Terminal.
4	Open the source busbar Disconnect (G892) and the line Disconnect (G893) to isolate the circuit breaker.	Step 4 is shown here to complete the operating sequence; the operation has no effect on the busbar protection.

Figure 6.139 shows the station after Step 1 in *Table 6.95*. Step 1 is standard operating procedure and requires no special busbar protection settings. Because tie-breaker Disconnect Z891 is still closed, both bus-zones B1 and B2 are active. Bus-Zone B1 has only one CT (tie-breaker Channel I02) in place, but because no

current flows through the tie breaker, the relay does not operate. Having both zones active provides the benefit of detecting faults on B1 during these operating conditions.

Figure 6.139 Bus-Zones B1 and B2 Are Balanced When All Transfer Disconnects Are Open

Closing Disconnect G898 in Step 2 of *Table 6.95* forms a parallel path. Current Is enters at the MADRID terminal and splits into i_a and i_b at the D892 and Busbar B2 junction. This current distribution unbalances B1 because current $-i_a$ is missing in the CAIRO CT. The two differential elements calculate the differential currents as follows:

Element for Busbar B1:

$$\begin{aligned} I_{diff} &= (I02) + 0 \text{ (no other CT in place)} \\ &= i_a + 0 \\ &= i_a \text{ (element is unbalanced)} \end{aligned}$$

Equation 6.23

Element for Busbar B2:

$$\begin{aligned} I_{diff} &= (I01) + (I03) + (I06) \\ &= (i_a + i_b) - i_a - i_b \\ &= 0 \text{ (element is balanced)} \end{aligned}$$

Equation 6.24

Figure 6.140 Current Distribution During Transfer Procedure Using Inboard CTs

In Step 3 of *Table 6.95*, we open the CAIRO circuit breaker and the parallel path no longer exists. Current i_b disappears and I_s flows as shown in *Figure 6.141*. The differential element for Busbar B2 is stable (I01 + I03 = 0), but the differential element for Busbar B1 is unbalanced. To conclude, the differential element for Busbar B1 is unbalanced during the transition period (when a parallel path exists) as well as when the terminal is on transfer.

Figure 6.141 Current Distribution After Opening the Circuit Breaker of the Terminal Going on Transfer

Because Disconnect G898 bypasses the CAIRO CT, we cannot provide differential protection for Busbar B1. Because we cannot provide differential protection for Busbar B1, we need to remove the existing differential B1 element to prevent misoperation. We remove differential B1 element by using a zone supervision setting (Z*n*S).

In this application, the tie-breaker current assignment to the differential elements depends on the position of only one of the tie-breaker disconnects: current Channel I01 is assigned to B2 when Z892 is closed. Likewise, current Channel I02 is assigned to B1 when Z891 is closed. The assignment of the feeder currents to the differential elements depends solely on the corresponding B1 and B2 disconnect positions (*n*891 and *n*892).

Consider also that by removing Differential Element B1, the transfer busbar is without protection. One solution is to use the tie-breaker I02 CT for the line protection, thereby including the transfer busbar as part of the line. When using the SEL-421 as line protection, program the selection functions in the relay to select Current I02 as an alternate current source.

To configure the correct disconnect combinations, use the following conditions:

- With no terminal on transfer, manipulate the tie-breaker CTs with the bus-zone-to-bus-zone connections.
- A terminal is on transfer when any *n*898 (*n* = D, E, F, and G) disconnect is closed.
- When a terminal is on transfer, disable the differential element for Busbar B1.

Set the Zone Supervision setting for Busbar B1 as follows: Z1S := NOT (89CL05 OR 89CL08 OR 89CL11 OR 89CL14). *Figure 6.142* shows the Zone Configuration settings for this application.

The zone configuration default settings are settings for a specific substation with arbitrarily selected alias names, serving only as an example. For the ease of setting the zone configuration settings for the new substation, delete the terminal-to-bus-zone default settings. With the terminal-to-bus-zone default settings deleted, the setting prompts no longer reference the default settings.

You can use a combination of primitive and alias names when entering the terminal-to-bus-zone and bus-zone-to-bus-zone connection settings. *Figure 6.142* shows the Zone Configuration settings for this application.

```
=>>SET Z <Enter>
Zone Config Group 1
Potential Transformer Ratio
Potential Transformer Ratio -VO1 (1-10000)          PTR1    := 2000   ?> <Enter>

Current Transformer Ratio
Current Transformer Ratio -IO1 (1-50000)            CTR01   := 600    ?800 <Enter>
Current Transformer Ratio -IO2 (1-50000)            CTR02   := 600    ?800 <Enter>
Current Transformer Ratio -IO3 (1-50000)            CTR03   := 600    ?> <Enter>

Zone Configuration: Terminal to Bus-Zone Connections
Terminal, Bus-Zone, Polarity (P,N)
IO1BZ1C := TIE1_A, ZONE1_A, P
?  DELETE 2OO <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO1,ZONE2_A,P <Enter>
TIE1_A to ZONE2_A Connection (SELogic Equation)
IO1BZ2V := NA
?  89CLO2 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO2,ZONE1_A,P <Enter>
TIE2_A to ZONE1_A Connection (SELogic Equation)
IO2BZ1V := NA
?  89CLO1 <Enter>

Terminal, Bus-Zone, Polarity (P,N)
?  IO3,ZONE1_A,P <Enter>
MADRI_A to ZONE1_A Connection (SELogic Equation)
IO3BZ1V := NA
?  89CLO3 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO3,ZONE2_A,P <Enter>
MADRI_A to ZONE2_A Connection (SELogic Equation)
IO3BZ2V := NA
?  89CLO4 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO4,ZONE1_A,P <Enter>
MILAN_A to ZONE1_A Connection (SELogic Equation)
IO4BZ1V := NA
?  89CLO6 <Enter>

Terminal, Bus-Zone, Polarity (P,N)
?  IO4,ZONE2_A,P <Enter>
MILAN_A to ZONE2_A Connection (SELogic Equation)
IO4BZ2V := NA
?  89CLO7 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO5,ZONE1_A, <Enter>
ROME_A to ZONE1_A Connection (SELogic Equation)
IO5BZ1V := NA
?  89CLO9 <Enter>

Terminal, Bus-Zone, Polarity (P,N)
?  IO5,ZONE2_A,P <Enter>
ROME_A to ZONE2_A Connection (SELogic Equation)
IO5BZ2V := NA
?  89CL10 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO6,ZONE1_A,P <Enter>
CAIRO_A to ZONE1_A Connection (SELogic Equation)
IO6BZ1V := NA
?  89CL12 <Enter>
```

Figure 6.142 Zone Configuration Group Settings for Application 6

```
Terminal, Bus-Zone, Polarity (P,N)
?  IO6,ZONE2_A,P <Enter>
CAIRO_A to ZONE2_A Connection (SELogic Equation)
IO6BZ2V := NA
?  89CL13 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?<Enter>

Zone Configuration: Bus-Zone to Bus-Zone Connections
Bus-Zone, Bus-Zone
?  ZONE1_A,ZONE2_A <Enter>
ZONE1_A to ZONE2_A Connection (SELogic Equation)
BZ1BZ2V := NA
?  (89CLO3 AND 89CLO4) OR (89CLO6 AND 89CLO7) OR (89CLO9 AND 89CL10) OR (89CL12\
 AND 89CL13) <Enter>
Connection to Remove Terminals when ZONE1_A and ZONE2_A merge (SELogic Equation)
BZ1BZ2R := NA
?  BZ1BZ2V <Enter>
Terminals Removed when ZONE1_A and ZONE2_A Bus-Zones merge (Ter k,...,Ter n)
BZ1BZ2M :=
?  TIE1_A,TIE2_A <Enter>

Trip Terminals TIE1_A, TIE2_A (Y,N)
BZ1BZ2T := N
?  Y <Enter>
Bus-Zone, Bus-Zone
?<Enter>
Zone Supervision
Differential Element Zone Supervision (Y,N)          E87ZSUP := N      ?Y <Enter>
Zone 1 Supervision (SELogic Equation)
Z1S := 1
?  NOT(89CLO5 OR 89CLO8 OR 89CL11 OR 89CL14) <Enter>
Zone 2 Supervision (SELogic Equation)
Z2S := 1
?<Enter>

Zone Switching Supervision
Zone Switching Supervision (Y,N)                     EZSWSUP := N      ?<Enter>
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.142 Zone Configuration Group Settings for Application 6 (Continued)

This concludes the zone configuration group settings. The next settings class is the protection group settings.

Protection Group Settings

Settings of this class comprise the protection functions, starting with the function enable settings. Default settings for the differential elements are 60 percent for Slope 1 and 80 percent for Slope 2. To change the slope settings, first enable the advanced settings by setting EADVS := Y. With EADVS := Y, the slope settings and incremental restrained and operating current settings become available.

For this application, we use the default values for the Sensitive Differential Element, the Restrained Differential Element and the Directional Element.

The protection philosophy calls for the blocking of the busbar protection for an open CT condition. Set E87SSUP := Y (see *Figure 5.11* and *Figure 5.18* for more information) to use the sensitive differential element for this requirement. Set TOS := N, E50 := N, E51 := N, E27 := N, E59 := N, and EADVS := N because we do not use the Coupler Security Logic, overcurrent elements, terminal out of service, or voltage elements in this application.

Because breaker failure protection measures each current channel, select the number of breaker failure logics (EBFL setting) equal to the number of current channels, not the number of circuit breakers.

This application has five circuit breakers, but six current channels (tie breaker has two CTs). Therefore, select six as the number of breaker failure logics for this application.

This application assumes a single breaker failure input from the tie-breaker protection. With a single breaker failure input from the tie-breaker protection, set both tie-breaker breaker failure initiate setting (XBF01 and XBF02) equal to IN201. For tie breakers with two breaker failure relays, allocate an additional relay input for the second breaker failure input, and equate each relay input to an XBF*nn* settings. For example, assume the two breaker failure inputs are assigned to relay input IN201 and relay input IN202. With these input assignments, set XBF01 := IN201 and XBF02 := IN202.

Setting NUMBK equal to five makes five corresponding circuit breaker auxiliary input equations (52A01–52A05), and five corresponding trip equations (TR01–TR05) available for setting. There are five trip equations available, but there are six analog channels (I01–I06) at the station. Each of the six analog channels has a corresponding differential trip bit that asserts (*Table 6.91*) when the differential element asserts. Be sure to include these differential trip bits in the trip equations of all circuit breakers you want to trip.

The trip logic latches the trip outputs TRIP*kk* after TR*kk* assertion. One way to deassert the trip outputs is to press the **TARGET RESET** pushbutton on the front panel. An alternative method is to enter specific reset conditions at the ULTR*kk* settings.

Each of the six analog channels also has a corresponding station breaker failure trip bit that asserts (*Table 6.92*) when the breaker failure element asserts. Be sure to include these station breaker failure trip bits in the trip equations of all circuit breakers you want to trip.

Because the tie breaker has two analog channels, but only one circuit breaker, include both differential trip bits (87BTR01 and 87BTR02) as well as both station breaker failure trip bits (SBFTR01 and SBFTR02) in the trip equation of the tie breaker (TR01). *Figure 6.143* shows the protection group settings for this application.

```
=>>SET <Enter>
Group 1
Relay Configuration
Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y      ? <Enter>
Coupler Security Logic (N,1-4)                       ECSL    := N      ? <Enter>

Terminal Out of Service (N,1-21)                     ETOS    := 5      ?N <Enter>
Breaker Failure Logic (N,1-21)                       EBFL    := 6      ? <Enter>
Definite Time Overcurrent Elements (N,1-21)          E50     := N      ? <Enter>
Inverse Time Overcurrent Elements (N,1-21)           E51     := N      ? <Enter>
Enable Under Voltage Elements (N,1-6)                E27     := N      ? <Enter>
Enable Over Voltage Elements (N,1-6)                 E59     := N      ? <Enter>

Advanced Settings (Y,N)                              EADVS   := N      ? <Enter>
Sensitive Differential Element
Sensitive Differential Element Pickup (0.05-1 pu)    S87P    := 0.10   ?> <Enter>
Restrained Differential Element
Restrained Diff Element Pickup (0.10-4 pu)           O87P    := 1.00   ?> <Enter>
Directional Element
Dir Element O/C Supervision Pickup (0.05-3 pu)       50DSP   := 0.05   ?> <Enter>

Breaker 01 Failure Logic
External Breaker Fail -BK01 (Y,N)                    EXBF01  := N      ?Y <Enter>
External Brkr Fail Init -BK01 (SELogic Equation)
XBF01 := NA
?  IN201 <Enter>
Brkr Fail Init Dropout Delay -BK01 (0.00-1000 cyc)   BFID001 := 1.50   ? <Enter>
```

Figure 6.143 Protection Group Settings for Application 6

```
Breaker 02 Failure Logic
External Breaker Fail -BK02 (Y,N)                    EXBF02  := N      ?Y <Enter>
External Brkr Fail Init -BK02 (SELogic Equation)
XBF02 := NA
?  IN201 <Enter>
Brkr Fail Init Dropout Delay -BK02 (0.00-1000 cyc)   BFID002 := 1.50   ? <Enter>
.
.
.

External Breaker Fail -BK06 (Y,N)                    EXBF06  := N      ?Y <Enter>
External Brkr Fail Init -BK06 (SELogic Equation)
XBF05 := NA
?  IN302<Enter>
Brkr Fail Init Dropout Delay -BK05 (0.00-1000 cyc)   BFID005 := 1.50   ? <Enter>

Trip Logic
Trip 01 (SELogic Equation)
TR01 := SBFTR01 OR 87BTR01
?  SBFTR01 OR 87BTR01 OR SBFTR02 OR 87BTR02 <Enter>
Unlatch Trip 01 (SELogic Equation)
ULTR01 := NA
? <Enter>
Trip 02 (SELogic Equation)
TR02 := SBFTR02 OR 87BTR02
?  SBFTR03 OR 87BTR03 <Enter>
Unlatch Trip 02 (SELogic Equation)
ULTR02 := NA
? <Enter>

Trip 03 (SELogic Equation)
TR03 := SBFTR03 OR 87BTR03
?  SBFTR04 OR 87BTR04 <Enter>
Unlatch Trip 03 (SELogic Equation)
ULTR03 := NA
? <Enter>
.
.
.

Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000 ?4 <Enter>
Event Report Trigger Equation (SELogic Equation)
.
.
.
Trip 05 (SELogic Equation)
TR05 := SBFTR05 OR 87BTR05 OR SBFTR06 OR 87BTR06
?  SBFTR06 OR 87BTR06 <Enter>
Unlatch Trip 05 (SELogic Equation)
ULTR05 := NA
? <Enter>
Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000 ?4 <Enter>
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.143 Protection Group Settings for Application 6 (Continued)

This concludes the protection group settings. The next settings class is control output settings.

Control Output Settings

In this setting class, we assign the logic or Relay Word bits in the relay to output contacts. We need five output contacts for our example. Although not specifically called for in the protection philosophy, it is good practice to also include the default TEST and ALARM outputs in the relay settings. Because each relay protects only one phase of the power system, combine the trip outputs from the three relays in a single output to the circuit breaker. Jumper (hardwire) the trip output from each relay, and connect the cable to the circuit breaker trip coil to any one of the three relays.

We include Protection Latch Bit PLT03 in the output equation. With PLT03 included in every output equation, the **RELAY TEST MODE** pushbutton disables all output contacts.

Because we do not use any output contacts from the main board for protection functions (OUT107 and OUT108 are used for alarming purposes), set OUT101–OUT106 = NA. *Figure 6.144* shows the control output settings.

```
=>>SET O <Enter>
Output
Main Board
OUT101 := TRIP01 AND NOT TNS_SW
?  NA <Enter>
OUT102 := TRIP02 AND NOT TNS_SW
?  NA <Enter>

OUT103 := TRIP03 AND NOT TNS_SW
?  NA <Enter>
OUT104 := TRIP04 AND NOT TNS_SW
?  NA <Enter>
OUT105 := TRIP05 AND NOT TNS_SW
?  NA <Enter>
OUT106 := NA
?  > <Enter>

Interface Board #1
OUT201 := NA
?  TRIP01 AND NOT PLT03 <Enter>
OUT202 := NA
?  TRIP02 AND NOT PLT03 <Enter>
OUT203 := NA
?  TRIP03 AND NOT PLT03 <Enter>
OUT204 := NA
?  TRIP04 AND NOT PLT03 <Enter>
OUT205 := NA
?  TRIP05 AND NOT PLT03 <Enter>
OUT206 := NA
?  END <Enter>

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

=>>
```

Figure 6.144 Control Output Settings for Application 6

Application 7: Double and Transfer Bus (Outboard CTs)

This application describes the busbar arrangement shown in *Figure 6.145*. The busbar arrangement consists of three busbars, four terminals, and a tie breaker. Use the following to set and configure the relay:

- Busbar classification
- Protection philosophy
- Protection function selection
- Number of SEL-487B Relays and I/O boards
- Input, logic, and output allocation
- Station layout update
- Relay setting and configuration

Figure 6.145 Double Bus and Transfer Bus With Bus Coupler (Tie Breaker) and Outboard CTs

Busbar Classification

The busbar classification provides general busbar layout and CT positioning (inboard or outboard) information and it declares the tie-breaker (bus coupler) configuration.

- Description:
  - Double bus with transfer busbar
- Current transformers:
  - Outboard (free standing)
- Disconnects:
  - 89A and 89B disconnect auxiliary contacts are available
- Bus coupler (tie breaker):
  - Single CT with one core used for busbar protection
- Future expansion:
  - Five feeders

Protection Philosophy

Although the SEL-487B offers a variety of protection and control functions, not every application uses all these functions. Carefully consider each application before stating the functional requirements. The protection philosophy for this application is as follows:

1. Rename only the terminals and bus-zones with alias names.
2. Block the busbar protection for an open-circuit CT.
3. Use the disconnect auxiliary contacts to dynamically configure the station.
4. Use the disconnect monitor logic.
5. Use external breaker failure protection.
6. Prevent the loss of Busbar B2 for a fault between the tie breaker and tie-breaker CT.

Protection Functions Selection

We select protection functions early in the relay setting and configuration process because the choice of protection functions determines the number of relay digital inputs and outputs necessary for the application. Study the protection philosophy to determine which protection and/or control functions to apply to any particular substation. For example, in this application, the protection philosophy calls for the use of breaker failure protection but not for overcurrent protection. The SEL-487B offers a number of protection functions as standard features, but it also offers the capability through SELOGIC control equations for you to create user-configurable functions.

To prevent tripping of Busbar B2 when there is a fault between the tie breaker and tie-breaker CT, we can delay tripping of Busbar B2 and trip the tie breaker first (see *Protection Group Settings on page 6.201*). We then remove the tie-breaker currents from the differential calculations of both zones to trip Busbar B1 and not Busbar B2.

To properly identify and categorize the protection philosophy requirements, group the protection functions as follows:

- standard protection functions (available in the relay)
- user-defined protection functions (created with SELOGIC control equations).

Standard Functions

Refer to *Protection Philosophy on page 6.183* and select the standard functions necessary for the application. *Table 6.96* shows the selection of standard functions.

Table 6.96 Selection of the Standard Protection Functions (Sheet 1 of 2)

Protection Functions	Selection	Comment
CT ratio mismatch ≤ 10:1	Yes	10:1 mismatch is the maximum allowable mismatch
Circuit breaker status logic	No	Not required
Disconnect monitor logic	Yes	89A and 89B disconnect contacts available
Differential protection	Yes	Busbar protection (zone specific and check zone)

Table 6.96 Selection of the Standard Protection Functions (Sheet 2 of 2)

Protection Functions	Selection	Comment
Dynamic zone selection logic	Yes	Use the zone selection to reconfigure the differential protection according to the disconnect positions.
Sensitive differential protection	Yes	CT open circuit detection
Zone supervision logic	Yes	Use the zone supervision logic as part of preventing the loss of Busbar B2 for a fault between the tie breaker and the tie-breaker CT.
Zone-switching supervision logic	No	89A and 89B disconnect contacts available, so this logic is not required.
Coupler security logic	Yes	Use the coupler security logic in a single CT application for enhanced protection for faults between the tie-breaker CT and the circuit breaker.
Circuit breaker failure protection	Yes	External breaker failure
Instantaneous overcurrent protection	No	Not required
Time-overcurrent protection	No	Not required
Phase voltage elements	No	Not required
Zero- or negative-sequence voltage elements	No	Not required

User-Defined Functions

Identify logic functions we need that is not part of the standard relay logic in the relay. In this application, we comply with the protection philosophy using the standard functions in the relay.

Number of Relays and I/O Boards

Selecting the relay has two parts:

- the number of relays (single-relay application or three-relay application)
- the number of interface boards (as many as four interface boards per relay).

The number of analog (CT) inputs determines the number of relays, and the number of digital inputs and outputs determines the number of interface boards.

Number of Relays

Each SEL-487B has 21 current channels and three voltage channels. For stations with as many as 21 CTs (per phase), we can install a single SEL-487B. For stations with more than 21 and as many as 63 CTs, we install 3 SEL-487B Relays. Use *Equation 6.25* to calculate the number of current channels at the station, and use *Equation 6.26* to calculate the number of zones at the station.

$$\text{\# of current channels required} = \text{\# of per-phase station CTs}$$

Equation 6.25

$$\text{\# of bus-zones required} = \text{\# of per-phase station CTs}$$

Equation 6.26

The number of per-phase CTs at the station is 15 (tie breaker has three CT cores), so one SEL-487B suffices. However, the requirement for 5 future feeders increases the number of per-phase CTs to 30. Because each SEL-487B has 21 analog input channels, we need 3 relays. This is known as a three-relay application.

In a three-relay application, each relay provides six zones of protection for one of the three phases of the power system. For example, wire all the A-phase CTs to Relay 1, the B-phase CTs to Relay 2, and the C-phase CTs to Relay 3. Settings for the three relays are identical; all three relays require the same information. Wire input and output contacts (from the circuit breaker or disconnects, for example) to one of the three relays, then jumper (hardwire) the input and output contacts to the other two relays.

This example shows the setting and configuration for the A-phase relay, so identified with an appended letter A (MADRI_A). For the other two relays, the settings and configuration are the same as for the A-phase relay, but the appended letter changes according to the letter designation of the relay. For example, the corresponding MADRI_A setting is MADRI_B in the B-phase relay, and MADRI_C in the C-phase relay.

Number of Relay Inputs

The protection philosophy and protection function selection determine the number of digital relay inputs and outputs required for each application.

The number of disconnect logics (NUMDS) required is the number of disconnects for which the protection philosophy requires disconnect monitoring logic. In this example, the tie breaker and each of the 4 feeders require 3 disconnect monitoring logics; the number of disconnect logics required therefore is 15. Each disconnect monitoring logic requires two disconnect auxiliary contact inputs: an 89A and an 89B contact. Use *Equation 6.27* to calculate the number of relay inputs required for the disconnect auxiliary contacts.

$$\text{\# relay inputs required} = 2 \bullet \text{\# disconnect monitoring logics}$$

Equation 6.27

The protection philosophy calls for external breaker failure as well as dynamic zone selection. Use the external breaker failure logic when the breaker failure relays are integrated in the terminal protection. The zone selection dynamically reconfigures the station according to the disconnect positions and records the terminals in each bus-zone. When a circuit breaker fails, the relay uses this information to only trip the terminals in the bus-zone with the failed circuit breaker. Wire a breaker failure output contact from each breaker failure relay on each of the terminals to the SEL-487B.

We will use the coupler security logic to prevent tripping of Busbar B2 when there is a fault between the tie breaker and the tie-breaker CT. The coupler security logic requires three inputs: a close signal, a circuit breaker 52A auxiliary contact, and an input for the accelerated tripping function (see *Figure 6.110* for more information). We need one input for the circuit breaker 52A auxiliary contact and one input for the closing signal. For the accelerated tripping input (ACTRP1), we use the output from the B2 differential element (87R2). *Table 6.97* summarizes the input contact necessary for this application.

Table 6.97 Relay Input Contacts Requirement

Input Description	Inputs
Number of relay inputs required for the disconnect contacts	2 • 15 = 30
Number of relay inputs required for breaker failure protection	5
Number of relay inputs required for the coupler security logic on the tie breaker	2 (one closing signal and one circuit breaker auxiliary 52A contact)
Total number of inputs	37

The relay main board has seven input contacts, an insufficient number of inputs for our application. Each interface board provides two sets of nine grouped inputs and six independent inputs. Use the grouped inputs for the disconnect auxiliary contact inputs, and use the six independent inputs for the breaker failure inputs. From the input perspective, we need two interface boards.

Number of Relay Output Contacts

Our example station has five circuit breakers, all of which are part of the busbar differential protection. Because all circuit breakers are part of the busbar differential protection, we want to trip each breaker when the differential protection operates. *Table 6.98* shows the breakdown and the number of relay output contacts necessary for tripping.

Table 6.98 Breakdown and Number of Relay Outputs Required

Output Description	Outputs
Number of relay output contacts required for breaker tripping	5
Total number of relay output contacts	5

The relay main board has eight standard output contacts (Output Contact 7 is used to assert when the RELAY TEST MODE pushbutton from the front panel is selected, and Output Contact 8 is used for alarming purposes in the default settings). However, the main board contacts are all standard output contacts. The interface boards have high-speed, high-interrupting output contacts that provide faster contact closure. Each interface board can provide six high-speed, high-interrupting output contacts and two standard output contacts. For fast busbar fault clearance, assign each circuit breaker trip output to a high-speed, high-interrupting output contact for each of the circuit breakers at the station. From the output contact perspective, we need one interface board.

The conclusion from the preceding analysis is that we need three SEL-487B Relays, each relay equipped with two interface boards.

Input, Logic, and Output Allocation and Alias Name Assignment

At this point, we have determined the following:

- The number of SEL-487B Relays required for the application
- The number of inputs
- The number of output contacts
- The selected protection functions

For example, we have matched the number of CTs at the station with the number of available analog channels in the relay. However, we still need to do the following:

- Link specific CT inputs to specific relay analog channels
- Link specific disconnect and circuit breaker inputs to specific relay inputs
- Link relay element/logic outputs to specific relay output contacts
- Assign alias names where appropriate

Assign a valid seven-character alias name to any of the following:

- Relay Word bit
- Analog Quantity
- Terminal Name
- Bus-Zone Name

Alias names are valid when they consist of a maximum of seven characters, and they are constructed with characters 0–9, uppercase A–Z, or the underscore (_).

CT-to-Analog Channel Allocation and CT Alias Assignment

The protection philosophy specifies that only the terminals and bus-zones need alias names. *Table 6.99* shows CT-to-relay analog channel allocations and alias assignments. For example, allocate the A-phase tie-breaker CT to relay channel I01, and assign to this CT the alias name TIE_A. The choice of CT-to-analog channel allocation is arbitrary; you can assign the CTs randomly to relay analog channels. *Table 6.99* shows the assignment for the A-phase relay starting with the tie-breaker CTs, followed by the four terminals, taken left-to-right from *Figure 6.145*.

Table 6.99 CTs-to-Analog Channel Allocations and Alias Assignments

CTs	Analog Channel	Alias
TIE-BREAKER CT, A-phase	I01	TIE_A
MADRID terminal, A-phase	I02	MADRI_A
MILAN terminal, A-phase	I03	MILAN_A
ROME terminal, A-phase	I04	ROME_A
CAIRO terminal, A-phase	I05	CAIRO_A

Bus-Zone Alias Assignment

Each SEL-487B provides six zones of protection. For the A-phase relay, we use three bus-zone alias names, as shown in *Table 6.100*.

Table 6.100 Alias Names for the Three Bus-Zones

Bus-Zone Name	Description	Alias
BZ1	Bus-Zone 1	ZONE1_A
BZ2	Bus-Zone 2	ZONE2_A
BZ3	Transfer busbar	TRANS_A

Input-to-Logic Allocation

Table 6.97 shows that we require 37 digital inputs. We now assign the digital inputs to the selected logic. Because of the functional requirements of this application, we do not need any digital inputs on the main board.

Input-to-Logic Allocation, Interface Board 1 (200)

Table 6.101 and *Table 6.102* show the disconnect and circuit breaker failure contact input allocations. Because Inputs IN201, IN202, IN203, IN213, IN214, and IN215 are independent inputs, we assign the circuit breaker failure (only one breaker failure initiate input for the tie breaker) initiate input signals, tie-breaker 52A auxiliary contact, and the tie-breaker closing signal to these relay inputs.

Table 6.101 Disconnect and Circuit Breaker Failure Contact Input Allocations

Input	Description
IN201	TIE-BREAKER breaker failure input
IN202	MADRID breaker failure input
IN203	MILAN breaker failure input
IN204	TIE-BREAKER disconnect (ZONE1_A) NO contact
IN205	TIE-BREAKER disconnect (ZONE1_A) NC contact
IN206	TIE-BREAKER disconnect (ZONE2_A) NO contact
IN207	TIE-BREAKER disconnect (ZONE2_A) NC contact
IN208	TIE-BREAKER disconnect (TRANS _A) NO contact
IN209	TIE-BREAKER disconnect (TRANS _A) NC contact
IN210	MADRID terminal disconnect (ZONE1_A) NO contact
IN211	MADRID terminal disconnect (ZONE1_A) NC contact
IN212	MADRID terminal disconnect (ZONE2_A) NO contact
IN213	TIE-BREAKER circuit breaker 52A auxiliary contact
IN214	TIE-BREAKER circuit breaker closing signal
IN216	MADRID terminal disconnect (ZONE2_A) NC contact
IN217	MADRID terminal disconnect (TRANS _A) NO contact
IN218	MADRID terminal disconnect (TRANS _A) NC contact
IN219	MILAN terminal disconnect (ZONE1_A) NO contact
IN220	MILAN terminal disconnect (ZONE1_A) NC contact
IN221	MILAN terminal disconnect (ZONE2_A) NO contact
IN222	MILAN terminal disconnect (ZONE2_A) NC contact
IN223	MILAN terminal disconnect (TRANS _A) NO contact
IN224	MILAN terminal disconnect (TRANS _A) NC contact

Input-to-Logic Allocation, Interface Board 2 (300)

Table 6.102 shows the disconnect and circuit breaker auxiliary contact input allocations. Because Inputs IN301, IN302, IN303, IN313, IN314, and IN315 are independent inputs, we assign the circuit breaker failure input signals to these relay inputs.

Table 6.102 Disconnect and Circuit Breaker Failure Contact Input Allocations

Input	Description
IN301	ROME breaker failure input
IN302	CAIRO breaker failure input
IN304	ROME terminal disconnect (ZONE1_A) NO contact
IN305	ROME terminal disconnect (ZONE1_A) NC contact
IN306	ROME terminal disconnect (ZONE2_A) NO contact
IN307	ROME terminal disconnect (ZONE2_A) NC contact
IN308	ROME terminal disconnect (TRANS _A) NO contact
IN309	ROME terminal disconnect (TRANS _A) NC contact
IN310	CAIRO terminal disconnect (ZONE1_A) NO contact
IN311	CAIRO terminal disconnect (ZONE1_A) NC contact
IN312	CAIRO terminal disconnect (ZONE2_A) NO contact
IN316	CAIRO terminal disconnect (ZONE2_A) NC contact
IN317	CAIRO terminal disconnect (TRANS _A) NO contact
IN318	CAIRO terminal disconnect (TRANS _A) NC contact

Assignment of the Selected Standard Logic

The following discussion references *Table 6.96* in explaining each selected function.

Disconnect Monitoring Logic

Figure 6.146 shows one of the 60 disconnect monitor logic circuits available in the relay.

Figure 6.146 Disconnect Monitoring Logic Circuit for Terminal O1

Table 6.103 shows the assignment of the disconnect auxiliary contact Relay Word bits.

Table 6.103 Disconnect Auxiliary Contact Relay Word Bits (Sheet 1 of 2)

Input	Description
89A01	TIE-BREAKER disconnect (ZONE1_A) NO contact
89B01	TIE-BREAKER disconnect (ZONE1_A) NC contact
89A02	TIE-BREAKER disconnect (ZONE2_A) NO contact
89B02	TIE-BREAKER disconnect (ZONE2_A) NC contact
89A03	TIE-BREAKER disconnect (TRANS_A) NO contact
89B03	TIE-BREAKER disconnect (TRANS_A) NC contact

Table 6.103 Disconnect Auxiliary Contact Relay Word Bits (Sheet 2 of 2)

Input	Description
89A04	MADRI_A disconnect (ZONE1_A) NO contact
89B04	MADRI_A disconnect (ZONE1_A) NC contact
89A05	MADRI_A disconnect (ZONE2_A) NO contact
89B05	MADRI_A disconnect (ZONE2_A) NC contact
89A06	MADRI_A disconnect (TRANS_A) NO contact
89B06	MADRI_A disconnect (TRANS_A) NC contact
89A07	MILAN_A disconnect (ZONE1_A) NO contact
89B07	MILAN_A disconnect (ZONE1_A) NC contact
89A08	MILAN_A disconnect (ZONE2_A) NO contact
89B08	MILAN_A disconnect (ZONE2_A) NC contact
89A09	MILAN_A disconnect (TRANS_A) NO contact
89B09	MILAN_A disconnect (TRANS_A) NC contact
89A10	ROME_A disconnect (ZONE1_A) NO contact
89B10	ROME_A disconnect (ZONE1_A) NC contact
89A11	ROME_A disconnect (ZONE2_A) NO contact
89B11	ROME_A disconnect (ZONE2_A) NC contact
89A12	ROME_A disconnect (TRANS_A) NO contact
89B12	ROME_A disconnect (TRANS_A) NC contact
89A13	CAIRO_A disconnect (ZONE1_A) NO contact
89B13	CAIRO_A disconnect (ZONE1_A) NC contact
89A14	CAIRO_A disconnect (ZONE2_A) NO contact
89B14	CAIRO_A disconnect (ZONE2_A) NC contact
89A15	CAIRO_A disconnect (TRANS_A) NO contact
89B15	CAIRO_A disconnect (TRANS_A) NC contact

Wire a normally open disconnect auxiliary contact (89A) and a normally closed disconnect auxiliary contact (89B) from each disconnect to individual relay inputs on the A-phase relay. Jumper (hardwire) the disconnect inputs to the other two relays. Relay Word bits 89CL*nn* assert when the disconnect monitoring logic interprets the disconnect main contacts as closed. Use Relay Word bits 89CL*nn* as conditions in the terminal-to-bus-zone SELOGIC control equations.

Differential Trip Logic and Differential Element Assignment

Figure 6.147 shows the differential trip logic for Differential Element 1. Relay Word bit 87Z1 asserts only if the zone supervision conditions permit an output from the AND gate. (See *Section 5: Protection Functions* for more information.) *Table 6.104* shows Relay Word bits and description for the differential protection outputs.

Table 6.104 Zone Differential Protection Output Relay Word Bits

Primitive Name	Description
87Z1	Zone 1 differential element trip
87Z2	Zone 2 differential element trip
87Z3	Transfer zone differential element trip

Differential trip bits 87BTR01–87BTR05 assert to trip the circuit breakers of the terminals in the faulted bus-zone. (See *Section 5: Protection Functions* for more information.)

Figure 6.147 Differential Trip Logic for Differential Element 1

Be sure to include the differential trip bits in the trip equations of all the terminals you want to trip when the differential elements operate (see *Global Settings on page 6.196*). *Table 6.105* shows the differential trip bit names and the associated terminal current channels.

Table 6.105 Differential Trip Bit and Associated Terminals

Differential Trip Bit	Description
87BTR01	Associated with Terminal 01
87BTR02	Associated with Terminal 02
87BTR03	Associated with Terminal 03
87BTR04	Associated with Terminal 04
87BTR05	Associated with Terminal 05

Breaker Failure Trip Logic and Station Breaker Failure Logic Output Assignment

Figure 6.148 shows the station breaker failure trip logic. Relay Word bits FBF01–FBF05 are the inputs to the station breaker failure logic; Relay Word bits SBFTR01–SBFTR05 are the outputs from the station breaker failure logic. Breaker failure trip bits SBFTR01–SBFTR05 assert to trip the circuit breakers of the terminals in the bus-zone with the failed circuit breaker. (See *Section 5: Protection Functions* for more information.)

Figure 6.148 Breaker Failure Trip Logic

Table 6.106 shows the station breaker failure Relay Word bits and the primitive names for the breaker failure protection outputs.

Table 6.106 Station Breaker Failure Trip Bits and Associated Terminals

Station Breaker Failure Trip Bits	Description
SBFTR01	Associated with Terminal 01
SBFTR02	Associated with Terminal 02
SBFTR03	Associated with Terminal 03
SBFTR04	Associated with Terminal 04
SBFTR05	Associated with Terminal 05

Be sure to include the station breaker failure trip bits in the trip equations of all the terminals you want to trip for breaker failure protection. In this example, we want to trip five circuit breakers.

Breaker Failure Input Assignments

This application uses external breaker failure protection. *Figure 6.149* shows the logic for the external breaker failure function.

Figure 6.149 Breaker Failure Logic for External Breaker Failure

We assign the relay breaker failure inputs shown in *Table 6.101* and *Table 6.102* to the appropriate XBF*qq* (*qq* = 01–05) of the breaker failure protection logic (see *Protection Group Settings on page 6.201*). *Table 6.107* shows the relay input and terminal assignments.

Table 6.107 Breaker Failure Logic Input Relay Word Bits

Logic Name	Description
IN201	TIE_A breaker failure protection asserted
IN202	MADRI_A breaker failure protection asserted
IN203	MILAN_A breaker failure protection asserted
IN301	ROME_A breaker failure protection asserted
IN302	CAIRO_A breaker failure protection asserted

Relay Logic-to-Output Contact Allocation and Output Contact Assignments

Table 6.98 shows the breakdown of the five relay outputs we need for this application. We now link the appropriate relay logic outputs to specific relay output contacts. *Table 6.108* shows TEST and ALARM protection logic output assignment to the main board output contacts. *Table 6.109* shows the linking of the trip logic outputs to the relay output contacts of Interface Board 1.

Output Assignment, Main Board

This application requires no other output contacts from the main board.

Table 6.108 Alias Names for the Main Board Output Contacts

Output Contact Assignment	Description	Output Contact Alias
OUT107	Relay in test mode	TEST
OUT108	Relay alarm	ALARM

Output Assignment, Interface Board 1 (200)

Each interface board of the SEL-487B can include six high-speed, high-interrupting output contacts. *Table 6.109* shows the assignments for the five terminals of the A-phase relay.

Table 6.109 Assignment of the Output Terminals

Output Contact Assignment	Description
OUT201[a]	TIE-BREAKER trip output
OUT202[a]	MADRID trip output
OUT203[a]	MILAN trip output
OUT204[a]	ROME trip output
OUT205[a]	CAIRO trip output

[a] High-speed, high-interrupting outputs.

Station Layout Update (A-Phase)

We are now ready to set and configure the relay. Write all relevant information on the station diagram, as shown in *Figure 6.150*.

1. Write down the bus-zone, terminal, and disconnect names.
2. Allocate the terminal CTs to the relay input current channels.
3. Allocate the terminal auxiliary contacts to the relay digital inputs.
4. Allocate the digital outputs from the relay to the terminals.

Figure 6.150 Substation Layout With Specific Terminal Information

Setting the Relay

The following describes the settings for this application. We set the following settings classes:

- Alias Settings
- Global Settings
- Zone Configuration Group Settings
- Protection Group Settings
- Control Output Settings

Alias Settings

We have identified and allocated the alias names to the analog channels and Relay Word bits. We now enter the alias names in the relay. Type **SET T <Enter>** to enter the alias settings class. Many default Relay Word bits have useful alias names ready for use. Type **LIST <Enter>** to see a list of default primitive names and associated alias names, as shown in *Figure 6.151*.

After inspecting the list, we decide the only useful alias names are those of the 16 LEDs, TEST, and ALARM.

```
=>>SET T <Enter>
Alias
Relay Aliases
(RW Bit or Analog Qty. or Terminal or Bus-Zone, 7 Character Alias [0-9 A-Z _])
1: IO1,"FDR_1"
?  LIST <Enter>
1: IO1,"FDR_1"
2: IO2,"FDR_2"
3: IO3,"FDR_3"
4: IO4,"TRFR_1"
5: IO5,"TB_1"
6: IO6,"TB_2"
7: BZ1,"BUS_1"
8: BZ2,"BUS_2"

.
.
.
68: TLED_23,"52_ALRM"
69: TLED_24,"IRIGLED"
1: IO1,"FDR_1"
?
```

Figure 6.151 List of Default Primitive Names and Associated Alias Names

Type **DELETE 43 <Enter>** at the first action prompt to delete the first 43 default alias names, as shown in *Figure 6.152*.

```
1: IO1,"FDR_1"
?  DELETE 43 <Enter>
```

Figure 6.152 Deletion of the First 43 Alias Names

Type **> <Enter>** to advance to the next available line in the settings list.

Enter the alias names for the six analog channels and Relay Word bits, as shown in *Figure 6.153*.

```
1: OUT107,"TEST"
?  > <Enter>
27:
?  IO1,TIE_A <Enter>
28:
?  IO2,MADRI_A <Enter>
29:
?  IO3, MILAN_A <Enter>
30:
?  IO4, ROME_A <Enter>
31:
?  IO5, CAIRO_A <Enter>
32:
?  BZ1,ZONE1_A <Enter>
33:
?  BZ2,ZONE2_A <Enter>
34:
?  BZ3,TRANS_A <Enter>
35:
?  END <Enter>
Alias
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.153 Analog Quantities and Relay Word Bit Alias Names

This concludes the alias settings. The next settings class is Global settings.

Global Settings

Global settings comprise settings that apply to all protection settings groups. For example, when changing from Protection Setting Group 1 to Protection Setting Group 2, Global settings such as station name and relay name still apply. *Figure 6.154* shows the settings changes we need for our example. Because we declared the alias names in the previous settings class, use either the alias names or the primitive names when entering settings.

Set NUMBK to 5 because there are five circuit breakers at the station. Setting NUMBK to 5 makes five corresponding circuit breaker auxiliary input equations (52A01–52A05), and five corresponding trip equations (TR01–TR05) available for setting.

Declare here the input for the breaker status logic (52A01) for current channel I01 (52A01 := IN213). Set the remaining four circuit breaker auxiliary input equations (52A02–52A05) to NA.

Setting NUMDS declares the number of disconnect logics we need, not the number of disconnect inputs. In our example, we need 15 disconnect logics. You can set each disconnect travel time individually with the 89ALP*pp* setting (*pp* = 01–15). Travel time is the period during which both disconnect auxiliary contacts are in the open position. Measure the travel time during commissioning and adjust the settings appropriately. Based on previous experience with similar equipment, we set the tie-breaker disconnect travel time to 400 cycles in this example.

```
=>>SET G <Enter>
Global
General Global Settings
Station Identifier (40 characters)
SID := "Station A"
?<Enter>
Relay Identifier (40 characters)
RID := "Relay 1"
?<Enter>

Number of Breakers (N,1-21)                        NUMBK   := 5      ?<Enter>
Number of Disconnects (N,1-60)                     NUMDS   := N      ?15 <Enter>
Nominal System Frequency (50,60 Hz)                NFREQ   := 60     ?> <Enter>
Global Enables
Station DC Battery Monitor (Y,N)                   EDCMON  := N      ?> <Enter>
Control Inputs (Global)
Input Pickup Delay (0.00-30 ms)                    GINPU   := 2.0   ?> <Enter>

Settings Group Selection
Select Setting Group 1 (SELogic Equation)
SS1 := NA
?  > <Enter>
Time and Date Management
Date Format (MDY,YMD,DMY)                          DATE_F  := MDY    ?> <Enter>

Breaker Inputs
N/O Contact Input -BK01 (SELogic Equation)
52A01 := NA
?  IN213 <Enter>
N/O Contact Input -BK02 (SELogic Equation)
52A02 := NA
? <Enter>
N/O Contact Input -BK03 (SELogic Equation)
52A03 := NA
?  > <Enter>

Disconnect Inputs and Timers
N/O Contact Input -DS01 (SELogic Equation)
89A01 := NA
?  IN204 <Enter>
N/C Contact Input -DS01 (SELogic Equation)
89B01 := NA
?  IN205 <Enter>
DS01 Alarm Pickup Delay (0-99999 cyc)              89ALP01 := 300    ?400 <Enter>

N/O Contact Input -DS02 (SELogic Equation)
89A02 := NA
?  IN206 <Enter>
N/C Contact Input -DS02 (SELogic Equation)
89B02 := NA
?  IN207 <Enter>
DS02 Alarm Pickup Delay (0-99999 cyc)              89ALP02 := 300    ?400 <Enter>
N/O Contact Input -DS03 (SELogic Equation)
89A03 := NA
?  IN208 <Enter>

N/C Contact Input -DS03 (SELogic Equation)
89B03 := NA
?  IN209 <Enter>
DS03 Alarm Pickup Delay (0-99999 cyc)              89ALP03 := 300    ?400 <Enter>
N/O Contact Input -DS04 (SELogic Equation)
89A04 := NA
?  IN210 <Enter>
N/C Contact Input -DS04 (SELogic Equation)
89B04 := NA
?  IN211 <Enter>

DS04 Alarm Pickup Delay (0-99999 cyc)              89ALP04 := 300    ?<Enter>
N/O Contact Input -DS05 (SELogic Equation)
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.154 Global Settings

This concludes the Global settings. The next settings class is the zone configuration Group settings.

Zone Configuration Group Settings

The terminal-to-bus-zone SELOGIC control equations identify an analog channel, a differential element, and the conditions for which the relay assigns the analog channel to the differential element. Dynamic zone selection provides a mechanism for automatically reconfiguring the zone of protection, without any wiring changes (see *Dynamic Zone Selection Logic on page 5.14* for more information).

In this example, the dynamic zone selection logic uses the disconnect auxiliary contacts status to determine the station configuration and assign the input currents from the CTs to the appropriate differential elements.

For each disconnect, wire an 89A and an 89B disconnect auxiliary contact to the relay. Because the disconnect simultaneously operates all three phases of the terminal, we state the disconnect status in the terminal-to-bus-zone SELOGIC control equations of all three relays. Because we wire a disconnect auxiliary contacts to only one relay, jumper (hardwire) the contact to the two other relays. For example, when we close the busbar disconnect on the Milan feeder, all three phases (MILAN_A, MILAN_B, and MILAN_C) operate together. Because the relay measures the three phases in three separate relays (phase MILAN_A in the A-phase relay, phase MILAN_B in B-phase relay, etc.), we need to convey the disconnect status to all three relays.

For this discussion, we define the following terms:

- Source busbar: the busbar to which all terminals are connected, except the terminal on transfer
- Transfer busbar: the busbar to which the terminal on transfer is connected
- Transfer disconnect: the disconnect that connects the feeder to the transfer busbar (Disconnect G898 on the CAIRO Feeder)

Although the relay is flexible enough to accept settings for many possible disconnect combinations, we will configure the relay according to the following operating conditions:

1. Only one terminal will be on transfer at any given time, i.e., the tie-breaker transfer disconnect (Z898) and the transfer disconnect (*n*898, *n* = D, E, F, G) of only one of the four terminals can be closed simultaneously.
2. Only Busbar B2 can be the source busbar.
3. The operating sequence to put a terminal on transfer is fixed. Because the operating sequence defines a set of operating rules, settings engineers can decide on appropriate terminal-to-bus-zone and bus-zone-to-bus-zone connection settings for each step. *Table 6.110* shows the operating sequence for the settings in this application; many other operating sequences are possible and in use.

Refer to *Figure 6.157* and consider a case in which we put the CAIRO Feeder on transfer. Assume that the tie breaker is closed and that tie-breaker disconnect Z891 and disconnect Z892 are closed.

Table 6.110 Fixed Operating Sequence to Put a Feeder on Transfer

Step Number	Description	Comment
1	Switch all terminals to the source busbar (B2).	Close all the disconnects that connect the terminals to ZONE2_A (D892, E892, etc.)
2	Open the tie-breaker circuit breaker. Open Disconnect Z891, and close Disconnect Z898.	Closing Disconnects Z891 and Z898 forms the path from source busbar to transfer busbar (Busbar B2 to Busbar T).
3	Close the tie-breaker circuit breaker.	Busbar B2 and Busbar T are at the same potential.
4	Close the transfer disconnect of the terminal going on transfer (G898).	The relay now forms a differential zone for the transfer busbar.
5	Open the circuit breaker of the terminal going on transfer (Cairo circuit breaker).	Terminal G is now on transfer. Operation of disconnect G893 does not affect the busbar protection, and is not mentioned.

The zone configuration default settings are settings for a specific substation with arbitrarily selected alias names serving only as an example.

We use a combination of the zone supervision and coupler security logic to prevent tripping Busbar 2 for a fault between the tie-breaker circuit breaker and CT. For the zone supervision setting, we supervise the BZ2 differential element output by the negated coupler security output (ZS2 := NOT CSL1) see the *Protection Group Settings on page 6.201* for more information.

For ease of setting the zone configuration settings for the new substation, delete the terminal-to-bus-zone default settings. With the terminal-to-bus-zone default settings deleted, the setting prompts no longer reference the default settings.

You can use a combination of primitive and alias names when entering the terminal-to-bus-zone and bus-zone-to-bus-zone connection settings. *Figure 6.155* shows the zone configuration settings for this application.

```
=>>SET Z <Enter>
Zone Config Group 1
Potential Transformer Ratio
Potential Transformer Ratio -V01 (1-10000)          PTR1    := 2000   ?> <Enter>
Current Transformer Ratio
Current Transformer Ratio -I01 (1-50000)            CTR01   := 600    ?800 <Enter>
Current Transformer Ratio -I02 (1-50000)            CTR02   := 600    ? <Enter>
Current Transformer Ratio -I03 (1-50000)            CTR03   := 600    ?> <Enter>

Zone Configuration: Terminal to Bus-Zone Connections
Terminal, Bus-Zone, Polarity (P,N)
IO1BZ1C := TIE_A, ZONE1_A, P
?  DELETE 200 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO1,ZONE2_A,P <Enter>

TIE_A to ZONE2_A Connection (SELogic Equation)
IO1BZ2V := NA
? (89CL01 OR 89CL03) AND 89CL02 AND (CB52A1 OR CBCLST1) <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO1,ZONE1_A,N <Enter>
TIE_A to ZONE1_A Connection (SELogic Equation)
IO1BZ1V := NA
?  89CL01 AND 89CL02 AND (CB52T1 OR CBCLST1) <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO1,TRANS_A,N <Enter>

TIE_A to TRANS_A Connection (SELogic Equation)
IO1BZ3V := NA
?  89CL03 AND 89CL02 AND (CB52T1 OR CBCLST1) <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO2,ZONE1_A,P <Enter>
MADRI_A to ZONE1_A Connection (SELogic Equation)
IO2BZ1V := NA
?  89CL04 <Enter>
```

Figure 6.155 Zone Configuration Group Settings

```
Terminal, Bus-Zone, Polarity (P,N)
?  IO2,ZONE2_A,P <Enter>
MADRI_A to ZONE2_A Connection (SELogic Equation)
IO2BZ2V := NA
?  89CLO5 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO2,TRANS_A,P <Enter>

MADRI_A to TRANS_A Connection (SELogic Equation)
IO2BZ3V := NA
?  89CLO6 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO3,ZONE1_A,P <Enter>
MILAN_A to ZONE1_A Connection (SELogic Equation)
IO3BZ1V := NA
?  89CLO7 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO3,ZONE2_A,P <Enter>
MILAN_A to ZONE2_A Connection (SELogic Equation)
IO3BZ2V := NA
?  89CLO8 <Enter>

Terminal, Bus-Zone, Polarity (P,N)
?  IO3,TRANS_A,P <Enter>
MILAN_A to TRANS_A Connection (SELogic Equation)
IO3BZ3V := NA
?  89CLO9 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO4,ZONE1_A,P <Enter>
ROME_A to ZONE1_A Connection (SELogic Equation)
IO4BZ1V := NA
?  89CL10 <Enter>

Terminal, Bus-Zone, Polarity (P,N)
?  IO4,ZONE2_A,P <Enter>
ROME_A to ZONE2_A Connection (SELogic Equation)
IO4BZ2V := NA
?  89CL11 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO4,TRANS_A,P <Enter>
ROME_A to TRANS_A Connection (SELogic Equation)
IO4BZ3V := NA
?  89CL12 <Enter>

Terminal, Bus-Zone, Polarity (P,N)
?  IO5,ZONE1_A,P <Enter>
CAIRO_A to ZONE1_A Connection (SELogic Equation)
IO5BZ1V := NA
?  89CL13 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO5,ZONE2_A,P <Enter>
CAIRO_A to ZONE2_A Connection (SELogic Equation)
IO5BZ2V := NA
?  89CL14 <Enter>

Terminal, Bus-Zone, Polarity (P,N)
?  IO5,TRANS_A,P <Enter>
CAIRO_A to TRANS_A Connection (SELogic Equation)
IO5BZ3V := NA
?  89CL15 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?<Enter>
Zone Configuration: Bus-Zone to Bus-Zone Connections
Bus-Zone, Bus-Zone
?  ZONE1_A,ZONE2_A <Enter>

ZONE1_A to ZONE2_A Connection (SELogic Equation)
BZ1BZ2V := NA
?  (89CLO4 AND 89CLO5) OR (89CLO7 AND 89CLO8) OR (89CL10 AND 89CL11) OR (89CL13\
 AND 89CL14) <Enter>
Connection to Remove Terminals when ZONE1_A and ZONE2_A merge (SELogic Equation)
BZ1BZ2R := NA
?  BZ1BZ2V <Enter>
Terminals Removed when ZONE1_A and ZONE2_A Bus-Zones merge (Ter k,...,Ter n)
BZ1BZ2M :=
?  IO1 <Enter>

Trip Terminals TIE_A (Y,N)
BZ1BZ2T := N
?  Y <Enter>
Bus-Zone, Bus-Zone
?<Enter>
Zone Supervision
Differential Element Zone Supervision (Y,N)          E87ZSUP := N      ?Y <Enter>
Zone 1 Supervision (SELogic Equation)
Z1S := 1
?<Enter>
```

Figure 6.155 Zone Configuration Group Settings (Continued)

```
Zone 2 Supervision (SELogic Equation)
Z2S := 1
?  NOT CSL1 <Enter>
Zone 3 Supervision (SELogic Equation)
Z3S := 1
?  <Enter>
Zone Switching Supervision
Zone Switching Supervision (Y,N)                    EZSWSUP := N      ?<Enter>

.
.
.

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

=>>
```

Figure 6.155 Zone Configuration Group Settings (Continued)

This concludes the zone configuration Group settings. The next settings class is the protection Group settings.

Protection Group Settings

Settings of this class comprise the protection functions, starting with the function enable settings. Default settings for the differential elements are 60 percent for Slope 1 and 80 percent for Slope 2. To change the slope settings, first enable the advanced settings by setting EADVS := Y. With EADVS := Y, the slope settings and incremental restrained and operating current settings become available.

For this application, we use the default values for the sensitive differential element, the restrained differential element and the directional element.

The protection philosophy calls for the blocking of the busbar protection for an open CT condition. Use the sensitive differential element for this requirement by setting E87SSUP := Y (see *Figure 6.11* and *Figure 6.17*). Because we do not use the terminal out of service, overcurrent elements, or voltage elements in this application, set ETOS := N, E50 := N, E51 := N, E27 := N, E59 := N, and EADVS := N.

Because the relay associates breaker failure protection with each current channel, select the number of breaker failure logics (EBFL setting) equal to the number of current channels, not the number of circuit breakers.

This application has five circuit breakers, and also five current channels (tie breaker has one CT channel). Therefore, select 5 as the number of breaker failure logics for this application. Setting NUMBK equal to 5 makes five corresponding circuit breaker auxiliary input equations (52A01–52A05), and five corresponding trip equations (TR01–TR05) available for setting. Be sure to include the Differential Trip bits in the trip equations of all circuit breakers you want to trip.

The trip logic latches the trip outputs TRIP*kk* after TR*kk* assertion. One way to deassert the trip outputs is to press the **TARGET RESET** pushbutton on the front panel. An alternative way is to enter specific reset conditions at the ULTR*kk* settings.

Each of the five analog channels also has a corresponding station breaker failure trip bit that asserts (*Table 6.107*) when the breaker failure element asserts.

Be sure to include these station breaker failure trip bits in the trip equations of all circuit breakers you want to trip.

We use a combination of the zone supervision and coupler security logics to prevent tripping Busbar 2 for faults between the tie-breaker circuit breaker and the CT.

Figure 6.156 shows the combination of the coupler security logic and the zone supervision, with the input settings applied. Notice that Gate 1 and Gate 2 represent the tie-breaker terminal-to-bus-zone connection settings; they are not part of the logic.

Figure 6.156 Combination of the Coupler Security Logic and the Zone Supervision to Prevent the Loss of Two Zones

Assume for this application that the maximum circuit breaker tripping time is 2 cycles and that the maximum closing time is 3 cycles. Refer to *Figure 6.156*, and notice that Inputs CB52A1 and CBCLS1 provide the circuit breaker status and the closing signal information to the relay. These two inputs are in parallel, complementing each other to provide accurate circuit breaker status during open-to-close and close-to-open circuit breaker operations.

When the operator issues a closing signal to the circuit breaker, Input CBCLS1 asserts, asserting Relay Word bit CBCLST1. We used CBCLST1 in the I01BZ1V, I01BZ2V, and I01BZ3V terminal-to-bus-zone settings. When Relay Word bits I01BZ1V, I01BZ2V, and I01BZ3V assert, the relay considers the CT in the differential calculations.

Set the timer dropout time (CBCLDO1) to a value longer than the maximum breaker closing time. In this example, allow a short safety margin and set CBCLDO1 to 5 cycles (default value).

Inserting the CTs in the differential equations before primary current flows emulates the early make, late break timing requirement for the disconnect auxiliary contacts. A setting of 5 cycles allows the circuit breaker ample time to change state, during which time the CB52A1 Relay Word bit asserts.

When opening the circuit breaker, the inverse applies. For a close-to-open circuit breaker operation, we must guard against prematurely removing the CTs from the differential equations due to circuit breaker auxiliary contact misalignment. We use CB52T1 in the tie-breaker terminal-to-bus-zone connection settings to

accomplish this for Zone 1 and Zone 3. However, because we supervise all Zone 2 faults, premature removal of the CTs does not adversely affect Zone 2 differential elements.

Two tie-breaker operating conditions are possible: when the tie breaker connects between Busbar B1 and Busbar B2 (Disconnect Z891 and Disconnect Z892 are closed) or when the tie breaker connects between Busbar B2 and the Transfer busbar (Disconnect Z892 and Disconnect Z898 are closed).

The following discussion describes the prevention of the loss of Busbar 2 when the tie breaker connects between Busbar B1 and Busbar B2, but the same argument applies when a feeder is on transfer.

Figure 6.157 shows Busbar B1, Busbar B2, the tie breaker, and two of the four terminals at the station. The challenge to the coupler security logic is to trip Busbar B1 and not Busbar B2 for Fault F1. This requirement contradicts the existing configuration because it calls for the coupler security logic to prevent the differential element of Busbar B2 from operating for an in-zone fault (fault on Busbar 2), and for the differential element of Busbar B1 to operate for an out-of-zone fault (fault on Busbar 2).

Figure 6.157 Single CT Application With Faults Between the Circuit Breaker and Tie-Breaker CT

Consider the operation when Fault F1 occurs without the coupler security logic. Differential protection B1 is stable, and differential protection B2 immediately trips the MADRID circuit breaker and the tie-breaker circuit breaker. However, tripping the MADRID circuit breaker and the tie-breaker circuit breaker does not clear Fault F1. Fault current still flows from the MILAN Feeder through Busbar B1 and into the fault. Although breaker failure protection will operate to trip the MILAN circuit breaker, this operation takes place after the breaker failure time delay. After the tie-breaker breaker failure timer times out, all circuit breakers in B1 trip, resulting in both B1 and B2 tripping to clear Fault F1.

If a delay in bus-zone protection operation is in order, implement the coupler security logic in a way that trips bus-zone B2 only when the tie-breaker circuit breaker is open. To prevent tripping of bus-zone B2, configure the relay to achieve the following:

1. Check if the tie breaker is closed. If the tie breaker is closed, trip only the tie breaker to interrupt the fault current from B2; trip no other circuit breakers. If the tie breaker is open, allow normal busbar protection tripping.
2. When the tie breaker is open, remove the tie-breaker CT from the differential calculations of B2 and eventually B1.

To check the tie-breaker status and remove the CT from the supervised zone when the tie breaker is open, use the tie-breaker auxiliary contact in the tie-breaker terminal-to-bus-zone connection settings. To remove the CT from the unsupervised zone, use the coupler status timed-out bit (CB52T1) in the tie-breaker terminal-to-bus-zone connection settings. To trip only the tie breaker for a fault on Busbar 2 requires the following two settings:

- supervising the BZ2 differential element
- issuing a trip signal to the tie breaker first

Supervise the BZ2 differential element output with the negated output from the coupler security logic (Z2S := NOT CSL1). We assign 87R2, the unsupervised output from the BZ2 differential element, to ACTRP1, the accelerated trip input of the coupler security logic. When accelerated trip timer output (ACTRPT1) asserts, Gate 4 in *Figure 6.156* turns off and Relay Word bit CSL1 deasserts. When Relay Word bit CSL1 deasserts, Relay Word bit Z2S asserts, removing the supervision from the BZ2 differential element.

Supervising the BZ2 differential element in this way prevents the tripping of all terminals in BZ2, including the tie breaker. To still trip the tie breaker, include 87R2, the unsupervised output from Differential Element 2, in the trip equation of the tie breaker.

After the tie breaker opens, we remove the tie-breaker CT from the differential calculations of BZ2, but not the BZ2 supervision. Maintain the BZ2 supervision for at least another 1.25 cycles (add a safety margin of 0.75 cycles) to allow the differential element to reset. Achieve this delay by setting ACTPPU1 to at least 4 cycles.

For Fault F1, BZ2 operates, asserting Relay Word bit 87R2. When Relay Word bit 87R2 asserts, the accelerated trip timer starts timing. Because of the BZ2 zone supervision (NOT CSL1), 87Z2 cannot assert, and only the bus coupler circuit breaker receives a trip signal.

Two cycles later, the tie breaker trips, interrupting the fault current contribution from BZ2. Assume the circuit breaker auxiliary contact changes state at the same time. When the auxiliary contact changes state, Relay Word bit CB52A1 deasserts, causing Relay Word bits I01BZ2V and eventually I01BZ1V to also deassert. When Relay Word bits I01BZ1V and I01BZ2V deassert, the relay removes the CTs from the differential calculations for BZ1 and BZ2. For Fault F1, the bus coupler circuit breaker is open, but fault current still flows through the CT. BZ2 is stable when the relay removes the CTs because the bus coupler circuit breaker is open, and terminals from BZ2 no longer contribute to the fault. However, removing the CTs causes BZ1 to operate because the BZ1 balancing current from the bus coupler CT disappeared. Removing the bus sectionalizer CTs also deasserts Relay Word bit 87R2, causing the accelerated trip timer to stop timing. Fault F1 is now cleared, by tripping the correct busbar, although after a time delay.

For Fault F2, the initial tripping is the same as for Fault F1: BZ2 operates, asserting Relay Word bit 87R2. When Relay Word bit 87R2 asserts, the accelerated trip timer starts timing. Because of the BZ2 zone supervision (NOT CSL1), 87Z2 cannot assert, and only the bus coupler circuit breaker receives a trip signal.

Two cycles later, the tie breaker trips, and the auxiliary contact changes state at the same time. When the auxiliary contact changes state, Relay Word bit CB52A1 deasserts, causing Relay Word bits I01BZ2V and eventually I01BZ1V to also deassert. When Relay Word bits I01BZ1V and I01BZ2V deassert, the relay removes the CTs from the differential calculations for BZ1 and BZ2. Because the bus coupler circuit breaker is open, terminals from BZ1 no longer contribute to the fault and BZ1 is stable. However, the BZ2 zone supervision (NOT CSL1) still supervises the BZ2 trip output for another two cycles. Two cycles later, Accelerate Trip Timer ACTRP1 times out, causing CSL1 to deassert. When Relay Word bit CSL1 deasserts, Relay Word bit Z2S asserts, removing the zone supervision from BZ2 and issuing a trip signal to all circuit breakers on Busbar 2.

Although each SEL-487B includes 21 trip logics, there is only one Minimum Trip Duration Time Delay (TDURD) setting.

Because the default setting is longer than the slowest tripping time, use the default setting of 12 cycles. *Figure 6.158* shows the Group 1 settings.

```
=>>SET <Enter>
Group 1
Relay Configuration
Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y      ? <Enter>
Coupler Security Logic (N,1-4)                       ECSL    := N      ?1 <Enter>
Terminal Out of Service (N,1-21)                     ETOS    := 5      ?N <Enter>
Breaker Failure Logic (N,1-21)                       EBFL    := 6      ?5 <Enter>
Definite Time Overcurrent Elements (N,1-21)          E50     := N      ? <Enter>
Inverse Time Overcurrent Elements (N,1-21)           E51     := N      ? <Enter>
Voltage Elements (Y,N)                               EVOLT   := Y      ?N <Enter>
Advanced Settings (Y,N)                              EADVS   := N      ? <Enter>

Sensitive Differential Element
Sensitive Differential Element Pickup (0.05-1 pu)    S87P    := 0.10   ?> <Enter>
Restrained Differential Element
Restrained Diff Element Pickup (0.10-4 pu)           O87P    := 1.00   ?> <Enter>
Directional Element
Dir Element O/C Supervision Pickup (0.05-3 pu)       50DSP   := 0.05   ?> <Enter>
Coupler 1 Security Logic
Coupler 1 Status (SELogic Equation)
CB52A1 := NA
?  IN213 <Enter>

Coupler 1 Status Dropout Delay (0.00-1000 cyc)       CB52DO1 := 4.00   ? <Enter>
Coupler 1 Close Command (SELogic Equation)
CBCLS1 := NA
?  IN214 <Enter>
Coupler 1 Close Command D/O Delay (0.00-1000 cyc)    CBCLDO1 := 5.00   ? <Enter>
Coupler 1 Acc Trip (SELogic Equation)
ACTRP1 := NA
?  87R2 <Enter>
Coupler 1 Acc Trip Pickup Delay (0.00-1000 cyc)      ACTPPU1 := 4.00   ? <Enter>

Breaker 01 Failure Logic
External Breaker Fail -BK01 (Y,N)                    EXBF01  := N      ?Y <Enter>
External Brkr Fail Init -BK01 (SELogic Equation)
XBF01 := NA
?  IN201 <Enter>
Breaker 02 Failure Logic
External Breaker Fail -BK02 (Y,N)                    EXBF02  := N      ?Y <Enter>
External Brkr Fail Init -BK02 (SELogic Equation)
XBF02 := NA
?  IN202 <Enter>
```

Figure 6.158 Protection Group Settings for Application 7

```
Breaker 03 Failure Logic
External Breaker Fail -BK03 (Y,N)                    EXBF03  := N      ?Y <Enter>
External Brkr Fail Init -BK03 (SELogic Equation)
XBF03 := NA
?  IN203 <Enter>
Breaker 04 Failure Logic
External Breaker Fail -BK04 (Y,N)                    EXBF04  := N      ?Y <Enter>
External Brkr Fail Init -BK04 (SELogic Equation)
XBF04 := NA
?  IN301<Enter>


External Breaker Fail -BK05 (Y,N)                    EXBF05  := N      ?Y <Enter>
External Brkr Fail Init -BK05 (SELogic Equation)
XBF05 := NA
?  IN302 <Enter>
Brkr Fail Init Dropout Delay -BK05 (0.00-1000 cyc)   BFIDO05 := 1.50   ? <Enter>

Trip Logic
Trip 01 (SELogic Equation)
TR01 := SBFTR01 OR 87BTR01
?  SBFTR01 OR 87BTR01 OR 87R2 <Enter>
Unlatch Trip 01 (SELogic Equation)
ULTR01 := NA
? <Enter>
Trip 02 (SELogic Equation)
TR02 := SBFTR02 OR 87BTR02
?  <Enter>
Unlatch Trip 02 (SELogic Equation)
ULTR02 := NA
? <Enter>

Trip 03 (SELogic Equation)
TR03 := SBFTR03 OR 87BTR03
?  <Enter>
Unlatch Trip 03 (SELogic Equation)
ULTR03 := NA
? <Enter>
.
.
.

Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000 ? <Enter>
Event Report Trigger Equation (SELogic Equation)
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.158 Protection Group Settings for Application 7 (Continued)

This concludes the protection group settings. The next settings class is the control output settings.

Control Output Settings

In this settings class, we assign the logic or Relay Word bits in the relay to output contacts. We need five output contacts for our example. Although not specifically called for in the protection philosophy, it is good practice to also include the default TEST and ALARM outputs in the relay settings.

Because each relay protects only one phase of the power system, combine the trip outputs from the three relays in a single output to the circuit breaker. Jumper (hardwire) the trip output from each relay. Connect the cable to the circuit breaker trip coil to any one of the three relays.

We include Protection Latch Bit PLT03 in the output equation. With PLT03 included in every output equation, the **RELAY TEST MODE** pushbutton disables all output contacts.

Because we do not use any output contacts from the main board for protection functions (OUT107 and OUT108 are used for alarming purposes), set OUT101–OUT106 = NA. *Figure 6.159* shows the control output settings.

```
=>>SET O <Enter>
Output
Main Board
OUT101 := TRIP01 AND NOT TNS_SW
?  NA <Enter>

OUT102 := TRIP02 AND NOT TNS_SW
?  NA <Enter>
OUT103 := TRIP03 AND NOT TNS_SW
?  NA <Enter>

OUT104 := TRIP04 AND NOT TNS_SW
?  NA <Enter>

OUT105 := TRIP05 AND NOT TNS_SW
?  NA <Enter>
OUT106 := NA
?  > <Enter>

Interface Board #1
OUT201 := NA
?  TRIP01 AND NOT PLT03 <Enter>
OUT202 := NA
?  TRIP02 AND NOT PLT03 <Enter>
OUT203 := NA
?  TRIP03 AND NOT PLT03 <Enter>
OUT204 := NA
?  TRIP04 AND NOT PLT03 <Enter>

OUT205 := NA
?  TRIP05 AND NOT PLT03 <Enter>
OUT206 := NA
?  END <Enter>
Output
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.159 Control Output Settings for Application 7

This concludes the settings for Application 7.

Application 8: Double and Transfer Bus (Inboard CTs)

This application describes the busbar arrangement shown in *Figure 6.160*. The busbar arrangement consists of three busbars, four terminals, and a tie breaker. Use the following to set and configure the relay:

- Busbar classification
- Protection philosophy
- Protection function selection
- Number of SEL-487B Relays and I/O boards
- Input, logic, and output allocation
- Station layout update
- Relay setting and configuration

Figure 6.160 Double Bus and Transfer Bus With Bus Coupler (Tie Breaker) and Inboard CTs

Busbar Classification

The busbar classification provides general busbar layout and CT positioning (inboard or outboard) information and declares the tie-breaker (bus coupler) configuration.

- Description: Double bus with transfer busbar
- Current transformers: Bushing (inboard)
- Disconnects: 89A and 89B disconnect auxiliary contacts are available
- Bus coupler (tie breaker): Two CTs, configured in overlap
- Future expansion: Four feeders

Protection Philosophy

Although the SEL-487B offers a variety of protection and control functions, not every application uses all these functions. Carefully consider each application before stating the functional requirements. The protection philosophy for this application is as follows:

1. Rename the terminals and bus-zones with alias names.
2. Block the busbar protection for an open-circuit CT.
3. Use the disconnect auxiliary contacts to dynamically configure the station.
4. Use the disconnect monitor logic.
5. Ensure stable differential protection for all operating conditions.

Protection Functions Selection

We select protection functions early in the relay setting and configuration process because the choice of protection functions determines the number of relay digital inputs and outputs necessary for the application. Study the protection philosophy to determine which protection and/or control functions to apply to any particular substation. The SEL-487B offers a number of protection functions as standard features, but it also offers the capability through SELOGIC control equations for you to create user-configurable functions. Requirement 5 of the protection philosophy calls for stable differential protection for all operating conditions. There are two network conditions when the differential protection can become unstable:

- when disconnects *n*891 and *n*892 (*n* = D, E, F, G) of any feeder are closed at the same time
- when the transfer disconnect of any feeder is closed

By following the correct operating sequence, and by declaring the appropriate conditions in the terminal-to-bus-zone and bus-zone-to-bus-zone connection settings of the zone selection logic, the relay is stable for all operating conditions.

Standard Functions

Refer to *Protection Philosophy on page 6.209* and select the standard functions necessary for the application. *Table 6.111* shows the selection of standard functions.

Table 6.111 Selection of the Standard Protection Functions (Sheet 1 of 2)

Protection Functions	Selection	Comment
CT ratio mismatch ≤ 10:1	Yes	10:1 mismatch is the maximum allowable mismatch
Circuit breaker status logic	No	Not required
Disconnect monitor logic	Yes	89A and 89B disconnect contacts available
Differential protection	Yes	Busbar protection (zone specific and check zone)
Dynamic zone selection logic	Yes	Use the zone selection to reconfigure the differential protection according to the disconnect positions.
Sensitive differential protection	Yes	Use the sensitive differential element as CT open-circuit detection.

Table 6.111 Selection of the Standard Protection Functions (Sheet 2 of 2)

Protection Functions	Selection	Comment
Zone supervision logic	No	Not required. We achieve relay stability with terminal-to-bus-zone and bus-zone-to-bus-zone connection settings.
Zone-switching supervision logic	No	89A and 89B disconnect contacts available, so this logic is not required.
Coupler security logic	No	Two CTs configured in overlap do not require the coupler security logic.
Circuit breaker failure protection	No	Not required
Instantaneous overcurrent protection	No	Not required
Time-overcurrent protection	No	Not required
Phase voltage elements	No	Not required
Zero- or negative-sequence voltage elements	No	Not required

User-Defined Functions

Identify logic functions we need that is not part of the standard relay logic in the relay. In this application, we comply with the protection philosophy using the standard functions in the relay.

Number of Relays and I/O Boards

Selecting the relay has two parts:

- the number of relays (single-relay application or three-relay application)
- the number of interface boards (as many as four interface boards per relay)

The number of analog (CT) inputs determines the number of relays, and the number of digital inputs and outputs determines the number of interface boards.

Number of Relays

Each SEL-487B has 21 current channels and three voltage channels. For stations with as many as 21 CTs (per phase), we can install a single SEL-487B. For stations with more than 21 and as many as 63 CTs, we install 3 SEL-487B Relays. Use *Equation 6.28* to calculate the number of current channels at the station, and use *Equation 6.29* to calculate the number of zones at the station.

$$\text{\# of current channels required} = \text{\# of per-phase station CTs}$$

Equation 6.28

$$\text{\# of bus-zones required} = \text{\# of per-phase station bus sections}$$

Equation 6.29

The number of per-phase CTs at the station is 18 (tie breaker has six CT cores), so one SEL-487B suffices. However, the requirement for four future feeders increases the number of per-phase CTs to 30. Because each SEL-487B has 21 analog input channels, we need three relays. This is known as a three-relay application. In a three-relay application, each relay provides six zones of protection

for one of the three phases of the power system. For example, wire all the A-phase CTs to Relay 1, all the B-phase CTs to Relay 2, and all the C-phase CTs to Relay 3. Settings for the three relays are identical; all three relays require the same information. Wire input and output contacts (from the circuit breaker or disconnects, for example) to one of the three relays, then jumper (hardwire) the input and output contacts to the other two relays.

This example shows the setting and configuration for the A-phase relay, so identified with an appended letter A (MADRI_A). For the other two relays, the settings and configuration are the same as for the A-phase relay, but the appended letter changes according to the letter designation of the relay. For example, the corresponding MADRI_A setting is MADRI_B in the B-phase relay, and MADRI_C in the C-phase relay.

Number of Relay Inputs

The protection philosophy and protection function selection determine the number of digital relay inputs and outputs required for each application.

The number of disconnect logics (NUMDS) required is the number of disconnects for which the protection philosophy requires disconnect monitoring logic. In this example, the tie breaker and each of the 4 feeders require 3 disconnect monitoring logics; the number of disconnect logics required is therefore 15. Each disconnect monitoring logic requires two disconnect auxiliary contact inputs: an 89A and an 89B contact. Use *Equation 6.30* to calculate the number of relay inputs required for the disconnect auxiliary contacts.

$$\text{\# relay inputs required} = 2 \bullet \text{\# disconnect monitoring logics}$$

Equation 6.30

Table 6.112 summarizes the input contact required for this application.

Table 6.112 Relay Input Contacts Requirement

Input Description	Inputs
Number of relay inputs required for the disconnect contacts	2 • 15 = 30
Total number of inputs	30

The relay main board has seven inputs, an insufficient number of inputs for our application. Each interface board provides two sets of nine grouped inputs and six independent inputs. Use the grouped inputs for the disconnect auxiliary contact inputs, and use the six independent inputs for future breaker failure inputs. From the input perspective, we need two interface boards.

Number of Relay Output Contacts

Our example station has five circuit breakers, all of which are part of the busbar differential protection. Because all circuit breakers are part of the busbar differential protection, we want to trip each breaker when the differential protection operates. *Table 6.113* shows the breakdown and the number of relay output contacts necessary for tripping.

Table 6.113 Breakdown and Number of Relay Outputs Required

Output Description	Outputs
Number of relay output contacts required for breaker tripping	5
Total number of relay output contacts	5

The relay main board has eight standard output contacts (Output Contact 7 is used to assert when the **RELAY TEST MODE** pushbutton from the front panel is selected, and Output Contact 8 is used for alarming purposes in the default settings). However, the main board output contacts are all standard output contacts. The interface boards have high-speed, high-interrupting output contacts that provide faster contact closure. Each interface board can provide six high-speed, high-interrupting output contacts and two standard output contacts. For fast busbar fault clearance, assign each circuit breaker trip output to a high-speed, high-interrupting output contact for each of the circuit breakers at the station. From the output contact perspective, we need one interface board.

The conclusion from the preceding analysis is that we need three SEL-487B Relays, each relay equipped with two interface boards.

Input, Logic, and Output Allocation and Alias Name Assignment

At this point, we have determined the following:

- The number of SEL-487B Relays required for the application
- The number of input contacts
- The number of output contacts
- The selected functions

For example, we have matched the number of CTs at the station with the number of available analog channels in the relay. However, we still need to do the following:

- Assign each CT input to a specific relay analog channel
- Assign each disconnect input to specific relay inputs
- Link relay element/logic outputs to specific relay output contacts
- Assign alias names where appropriate

Assign a valid seven-character alias name to any of the following:

- Relay Word bit
- Analog Quantity
- Terminal Name
- Bus-Zone Name

Alias names are valid when they consist of a maximum of seven characters, and they are constructed with characters 0–9, uppercase A–Z, or the underscore (_).

CT-to-Analog Channel Allocation and CT Alias Assignment

The protection philosophy specifies that only the terminals and bus-zones need alias names. *Table 6.114* shows CT-to-relay analog channel allocations and alias assignments. For example, allocate the A-phase tie-breaker CT to relay channel I01, and assign to this CT the alias name TIE1_A. The choice of CT-to-analog channel allocation is arbitrary; you can assign the CTs randomly to relay analog channels. *Table 6.114* shows the assignment for the A-phase relay starting with the tie-breaker CTs, followed by the four terminals, taken left-to-right from *Figure 6.160*.

Table 6.114 CTs-to-Analog Channel Allocations and Alias Assignments

CTs	Analog Channel	Alias
TIE-BREAKER CT1, A-phase	I01	TIE1_A
TIE-BREAKER CT2, A-phase	I02	TIE2_A
MADRID terminal, A-phase	I03	MADRI_A
MILAN terminal, A-phase	I04	MILAN_A
ROME terminal, A-phase	I05	ROME_A
CAIRO terminal, A-phase	I06	CAIRO_A

Bus-Zone Alias Assignment

Each SEL-487B provides six zones of protection. Although there are three busbars at the station, we only provide differential protection for Busbar B1 and Busbar B2. Because the feeders have bushing CTs, the transfer busbar never forms part of the busbar protection. For the A-phase relay, we use two bus-zones with alias names as shown in *Table 6.115*.

Table 6.115 Alias Names for the Two Bus-Zones

Bus-Zone Name	Description	Alias
BZ1	Bus-Zone 1	ZONE1_A
BZ2	Bus-Zone 2	ZONE2_A

Input-to-Logic Allocation

Table 6.112 shows that we require 30 digital inputs. We now assign the digital input contacts to the selected logic. Because of the functional requirements of this application, we do not need any digital inputs on the main board.

Input-to-Logic Allocation, Interface Board 1 (200)

Table 6.116 and *Table 6.117* show the disconnect auxiliary contact input allocations. Because Inputs IN201, IN202, IN203, IN213, IN214, and IN215 are independent inputs, we preserve these for future circuit breaker failure inputs.

Table 6.116 Disconnect Contact Input Allocations (Sheet 1 of 2)

Input	Description
IN204	TIE-BREAKER disconnect (ZONE1_A) NO contact
IN205	TIE-BREAKER disconnect (ZONE1_A) NC contact
IN206	TIE-BREAKER disconnect (ZONE2_A) NO contact
IN207	TIE-BREAKER disconnect (ZONE2_A) NC contact
IN208	TIE-BREAKER disconnect (TRANS_A) NO contact
IN209	TIE-BREAKER disconnect (TRANS_A) NC contact
IN210	MADRID terminal disconnect (ZONE1_A) NO contact
IN211	MADRID terminal disconnect (ZONE1_A) NC contact
IN212	MADRID terminal disconnect (ZONE2_A) NO contact
IN216	MADRID terminal disconnect (ZONE2_A) NC contact
IN217	MADRID terminal disconnect (TRANS_A) NO contact
IN218	MADRID terminal disconnect (TRANS_A) NC contact

Table 6.116 Disconnect Contact Input Allocations (Sheet 2 of 2)

Input	Description
IN219	MILAN terminal disconnect (ZONE1_A) NO contact
IN220	MILAN terminal disconnect (ZONE1_A) NC contact
IN221	MILAN terminal disconnect (ZONE2_A) NO contact
IN222	MILAN terminal disconnect (ZONE2_A) NC contact
IN223	MILAN terminal disconnect (TRANS_A) NO contact
IN224	MILAN terminal disconnect (TRANS_A) NC contact

Input-to-Logic Allocation, Interface Board 2 (300)

Table 6.117 shows the disconnect and auxiliary contact input allocations. Because Inputs IN301, IN302, IN303, IN313, IN314, and IN315 are independent inputs, we preserve these inputs for future circuit breaker failure inputs.

Table 6.117 Disconnect Contact Input Allocations

Input	Description
IN304	ROME terminal disconnect (ZONE1_A) NO contact
IN305	ROME terminal disconnect (ZONE1_A) NC contact
IN306	ROME terminal disconnect (ZONE2_A) NO contact
IN307	ROME terminal disconnect (ZONE2_A) NC contact
IN308	ROME terminal disconnect (TRANS _A) NO contact
IN309	ROME terminal disconnect (TRANS _A) NC contact
IN310	CAIRO terminal disconnect (ZONE1_A) NO contact
IN311	CAIRO terminal disconnect (ZONE1_A) NC contact
IN312	CAIRO terminal disconnect (ZONE2_A) NO contact
IN316	CAIRO terminal disconnect (ZONE2_A) NC contact
IN317	CAIRO terminal disconnect (TRANS _A) NO contact
IN318	CAIRO terminal disconnect (TRANS _A) NC contact

Assignment of the Selected Standard Logic

The following discussion references *Table 6.111* in explaining each selected function.

Disconnect Monitoring Logic

Figure 6.161 shows the disconnect monitor logic circuit available in the relay. See *Figure 6.120* for more information.

Figure 6.161 One of the Disconnect Monitoring Logic Circuits Available in the Relay

Table 6.118 shows the assignment of the disconnect auxiliary contact Relay Word bits.

Table 6.118 Disconnect Auxiliary Contact Relay Word Bits (Sheet 1 of 2)

Input	Description
89A01	TIE-BREAKER disconnect (ZONE1_A) NO contact
89B01	TIE-BREAKER disconnect (ZONE1_A) NC contact
89A02	TIE-BREAKER disconnect (ZONE2_A) NO
89B02	TIE-BREAKER disconnect (ZONE2_A) NC
89A03	TIE-BREAKER disconnect (TRANS_A) NO
89B03	TIE-BREAKER disconnect (TRANS _A) NC
89A04	MADRI_A disconnect (ZONE1_A) NO contact
89B04	MADRI_A disconnect (ZONE1_A) NC contact
89A05	MADRI_A disconnect (ZONE2_A) NO contact
89B05	MADRI_A disconnect (ZONE2_A) NC contact
89A06	MADRI_A disconnect (TRANS_A) NO contact
89B06	MADRI_A disconnect (TRANS_A) NC contact
89A07	MILAN_A disconnect (ZONE1_A) NO contact
89B07	MILAN _A disconnect (ZONE1_A) NC contact
89A08	MILAN _A disconnect (ZONE2_A) NO contact
89B08	MILAN _A disconnect (ZONE2_A) NC contact
89A09	MILAN _A disconnect (TRANS_A) NO contact
89B09	MILAN _A disconnect (TRANS_A) NC contact
89A10	ROME_A disconnect (ZONE1_A) NO contact
89B10	ROME _A disconnect (ZONE1_A) NC contact
89A11	ROME _A disconnect (ZONE2_A) NO contact
89B11	ROME _A disconnect (ZONE2_A) NC contact
89A12	ROME _A disconnect (TRANS_A) NO contact
89B12	ROME _A disconnect (TRANS_A) NC contact
89A13	CAIRO _A disconnect (ZONE1_A) NO contact
89B13	CAIRO _A disconnect (ZONE1_A) NC contact
89A14	CAIRO _A disconnect (ZONE2_A) NO contact
89B14	CAIRO _A disconnect (ZONE2_A) NC contact

Table 6.118 Disconnect Auxiliary Contact Relay Word Bits (Sheet 2 of 2)

Input	Description
89A15	CAIRO _A disconnect (TRANS_A) NO contact
89B15	CAIRO _A disconnect (TRANS_A) NC contact

Wire a normally open disconnect auxiliary contact (89A) and a normally closed disconnect auxiliary contact (89B) from each disconnect to individual relay inputs on the A-phase relay. Jumper (hardwire) the disconnect input contacts to the other two relays. Relay Word bits 89CL*nn* assert when the disconnect monitoring logic interprets the disconnect main contacts as closed. Use Relay Word bits 89CL*nn* as conditions in the terminal-to-bus-zone SELOGIC control equations.

Differential Trip Logic and Differential Element Assignment

Figure 6.162 shows the differential trip logic for Differential Element 1. Relay Word bit 87Z1 asserts only if the zone supervision conditions permit an output from the AND gate. (See *Section 5: Protection Functions* for more information.) *Table 6.119* shows Relay Word bits and description for the zone differential protection outputs. Because of the bushing (inboard) CTs, we cannot provide differential protection for the transfer busbar.

Table 6.119 Zone Differential Protection Output Relay Word Bits

Primitive Name	Description
87Z1	Zone 1 differential element trip
87Z2	Zone 2 differential element trip

Differential trip bits 87BTR01–87BTR06 assert to trip the circuit breakers of the terminals in the faulted bus-zone. (See *Section 5: Protection Functions* for more information.)

Figure 6.162 Differential Trip Logic for Differential Element 1

Be sure to include the differential trip bits in the trip equations of all the terminals you want to trip when the differential elements operate (see *Global Settings on page 6.220* for more information). *Table 6.120* shows the differential trip bit names and the associated terminal current channels.

Table 6.120 Differential Trip Bit Names and Associated Terminal Names

Differential Trip Bit	Description
87BTR01	Associated with Terminal 01
87BTR02	Associated with Terminal 02
87BTR03	Associated with Terminal 03
87BTR04	Associated with Terminal 04
87BTR05	Associated with Terminal 05
87BTR06	Associated with Terminal 06

Relay Logic-to-Output Contact Allocation and Output Contact Assignments

Table 6.113 shows the relay outputs we need for this application. We now link the appropriate relay logic outputs to specific relay output contacts. *Table 6.121* shows TEST and ALARM protection logic output assignment to the main board output contacts. *Table 6.122* shows the linking of the trip logic outputs to the relay output contacts of Interface Board 1.

Output Assignment, Main Board

This application requires no other output contacts from the main board.

Table 6.121 Alias Names for the Main Board Output Contacts

Output Contact Assignment	Description	Output Contact Alias
OUT107	Relay in test mode	TEST
OUT108	Relay alarm	ALARM

Output Assignment, Interface Board 1 (200)

Each interface board of the SEL-487B can include six high-speed, high-interrupting output contacts. *Table 6.122* shows the assignment of the A-phase relay output terminals.

Table 6.122 Assignment of the Output Terminals

Output Contact Assignment	Description
OUT201	TIE-BREAKER trip logic output
OUT202a	MADRID trip logic output
OUT203a	MILAN trip logic output
OUT204a	ROME trip logic output
OUT205a	CAIRO trip logic output

Station Layout Update (A-Phase)

We are now ready to set and configure the relay. Write all the relevant information on the station diagram, as shown in *Figure 6.163*.

1. Write down the bus-zone, terminal, and disconnect names.
2. Draw in the overlapping zone on the bus section to clearly identify the terminal/zone allocation.
3. Allocate the terminal CTs to the relay input current channels.
4. Allocate the terminal auxiliary contacts to the relay digital inputs.
5. Allocate the digital outputs from the relay to the terminals.

Figure 6.163 Substation Layout With Specific Terminal Information

Setting the Relay

The following describes the settings for this application. For this application, we set the following setting classes:

- Alias Settings
- Global Settings
- Zone Configuration Group Settings
- Protection Group Settings
- Control Output Settings

Alias Settings

We have identified and allocated the alias names to the analog channels and Relay Word bits. We now enter the alias names in the relay. Type **SET T <Enter>** to enter the alias setting class. Many default Relay Word bits have useful alias names ready for use. Type **LIST <Enter>** to see a list of default primitive names and associated alias names, as shown in *Figure 6.164*.

After inspecting the list, we decide the only useful alias names are those of the 16 LEDs, TEST, and ALARM.

```
=>>SET T <Enter>
Alias
Relay Aliases
(RW Bit or Analog Qty. or Terminal or Bus-Zone, 7 Character Alias [0-9 A-Z _])
1: IO1,"FDR_1"
?  LIST <Enter>
1: IO1,"FDR_1"
2: IO2,"FDR_2"
3: IO3,"FDR_3"
4: IO4,"TRFR_1"
5: IO5,"TB_1"
6: IO6,"TB_2"
7: BZ1,"BUS_1"
8: BZ2,"BUS_2"
.
.
.
68: TLED_23,"52_ALRM"
69: TLED_24,"IRIGLED"
1: IO1,"FDR_1"
?
```

Figure 6.164 List of Default Primitive Names and Associated Alias Names

Type **DELETE 43 <Enter>** at the first action prompt to delete the first 43 default alias names, as shown in *Figure 6.165*.

```
1: IO1,"FDR_1"
?  DELETE 43 <Enter>
```

Figure 6.165 Deletion of the First 43 Alias Names

Type **> <Enter>** to advance to the next available line in the settings list.

Enter the alias names for the six analog channels and Relay Word bits, as shown in *Figure 6.166*.

```
1: OUT107,"TEST"
?  > <Enter>
27:
?  IO1,TIE1_A <Enter>
28:
?  IO2,TIE2_A <Enter>
29:
?  IO3,MADRI_A <Enter>
30:
?  IO4,MILAN_A <Enter>
31:
?  IO5,ROME_A <Enter>
32:
?  IO6,CAIRO_A <Enter>
33:
?  BZ1,ZONE1_A <Enter>
```

Figure 6.166 Analog Quantities and Relay Word Bits Alias Names

```
34:
?  BZ2,ZONE2_A <Enter>
35:
?  END <Enter>
Alias

.
.
.

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

=>>
```

Figure 6.166 Analog Quantities and Relay Word Bits Alias Names (Continued)

This concludes the alias settings. The next settings class is Global settings.

Global Settings

Global settings comprise settings that apply to all protection settings groups. For example, when changing from Protection Setting Group 1 to Protection Setting Group 2, Global settings such as station name and relay name still apply. *Figure 6.167* shows the setting changes we need for our example. Because we declared the alias names in the alias setting class, use either the alias names or the primitive names when entering settings.

The NUMBK setting declares the number of circuit breakers at the station. In our example, there are five circuit breakers at the station, and we set NUMBK to 5. Setting NUMBK to 5 makes five corresponding circuit breaker auxiliary input equations (52A01–52A05), and five corresponding trip equations (TR01–TR05) available for setting.

In this application, we do not require circuit breaker auxiliary contacts, therefore set all circuit breaker auxiliary input equations to NA.

The NUMDS setting declares the number of disconnect monitor logics we need, not the number of disconnect inputs. In our example, we need 15 disconnect monitor logics. You can set each disconnect travel time individually with the 89ALP*pp* setting (*pp* = 01–15). Travel time is the period during which both disconnect auxiliary contacts are in the open position. Measure the travel time during commissioning and adjust the settings appropriately. Based on previous experience with similar equipment, we set the tie-breaker disconnect travel time to 400 cycles in this example.

```
=>>SET G <Enter>
Global
General Global Settings
Station Identifier (40 characters)
SID := "Station A"
?<Enter>

Relay Identifier (40 characters)
RID := "Relay 1"
?<Enter>
Number of Breakers (N,1-21)                        NUMBK   := 5      ? <Enter>
Number of Disconnects (N,1-60)                     NUMDS   := N      ?15 <Enter>
Nominal System Frequency (50,60 Hz)                NFREQ   := 60     ?> <Enter>

Global Enables
Station DC Battery Monitor (Y,N)                   EDCMON  := N      ?> <Enter>
Control Inputs (Global)
Input Pickup Delay (0.00-30 ms)                    GINPU   := 2.0    ?> <Enter>
```

Figure 6.167 Global Settings for Application 8

```
Settings Group Selection
Select Setting Group 1 (SELogic Equation)
SS1 := NA
?  > <Enter>
Time and Date Management
Date Format (MDY,YMD,DMY)                                DATE_F  := MDY    ?> <Enter>

Breaker Inputs
N/O Contact Input -BK01 (SELogic Equation)
52A01 := NA
?  > <Enter>
Disconnect Inputs and Timers
N/O Contact Input -DS01 (SELogic Equation)
89A01 := NA
?  IN204 <Enter>

N/C Contact Input -DS01 (SELogic Equation)
89B01 := NA
?  IN205 <Enter>
DS01 Alarm Pickup Delay (0-99999 cyc)                    89ALP01 := 300    ?400 <Enter>
N/O Contact Input -DS02 (SELogic Equation)
89A02 := NA
?  IN206 <Enter>
N/C Contact Input -DS02 (SELogic Equation)
89B02 := NA
?  IN207 <Enter>
DS02 Alarm Pickup Delay (0-99999 cyc)                    89ALP02 := 300    ?400 <Enter>

N/O Contact Input -DS03 (SELogic Equation)
89A03 := NA
?  IN208 <Enter>
N/C Contact Input -DS03 (SELogic Equation)
89B03 := NA
?  IN209 <Enter>
DS03 Alarm Pickup Delay (0-99999 cyc)                    89ALP03 := 300    ? <Enter>
N/O Contact Input -DS04 (SELogic Equation)
89A04 := NA
?  IN210 <Enter>
N/C Contact Input -DS04 (SELogic Equation)
89B04 := NA
?  IN211 <Enter>
DS04 Alarm Pickup Delay (0-99999 cyc)                    89ALP04 := 300    ? <Enter>

N/O Contact Input -DS05 (SELogic Equation)
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.167 Global Settings for Application 8 (Continued)

This concludes the Global settings. The next settings class is the zone configuration group settings.

Zone Configuration Group Settings

The terminal-to-bus-zone SELOGIC control equations identify an analog channel, a differential element, and the conditions for which the relay assigns the analog channel to the differential element. Dynamic zone selection provides a mechanism for automatically reconfiguring the zone of protection, without any wiring changes. In this example, the dynamic zone selection logic uses the disconnect auxiliary contacts status to determine the station configuration and assign the input currents from the CTs to the appropriate differential elements.

For each terminal, wire an 89A and an 89B disconnect auxiliary contact to the relay. Because the disconnect simultaneously operates all three phases of the terminal, we state the disconnect status in the terminal-to-bus-zone SELOGIC control equations of all three relays.

Because we wire a disconnect auxiliary contact to only one relay, jumper (hardwire) the contact to the two other relays. For example, when we close the busbar disconnect on the MILAN feeder, all three phases (MILAN_A, MILAN_B, and

MILAN_C) operate together. Because the relay measures the three phases in three separate relays (phase MILAN_A in the A-phase relay, phase MILAN_B in B-phase relay, etc.), we need to convey the disconnect status to all three relays.

For this discussion, we define the following terms:

- Source busbar: the busbar to which all terminals are connected, except the terminal on transfer
- Transfer busbar: the busbar to which the terminal on transfer is connected
- Transfer disconnect: the disconnect, when closed, bypasses the feeder circuit breaker (e.g., Disconnect G898 on the CAIRO Feeder)

Although the relay is flexible enough to accept settings for many disconnect combinations, we will configure the relay according to a fixed operating sequence. Because the operating sequence defines a set of operating rules, settings engineers can decide on appropriate terminal-to-bus-zone and bus-zone-to-bus-zone settings for each step. The following defines the operating sequence for this application; many other operating sequences are possible and in use:

1. Only one feeder will be on transfer at any given time, i.e., the tie-breaker transfer disconnect (Z898) and the transfer disconnect (*n*898, *n* = D, E, F, and G) of only one of the four terminals can be closed simultaneously.
2. Only Busbar B2 can be the source busbar.
3. No busbar protection exists for the transfer busbar. The transfer busbar is always part of the line protection. This is the key statement from the setting viewpoint. By declaring appropriate terminal-to-bus-zone connection conditions, we can prevent relay misoperation when putting a feeder on transfer. In particular, we do not assign a differential element for the transfer busbar. Remove channel I02 from Busbar B1 differential calculations when any transfer disconnect closes.

The zone configuration default setting are settings for a specific substation with arbitrarily selected alias names, serving only as an example.

For ease of setting the zone configuration settings for the new substation, delete the terminal-to-bus-zone default settings. With the terminal-to-bus-zone default settings deleted, the setting prompts no longer reference the default settings.

You can use a combination of primitive and alias names when entering the terminal-to-bus-zone and bus-zone-to-bus-zone settings. *Figure 6.168* shows the Zone configuration settings for this application.

```
=>>SET Z <Enter>
Zone Config Group 1
Potential Transformer Ratio
Potential Transformer Ratio -VO1 (1-10000)          PTR1    := 2000   ?> <Enter>
Current Transformer Ratio
Current Transformer Ratio -IO1 (1-50000)            CTR01   := 600    ?800 <Enter>

Current Transformer Ratio -IO2 (1-50000)            CTR02   := 600    ?800 <Enter>
Current Transformer Ratio -IO3 (1-50000)            CTR03   := 600    ?> <Enter>
Zone Configuration: Terminal to Bus-Zone Connections
Terminal, Bus-Zone, Polarity (P,N)
IO1BZ1C := TIE1_A, ZONE1_A, P
?  DELETE 200 <Enter>

Terminal, Bus-Zone, Polarity (P,N)
?  IO1,ZONE2_A,P <Enter>
TIE1_A to ZONE2_A Connection (SELogic Equation)
IO1BZ2V := NA
?  89CLO2 <Enter>
```

Figure 6.168 Zone Configuration Group Settings for Application 8

```
Terminal, Bus-Zone, Polarity (P,N)
?  IO2,ZONE1_A,P <Enter>
TIE2_A to ZONE1_A Connection (SELogic Equation)
IO2BZ1V := NA
?  89CLO2 AND 89CLO1 AND NOT(89CLO3 OR 89CLO6 OR 89CLO9 OR 89CL12 OR 89CL15)
   <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO3,ZONE1_A,P <Enter>
MADRI_A to ZONE1_A Connection (SELogic Equation)
IO3BZ1V := NA
?  89CLO4 <Enter>

Terminal, Bus-Zone, Polarity (P,N)
?  IO3,ZONE2_A,P <Enter>
MADRI_A to ZONE2_A Connection (SELogic Equation)
IO3BZ2V := NA
?  89CLO5 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO4,ZONE1_A,P <Enter>
MILAN_A to ZONE1_A Connection (SELogic Equation)
IO4BZ1V := NA
?  89CLO7 <Enter>

Terminal, Bus-Zone, Polarity (P,N)
?  IO4,ZONE2_A,P <Enter>
MILAN_A to ZONE2_A Connection (SELogic Equation)
IO4BZ2V := NA
?  89CLO8 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO5,ZONE1_A,P <Enter>
ROME_A to ZONE1_A Connection (SELogic Equation)
IO5BZ1V := NA
?  89CL10 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO5,ZONE2_A,P <Enter>

ROME_A to ZONE2_A Connection (SELogic Equation)
IO5BZ2V := NA
?  89CL11 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO6,ZONE1_A,P <Enter>
CAIRO_A to ZONE1_A Connection (SELogic Equation)
IO6BZ1V := NA
?  89CL13 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?  IO6,ZONE2_A,P <Enter>

CAIRO_A to ZONE2_A Connection (SELogic Equation)
IO6BZ2V := NA
?  89CL14 <Enter>
Terminal, Bus-Zone, Polarity (P,N)
?<Enter>
Zone Configuration: Bus-Zone to Bus-Zone Connections
Bus-Zone, Bus-Zone
?  ZONE1_A,ZONE2_A <Enter>
ZONE1_A to ZONE2_A Connection (SELogic Equation)
BZ1BZ2V := NA
?  (89CLO4 AND 89CLO5) OR (89CLO7 AND 89CLO8) OR (89CL10 AND 89CL11) OR (89CL13\
 AND 89CL14) <Enter>

Connection to Remove Terminals when ZONE1_A and ZONE2_A merge (SELogic Equation)
BZ1BZ2R := NA
?  (89CLO4 AND 89CLO5) OR (89CLO7 AND 89CLO8) OR (89CL10 AND 89CL11) OR (89CL13\
 AND 89CL14) <Enter>
Terminals Removed when ZONE1_A and ZONE2_A Bus-Zones merge (Ter k,...,Ter n)
BZ1BZ2M :=
?  TIE1_A,TIE2_A <Enter>

Trip Terminals TIE1_A, TIE2_A (Y,N)
BZ1BZ2T := N
?  Y <Enter>
Bus-Zone, Bus-Zone
?<Enter>
Zone Supervision
Differential Element Zone Supervision (Y,N)          E87ZSUP := N      ?<Enter>
Zone Switching Supervision
Zone Switching Supervision (Y,N)                     EZSWSUP := N      ?<Enter>

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

=>>
```

Figure 6.168 Zone Configuration Group Settings for Application 8 (Continued)

This concludes the zone configuration group settings. The next settings class is the protection group settings.

Protection Group Settings

Settings of this class comprise the protection functions, starting with the function enable settings. Default settings for the differential elements are 60 percent for Slope 1 and 80 percent for Slope 2. To change the slope settings, first enable the advanced settings by setting EADVS := Y. With EADVS := Y, the slope settings and incremental restrained and operating current settings become available.

For this application, we use the default values for the sensitive differential element, the restrained differential element, and the directional element.

The protection philosophy calls for the blocking of the busbar protection for an open CT condition. Use the sensitive differential element for this requirement by setting E87SSUP := Y (see *Figure 6.11* and *Figure 6.17* for more information).

Because we do not use the coupler security logic, overcurrent elements, terminal out of service, breaker failure protection, or voltage elements in this application, set ESCL := N, ETOS := N, EBFL := N, E50 := N, E51 := N, E27 := N, E59 := N, and EADVS := N.

Setting NUMBK equal to 5 makes five corresponding circuit breaker auxiliary input equations (52A01–52A05), and five corresponding trip equations (TR01–TR05) available for setting. There are five trip equations available, but there are six analog channels (I01–I06) at the station. Each of the six analog channels has a corresponding differential trip bit that asserts (*Table 6.120*) when the differential element asserts. Be sure to include these differential trip bits in the trip equations of all circuit breakers you want to trip.

The trip logic latches the trip outputs TRIP*kk* after TR*kk* assertion. One way to deassert the trip outputs is to press the **TARGET RESET** pushbutton on the front panel. An alternative method is to enter specific reset conditions at the ULTR*kk* settings.

Although each SEL-487B includes 21 trip logics, there is only one Minimum Trip Duration Time Delay (TDURD) setting.

Because the default setting is longer than the slowest tripping time, use the default setting of 12 cycles. *Figure 6.169* shows the Group 1 settings.

```
=>>SET <Enter>
Group 1
Relay Configuration
Sensitive Differential Element Supervision (Y,N)     E87SSUP := Y      ? <Enter>
Coupler Security Logic (N,1-4)                       ECSL    := N      ? <Enter>
Terminal Out of Service (N,1-21)                     ETOS    := 5      ?N <Enter>
Breaker Failure Logic (N,1-21)                       EBFL    := 6      ?N <Enter>
Definite Time Overcurrent Elements (N,1-21)          E50     := N      ? <Enter>

Inverse Time Overcurrent Elements (N,1-21)           E51     := N      ? <Enter>
Voltage Elements (Y,N)                               EVOLT   := Y      ?N <Enter>
Advanced Settings (Y,N)                              EADVS   := N      ? <Enter>
Sensitive Differential Element
Sensitive Differential Element Pickup (0.05-1 pu)    S87P    := 0.10   ?> <Enter>
Restrained Differential Element
Restrained Diff Element Pickup (0.10-4 pu)           O87P    := 1.00   ?> <Enter>

Directional Element
Dir Element O/C Supervision Pickup (0.05-3 pu)       50DSP   := 0.05   ?> <Enter>
```

Figure 6.169 Protection Group Settings for Application 8

```
Trip Logic
Trip O1 (SELogic Equation)
TRO1 := SBFTRO1 OR 87BTRO1
?  87BTRO1 OR 87BTRO2 <Enter>
Unlatch Trip O1 (SELogic Equation)
ULTRO1 := NA
? <Enter>

Trip O2 (SELogic Equation)
TRO2 := SBFTRO2 OR 87BTRO2
?  87BTRO3 <Enter>
Unlatch Trip O2 (SELogic Equation)
ULTRO2 := NA
? <Enter>
Trip O3 (SELogic Equation)
TRO3 := SBFTRO3 OR 87BTRO3
?  87BTRO4 <Enter>
Unlatch Trip O3 (SELogic Equation)
ULTRO3 := NA
? <Enter>

Trip O4 (SELogic Equation)
TRO4 := SBFTRO4 OR 87BTRO4
?  87BTRO5 <Enter>
Unlatch Trip O4 (SELogic Equation)
ULTRO4 := NA
? <Enter>
Trip O5 (SELogic Equation)
TRO5 := SBFTRO5 OR 87BTRO5 OR SBFTRO6 OR 87BTRO6
?  87BTRO6 <Enter>
Unlatch Trip O5 (SELogic Equation)
ULTRO5 := NA
? <Enter>

Minimum Trip Duration Time Delay (2.000-8000 cyc)    TDURD   := 12.000 ? <Enter>
Event Report Trigger Equation (SELogic Equation)
.
.
.

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

=>>
```

Figure 6.169 Protection Group Settings for Application 8 (Continued)

This concludes the protection group settings. The next settings class is the control output settings.

Control Output Settings

In this settings class, we assign the logic or Relay Word bits in the relay to output contacts. We need five output contacts for our example. Although not specifically called for in the protection philosophy, it is good practice to also include the default TEST and ALARM outputs in the relay settings.

Because each relay protects only one phase of the power system, combine the trip outputs from the three relays in a single output to the circuit breaker. Jumper (hardwire) the trip output from each relay. Connect the cable to the circuit breaker trip coil to any one of the three relays.

We include Protection Latch Bit PLT03 in the output equation. With PLT03 included in every output equation, the **RELAY TEST MODE** pushbutton disables all output contacts.

Because we do not use any output contacts from the main board for protection functions (OUT107 and OUT108 are used for alarming purposes), set OUT101–OUT106 = NA. *Figure 6.170* shows the control output settings.

```
=>>SET O <Enter>
Output
Main Board
OUT101 := TRIP01 AND NOT TNS_SW
?  NA <Enter>
OUT102 := TRIP02 AND NOT TNS_SW
?  NA <Enter>
OUT103 := TRIP03 AND NOT TNS_SW
?  NA <Enter>
OUT104 := TRIP04 AND NOT TNS_SW
?  NA <Enter>
OUT105 := TRIP05 AND NOT TNS_SW
?  NA <Enter>
OUT106 := NA
?  > <Enter>

Interface Board #1
OUT201 := NA
?  TRIP01 AND NOT PLT03 <Enter>
OUT202 := NA
?  TRIP02 AND NOT PLT03 <Enter>
OUT203 := NA
?  TRIP03 AND NOT PLT03 <Enter>
OUT204 := NA
?  TRIP04 AND NOT PLT03 <Enter>
OUT205 := NA
?  TRIP05 AND NOT PLT03 <Enter>
OUT206 := NA
?  END <Enter>
Output
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.170 Control Output Settings for Application 8

This concludes the settings for Application 8.

SECTION 7

Metering, Monitoring, and Reporting

The SEL-487B relay provides extensive capabilities for monitoring substation components, metering important power system parameters, and reporting on power system performance. The relay provides the following useful features:

- *Metering on page 7.1*
- *Station DC Battery System Monitor on page 7.7*
- *Reporting on page 7.8*

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-487B.

Metering

The SEL-487B provides one-cycle average metering for measuring power system conditions and differential protection values. Each SEL-487B processes 21 currents, 3 voltages, and 1 battery monitor.

Use the **MET** command to access the metering functions. Issuing the **MET** command with no options returns the fundamental frequency primary measurement quantities listed in *Table 7.1*.

Table 7.1 Instantaneous Metering Quantities—Voltages and Currents

Metered Quantity	Symbol	Units
Phase voltage magnitude	V01–V03	kV
Phase voltage angle	∠V01, –∠V03	degrees
Phase current magnitude	I01–I21	A
Phase current angle	∠I01, –∠I21	degrees

The **MET** command followed by a number, **MET *k***, specifies the number of times the command will repeat (*k* can range from 1 to 32767). This is useful for troubleshooting or investigating uncharacteristic power system conditions. With other command options, you can view currents from the terminals.

Table 7.2 shows the **MET** command options, followed by a short description of each option.

Table 7.2 MET Command—Metering Only (Sheet 1 of 2)

Name[a]	Description
MET *k*	Displays fundamental primary phase information *k* times for all terminals
MET *k* CZ*q*	Displays fundamental primary phase information *k* times for all terminals in Check Zone *q*
MET *k* Z*n*	Displays fundamental primary phase information *k* times for all terminals in Zone *n*

Table 7.2 MET Command—Metering Only (Sheet 2 of 2)

Name[a]	Description
MET SEC k	Displays fundamental secondary phase information *k* times for all terminals
MET SEC *k* CZ*q*	Displays fundamental secondary phase information *k* times for all terminals in Check Zone *q*
MET SEC *k* Z*n*	Displays fundamental secondary phase information *k* times for all terminals in Zone *n*
MET DIF	Displays per unit operating and restraint currents for all active zones
MET BAT	Displays station battery measurements
MET RBM	Reset station battery max/min measurements
MET ANA	Displays the analog values used with MIRRORED BITS communications
MET PMV	Displays all the Protection Math Variables
MET AMV	Displays all the Automation Math Variables

[a] k = 1–32767; n = 1–6; q = 1–3.

Instantaneous Metering

NOTE: The SEL-487B-1 does not support frequency tracking. Metering accuracies are specified at nominal frequency.

Use the **MET** command to obtain the current and voltage quantities in primary values, as shown in *Table 7.3*.

Table 7.3 Information Available With the MET Command

Command	Information
MET	Primary current magnitudes and angles from all 21 terminals in amperes. Primary voltage magnitudes and angles from the 3 voltage inputs in kV.

Figure 7.1 shows the relay response to the **MET** command.

```
=>>MET <Enter>

Relay 1                                    Date: 04/21/2011  Time: 15:55:01.820
Station A                                  Serial Number: 1131840172

       Primary Currents
Terminal    MAG(A)   ANG(DEG)          Terminal    MAG(A)   ANG(DEG)
 FDR_1     2397.801     0.00            I12          0.000    24.81
 FDR_2     2997.321     0.00            I13          0.000    58.82
 FDR_3     1797.586   180.00            I14          0.000    28.81
 TRFR_1    3597.324   180.00            I15          0.000    83.86
 TB_1      5398.234   180.00            I16          0.000  -130.34
 TB_2      5397.541     0.00            I17          0.000  -142.62
 I07          0.000    37.69            I18          0.000  -118.68
 I08          0.000   168.78            I19          0.000  -146.11
 I09          0.000   169.83            I20          0.000    80.32
 I10          0.000   96.44             I21          0.000   -19.29
 I11          0.000   136.89

       Primary Voltages
Terminal    MAG(kV)  ANG(DEG)
 V01        141.969     0.00
 V02        132.001  -120.06
 V03        128.031   119.99


=>>
```

Figure 7.1 Relay Response to the MET Command

All angles are referenced to the voltage connected to Voltage Terminal V01. If voltage at Terminal V01 is not available, the relay selects V02 and then V03 as reference. In the absence of voltage inputs, the relay references the current input of I01, provided the current is above 0.05 • I_{NOM}. If I01 is not above this current

level, the relay references the current from I02, if available. If I02 is not available, the relay continues to I03, I04, and so on until it finds a current input above $0.05 \bullet I_{NOM}$.

For check-zone-specific primary values information, use the **MET CZ*q*** (*q* = 1–3) command. *Table 7.4* shows the information, including the CT polarity, included in Check Zone *q*.

Table 7.4 Information Available With the MET CZq Command

Command[a]	Information
MET CZ*q*	Primary current magnitudes, angles, and CT polarities from the active terminals in amperes. Primary voltage magnitudes and angles from the three voltage inputs in kV.

[a] q = 1–3.

For the relay to display any measured values, at least one Terminal-to-Check-Zone equation must be a logical 1 (i.e., at least one terminal must be connected to the Check Zone). *Figure 7.2* shows the relay response to the **MET CZ1** command if no such connection exists.

```
=>>MET CZ1 <Enter>

Specified zone is inactive
```

Figure 7.2 Response to MET CZ1 Command When All Terminals Are Inactive

Figure 7.3 shows the relay response of one phase in a three-relay application when Terminals I01 and I02 are connected to Check Zone 1.

```
=>>MET CZ1 <Enter>

Relay 1                                    Date: 02/06/2015 Time: 23:51:51.027
Station A                                  Serial Number: 1131840172

Current Terminals in Check Zone 1

       Primary Currents
Terminal    MAG(A)   ANG(DEG)  POL
 FDR_1       98.131     0.00    P
 FDR_2       98.677   180.00    P

       Primary Voltages
Terminal    MAG(kV)  ANG(DEG)
 V01        133.990     0.00
 V02        133.990  -119.99
 V03        133.990   120.00

=>>
```

Figure 7.3 Response to the MET CZ1 Command of One Phase in a Three-Relay Application

For zone-specific primary values information, use the **MET Z*n*** (*n* = 1–6) command. *Table 7.5* shows the information, including the CT polarity and Bus-Zones, included in Protection Zone *n*, if two Bus-Zones are combined.

Table 7.5 Information Available With the MET Zn Command

Command[a]	Information
MET Z*n*	Primary current magnitudes, angles, and CT polarities from the active terminals in Amperes. Primary voltage magnitudes and angles from the three voltage inputs in kV. Bus-Zones in Protection Zone *n*.

[a] n = 1–6.

For the relay to display any measured values, at least one Terminal-to-Bus-Zone equation must be a logical 1 (i.e., at least one terminal must be connected to the specified Bus-Zone). *Figure 7.4* shows the relay response to the **MET Z*n*** command if no such connection exists.

```
=>>MET Z1 <Enter>

All terminals in the specified zone are inactive
```

Figure 7.4 Response to MET Z1 Command When All Terminals Are Inactive

Figure 7.5 shows the relay response of one phase in a three-relay application when Terminals I01 and I02 are connected to Bus-Zone 1.

```
=>>MET Z1 <Enter>

Relay 1                                    Date: 02/27/2015 Time: 13:56:37.718
Station A                                  Serial Number: 1131840172
Current Terminals in Protection Zone 1
       Primary Currents
Terminal    MAG(A)   ANG(DEG)  POL
 FDR_1       98.131     0.00    P
 FDR_2       98.677   180.00    P
       Primary Voltages
Terminal    MAG(kV)  ANG(DEG)
 V01        133.990     0.00
 V02        133.990  -119.99
 V03        133.990   120.00
Bus-Zones in Protection Zone 1
BUS_1

=>>
```

Figure 7.5 Response to the MET Z1 Command of One Phase in a Three-Relay Application

MET SEC provides secondary information similar to the **MET** command, but includes the CT and PT ratios, as shown in *Table 7.6*.

Table 7.6 Information Available With the MET SEC Command

Command	Information
MET SEC	Secondary current magnitudes, angles, and CT ratios from all 21 terminals in amperes. Secondary voltage magnitudes and angles from the three voltage inputs in volts, and each PT ratio.

Figure 7.6 shows the relay response to the **MET SEC** command of one phase in a three-relay application.

```
=>>MET SEC <Enter>

Relay 1                                        Date: 04/21/2015 Time: 17:05:15.192
Station A                                      Serial Number: 1131840172

          Secondary Currents
Terminal   MAG(A)  ANG(DEG)  CTR        Terminal   MAG(A)  ANG(DEG)  CTR
 FDR_1      3.996     0.00    600         I12        0.000   164.98    600
 FDR_2      4.997     0.00    600         I13        0.001   -44.57    600
 FDR_3      2.996   180.00    600         I14        0.001   -77.58    600
 TRFR_1     5.996   180.00    600         I15        0.001    -2.76    600
 TB_1       8.997   180.00    600         I16        0.002   -35.83    600
 TB_2       8.993     0.00    600         I17        0.000   -42.29    600
 I07        0.002   -71.23    600         I18        0.001  -133.51    600
 I08        0.002  -108.60    600         I19        0.002  -177.14    600
 I09        0.002   -22.11    600         I20        0.001   165.61    600
 I10        0.000    34.53    600         I21        0.002   -21.72    600
 I11        0.000   -58.25    600

          Secondary Voltages
Terminal   MAG(V)  ANG(DEG)  PTR
 V01       63.982     0.00   2000
 V02       64.011  -120.06   2000
 V03       64.021   120.00   2000


=>>
```

Figure 7.6 Relay Response to the MET SEC Command of One Phase of a Three-Relay Application

For check-zone-specific secondary information, use the **MET SEC CZ*q*** (*q* = 1–3) command. The information includes the CT polarity, as shown in *Table 7.7*.

Table 7.7 Information Available With the MET SEC CZq Command

Command[a]	Information
MET SEC CZ*q*	Secondary current magnitudes, angles, CT ratios, and polarities from the active terminals in Check Zone *q* in amperes. Secondary voltage magnitudes and angles from the three voltage inputs in volts, and each PT ratio.

[a] q = 1–3.

Figure 7.7 shows the relay response to the **MET SEC CZ1** command of one phase in a three-relay application with these terminals connected to Check Zone 1.

```
=>>MET SEC CZ1 <Enter>

Relay 1                                        Date: 02/06/2015 Time: 23:51:51.027
Station A                                      Serial Number: 1131840172

Current Terminals in Check Zone 1

          Secondary Currents
Terminal   MAG(A)  ANG(DEG)  CTR  POL
 FDR_1      3.996    0.00     600  P
 FDR_2      4.997    0.00     600  P

          Secondary Voltages
Terminal   MAG(V)  ANG(DEG)  PTR
 V01       66.996     0.00   1000
 V02       66.996  -120.00   2000

=>>
```

Figure 7.7 Response to the MET SEC CZ1 Command of One Phase in a Three-Relay Application

For zone-specific secondary information, use the **MET SEC Z*n*** (*n* = 1–6) command. The information includes the CT polarity, as shown in *Table 7.8*.

Table 7.8 Information Available With the MET SEC Zn Command

Command[a]	Information
MET SEC Z*n*	Secondary current magnitudes, angles, CT ratios, and polarities from the active terminals in the specific zone in amperes. Secondary voltage magnitudes and angles from the three voltage inputs in volts, and each PT ratio. Bus-Zones in Protection Zone *n*.

[a] n = 1–6.

Figure 7.8 shows the relay response to the **MET SEC Z*n*** command of one phase in a three-relay application with these terminals connected to Bus-Zone 1.

```
=>>MET SEC Z1 <Enter>

Relay 1                                    Date: 05/14/2015 Time: 15:00:43.237
Station A                                  Serial Number: 1131840172
Current Terminals in Protection Zone 1
          Secondary Currents
Terminal   MAG(A)  ANG(DEG)  CTR  POL
 FDR_1      3.996     0.00    600  P
 FDR_2      4.997     0.00    600  P
 TB_1       8.997   180.00    600  P
          Secondary Voltages
Terminal   MAG(V)  ANG(DEG)  PTR
 V01       66.996     0.00   1000
 V02       66.996  -120.00   2000
 V03       66.996   120.00   2000
Bus-Zones in Protection Zone 1
BUS_1

=>>
```

Figure 7.8 Relay Response to the MET SEC Z1 Command of One Phase in a Three-Relay Application

Differential Metering

NOTE: A zone is active when any IqqBZpV (qq = 01–21, p = 1–6) Relay Word bit asserts. For example, Zone 1 becomes active when Relay Word bit I01BZ1V asserts. The check zone is active when any IqqCZ1V (qq = 01–21) Relay Word bit asserts and ECHKZN := Y.

View the differential currents of all active zones with the **MET DIF** command. The information includes per unit operating and restraint currents from each active zone, as well as the reference current, as shown in *Table 7.9*. The reference current is the product of the SEL-487B nominal current and the maximum CT ratio in an active zone as defined in the zone configuration settings.

Table 7.9 Information Available With the MET DIF Command

Command	Information
MET DIF	Operate current of all active zones and check zones in per unit. Restraint current of all active zones and check zones in per unit. Product of relay nominal current and highest CT ratio of the connected CTs, used as reference current.

Figure 7.9 shows the relay response to the **MET DIF** command of one phase in a three-relay application when Bus-Zones 1 and 2 are active.

```
=>>MET DIF <Enter>

Relay 1                                    Date: 02/27/2015 Time: 14:28:06.955
Station A                                  Serial Number: 1131840172
       Operate Currents     Restraint Currents
           (Per Unit)            (Per Unit)
ZONE          IOP                  IRT
  1           0.00                 0.25
  2           0.01                 0.44
Current Reference (A)
IREF
800


=>>
```

Figure 7.9 Relay Response to the MET DIF Command of One Phase in a Three-Relay Application

Station DC Battery System Monitor

The SEL-487B automatically monitors station battery system health by measuring the dc voltage, ac ripple, and voltage between each battery terminal and ground. Each relay provides one dc monitor channel, Vdc1. See *Section 8: Monitoring in the SEL-400 Series Relays Instruction Manual* for a complete description of the battery monitor.

Figure 7.10 Typical Station DC Battery System

The dc battery monitor measures the station battery voltage applied at the rear-panel terminals labeled **Vdc1** (+ and –). In a three-relay application, connect the 125 Vdc supply to the monitoring connections of the first relay, and the 48 Vdc supply to the monitoring connections of the second relay. See *Section 6: Protection Application Examples* for more information about single- and three-relay applications.

Reporting

The SEL-487B Relay 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-487B.

Data Processing

The SEL-487B processes protection logic at a different rate than other SEL-400 Series Relays. *Table 7.10* summarizes the available analog quantities from protection elements and the processing rate of each. Notice that the relay processes the protection elements at two different rates:

- Current Differential Elements, Check Zone Elements, Breaker Failure Protection, Under- and Overvoltage Elements = every 1/12 cycle
- Overcurrent Elements (50/51) protection elements = every 1/6 cycle

Table 7.10 Protection Element Analog Quantities and Processing Rates

Analog Quantity	Description	Sample Rate (Power System Cycle)
I*nn*FIM, I*nn*FIA(*nn* = 1–21)	Filtered Instantaneous Phase Current Magnitude, Angle	1/12
V*mm*FM, V*mm*FA (*mm* = 01–03)	Filtered Instantaneous Phase Voltage Magnitude, Angle	1/12
DC1	DC Monitor Voltage	1/12
PMV*nn* (*nn* = 01–64)	Protection Math Variable	1/12
51P*mm* (*mm* = 1–21)	51 Element Pickup Setting	1/6
51TD*mm* (*mm* = 1–21)	51 Element Time Dial Setting	1/6

Table 7.11 summarizes the available digital inputs and the processing rate of each.

Table 7.11 Processing Rates of Digital Inputs

Digitals	Sample Rate (Power System Cycle)
100 rows of event reporting digital elements	1/12
Un-debounced digital contact inputs	2 kHz

Duration of Data Captures and Event Reports

The SEL-487B stores high-resolution raw and filtered data. The number of stored high-resolution raw data captures and event reports is a function of the quantity of data contained in each capture.

Table 7.12 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 11 data captures when ERDIG = S. These and smaller LER settings are sufficient for most power system disturbances.

The relay stores high-resolution raw and filtered event data in nonvolatile memory. *Table 7.12* lists the storage capability of the SEL-487B for common event reports.

The lower rows of *Table 7.12* show the number of event reports the relay stores with the maximum data capture lengths (LER) 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 7.12 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	103	128	147	168
0.50 seconds	71	70	85	114
1.0 seconds	37	40	45	55
3.0 seconds	11	14	15	20
6.0 seconds	N/A	6	8	10
12.0 seconds	N/A	N/A	4	5
24.0 seconds	N/A	N/A	N/A	2

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 7.13*.

Table 7.13 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	102	113
0.50 seconds	43	52	58	65
1.0 seconds	N/A	27	31	35
3.0 seconds	N/A	N/A	10	12
6.0 seconds	N/A	N/A	N/A	5
12.0 seconds	N/A	N/A	N/A	N/A
24.0 seconds	N/A	N/A	N/A	N/A

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-487B.

Base Set of Relay Word Bits

The following Relay Word bits are always included in COMTRADE event reports: ZONE1–ZONE6, CZONE1–CZONE3, 87BTR, 87BTR01–87BTR21, SBFTR, SBFTR01–SBFTR21, TRIP, TRIP01–TRIP21, 87Z1–87Z6, BFZ1–BFZ6, ER, RMB*n*A, TMB*n*A, RMB*n*B, TMB*n*B, ROKA, RBADA, CBADA, LBOKA, ROKB, RBADB, CBADB, LBOKB, TLED_1, TLED_2, TLED_3, TLED_4, TLED_5, TLED_6, TLED_7, TLED_8, TLED_9, TLED_10, TLED_11, TLED_12, TLED_13, TLED_14, TLED_15, TLED_16, TLED_17, TLED_18, TLED_19, TLED_20, TLED_21, TLED_22, TLED_23, TLED_24, Z1BZ1, Z1BZ2, Z1BZ3, Z1BZ4, Z1BZ5, Z1BZ6, Z2BZ2, Z2BZ3, Z2BZ4, Z2BZ5, Z2BZ6, Z3BZ3, Z3BZ4, Z3BZ5, Z3BZ6, Z4BZ4, Z4BZ5, Z4BZ6, Z5BZ5, Z5BZ6, Z6BZ6.

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 is 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 Reports

Report Header and Analog Section of the Event Report

The first portion of an event report is the report header and the analog section. See *Figure 7.11* for the location of items included in a sample analog section of an event report. If you want to view only the analog portion of an event report, use the **EVE A** command.

The report header is the standard SEL-487B header, listing the relay identifiers, event number, date, and time. Report headers help you organize report data. Each event report begins with information about the relay and the event, such as the RID setting (Relay ID), the SID setting (Station ID), and the firmware checksum (CID). The FID string identifies the relay model, Flash firmware version, and the date code of the firmware. See *Appendix A: Firmware, ICD File, and Manual Versions* for a description of the FID string. To complete the header, the relay reports a date and time stamp to indicate the internal clock time when the relay triggered the event.

The event report column labels follow the header. The data underneath the analog column labels contain samples of power system voltages and currents in primary kilovolts and primary amperes, respectively. These quantities are instantaneous values scaled by $\sqrt{2}/2$ (0.707). Although you may not use all 24 channels of the SEL-487B in your application, all 24 channels' samples are always displayed in the event report. To display all 24 channels, the event report consists of three groups. Current channels I01–I11 are displayed in the first group as shown in *Figure 7.11*. The second group contains I12–I21, and the third group contains voltage channels V01–V03.

Figure 7.11 contains selected data from the analog section of a 4-samples/cycle event report. The bracketed numbers at the left of the report (for example, [5]) indicate the cycle number; *Figure 7.11* presents eight cycles of 4-samples/cycle data. The trigger row includes a > character to indicate the trigger point. This is the dividing point between the pre-fault or PRE time and the fault or remainder of the data capture.

The row that the relay uses for the fault analogs in the event summary is the row 1.25 cycles after the event trigger. The relay marks this row on the event report with an asterisk (*) character immediately after the last analog column.

```
=>>EVE <Enter>

Relay 1                                   Date: 06/06/2015  Time: 16:27:50.514
Station A                                 Serial Number: 1131840172

FID=SEL-487B-1-R309-V1-Z010005-D20151102   Event Number = 10006     CID=0xA0B5

  Currents (Pri. Amps)
  I01    I02    I03    I04    I05    I06    I07    I08    I09    I10    I11
 [1]

   -596   -595    596    595   1194  -1191     -1     -2     -1      0      0
    -79    -82     80     79    159   -157     -1      0      2      0      0
    596    595   -595   -594  -1193   1190      1      0      0      0      0
     80     82    -80    -80   -160    158      1     -1     -2      0      0

 [2]
   -595   -595    594    594   1194  -1190     -1      0      0      0      0
    -80    -83     80     80    159   -159     -1      1      2      0      0
    595    595   -594   -594  -1193   1190      1      1      0      0      1
     81     84    -80    -81   -160    160      2      0     -2      0      0
 [3]
   -596   -596    595    594   1192  -1190     -1     -1      0      0      0
    -81    -82     80     81    161   -160     -1      0      2      0      0
    595    595   -595   -594  -1193   1190      2      1      0      0     -1
     81     83    -81    -81   -162    160      0     -1     -2      0      0
 [4]
   -596   -594    595    594   1193  -1190     -2     -1      1      0      1
    -82    -84     81     81    163   -161      0      1      2      0      0
    596    595   -594   -594  -1193   1190      1      0      0      0      0
     82     84    -81    -82   -163    161      1      0     -2      0      0
 [5]
   -596   -595    595    595   1192  -1189     -1      0      0      0      0
    -82    -85     81     82    164   -163     -1      0      2      0      0
    595    595   -594   -594  -1193   1190      1      0      0      0      0
     82     85    -81    -82   -165    163      1      0     -2     -1      1
 [6]
   -595   -594    595    594   1193  -1190     -1      0      1      0      0
    -83    -86     82     82    166   -162      0      1      3     -1     -1
   1955    595   -595   -594  -1193   1189      1      1     -1      1      0
    479     86    -83    -82   -166    164      0     -1     -2      1      0

 [7]

  -4938   -595    594    593   1193  -1189     -1     -1      1     -2      0>

    -891    -86     83     83    166   -166      0      0      2      1      0
    6552    594   -595   -594  -1192   1190      1      1      0      0      0
     910     86    -83    -83   -167    165      0      0     -2      0      1
 [8]
  -6550   -595    594    594   1192  -1190     -1      0      0      0     -1
   -910    -86     84     84    168   -165     -1      0      2     -1      0*
   6551    595   -593   -593  -1191   1189      1      0      0      1      1
    910     86    -84    -84   -169    166      1      1     -1      0      0

  .
  .
  .

  =>>
```

Header

Firmware ID

One Cycle of Data

Trigger

Figure 7.11 Analog Section of the Event Report

Table 7.14 Event Report Metered Analog Quantities

Analog Quantity	Description
I01–I21	Filtered current vector
V01–V03	Filtered voltage vector

For the event report (different from the raw data oscillography), you can select as many as 20 additional analog quantities from the available analog quantities in the relay (see *Section 12: Analog Quantities*). These user-defined analog quantities follow the 24 fixed channels.

Differential Report

The differential report is not a part of the **EVE** command (without any parameters) response. Use the **EVE DIF** command to specify that the differential report is to be displayed. If so specified, the fixed and user-configurable analog quantities will no longer be displayed, although the event summary and relay settings will be appended following the differential quantities. The analog part of the differential report only displays differential current for each active differential zone and active check zone, as shown in *Figure 7.12*.

```
=>>EVE DIF <Enter>

Relay 1                                     Date: 06/06/2015 Time: 16:27:50.514
Station A                                   Serial Number: 1131840172
FID=SEL-487B-1-R309-V1-Z010005-D20151102    Event Number = 10006     CID=0xA0B5

                   Differential Quantities (Per Unit)
 IOP1  IRT1  IOP2  IRT2


[1]
 0.00  0.80  0.00  0.80
 0.00  0.80  0.00  0.80
 0.00  0.80  0.00  0.80
 0.00  0.80  0.00  0.80
.
.
.
[7]
 1.45  2.26  0.00  0.80>
 1.47  2.27  0.00  0.80
 2.00  2.81  0.00  0.80
 2.00  2.81  0.00  0.80
[8]
 2.00  2.81  0.00  0.80
 2.00  2.81  0.00  0.80*
 2.00  2.81  0.00  0.80
 2.00  2.81  0.00  0.80


Differential Quantities (Per Unit)
 IOPCZ1 IRTCZ1

[1]
 0.00   0.80
 0.00   0.80
 0.00   0.80
 0.00   0.80
.
.
.
[7]
 1.45   2.25 >
 1.47   2.27
 2.00   2.80
 2.01   2.81
[8]
 2.01   2.80
 2.01   2.80 *
 2.01   2.80
 2.01   2.80
[9]
 2.01   2.80
 2.01   2.80
 2.01   2.80
 2.01   2.80
```

Figure 7.12 Differential Report

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 7.13* for the locations of items in a sample event report digital section. If you want to view only the digital portion of an event report, use the **EVE D** command (see *Section 14: ASCII Command Reference in the SEL-400 Series Relays Instruction*

Manual for details). 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 in event summary (1.25 cycles after the trigger point) with an asterisk (*) character at the right of the last digital element column.

```
ZZ        D         FFFTT   N
12     TT I T FFFTT 1231BO  O
__ FFFTBB FBN 1231B _____U  A
TT 123112 FFS _____ TTTTTT TL
RR ______ ___ BBBBB RRRRR1 EA
II BBBBBB EES FFFFF IIIIIO SR
PP FFFFFF NNW IIIII PPPPP6 TM

[1]
.. ...... ... ..... ...... .*
.. ...... ... ..... ...... .*
.. ...... ... ..... ...... .*
.. ...... ... ..... ...... .*

[2]
.. ...... ... ..... ...... .*
.. ...... ... ..... ...... .*
.. ...... ... ..... ...... .*
.. ...... ... ..... ...... .*

[3]
.. ...... ... ..... ...... .*
.. ...... ... ..... ...... .*
.. ...... ... ..... ...... .*
.. ...... ... ..... ...... .*

[4]
.. ...... ... ..... ...... .*
.. ...... ... ..... ...... .*
.. ...... ... ..... ...... .*
.. ...... ... ..... ...... .*

[5]
.. ...... ... ..... ...... .*
.. ...... ... ..... ...... .*
.. ...... ... ..... ...... .*
.. ...... ... ..... ...... .*

[6]
.. ...... ... ..... ...... .*
.. ...... ... ..... ...... .*
.. ...... ... ..... ...... .*
.. ...... ... ..... ...... .*

[7]
*. ...... ... ..... **..*. .*>
*. ...... ... ..... **..*. .*
*. ...... ... ..... **..*. .*
*. ...... ... ..... **..*. .*

[8]
*. ...... ... ..... **..*. .*
*. ...... ... ..... **..*. .*
*. ...... ... ..... **..*. .*
*. ...... ... ..... **..*. .*
```

Figure 7.13 Digital Section of the Event Report

Event Summary Section of the Event Report

The third portion of an event report is the summary section. See *Figure 7.14* for the location of items included in a sample summary section of an event report. If you want to exclude the summary portion from an event report, use the **EVE NSUM** command. See *EVENT on page 14.33 in the SEL-400 Series Relays Instruction Manual* for details.

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. See *Event Summary on page 7.14* for a description of the items in the summary portion of the event report.

```
=>>SUM <Enter>

Relay 1                                Date: 03/02/2015          Time: 12:33:51.078
                                       Serial Number: 1131840172
Event: 87BTR                                                     Time Source: OTHER
Event Number: 10057                                              Group: 1
Targets: TLED_1 TLED_6 TLED_7 TLED_8

Fault:  I01    I02    I03    I04    I05    I06    I07    I08    I09     I10    I11
MAG(A) 14964  14966  14968  14969  14957  14966  22146  22138  22135   14960  14959
ANG(DEG) 178    59     -61    179    59     -61     0    -120    120    -179     61

        I12    I13    I14    I15    I16    I17   I18     I19    I20     I21
MAG(A) 14973  14967  14964  14968  22140  22134  22136  1167.8 1167.8  1167.8
ANG(DEG) -59   -178    62    -58     2    -117   123       0    -120    121


        V01   V02    V03
MAG(kV) 67.8  67.8   67.8
ANG(DEG) 0   -120    121

Tripped Terminals
I07     I08    I09    I10    I11    I12    I16    I17    I18

Bus-Zones in Protection Zone 4
BZ4
.
.
.
Bus-Zones in Protection Zone 6
BZ6


=>>
```

Figure 7.14 Summary Section of the Event Report

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 7.15* for a sample event summary.

```
Relay SEL-487B-1                        Date: 06/18/2014  Time: 19:49:20.975
Station A                               Serial Number: 2014237527
```

Report Header

```
Event: ER                                                Time Source: HIRIG

Event Number: 10004                                              Group: 1

Targets:TLED_1 TLED_2 TLED_3
```

Event Information

```
Fault:   I01    I02    I03    I04    I05    I06    I07    I08    I09    I10    I11
MAG(A)   15783  12343  15669  15789  12344  15671  15794  12348  15672  11615  512
ANG(DEG)  -32   -140    102    -32   -140    102    -32   -140    102    -45   -161

         I12    I13    I14    I15    I16    I17    I18    I19    I20    I21
MAG(A)    1845  11616    512   1846  11616    512   1846  11625    512   1846
ANG(DEG)   90    -45   -161     90    -45   -161     90    -45   -161     90

         V01     V02     V03
MAG(kV)   26.9    38.6    32.5
ANG(DEG)   0    -104     124
```

Fault Data

Figure 7.15 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
- Event number
- Active settings group at trigger time
- Targets
- Fault currents and voltages
- Tripped terminals
- Bus-Zone in protection zone

Targets are displayed only if a rising edge of Relay Word bits 87BTR, SBFTR, or TRIP asserted before the end of the event report. When a trip occurs, the relay displays the aliases of the latched targeting bits asserted on the last row of the event. Current and voltage analog quantities in the summary are the values 1.25 cycles after the event trigger.

Table 7.15 defines the various event types in fault reporting priority. Fault event type 87BTR (busbar protection trip) has reporting priority over event type SBFTR (breaker failure). If more than one event type asserts, the relay reports only the highest priority event type. 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.

Table 7.15 Event Types

Event Type	Event Trigger
87BTR	Rising edge of Relay Word Bit 87BTR, the OR combination of a busbar - protection trip output to any Terminal.
SBFTR	Rising edge of Relay Word Bit SBFTR, the OR combination of a breaker failure trip output to any Terminal.
TRIP	Rising edge of Relay Word Bit TRIP.
ER	The relay generates the event with elements in the SELOGIC control equation ER.
TRIG	The relay generates the event in response to the **TRI** command.

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.) See *Figure 7.16* for a sample event history.

The event history contains the following:

- Standard report header
- Relay and terminal identification
- Event date and time
- Event type
- Time source
- Event number

- Active settings group at trigger time
- Targets
- Fault currents and voltages
- Tripped terminals
- Bus-Zones in protection zones

Figure 7.16 is a sample event history from a computer terminal.

```
=>>HIS<Enter>

Relay 1                                          Date: 06/07/2015  Time: 14:44:27.063
Station A                                        Serial Number: 1131840172

#        DATE        TIME       EVENT  GRP  TARGETS
10006 06/06/2015 16:27:50.514 87BTR   1   87_DIFF ZONE_1
10005 06/06/2015 15:52:39.732 ER      1
10004 06/06/2015 15:52:34.742 87BTR   1   87_DIFF ZONE_1 ZONE_2

10003 05/25/2015 20:37:20.899 87BTR   1   87_DIFF ZONE_1 ZONE_2
10002 05/19/2015 10:53:59.742 87BTR   1   87_DIFF ZONE_1 ZONE_2
10001 05/18/2015 21:15:45.369 87BTR   1   87_DIFF ZONE_1 ZONE_2
10000 05/18/2015 20:46:13.497 87BTR   1   87_DIFF ZONE_1 ZONE_2
 Event                         Event  Active
 Number                         Type  Group
```

Figure 7.16 Sample Event History

The event types in the event history are the same as the event types in the event summary. See *Table 7.15* for event types.

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-487B relay.

⚠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 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 the applications sections of the instruction manual where appropriate.

The settings prompts in this section are similar to the ASCII terminal and ACSELERATOR QuickSet SEL-5030 Software prompts. The 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 on page 8.1*
- *Global Settings on page 8.3*
- *Zone Configuration Settings on page 8.7*
- *Group Settings on page 8.12*
- *Protection Freeform SELOGIC Control Equations on page 8.20*
- *Automation Freeform SELOGIC Control Equations on page 8.20*
- *Notes Settings on page 8.20*
- *Output Settings on page 8.21*
- *Front-Panel Settings on page 8.21*
- *Report Settings on page 8.24*
- *Port Settings on page 8.25*
- *DNP3 Settings—Custom Maps on page 8.25*

Alias Settings

See *Alias Settings on page 12.25 in the SEL-400 Series Relays Instruction Manual* for a complete description of alias settings. The SEL-487B supports aliases for terminal names and bus-zone names, in addition to Relay Word bits and analog quantities. *Table 8.1* lists the default alias settings for the SEL-487B.

Table 8.1 Default Alias Settings (Sheet 1 of 3)

Label	Default
I01	FDR_1
I02	FDR_2
I03	FDR_3

Table 8.1 Default Alias Settings (Sheet 2 of 3)

Label	Default
I04	TRFR_1
I05	TB_1
I06	TB_2
BZ1	BUS_1
BZ2	BUS_2
FBF01	F1_BF
FBF02	F2_BF
FBF03	F3_BF
FBF04	T1_BF
FBF05	TB1_BF
FBF06	TB2_BF
87Z1	Z1_TRIP
87Z2	Z2_TRIP
IN101	F1_BFI
IN102	F2_BFI
IN103	F3_BFI
IN104	T1_BFI
IN105	TB_BFI
PLT01	DIFF_EN
PLT02	BF_EN
PLT03	TNS_SW
87ST1	CTZ1_AN
87ST2	CTZ2_AN
SBFTR01	F1_BFT
SBFTR02	F2_BFT
SBFTR03	F3_BFT
SBFTR04	T1_BFT
SBFTR05	TB1_BFT
SBFTR06	TB2_BFT
87BTR01	F1_DPT
87BTR02	F2_ DPT
87BTR03	F3_ DPT
87BTR04	T1_ DPT
87BTR05	TB1_ DPT
87BTR06	TB2_ DPT
OUT101	F1_TRP
OUT102	F2_TRP
OUT103	F3_TRP
OUT104	T1_TRP
OUT105	TB_TRP
OUT107	TEST

Table 8.1 Default Alias Settings (Sheet 3 of 3)

Label	Default
OUT108	NOALARM
TLED_1	87_DIFF
TLED_2	BK_FAIL
TLED_3	ZONE_1
TLED_4	ZONE_2
TLED_5	ZONE_3
TLED_6	ZONE_4
TLED_7	ZONE_5
TLED_8	ZONE_6
TLED_9	50_TRIP
TLED_10	51_TRIP
TLED_11	CT_ALRM
TLED_12	87_BLK
TLED_13	TOS
TLED_14	89_OIP
TLED_15	89_ALRM
TLED_16	PT_ALRM
TLED_17	27_LED
TLED_18	59_LED
TLED_19	V01_ON
TLED_20	V02_ON
TLED_21	V03_ON
TLED_22	FLT_LED
TLED_23	52_ALRM
TLED_24	IRIGLED

Global Settings

Table 8.2 Global Settings Categories (Sheet 1 of 2)

Settings	Reference
General Global Settings	*Table 8.3*
Global Enables	*Table 8.4*
Station DC Monitor	*Table 8.5*
Control Inputs (Global)	*Table 8.6*
Main Board Control Inputs	*Table 8.7*
Interface Board #1 Control Inputs	*Table 8.8*
Interface Board #2 Control Inputs	*Table 8.9*
Interface Board #3 Control Inputs	*Table 8.10*
Interface Board #4 Control Inputs	*Table 8.11*
Settings Group Selection	*Table 8.12*

Table 8.2 Global Settings Categories (Sheet 2 of 2)

Settings	Reference
Time and Date Management	*Table 8.13*
Data Reset Control	*Table 8.14*
Breaker Inputs	*Table 8.15*
Disconnects Inputs and Timers	*Table 8.16*
DNP	*Table 8.18*

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
NUMBK	Number of Breakers (N, 1–21)	5
NUMDS	Number of Disconnects (N, 1–60)	N
NFREQ	Nominal System Frequency (50, 60 Hz)	60

Table 8.4 Global Enables

Setting	Prompt	Default
EDCMON	Station DC Battery Monitor (Y, N)	N
EICIS	Independent Control Input Settings (Y, N)	N
EDRSTC	Data Reset Control (Y, N)	N
EGADVS	Advanced Global Settings (Y, N)	N

Table 8.5 Station DC Monitor

Setting	Prompt	Default
DC1LFP	Low Level Fail Pickup (OFF, 15–300 Vdc)	100
DC1LWP	Low Level Warn Pickup (OFF, 15–300 Vdc)	127
DC1HWP	High Level Warn Pickup (OFF, 15–300 Vdc)	137
DC1HFP	High Level Fail Pickup (OFF, 15–300 Vdc)	142
DC1RP	Peak-to-Peak AC Ripple Pickup (1–300 Vac)	9
DC1GF	Ground Detection Factor (1.00–2.00)	1.05

Table 8.6 Control Inputs (Global)

Setting	Prompt	Default	Increment
GINPU	Input Pickup Delay (0.0–30 ms)	2.0	0.5
GINDO	Input Dropout Delay (0.0–30 ms)	2.0	0.5

Table 8.7 Main Board Control Inputs

Setting	Prompt	Default	Increment
IN101PU	Input IN101 Pickup Delay (0.0–30 ms)	2.0[a]	0.5
IN101DO	Input IN101 Dropout Delay (0.0–30 ms)	2.0[a]	0.5
• • •	• • •	• • •	• • •
IN107PU	Input IN107 Pickup Delay (0.0–30 ms)	2.0[a]	0.5
IN107DO	Input IN107 Dropout Delay (0.0–30 ms)	2.0[a]	0.5

[a] If EICIS = N, these settings are the same as GINPU and GINDO.

Table 8.8 Interface Board #1 Control Inputs

Setting	Prompt	Default	Increment
IN201PU	Input IN201 Pickup Delay (0.0–30 ms)	2.0[a]	0.5
IN201DO	Input IN201 Dropout Delay (0.0–30 ms)	2.0[a]	0.5
• • •	• • •	• • •	• • •
IN224PU	Input IN224 Pickup Delay (0.0–30 ms)	2.0[a]	0.5
IN224DO	Input IN224 Dropout Delay (0.0–30 ms)	2.0[a]	0.5

[a] If EICIS = N, these settings are the same as GINPU and GINDO.

Table 8.9 Interface Board #2 Control Inputs

Setting	Prompt	Default	Increment
IN301PU	Input IN301 Pickup Delay (0.0–30 ms)	2.0[a]	0.5
IN301DO	Input IN301 Dropout Delay (0.0–30 ms)	2.0[a]	0.5
• • •	• • •	• • •	• • •
IN324PU	Input IN324 Pickup Delay (0.0–30 ms)	2.0[a]	0.5
IN324DO	Input IN324 Dropout Delay (0.0–30 ms)	2.0[a]	0.5

[a] If EICIS = N, these settings are the same as GINPU and GINDO.

Table 8.10 Interface Board #3 Control Inputs

Setting	Prompt	Default	Increment
IN401PU	Input IN401 Pickup Delay (0.0–30 ms)	2.0[a]	0.5
IN401DO	Input IN401 Dropout Delay (0.0–30 ms)	2.0[a]	0.5
• • •	• • •	• • •	• • •
IN424PU	Input IN424 Pickup Delay (0.0–30 ms)	2.0[a]	0.5
IN424DO	Input IN424 Dropout Delay (0.0–30 ms)	2.0[a]	0.5

[a] If EICIS = N, these settings are the same as GINPU and GINDO.

Table 8.11 Interface Board #4 Control Inputs

Setting	Prompt	Default	Increment
IN501PU	Input IN501 Pickup Delay (0.0–30 ms)	2.0[a]	0.5
IN501DO	Input IN501 Dropout Delay (0.0–30 ms)	2.0[a]	0.5
• • •	• • •	• • •	• • •
IN524PU	Input IN524 Pickup Delay (0.0–30 ms)	2.0[a]	0.5
IN524DO	Input IN524 Dropout Delay (0.0–30 ms)	2.0[a]	0.5

[a] If EICIS = N, these settings are the same as GINPU and GINDO.

Table 8.12 Settings Group Selection

Setting	Prompt	Default
SS1	Select Setting Group 1 (SELOGIC Equation)	NA
SS2	Select Setting Group 2 (SELOGIC Equation)	NA
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 (1–54000 cycles)	180

Table 8.13 Time and Date Management

Setting	Prompt	Default
DATE_F	Date Format (MDY, YMD, DMY)	MDY
IRIGC	IRIG-B Control Bits Definition (NONE, C37.118)	NONE
UTCOFF[a]	Offset From UTC to Local Time (–15.5 to 15.5)	–8
BEG_DST[b]	Begin DST (*hh*, *n*, *d*, *mm*, or OFF)	"2, 2, 1, 3"
END_DST	End DST (*hh*, *n*, *d*, or *mm*)	"2, 1, 1, 11"

[a] All data, reports, and commands from the relay are 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 IEC 61850 data.)

[b] 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 1st, 2nd, 3rd, 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 8.14 Data Reset Control

Setting	Prompt	Default
RST_BAT	Reset Battery Monitoring (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 8.15 Breaker Inputs

Setting	Prompt	Default
52A01	N/O Contact Input–BK01 (SELOGIC Equation)	NA
• • •	• • •	• • •
52A21	N/O Contact Input–BK21 (SELOGIC Equation)	NA

Table 8.16 Disconnect Inputs

Setting	Prompt	Default	Increment
89A01	N/O Contact Inputs–DS01 (SELOGIC Equation)	NA	
89B01	N/C Contact Inputs–DS01 (SELOGIC Equation)	NA	
89ALP01	DS01 Alarm Pickup Delay (0–99999 cyc)	300	1
• • •	• • •	• • •	
89A60	N/O Contact Inputs–DS60 (SELOGIC Equation)	NA	
89B60	N/C Contact Inputs–DS60 (SELOGIC Equation)	NA	
89ALP60	DS60 Alarm Pickup Delay (0–99999 cyc)	300	1

Table 8.17 Access Control

Setting	Prompt	Default
EACC	Enable ACC access level (SELOGIC Equation)	1
E2AC	Enable ACC–2AC access levels (SELOGIC Equation)	1

Table 8.18 DNP

Setting	Prompt	Default	Increment
EVELOCK	Event Summary Lock Period (0–1000 s)	0	1
DNPSRC	DNP Session Time Base (LOCAL,UTC)	UTC	

Make *Table 8.19* settings when advanced Global settings are enabled (EGADVS := Y) and only for unique system configurations. Changing the OPHDO setting affects the filtered current level that declares an open phase, which has effects throughout the protection logic. SEL recommends leaving the OPHDO setting at the default value.

Table 8.19 Open-Phase Logic

Setting	Prompt	Default
OPHDO[a]	Line Open Phase Threshold (0.01–5 A, sec)	0.2

[a] Range and default value shown are for a 5 A relay. For a 1 A relay, divide the range and default value by 5.

Zone Configuration Settings

The following zone configuration settings are the default settings for all six settings groups. You can set each of the six zone configuration settings groups independently.

Table 8.20 Zone Configuration Settings Categories

Settings	Reference
Potential Transformer Ratios	*Table 8.21*
Current Transformer Ratios	*Table 8.22*
Terminal-to-Bus-Zone Connections	*Table 8.23*, *Table 8.24*
Bus-Zone-to-Bus-Zone Connections	*Table 8.25*, *Table 8.26*
Zone Supervision	*Table 8.27*
Zone Switching Supervision	*Table 8.28*
Zone Open CT Detection	*Table 8.29*
Check Zone Configuration and Terminal-to-Check-Zone Connections	*Table 8.30*, *Table 8.31*
Check Zone Supervision	*Table 8.32*
Current Normalization Factor	[a]

[a] This setting is included here because it appears in the read-back information as TAPnn values (nn = 01–21). However, the user cannot set these values; the SEL-487B calculates these internally using the nominal current and CT ratios. See Section 5: Protection Functions for more information.

Table 8.21 Potential Transformer Ratios

Setting	Prompt	Default
PTR1	Potential Transformer Ratio–V01 (1–10000)	2000
PTR2	Potential Transformer Ratio–V02 (1–10000)	2000
PTR3	Potential Transformer Ratio–V03 (1–10000)	2000

Table 8.22 Current Transformer Ratios

Setting	Prompt	Default
CTR01	Current Transformer Ratio–I01 (1–50000)	600
CTR02	Current Transformer Ratio–I02 (1–50000)	600
• • •	• • •	• • •
CTR21	Current Transformer Ratio–I21 (1–50000)	600

Table 8.23 Terminal-to-Bus-Zone Connections, Terminal Emulation Program View (Sheet 1 of 2)

Setting	Prompt	Default
I01BZ1C	Terminal, Bus-Zone, Polarity (P, N)	FDR_1, BUS_1,P
I01BZ1V	FDR_1 to BUS_1 Connection (SELOGIC Equation)	DIFF_EN AND NOT TOS01
I02BZ1C	Terminal, Bus-Zone, Polarity (P, N)	FDR_2, BUS_1,P
I02BZ1V	FDR_2 to BUS_1 Connection (SELOGIC Equation)	DIFF_EN AND NOT TOS02
I03BZ2C	Terminal, Bus-Zone, Polarity (P, N)	FDR_3, BUS_2,P
I03BZ2V	FDR_3 to BUS_2 Connection (SELOGIC Equation)	DIFF_EN AND NOT TOS03
I04BZ2C	Terminal, Bus-Zone, Polarity (P, N)	TRFR_1, BUS_2,P
I04BZ2V	TRFR_1 to BUS_2 Connection (SELOGIC Equation)	DIFF_EN AND NOT TOS04
I05BZ1C	Terminal, Bus-Zone, Polarity (P, N)	TB_1, BUS_1,P
I05BZ1V	TB_1 to BUS_1 Connection (SELOGIC Equation)	DIFF_EN AND NOT TOS05

Table 8.23 Terminal-to-Bus-Zone Connections, Terminal Emulation Program View (Sheet 2 of 2)

Setting	Prompt	Default
I06BZ2C	Terminal, Bus-Zone, Polarity (P, N)	TB_2, BUS_2,P
I06BZ2V	TB_2 to BUS_2 Connection (SELOGIC Equation)	DIFF_EN AND NOT TOS05
• • •	• • •	• • •
I*nn*BZ*p*C[a, b]	Terminal, Bus-Zone, Polarity (P, N)	None
I*nn*BZ*p*V	I*nn* to BZ*p* Connection (SELOGIC Equation)	NA

[a] nn = 1–21.
[b] p = 1–6.

Table 8.24 Terminal-to-Bus-Zone Connections, QuickSet View

Setting	Prompt	Default
CT01BZ1	Connect Terminal 01 to Bus-Zone 1 (Select: Y, N)	Y
TBZT1	Terminal I01	FDR_1[d]
TBZB1	Bus-Zone BZ1	BUS_1[d]
TBZP1	Polarity I01-BZ1 (Select: P, N)	P
I01BZ1V	Terminal to Bus Connection Logic (SELOGIC Equation)	DIFF_EN AND NOT TOS01
CT01BZ2	Connect Terminal 01 to Bus-Zone 2 (Select: Y, N)	N
TBZT2	Terminal I01	[d]
TBZB2	Bus-Zone BZ2	[d]
TBZP2	Polarity I01-BZ2 (Select: P,N)	P
I01BZ2V	Terminal to Bus Connection Logic (SELOGIC Equation)	NA
• • •	• • •	• • •
CT*nn*BZ*p*[a,b]	Connect Terminal *nn* to Bus-Zone *p* (Select: Y, N)	Y
TBZT*b*[c]	Terminal I*nn*	[d]
TBZB*b*[c]	Bus-Zone BZ*p*	[d]
TBZP*b*[c]	Polarity I*nn*-BZ*p* (Select: P, N)	P
I*nn*BZ*p*V[a,b]	Terminal to Bus Connection Logic (SELOGIC Equation)	NA

[a] nn = 1–21.
[b] p = 1–6.
[c] b = 1–126. The setting shown in the Terminal Emulation Program, InnBZpC, is equivalent to the combination of the three block settings: TBZTb, TBZBb, TBZPb. These settings are separated into 126 blocks in the QuickSet view to show configuration options for every terminal to bus-zone connection option. (21 terminals • 6 bus zones = 126 blocks).
[d] This setting is shown for clarity and not user configurable. It is active when CTnnBZp = Y and defaults to the terminal, bus, or alias name.

Table 8.25 Bus-Zone-to-Bus-Zone Connections, Terminal Emulation Program View (Sheet 1 of 2)

Setting	Prompt	Default
BZ*p*BZ*m*C[a, b]	Bus-Zone, Bus-Zone	None
BZ*p*BZ*m*V[a, b]	BZ*p* to BZ*m* Connection (SELOGIC Equation)	NA

Table 8.25 Bus-Zone-to-Bus-Zone Connections, Terminal Emulation Program View (Sheet 2 of 2)

Setting	Prompt	Default
BZ*p*BZ*m*R[a, b]	Connection to Remove Terminals when BZ*p* and BZ*m* merge (SELOGIC Equation)	NA
BZ*p*BZ*m*M[a, b]	Terminals Removed when BZ*p* and BZ*m* Bus-Zones merge (Ter *k*,. . .,Ter *n*)[c]	None
BZ*p*BZ*m*T[a, b]	Trip Terminals Ter *k*, . . ., Ter *n* (Y, N)	N

[a] p = 1–6.
[b] m = 1–6.
[c] Terminal k, Terminal 1, or Terminal n (maximum of four terminals from 01–21).

Table 8.26 Bus-Zone-to-Bus-Zone Connections, QuickSet View (Sheet 1 of 2)

Setting	Prompt	Default
CBZ1BZ2	Connect Bus-Zone 1 to Bus-Zone 2 (Select: Y, N)	N
BZBZ11	Bus-Zone BZ1	BUS_1[a]
BZBZ21	Bus-Zone BZ2	BUS_2[a]
BZ1BZ2V	Bus to Bus Connection Logic (SELOGIC Equation)	NA
BZ1BZ2R	Removed Terminal Logic (SELOGIC Equation)	NA
CPT11	Terminals to be removed when BZBZ11 and BZBZ21 merge (Select: <Blank>, FDR_1, FDR_2, FDR_3, TRFR_1, TB_1, TB_2)	<Blank>
CPT21	Terminals to be removed when BZBZ11 and BZBZ21 merge (Select: <Blank>, FDR_1, FDR_2, FDR_3, TRFR_1, TB_1, TB_2)	<Blank>
CPT31	Terminals to be removed when BZBZ11 and BZBZ21 merge (Select: <Blank>, FDR_1, FDR_2, FDR_3, TRFR_1, TB_1, TB_2)	<Blank>
CPT41	Terminals to be removed when BZBZ11 and BZBZ21 merge (Select: <Blank>, FDR_1, FDR_2, FDR_3, TRFR_1, TB_1, TB_2)	<Blank>
BZBZT1	Trip Selected Terminal(s) above? (Select: Y, N)	N
• • •	• • •	• • •
CBZ*p*BZ*m*[b, c]	Connect Bus-Zone *p* to Bus-Zone *m* (Select: Y, N)	N
BZBZ1*b*[d]	Bus-Zone BZ*p*	BZ*p*[a]
BZBZ2*b*	Bus-Zone BZ*m*	BZ*m*[a]
BZ*p*BZ*m*V	Bus to Bus Connection Logic (SELOGIC Equation)	NA
BZ*p*BZ*m*R	Removed Terminal Logic (SELOGIC Equation)	NA
CPT1*b*[e]	Terminals to be removed when BZBZ1*b* and BZBZ2*b* merge (Select: <Blank>)	<Blank>
CPT2*b*	Terminals to be removed when BZBZ1*b* and BZBZ2*b* merge (Select: <Blank>)	<Blank>
CPT3*b*	Terminals to be removed when BZBZ1*b* and BZBZ2*b* merge (Select: <Blank>)	<Blank>

Table 8.26 Bus-Zone-to-Bus-Zone Connections, QuickSet View (Sheet 2 of 2)

Setting	Prompt	Default
CPT4*b*	Terminals to be removed when BZBZ1*b* and BZBZ2*b* merge (Select: <Blank>)	<Blank>
BZBZT*b*	Trip Selected Terminal(s) above? (Select: Y, N)	N

[a] This setting is shown for clarity and not user configurable. It is active when CBZpBZm =Y and defaults to the bus or alias name.
[b] p = 1–6.
[c] m = 1–6.
[d] b = 1–15. These settings are separated into 15 blocks in the QuickSet view to show configuration options for every bus-zone-to-bus-zone connection option.
[e] The setting shown in the Terminal Emulation Program, BZpBZmM, is equivalent to the combination of the four QuickSet block settings: CPT1b, CPT2b, CPT3b, CPT4b.

Table 8.27 Zone Supervision

Setting	Prompt	Default
E87ZSUP	Differential Element Zone Supervision (Y, N)	N
Z1S	Zone 1 Supervision (SELOGIC Equation)	1
Z2S	Zone 2 Supervision (SELOGIC Equation)	1
Z3S	Zone 3 Supervision (SELOGIC Equation)	1
Z4S	Zone 4 Supervision (SELOGIC Equation)	1
Z5S	Zone 5 Supervision (SELOGIC Equation)	1
Z6S	Zone 6 Supervision (SELOGIC Equation)	1

Table 8.28 Zone Switching Supervision

Setting	Prompt	Default
EZSWSUP	Zone Switching Supervision (Y, N)	N
ZSWO	Zone Switching Operation (SELOGIC Equation)	NA
RZSWOAL	Reset Zone Switching Op Alarm (SELOGIC Equation)	NA
ZSWOPU	Zone Switching Op Pickup Delay (0–99999 cyc)	1800

Table 8.29 Zone Open CT Detection

Setting	Prompt	Default
ROCTZ1	Reset Zone 1 Open CT Detector (SELOGIC Equation)	RSTOCT1
ROCTZ2	Reset Zone 2 Open CT Detector (SELOGIC Equation)	RSTOCT2
ROCTZ3	Reset Zone 3 Open CT Detector (SELOGIC Equation)	RSTOCT3
ROCTZ4	Reset Zone 4 Open CT Detector (SELOGIC Equation)	RSTOCT4
ROCTZ5	Reset Zone 5 Open CT Detector (SELOGIC Equation)	RSTOCT5
ROCTZ6	Reset Zone 6 Open CT Detector (SELOGIC Equation)	RSTOCT6

Table 8.30 Check Zone Configuration and Terminal-to-Check-Zone Connections, Terminal Emulation Program View

Setting	Prompt	Default
ECHKZN	Enable Check Zones at Station (Y, N)	N
I*nn*CZ*p*C[a, b]	Terminal, Check-Zone, Polarity (P, N)	None
EADVCZ	Enable Advance Check Zone Settings (Y, N)	N

Table 8.30 Check Zone Configuration and Terminal-to-Check-Zone Connections, Terminal Emulation Program View

Setting	Prompt	Default
CZ*pq*R[b, c]	Include Coupler *q* in Check Zone *p* (SELOGIC Equation)	NA
CZ*pq*M[a, b, c]	I*nn* to CZ*p* Connection (SELOGIC Equation)	

[a] nn = 1–21.
[b] p = 1–3.
[c] q = 1–4.

Table 8.31 Check Zone Configuration and Terminal-to-Check-Zone Connections, QuickSet View

Setting	Prompt	Default
CT01CZ1	Connect Terminal 1 to Check-Zone 1 (Select: Y, N)	N
TCZT1	Terminal I01	FDR_1[a]
TCZC1	Check Zone CZ1	CZ1[a]
TCZP1	Polarity I01-CZ1 (Select: P, N)	P
• • •	• • •	• • •
CT*nn*CZ*p*[b,c]	Connect Terminal I*nn* to Check-Zone *p* (Select: Y, N)	N
TCZT*b*[d]	Terminal I*nn*	I*nn*[a]
TCZC*b*	Check Zone CZ*p*	CZ*p*[a]
TCZP*b*	Polarity I*nn*-CZ*p* (Select: P, N)	P

[a] This setting is shown for clarity and not user configurable. It is active when CTnnCZp = Y and defaults to the terminal, check zone or alias name.
[b] nn = 1–21.
[c] p = 1–3.
[d] b = 1–63. These settings are separated into 63 blocks in the QuickSet view to show configuration options for every terminal-to-check-zone connection option (21 terminals • 3 check zones). The setting shown in the Terminal Emulation Program, InnCZpC, is equivalent to the combination of the three QuickSet block settings: TCZTb, TCZCb, TCZPb.

Table 8.32 Check Zone Supervision

Setting	Prompt	Default
E87CZSP	Differential Element Check Zone Supervision (Y, N)	N
CZ*n*S[a]	Check Zone *n* Supervision (SELOGIC Control Equation)[b]	1

[a] n = 1–3.
[b] 0 is not a valid value for this setting.

Group Settings

Table 8.33 Group Settings Categories (Sheet 1 of 2)

Settings	Reference
Relay Configuration	*Table 8.34*
Sensitive Differential Elements	*Table 8.35*
Check Zone Sensitive Differential Elements	*Table 8.36*
Restrained Differential Elements	*Table 8.37*

Table 8.33 Group Settings Categories (Sheet 2 of 2)

Settings	Reference
Check Zone Restrained Differential Elements	*Table 8.38*
Phase Directional Element	*Table 8.39*
Coupler Security Logic	*Table 8.40*
Terminal Out of Service	*Table 8.41*
Breaker Failure Logic	*Table 8.42*
Definite-Time Overcurrent Elements	*Table 8.43*
Inverse-Time Overcurrent Elements	*Table 8.44*
Under- and Overvoltage Elements	*Table 8.45*, *Table 8.46*
Trip Logic	*Table 8.47*

Table 8.34 Relay Configuration

Setting	Prompt	Default
E87SSUP	Sensitive Differential Element Supervision (Y, N)	Y
ECSL	Coupler Security Logic (N, 1–4)	N
ETOS	Terminal Out of Service (N, 1–21)	5
EBFL	Breaker Failure Logic (N, 1–21)	6
E50	Definite-Time Overcurrent Elements (N, 1–21)	N
E51	Inverse-Time Overcurrent Elements (N, 1–21)	N
EADVS	Advanced Settings (Y, N)	N
E27	Enable Under Voltage Elements (N, 1–6)	N
E59	Enable Over Voltage Elements (N, 1–6)	N

Table 8.35 Sensitive Differential Elements

Setting	Prompt	Default	Increment
S87P	Sensitive Differential Element Pickup (0.05–1 pu)	0.10	0.01
87STPU	87S Timer Pickup Delay (50–6000 cyc)	300	1

Table 8.36 Check Zone Sensitive Differential Elements[a]

Setting	Prompt	Default	Increment
CZS87P	Check Zone Sensitive Differential Element Pickup (0.05–1 pu)	0.10	0.01
CZ87STP	Check Zone 87S Time Pickup Delay (50–6000 cyc)	300	1

[a] Available when ECHKZN := Y.

Table 8.37 Restrained Differential Elements

Setting	Prompt	Default	Increment
O87P	Restrained Diff Element Pickup (0.10–4 pu)	1.00	0.01
SLP1	Restrained Slope 1 Percentage (15–90%)	60	1
SLP2	Restrained Slope 2 Percentage (50–90%)	80	1
RTDI	Incr Restrained Current Threshold (0.10–10 pu)	1.20	0.01
OPDI	Incr Operating Current Threshold (0.10–10 pu)	1.20	0.01

Table 8.38 Check Zone Restrained Differential Elements[a]

Setting	Prompt	Default	Increment
CZO87P	Check Zone Restrained Diff Element Pickup (0.10–4 pu)	1.00	0.01
CZSLP1	Check Zone Restrained Slope 1 Percentage (5–90%)	60	1
CZSLP2	Check Zone Restrained Slope 2 Percentage (15–90%)	80	1
CZRTDI	Check Zone Incr Restrained Current Threshold (0.10–10 pu)	1.20	0.01
CZOPDI	Check Zone Incr Operating Current Threshold (0.10–10 pu)	1.20	0.01

[a] Available when ECHKZN := Y.

Table 8.39 Phase Directional Element

Setting	Prompt	Default	Increment
50DSP	Dir Element O/C Supervision Pickup (0.05–3 pu)	0.05	0.01

Table 8.40 Coupler Security Logic (1–4)

Setting	Prompt	Default	Increment
CB52A1	Coupler 1 Status (SELOGIC Equation)	NA	
CB52DO1	Coupler 1 Status Dropout Delay (0.00–1000 cyc)	4	0.083
CBCLS1	Coupler 1 Close Command (SELOGIC Equation)	NA	
CBCLDO1	Coupler 1 Close Command D/O Delay (0.00–1000 cyc)	5	0.083
ACTRP1	Coupler 1 Acc Trip (SELOGIC Equation)	NA	
ACTPPU1	Coupler 1 Acc Trip Pickup Delay (0.00–1000 cyc)	4	0.083
• • •	• • •	• • •	• • •
CB52A4	Coupler 4 Status (SELOGIC Equation)	NA	
CB52DO4	Coupler 4 Status Dropout Delay (0.00–1000 cyc)	4	0.083
CBCLS4	Coupler 4 Close Command (SELOGIC Equation)	NA	
CBCLDO4	Coupler 4 Close Command D/O Delay (0.00–1000 cyc)	5	0.083
ACTRP4	Coupler 4 Acc Trip (SELOGIC Equation)	NA	
ACTPPU4	Coupler 4 Acc Trip Pickup Delay (0.00–1000 cyc)	4	0.083

Table 8.41 Terminal Out of Service (1–21)

Setting	Prompt	Default
TOS01	Terminal 01 Out-of-Service (SELOGIC Equation)	LB01
TOS02	Terminal 02 Out-of-Service (SELOGIC Equation)	LB02
TOS03	Terminal 03 Out-of-Service (SELOGIC Equation)	LB03
TOS04	Terminal 04 Out-of-Service (SELOGIC Equation)	LB04
TOS05	Terminal 05 Out-of-Service (SELOGIC Equation)	LB05
TOS06	Terminal 06 Out-of-Service (SELOGIC Equation)	NA
• • •	• • •	• • •
TOS21	Terminal 21 Out-of-Service (SELOGIC Equation)	NA

Table 8.42 Breaker Failure Logic (1–21) (Sheet 1 of 3)

Setting	Prompt	Default	Increment
Breaker 01 Failure Logic			
EXBF01	External Breaker Fail–BK01 (Y, N)	N	
XBF01	External Brkr Fail Init–BK01 (SELOGIC Equation)	NA	
50FP01	Fault Current Pickup–BK01 (0.50–50 amps, sec)	3.00	0.01
BFPU01	Brkr Fail Init Pickup Delay–BK01 (0.00–6000 cyc)	6.00	0.083
RTPU01	Retrip Delay–BK01 (0.00–6000 cyc)	3.00	0.083
BFI01	Breaker Fail Initiate–BK01 (SELOGIC Equation)	F1_BFI AND BF_EN	
ATBFI01	Alt Breaker Fail Initiate–BK01 (SELOGIC Equation)	NA	
EBFIS01	Breaker Fail Initiate Seal-In–BK01 (Y, N)	N	
BFISP01	Breaker Fail Init Seal-In Delay–BK01 (0.00–1000 cyc)	0.50	0.083
BFIDO01	Brkr Fail Init Dropout Delay–BK01 (0.00–1000 cyc)	1.50	0.083
Breaker 02 Failure Logic			
EXBF02	External Breaker Fail–BK02 (Y, N)	N	
XBF02	External Brkr Fail Init–BK02 (SELOGIC Equation)	NA	
50FP02	Fault Current Pickup–BK02 (0.50–50 amps, sec)	3.00	0.01
BFPU02	Brkr Fail Init Pickup Delay–BK02 (0.00–6000 cyc)	6.00	0.083
RTPU02	Retrip Delay–BK02 (0.00–6000 cyc)	3.00	0.083
BFI02	Breaker Fail Initiate–BK02 (SELOGIC Equation)	F2_BFI AND BF_EN	
ATBFI02	Alt Breaker Fail Initiate–BK02 (SELOGIC Equation)	NA	
EBFIS02	Breaker Fail Initiate Seal-In–BK02 (Y, N)	N	
BFISP02	Breaker Fail Init Seal-In Delay–BK02 (0.00–1000 cyc)	0.50	0.083
BFIDO02	Brkr Fail Init Dropout Delay–BK02 (0.00–1000 cyc)	1.50	0.083
Breaker 03 Failure Logic			
EXBF03	External Breaker Fail–BK03 (Y, N)	N	
XBF03	External Brkr Fail Init–BK03 (SELOGIC Equation)	NA	
50FP03	Fault Current Pickup–BK03 (0.50–50 amps, sec)	3.00	0.01
BFPU03	Brkr Fail Init Pickup Delay–BK03 (0.00–6000 cyc)	6.00	0.083
RTPU03	Retrip Delay–BK03 (0.00–6000 cyc)	3.00	0.083
BFI03	Breaker Fail Initiate–BK03 (SELOGIC Equation)	F3_BFI AND BF_EN	
ATBFI03	Alt Breaker Fail Initiate–BK03 (SELOGIC Equation)	NA	
EBFIS03	Breaker Fail Initiate Seal-In–BK03 (Y, N)	N	
BFISP03	Breaker Fail Init Seal-In Delay–BK03 (0.00–1000 cyc)	0.50	0.083
BFIDO03	Brkr Fail Init Dropout Delay–BK03 (0.00–1000 cyc)	1.50	0.083

Table 8.42 Breaker Failure Logic (1–21) (Sheet 2 of 3)

Setting	Prompt	Default	Increment
Breaker 04 Failure Logic			
EXBF04	External Breaker Fail–BK04 (Y, N)	N	
XBF04	External Brkr Fail Init–BK04 (SELOGIC Equation)	NA	
50FP04	Fault Current Pickup–BK04 (0.50–50 amps, sec)	3.00	0.01
BFPU04	Brkr Fail Init Pickup Delay–BK04 (0.00–6000 cyc)	6.00	0.083
RTPU04	Retrip Time Delay–BK04 (0.00–6000 cyc)	3.00	0.083
BFI04	Breaker Fail Initiate–BK04 (SELOGIC Equation)	T1_BFI AND BF_EN	
ATBFI04	Alt Breaker Fail Initiate–BK04 (SELOGIC Equation)	NA	
EBFIS04	Breaker Fail Initiate Seal-In–BK04 (Y, N)	N	
BFISP04	Breaker Fail Init Seal-In Delay–BK04 (0.00–1000 cyc)	0.50	0.083
BFIDO04	Brkr Fail Init Dropout Delay–BK04 (0.00–1000 cyc)	1.50	0.083
Breaker 05 Failure Logic			
EXBF05	External Breaker Fail–BK05 (Y, N)	N	
XBF05	External Brkr Fail Init–BK05 (SELOGIC Equation)	NA	
50FP05	Fault Current Pickup–BK05 (0.50–50 amps, sec)	3.00	0.01
BFPU05	Brkr Fail Init Pickup Delay–BK05 (0.00–6000 cyc)	6.00	0.083
RTPU05	Retrip Delay–BK05 (0.00–6000 cyc)	3.00	0.083
BFI05	Breaker Fail Initiate–BK05 (SELOGIC Equation)	TB_BFI AND BF_EN	
ATBFI05	Alt Breaker Fail Initiate–BK05 (SELOGIC Equation)	NA	
EBFIS05	Breaker Fail Initiate Seal-In–BK05 (Y, N)	N	
BFISP05	Breaker Fail Init Seal-In Delay–BK05 (0.00–1000 cyc)	0.50	0.083
BFIDO05	Brkr Fail Init Dropout Delay–BK05 (0.00–1000 cyc)	1.50	0.083
Breaker 06 Failure Logic			
EXBF06	Enable External Breaker Fail–BK06 (Y, N)	N	
XBF06	External Brkr Fail Init–BK06 (SELOGIC Equation)	NA	
50FP06	Fault Current Pickup–BK06 (0.50–50 amps, sec)	3.00	0.01
BFPU06	Brkr Fail Init Pickup Delay–BK06 (0.00–6000 cyc)	6.00	0.083
RTPU06	Retrip Delay–BK06 (0.00–6000 cyc)	3.00	0.083
BFI06	Breaker Fail Initiate–BK06 (SELOGIC Equation)	IN106 AND BF_EN	
ATBFI06	Alt Breaker Fail Initiate–BK06 (SELOGIC Equation)	NA	
EBFIS06	Breaker Fail Initiate Seal-In–BK06 (Y, N)	N	
BFISP06	Breaker Fail Init Seal-In Delay–BK06 (0.00–1000 cyc)	0.50	0.083
BFIDO06	Brkr Fail Init Dropout Delay–BK06 (0.00–1000 cyc)	1.50	0.083

Table 8.42 Breaker Failure Logic (1–21) (Sheet 3 of 3)

Setting	Prompt	Default	Increment
Breaker 07 Failure Logic			
EXBF07	External Breaker Fail–BK07 (Y, N)	N	
XBF07	External Brkr Fail Init–BK07 (SELOGIC Equation)	NA	
50FP07	Fault Current Pickup–BK07 (0.50–50 amps, sec)	3.00	0.01
BFPU07	Brkr Fail Init Pickup Delay–BK07 (0.00–6000 cyc)	6.00	0.083
RTPU07	Retrip Delay–BK07 (0.00–6000 cyc)	3.00	0.083
BFI07	Breaker Fail Initiate–BK07 (SELOGIC Equation)	NA	
ATBFI07	Alt Breaker Fail Initiate–BK07 (SELOGIC Equation)	NA	
EBFIS07	Breaker Fail Initiate Seal-In–BK07 (Y, N)	N	
BFISP07	Breaker Fail Init Seal-In Delay–BK07 (0.00–1000 cyc)	0.50	0.083
BFIDO07	Brkr Fail Init Dropout Delay–BK07 (0.00–1000 cyc)	1.50	0.083
Breaker 08 Failure Logic			
EXBF08	External Breaker Fail–BK08 (Y, N)	Y	
XBF08	External Brkr Fail Init–BK08 (SELOGIC Equation)	NA	
50FP08	Fault Current Pickup–BK08 (0.50–50 amps, sec)	3.00	0.01
BFPU08	Brkr Fail Init Pickup Delay–BK08 (0.00–6000 cyc)	6.00	0.083
RTPU08	Retrip Delay–BK08 (0.00–6000 cyc)	3.00	0.083
BFI08	Breaker Fail Initiate–BK08 (SELOGIC Equation)	NA	
ATBFI08	Alt Breaker Fail Initiate–BK08 (SELOGIC Equation)	NA	
EBFIS08	Breaker Fail Initiate Seal-In–BK08 (Y, N)	N	
BFISP08	Breaker Fail Init Seal-In Delay–BK08 (0.00–1000 cyc)	0.50	0.083
BFIDO08	Brkr Fail Init Dropout Delay–BK08 (0.00–1000 cyc)	1.50	0.083
• • •	• • •	• • •	• • •
Breaker 21 Failure Logic			
EXBF21	External Breaker Fail–BK21 (Y, N)	Y	
XBF21	External Brkr Fail Init–BK21 (SELOGIC Equation)	NA	
50FP21	Fault Current Pickup–BK21 (0.50–50 amps, sec)	3.00	0.01
BFPU21	Brkr Fail Init Pickup Delay–BK21 (0.00–6000 cyc)	6.00	0.083
RTPU21	Retrip Delay–BK21 (0.00–6000 cyc)	3.00	0.083
BFI21	Breaker Fail Initiate–BK21 (SELOGIC Equation)	NA	
ATBFI21	Alt Breaker Fail Initiate–BK21 (SELOGIC Equation)	NA	
EBFIS21	Breaker Fail Initiate Seal-In–BK21 (Y, N)	N	
BFISP21	Breaker Fail Init Seal-In Delay–BK21 (0.00–1000 cyc)	0.50	0.083
BFIDO21	Brkr Fail Init Dropout Delay–BK21 (0.00–1000 cyc)	1.50	0.083

Table 8.43 Definite-Time Overcurrent Elements

Setting	Prompt	Default	Increment
50P01P	Terminal 01 Pickup (OFF, 0.25–100 amps, sec)	OFF	0.01
50P01D	Terminal 01 Pickup Delay (0.00–99999 cyc)	10.00	0.167
• • •	• • •	• • •	• • •
50P21P	Terminal 21 Pickup (OFF, 0.25–100 amps, sec)	OFF	0.01
50P21D	Terminal 21 Pickup Delay (0.00–99999 cyc)	10.00	0.167

Table 8.44 Inverse-Time Overcurrent Elements

Setting	Prompt	Default
51O01	Inverse Time O/C 01 Operate Quantity	I01FIM
51P01[a]	Inverse Time O/C 01 Pickup (SELOGIC Equation) (0.25–16 A, sec)	0.50
51C01	Inverse Time O/C 01 Curve (U1–U5, C1–C5)	U1
51TD01	Inverse Time O/C 01 Time Dial (0.50–15) [U1–U5] or Inverse Time O/C 01 Time Dial (0.05–1) [C1–C5]	0.50
51RS01	Inverse Time O/C 01 EM Reset (Y, N)	Y
51TC01	Inverse Time O/C 01 Torque Cont (SELOGIC Equation)	1
• • •	• • •	• • •
51O21	Inverse Time O/C 21 Operate Quantity	I21FIM
51P21[a]	Inverse Time O/C 21 Pickup (SELOGIC Equation) (0.50–16 A, sec)	0.50
51C21	Inverse Time O/C 21 Curve (U1–U5, C1–C5)	U1
51TD21	Inverse Time O/C 21 Time Dial (0.50–15) [U1–U5] or Inverse Time O/C 21 Time Dial (0.05–1) [C1–C5]	0.50
51RS21	Inverse Time O/C 21 EM Reset (Y, N)	Y
51TC21	Inverse Time O/C 21 Torque Cont (SELOGIC Equation)	1

[a] The acceptable range of result of the math equation must be within specific limits depending on the nominal current. For 5 A nominal current input, the range is 0.25–16.0 A, sec. For 1 A nominal current input, 0.05–3.2 A, sec. See Section 5: Protection Functions for more information.

Table 8.45 Undervoltage Elements

Setting	Prompt	Default	Increment
270*n*[a]	U/V Element *n* Operating Quantity	V1FIM	
27P*n*P1[a]	U/V Element *n* Level 1 P/U (2.00–300 V, sec)	20.00	0.01
27TC*n*[a]	U/V Element *n* Torque Control (SELOGIC Eqn)	1	
27P*n*D1[a]	U/V Element *n* Level 1 Delay (0.00–16000 cyc)	10.00	0.167
27P*n*P2[a]	U/V Element *n* Level 2 P/U (2.00–300 V, sec)	15.00	0.01

[a] n = 1–6.

Table 8.46 Overvoltage Elements

Setting	Prompt	Default	Increment
590*n*[a]	O/V Element *n* Operating Quantity	V1FIM	
59P*n*P1[a]	O/V Element *n* Level 1 P/U (2.00–300 V, sec)	76.00	0.01
59TC*n*[a]	O/V Element *n* Torque Control (SELOGIC Eqn)	1	
59P*n*D1[a]	O/V Element *n* Level 1 Delay (0.00–16000 cyc)	10.00	0.167
59P*n*P2[a]	O/V Element *n* Level 2 P/U (2.00–300 V, sec)	80.00	0.01

[a] n = 1–6.

Table 8.47 Trip Logic

Setting	Prompt	Default	Increment
TR01	Trip 01 (SELOGIC Equation)	F1_BFT OR F1_DPT	
ULTR01	Unlatch Trip 01 (SELOGIC Equation)	NA	
TR02	Trip 02 (SELOGIC Equation)	F2_BFT OR F2_DPT	
ULTR02	Unlatch Trip 02 (SELOGIC Equation)	NA	
TR03	Trip 03 (SELOGIC Equation)	F3_BFT OR F3_DPT	
ULTR03	Unlatch Trip 03 (SELOGIC Equation)	NA	
TR04	Trip 04 (SELOGIC Equation)	T1_BFT OR T1_DPT	
ULTR04	Unlatch Trip 04 (SELOGIC Equation)	NA	
TR05	Trip 05 (SELOGIC Equation)	TB1_BFT OR TB1_DPT OR TB2_BFT OR TB2_DPT	
ULTR05	Unlatch Trip 05 (SELOGIC Equation)	NA	
TR06	Trip 06 (SELOGIC Equation)	NA	
ULTR06	Unlatch Trip 06 (SELOGIC Equation)	NA	
• • •	• • •	• • •	
TR21	Trip 21 (SELOGIC Equation)	NA	
ULTR21	Unlatch Trip 21 (SELOGIC Equation)	NA	
TDURD	Minimum Trip Duration Time Delay (2.000–8000 cyc)	12.000	0.083
ER	Event Report Trigger Equation (SELOGIC Equation)	R_TRIG 87ST	

Protection Freeform SELOGIC Control Equations

The following protection freeform SELOGIC control equation settings are the default settings for all six settings groups. You can set each of the six protection freeform SELOGIC control equation settings groups independently. See *Multiple Setting Groups on page 12.4 in the SEL-400 Series Relays Instruction Manual*.

Table 8.48 Protection Freeform SELOGIC Control Equations

Label	Default
PLT01S :=	NOT DIFF_EN AND PLT04 # DIFFERENTIAL ENABLED
PLT01R :=	PCT02Q AND DIFF_EN AND NOT PLT04
PLT02S :=	NOT BF_EN AND PLT05 # BREAKER FAILURE ENABLED
PLT02R :=	PCT03Q AND BF_EN AND NOT PLT05
PLT03S :=	NOT TNS_SW AND PLT06 # RELAY TEST MODE
PLT03R :=	PCT04Q AND TNS_SW AND NOT PLT06
PLT04S :=	PB1_PUL AND NOT DIFF_EN # ONLY ONE OP PER PB1 PRESS
PLT04R :=	PB1_PUL AND DIFF_EN
PLT05S :=	PB2_PUL AND NOT BF_EN # ONLY ONE OP PER PB2 PRESS
PLT05R :=	PB2_PUL AND BF_EN
PLT06S :=	PB4_PUL AND NOT TNS_SW # ONLY ONE OP PER PB4 PRESS
PLT06R :=	PB4_PUL AND TNS_SW
PCT01PU :=	240
PCT01IN :=	PCT01IN := 3V2FIM > 20 OR 3V0FIM > 20
PCT02PU :=	60 # 1 SEC DELAY DISABLE ON PB1
PCT02IN :=	PB1
PCT03PU :=	60 # 1 SEC DELAY DISABLE ON PB2
PCT03IN :=	PB2
PCT04PU :=	60 # 1 SEC DELAY DISABLE ON PB4
PCT04IN :=	PB4

Automation Freeform SELOGIC Control Equations

See *Automation Freeform SELOGIC Control Equations on page 12.26 in the SEL-400 Series Relays Instruction Manual* for a description of automation SELOGIC control equations. The SEL-487B supports 10 blocks of 100 lines.

Notes Settings

Use the Notes settings like a text pad to leave notes about the relay. See *Notes Settings on page 12.29 in the SEL-400 Series Relays Instruction Manual* for additional information on Notes settings.

Output Settings

Output Settings on page 12.26 in the SEL-400 Series Relays Instruction Manual contains a description of the relay's output settings. This subsection describes SEL-487B-specific default values.

Table 8.49 Main Board

Setting	Default
OUT101	TRIP01 AND NOT TNS_SW
OUT102	TRIP02 AND NOT TNS_SW
OUT103	TRIP03 AND NOT TNS_SW
OUT104	TRIP04 AND NOT TNS_SW
OUT105	TRIP05 AND NOT TNS_SW
OUT106	NA
OUT107	TNS_SW #RELAY TEST MODE
OUT108	NOT (SALARM OR HALARM)

All interface board default output SELOGIC equations default to NA.

Front-Panel Settings

See *Front-Panel Settings on page 12.20 in the SEL-400 Series Relays Instruction Manual* for a complete description of front-panel settings. This subsection lists the SEL-487B-specific default settings values.

Table 8.50 Front-Panel Settings (Sheet 1 of 4)

Setting	Default
FP_TO	15
EN_LEDC[a]	G
TR_LEDC[a]	R
PB1_LED	DIFF_EN # Differential Protection Enabled
PB1_COL[a]	AO
PB2_LED	BF_EN # Breaker Failure Enabled
PB2_COL[a]	AO
PB3_LED	NA
PB3_COL[a]	AO
PB4_LED	TNS_SW # Test Normal Switch Enabled
PB4_COL[a]	AO
PB5_LED	NA
PB5_COL[a]	AO
PB6_LED	NA
PB6_COL[a]	AO
PB7_LED	NA
PB7_COL[a]	AO

Table 8.50 Front-Panel Settings (Sheet 2 of 4)

Setting	Default
PB8_LED	NA
PB8_COL[a,b]	AO
PB9_LED[b]	NA
PB9_COL[a,b]	AO
PB10LEDb	NA
PB10COL[a,b]	AO
PB11LED[b]	NA
PB11COL[a,b]	AO
PB12LED[b]	NA
PB12COL[a,b]	AO
T1_LED	87BTR
T1LEDL	Y
T1LEDC[a]	RO
T2_LED	SBFTR
T2LEDL	Y
T2LEDC[a]	RO
T3_LED	Z1_TRIP
T3LEDL	Y
T3LEDC[a]	RO
T4_LED	Z2_TRIP
T4LEDL	Y
T4LEDC[a]	RO
T5_LED	87Z3
T5LEDL	Y
T5LEDC[a]	RO
T6_LED	87Z4
T6LEDL	Y
T6LEDC[a]	RO
T7_LED	87Z5
T7LEDL	Y
T7LEDC[a]	RO
T8_LED	87Z6
T8LEDL	Y
T8LEDC[a]	RO
T9_LED	50P01T OR 50P02T OR. . .50P21T
T9LEDL	Y
T91LEDC[a]	RO
T10_LED	51T01 OR 51T02 OR. . .51T21
T10LEDL	Y
T10LEDC[a]	RO

Table 8.50 Front-Panel Settings (Sheet 3 of 4)

Setting	Default
T11_LED	87ST
T11LEDL	N
T11LEDC[a]	RO
T12_LED	NOT (Z1S AND Z2S AND. . .Z6S)
T12LEDL	Y
T12LEDC[a]	RO
T13_LED	TOS01 OR TOS02 OR. . .TOS21
T13LEDL	N
T13LEDC[a]	RO
T14_LED	89IOP
T14LEDL	N
T14LEDC[a]	RO
T15_LED	89AL
T15LEDL	N
T15LEDC[a]	RO
T16_LED	PCT01Q
T16LEDL	Y
T16LEDC[a]	RO
T17_LED[c]	271P1 OR 272P1 OR 272P2 OR 273P1 OR 273P2
T17LEDLc	N
T17LEDC[a,c]	RO
T18_LED[c]	591P1 OR 591P2 OR 292P1 OR 592P2 OR 593P1 OR 593P2
T18LEDL[c]	N
T18LEDC[a,c]	RO
T19_LED[c]	V01FIM>55
T19LEDL[c]	N
T19LEDC[a,c]	RO
T20_LED[c]	V02FIM>55
T20LEDL[c]	N
T20LEDC[a,c]	RO
T21_LED[c]	V03FIM>55
T21LEDL[c]	N
T21LEDC[a,c]	RO
T22_LED[c]	FAULT
T22LEDL[c]	N
T22LEDC[a,c]	RO
T23_LED[c]	52AL
T23LEDL[c]	N
T23LEDC[a,c]	RO
T24_LED[c]	TIRIG

Table 8.50 Front-Panel Settings (Sheet 4 of 4)

Setting	Default
T24LEDL[c]	N
T24LEDC[a,c]	RO

[a] LED color settings are only available on HMI2 models.
[b] PB9–PB12 settings are only available on 12-pushbutton models.
[c] T17LED–T24LED settings are only available on 12-pushbutton models.

The SEL-487B supports the SCROLD, STA_BAT, FUND_VI, DIFF, and ZONECFG choices for selectable screens, as described in *Table 12.38 in the SEL-400 Series Relays Instruction Manual*.

Report Settings

The SEL-487B contains the Report Settings described in *Report Settings on page 12.28 in the SEL-400 Series Relays Instruction Manual*.

Table 8.51 Default Event Report Settings (Sheet 1 of 2)

Position	Primitive Name	Alias Name
1	87Z1	Z1_TRIP
2	87Z2	Z2_TRIP
3	#	
4	FBF01	F1_BF
5	FBF02	F2_BF
6	FBF03	F3_BF
7	FBF04	T1_BF
8	FBF05	TB1_BF
9	FBF06	TB2_BF
10	#	
11	PLT01	DIFF_EN
12	PLT02	BF_EN
13	PLT03	TNS_SW
14	#	
15	IN101	F1_BFI
16	IN102	F2_BFI
17	IN103	F3_BFI
18	IN104	T1_BFI
19	IN105	TB_BFI
20	#	
21	OUT101	F1_TRIP
22	OUT102	F2_TRIP
23	OUT103	F3_TRIP
24	OUT104	T1_TRIP
25	OUT105	TB_TRIP

Table 8.51 Default Event Report Settings (Sheet 2 of 2)

Position	Primitive Name	Alias Name
26	OUT106	
27	#	
28	OUT107	TEST
29	OUT108	NOALARM

Port Settings

The SEL-487B Port settings are described in *Port Settings on page 12.6 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 included in the SEL-487B, except FMRDMND and FMRBRKR.

Table 8.52 MIRRORED BITS Protocol Default Settings

Setting	Default
MBANA1	PMV58
MBANA2	PMV59
MBANA3	PMV60
MBANA4	PMV61
MBANA5	PMV62
MBANA6	PMV63
MBANA7	PMV64

DNP3 Settings—Custom Maps

The SEL-487B DNP3 custom map settings operate as described in *DNP3 Settings—Custom Maps on page 12.19 in the SEL-400 Series Relays Instruction Manual*. See *Section 10: Communications Interfaces* for the default map configuration.

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SECTION 9

ASCII Command Reference

You can use a communications terminal or terminal emulation program to set and operate the SEL-487B relay. This section explains the commands that you send to the SEL-487B using 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-487B.

This section lists American National Standard Code for Information Interchange (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, Zone *n* = 1–6, remote bit number *nn* = 01–96, 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 (upper- or lowercase); 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-487B 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.

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-487B List of Commands (Sheet 1 of 2)

Command	Location of Command in *Section 14: ASCII Command Reference* in the SEL-400 Series Relays Instruction Manual
2ACCESS	*2ACCESS on page 14.1*
AACCESS	*AACCESS on page 14.3*
ACCESS	*ACCESS on page 14.3*
BACCESS	*BACCESS on page 14.3*
BNAME	*BNAME on page 14.4*
CAL	*CAL on page 14.5*
CASCII	*CASCII on page 14.6*
CEVENT	*CEVENT on page 14.7* (In the SEL-487B, **CEV L** provides a 12-samples/cycle large-resolution event report.)
CFG CTNOM *i*	*CFG CTNOM on page 14.10* (in the SEL-487B, the nominal current choices are 1 and 5 for 1 A nominal and 5 A nominal CT inputs.)
CFG NFREQ *f*	*CFG NFREQ on page 14.11*
CHISTORY	*CHISTORY on page 14.11*
COMMUNICATIONS *c*	*COMMUNICATIONS on page 14.12*
CONTROL *nn*	*CONTROL nn on page 14.25*
COPY	*COPY on page 14.26* (In addition to the typical classes, the zone (Z) class can also be copied using the **COPY** command.)
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*
EVENT	*EVENT on page 14.33* (The SEL-487B supports large resolution 12-samples/cycle event reports.)
EXIT	*EXIT on page 14.37*
FILE	*FILE on page 14.37*
GOOSE	*GOOSE on page 14.38*
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*

Table 9.1 SEL-487B List of Commands (Sheet 2 of 2)

Command	Location of Command in *Section 14: ASCII Command Reference* in the SEL-400 Series Relays Instruction Manual
MET BAT	*MET BAT on page 14.48* (The SEL-487B provides battery metering for one battery monitor channel.)
MET CZ*q*	See *MET CZq on page 9.4* in this section.
MET DIF	See *MET DIF on page 9.4* in this section.
MET PMV	*MET PMV on page 14.50*
MET SEC	See *MET SEC on page 9.5* in this section.
MET SEC CZ*n*	See *MET SEC CZq on page 9.5* in this section.
MET SEC Z*n*	See *MET SEC Zn on page 9.5* in this section.
MET Z*n*	See *MET Zn on page 9.5* in this section.
OACCESS	*OACCESS on page 14.51*
OPEN *n*	*OPEN n on page 14.51* (The SEL-487B supports 21 circuit breakers, designated 1–21.)
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*
SER	*SER on page 14.56*
SET	*SET on page 14.58* (*Table 9.9* lists the options available in the SEL-487B.)
SHOW	*SHOW on page 14.59* (*Table 9.10* lists the class and instance options available in the SEL-487B.)
SNS	*SNS on page 14.60*
STATUS	*STATUS on page 14.60*
SUMMARY	*SUMMARY on page 14.62*
TARGET	*TARGET on page 14.63*
TEST DB	*TEST DB on page 14.65*
TEST DB2	*TEST DB2 on page 14.66*
TEST FM	*TEST FM on page 14.68*
TIME	*TIME on page 14.71*
TRIGGER	*TRIGGER on page 14.73*
VECTOR	*VECTOR on page 14.73*
VERSION	*VERSION on page 14.73*
VIEW	*VIEW on page 14.75*
ZONE	See *ZONE on page 9.7* in this section.
ZON T	See *ZON T on page 9.8* in this section.
ZON *k*	See *ZON k on page 9.8* in this section.

METER

The **METER** command displays reports about quantities the relay measures in the power system and internal relay operating quantities. For more information on power system measurements, see *Section 7: Metering, Monitoring, and Reporting*.

MET

NOTE: Data obtained with the **MET** command during dynamic zone selection may be unreliable.

Use the **MET** command to view fundamental metering quantities. The relay filters harmonics to present only measured quantities at the power system fundamental operating frequency.

Table 9.2 MET Command

Command	Description	Access Level
MET	Display fundamental metering data.	1, B, P, A, O, 2
MET *k*	Display fundamental metering data successively for *k* times.	1, B, P, A, O, 2

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 CZq

Use the **MET CZ*q*** (*q* = 1–3) command to view the current magnitude, angle, and polarity of each terminal in Check Zone *q* and the voltage in primary values.

Table 9.3 MET CZq Command

Command[a]	Description	Access Level
MET CZ*q*	Display primary metering data for Check Zone *q*.	1, B, P, A, O, 2
MET CZ*q* *k*	Display primary metering data for Check Zone *q* successively for *k* times.	1, B, P, A, O, 2

[a] q = 1–3.

If an alias name for the terminal exists, the relay displays the alias name.

MET DIF

Use the **MET DIF** command to view the operate and restraint differential currents in the active zones in per unit values as well as the reference current (IREF).

Table 9.4 MET DIF Command

Command	Description	Access Level
MET DIF	Display the operate and restraint differential currents and IREF metering data.	1, B, P, A, O, 2
MET DIF *k*	Display the operate and restraint differential currents and IREF metering data successively for *k* times.	1, B, P, A, O, 2

MET SEC

Use the **MET SEC** command to view the current magnitude, angle, and CT ratio of each terminal. The view also includes voltage magnitudes in secondary values.

Table 9.5 MET SEC Command

Command	Description	Access Level
MET SEC	Display secondary metering data.	1, B, P, A, O, 2
MET SEC *k*	Display secondary metering data successively for *k* times.	1, B, P, A, O, 2

If an alias name for the terminal exists, the relay displays the alias name.

MET SEC CZq

Use the **MET SEC CZ*q*** (*q* = 1–3) command to view the current magnitude, angle, CT ratio, and polarity of each terminal in Check Zone *q* and the voltage in secondary values.

Table 9.6 MET SEC CZq Command

Command[a]	Description	Access Level
MET SEC CZ*q*	Display secondary metering data for Check Zone *q*.	1, B, P, A, O, 2
MET SEC CZ*q* *k*	Display secondary metering data for Check Zone *q* successively for *k* times.	1, B, P, A, O, 2

[a] q = 1–3.

If an alias name for the terminal exists, the relay displays the alias name.

MET SEC Zn

Use the **MET SEC Z*n*** command to view the current magnitude, angle, CT ratio, and polarity of each terminal in a particular protection zone (*n* = 1–6), the bus-zones in Protection Zone *n*, and the voltage in secondary values.

Table 9.7 MET SEC Zn Command

Command[a]	Description	Access Level
MET SEC Z*n*	Display secondary metering data.	1, B, P, A, O, 2
MET SEC Z*n* *k*	Display secondary metering data successively for *k* times.	1, B, P, A, O, 2

[a] Parameter n is 1–6 to indicate 6 zones.

If an alias name for the terminal exists, the relay displays the alias name.

MET Zn

Use the **MET Z*n*** command to view the current magnitude, angle, and polarity of each terminal in a particular protection zone (*n* = 1–6), the bus-zones in Protection Zone *n*, and the voltage in primary values.

Table 9.8 MET Zn Command

Command	Description	Access Level
MET Z*n*	Display primary metering data.	1, B, P, A, O, 2
MET Z*n k*	Display primary metering data successively for *k* times.	1, B, P, A, O, 2

If an alias name for the terminal exists, the relay displays the alias name.

SET

Table 9.9 lists the options specifically available in the SEL-487B.

Table 9.9 SET Command Overview

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 D	Set the serial port DNP3 remapping settings, beginning at the first setting in this class.	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
SET L *n*[a]	Set the Protection SELOGIC relay settings for Group *n*.	P, 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 Z	Set the active group zone configuration settings, beginning at the first setting.	P, 2
SET Z *n*[a]	Set the configuration setting for Group *n*, beginning at the first setting.	P, 2

[a] Parameter n = 1–6, representing Group 1–Group 6.
[b] Parameter m = 1–10, representing Block 1–Block 10.
[c] Parameter p = 1–3, F, or 5, corresponding to Port 1–Port 3, Port F, or Port 5.

SHOW

Table 9.10 lists the class and instance options available in the SEL-487B.

Table 9.10 SHO Command Overview

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 Group n settings, beginning at the first setting in Group *n*.	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 D	Show the serial DNP3 remapping settings.	1, B, 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
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 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 Z	Show the zone configuration settings for the active group.	1, B, P, A, O, 2
SHO Z *n*[a]	Show the zone configuration settings for Group *n*.	1, B, P, A, O, 2

[a] Parameter n = 1–6, representing Group 1–Group 6.
[b] Parameter m = 1–10, representing Block 1–Block 10.
[c] Parameter p = 1–3, F, and 5 which corresponds to Port 1–Port 3, Port F, and Port 5.

ZONE

The **ZONE** command causes the relay to display the active protection zones and the terminal and bus-zone names in each active protection zone, where active means a zone with at least one terminal in the zone.

Use the **ZON** command to display the terminal and bus-names associated with all active zones.

Table 9.11 ZON Command

Command	Description	Access Level
ZON	Display the terminal and bus-zone names associated with all active zones.	1, B, P, A, O, 2

ZON T

Use the **ZON T** command to display the terminal names in each active zone, selected for tripping by differential and breaker failure protection.

Table 9.12 ZON T Command

Command	Description	Access Level
ZON T	Display the terminals programmed for tripping in all zones.	1, B, P, A, O, 2

When two zones combine, the combined zone includes the terminals from both merged zones. Not all terminals in the combined zone may be required to trip for a differential element operation. **ZON T** provides a list of all terminals assigned to trip in all the zones at the station, and **ZON T *k*** provides a list of the terminals to trip in a specific zone.

ZON k

Use the **ZON *k*** (k = 1–6) command to display the terminals in Zone k, if Zone k is active.

Table 9.13 ZON k Command

Command	Description	Access Level
ZON *k*[a]	Display the terminals in Zone *k*.	1, B, P, A, O, 2

[a] Parameter k is 1–6.

SECTION 10

Communications Interfaces

Section 15: Communications Interfaces through *Section 18: Synchrophasors in the SEL-400 Series Relays Instruction Manual* describe the various communications interfaces and protocols used in SEL-400 series relays. This section describes aspects of the communications protocols that are unique to the SEL-487B. The following topics are discussed:

- *Communications Database on page 10.1*
- *DNP3 Communication on page 10.6*
- *IEC 61850 Communication on page 10.13*

Communications Database

The SEL-487B maintains a database to describe itself to external devices via the SEL 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 14: ASCII Command Reference in the SEL-400 Series Relays Instruction Manual* for more information on the **MAP** and **VIEW** commands.

Table 10.1 SEL-487B 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
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
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-487B 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-487B 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	FREQ	float	System frequency (Hertz)
1006	VDC	float	Battery voltage (Volts)
1008, 100A	I01	float[2]	I01 current magnitude (amperes primary) and phase (degrees)
100C, 100E	I02	float[2]	I02 current magnitude (amperes primary) and phase (degrees)
1010, 1012	I03	float[2]	I03 current magnitude (amperes primary) and phase (degrees)
1014, 1016	I04	float[2]	I04 current magnitude (amperes primary) and phase (degrees)
1018. 101A	I05	float[2]	I05 current magnitude (amperes primary) and phase (degrees)
101C, 101E	I06	float[2]	I06 current magnitude (amperes primary) and phase (degrees)
1020, 1022	I07	float[2]	I07 current magnitude (amperes primary) and phase (degrees)
1024, 1026	I08	float[2]	I08 current magnitude (amperes primary) and phase (degrees)
1028, 102A	I09	float[2]	I09 current magnitude (amperes primary) and phase (degrees)
102C, 102E	I10	float[2]	I10 current magnitude (amperes primary) and phase (degrees)
1030, 1032	I11	float[2]	I11 current magnitude (amperes primary) and phase (degrees)

Table 10.3 SEL-487B Database Structure—METER Region (Sheet 2 of 3)

Address (Hex)	Name	Type	Description
1034, 1036	I12	float[2]	I12 current magnitude (amperes primary) and phase (degrees)
1038, 103A	I13	float[2]	I13 current magnitude (amperes primary) and phase (degrees)
103C, 103E	I14	float[2]	I14 current magnitude (amperes primary) and phase (degrees)
1040, 1042	I15	float[2]	I15 current magnitude (amperes primary) and phase (degrees)
1044, 1046	I16	float[2]	I16 current magnitude (amperes primary) and phase (degrees)
1048, 104A	I17	float[2]	I17 current magnitude (amperes primary) and phase (degrees)
104C, 104E	I18	float[2]	I18 current magnitude (amperes primary) and phase (degrees)
1050, 1052	I19	float[2]	I19 current magnitude (amperes primary) and phase (degrees)
1054, 1056	I20	float[2]	I20 current magnitude (amperes primary) and phase (degrees)
1058, 105A	I21	float[2]	I21 current magnitude (amperes primary) and phase (degrees)
105C	RSRVD1	float[6]	Reserved for 3 future currents; always report as 0
1068, 106A	V01	float[2]	V01 voltage magnitude (Volts primary) and phase (degrees)
106C, 106E	V02	float[2]	V02 voltage magnitude (Volts primary) and phase (degrees)
1070, 1072	V03	float[2]	V03 voltage magnitude (Volts primary) and phase (degrees)
1074	RSRVD2	float[6]	Reserved for 3 future voltages; always report as 0
1080	IOP1	float	Zone 1 Operating Current (per unit)
1082	IOP2	float	Zone 2 Operating Current (per unit)
1084	IOP3	float	Zone 3 Operating Current (per unit)
1086	IOP4	float	Zone 4 Operating Current (per unit)
1088	IOP5	float	Zone 5 Operating Current (per unit)
108A	IOP6	float	Zone 6 Operating Current (per unit)
108C	IRT1	float	Zone 1 Restraint Current (per unit)
108E	IRT2	float	Zone 2 Restraint Current (per unit)
1090	IRT3	float	Zone 3 Restraint Current (per unit)
1092	IRT4	float	Zone 4 Restraint Current (per unit)
1094	IRT5	float	Zone 5 Restraint Current (per unit)
1096	IRT6	float	Zone 6 Restraint Current (per unit)
1098	IOPCZ1	float	Check Zone 1 Operating Current (per unit)
109A	IRTCZ1	float	Check Zone 1 Restraint Current (per unit)
109C	IOPCZ2	float	Check Zone 2 Operating Current (per unit)
109E	IRTCZ2	float	Check Zone 2 Restraint Current (per unit)

Table 10.3 SEL-487B Database Structure—METER Region (Sheet 3 of 3)

Address (Hex)	Name	Type	Description
10A0	IOPCZ3	float	Check Zone 3 Operating Current (per unit)
10A2	IRTCZ3	float	Check Zone 3 Restraint Current (per unit)

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 10.4* for the map. See *Section 11: Relay Word Bits* for detailed information on the Relay Word bits.

Table 10.4 SEL-487B 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[~499]	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 10.5* for the map.

Table 10.5 SEL-487B Database Structure—HISTORY Region

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)
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	TARGETS	char[1000]	System targets from event (100 characters per event)

The STATUS region contains complete relay status information. This region is updated every 5 seconds. See *Table 10.6* for the map.

Table 10.6 SEL-487B 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 10.7* for the map.

Table 10.7 SEL-487B 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]
FREQ         1004h              float
VDC          1006h              float
IO1          1008h              float[2]
IO2          100ch              float[2]
IO3          1010h              float[2]
IO4          1014h              float[2]
IO5          1018h              float[2]
IO6          101ch              float[2]
IO7          1020h              float[2]
IO8          1024h              float[2]
IO9          1028h              float[2]
I10          102ch              float[2]
I11          1030h              float[2]
I12          1034h              float[2]
I13          1038h              float[2]
I14          103ch              float[2]
I15          1040h              float[2]
I16          1044h              float[2]
I17          1048h              float[2]
I18          104ch              float[2]
I19          1050h              float[2]
I20          1054h              float[2]
I21          1058h              float[2]
RSRVD1       105ch              float[6]
VO1          1068h              float[2]
VO2          106ch              float[2]
VO3          1070h              float[2]
RSRVD2       1074h              float[6]
IOP1         1080h              float
IOP2         1082h              float
IOP3         1084h              float
IOP4         1086h              float
IOP5         1088h              float
IOP6         108ah              float
IRT1         108ch              float
IRT2         108eh              float
IRT3         1090h              float
IRT4         1092h              float
IRT5         1094h              float
IRT6         1096h              float
IOPCZ1       1098h              float
IRTCZ1       109ah              float
IOPCZ2       109ch              float
IRTCZ2       109eh              float
IOPCZ3       10a0h              float
IRTCZ3       10a2h              float
```

Figure 10.1 MAP 1:METER Command Example

DNP3 Communication

DNP3 operation is described in *Section 16: DNP3 Communication* in the *SEL-400 Series Relay Instruction Manual*. This subsection describes aspects of DNP3 communications that are unique to the SEL-487B.

Reference Data Map

Table 10.8 shows the SEL-487B DNP3 reference data map. The reference data map contains all of the data available to the DNP3 protocol. You can use the default map or the custom DNP3 mapping functions of the SEL-487B to include only the points required by your application.

The entire Relay Word (*Table 11.1*) 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.

The SEL-487B 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 10.8 SEL-487B DNP3 Reference Data Map (Sheet 1 of 3)

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	Relay Word	Relay Word bit label. See *Section 11: Relay Word Bits*.
Binary Outputs		
10, 12	RB01–RB96	Remote bits RB01–RB96
10, 12	RB01:RB02 RB03:RB04 RB05:RB06 • • • RB93:RB94 RB95:RB96	Remote bit pairs RB01–RB96
10, 12	OC*n*	Pulse Open Circuit Breaker *n* command, where *n* = 1–21
10, 12	OC*n*:NOOP	Open/Close pair for Circuit Breaker *n*, where *n* = 1–21 (the close portion has no action)
10, 12	RST_BAT	Reset battery monitor data
10, 12	RSTTRGT	Reset front-panel targets
10, 12	RSTDNPE	Reset (clear) DNP3 Event Summary AIs
10, 12	NXTEVE	Load next fault event into DNP3 Event Summary AIs
Binary Counters		
20, 22	ACTGRP	Active settings group
20, 22	ACN01CV–ACN32CV	Automation SELOGIC counter value 1–32
20, 22	PCN01CV–PCN32CV	Protection SELOGIC counter value 1–32
Analog Inputs		
30, 32	I*nn*FM[a]	1-cycle average phase current (magnitude), where *nn* = 01–21
30, 32	I*nn*FA[a]	1-cycle average phase current (angle), where *nn* = 01–21
30, 32	V*mm*FM[b]	1-cycle average phase voltage (magnitude), where *mm* = 01–03
30, 32	V*mm*FA[b]	1-cycle average phase voltage (angle), where *mm* = 01–03

Table 10.8 SEL-487B DNP3 Reference Data Map (Sheet 2 of 3)

Object	Label	Description
30, 32	DC1[c]	Station battery 1 dc voltage
30, 32	IOP*k*F[d]	Zone *k* one-cycle average operating current (*k* = 1–6)
30, 32	IRT*k*F[d]	Zone *k* one-cycle average restraint current (*k* = 1–6)
30, 32	IOPCZ*p*F[d]	Check Zone *p* one-cycle average operating current (*p* = 1–3)
30, 32	IRTCZ*p*F[d]	Check Zone *p* one-cycle average restraint current (*p* = 1–3)
30, 32	PMV001–PMV064[c]	Protection SELOGIC math variables
30, 32	AMV001–AMV256[c]	Automation SELOGIC math variables
30, 32	PNC01CV–PNC32CV[c]	Protection SELOGIC counter current value
30, 32	TODMS[c]	UTC time of day in milliseconds (0–86400000)
30, 32	ANC01CV–ANC32CV[c]	Automation SELOGIC counter current value
30, 32	ACTGRP[c]	Active group setting
30, 32	THR[c]	UTC time, hour (0–23)
30, 32	TMIN[c]	UTC time, minute (0–59)
30, 32	TSEC[c]	UTC time, seconds (0–59)
30, 32	TMSEC[c]	UTC time, milliseconds (0–999)
30, 32	DDOM[c]	UTC date, day of the month (1–31)
30, 32	DMON[c]	UTC date, month (1–12)
30, 32	DYEAR[c]	UTC date, year (2000–2200)
30, 32	TLODMS[c]	Local time of day in milliseconds (0–86400000)
30, 32	TLHR[c]	Local time, hour (0–23)
30, 32	TLMIN[c]	Local time, minute (0–59)
30, 32	TLSEC[c]	Local time, seconds (0–59)
30, 32	TLMSEC[c]	Local time, milliseconds (0–999)
30, 32	DLDOM[c]	Local date, day of the month (1–31)
30, 32	DLDOY[c]	Local date, day of the year (1–366)
30, 32	DLMON[c]	Local date, month (1–12)
30, 32	DLYEAR[c]	Local date, year (2000–2200)
30, 32	RA001–RA256[c]	Remote analogs from Ethernet card
30, 32	RAO01–RAO64[c]	Remote analog output
30, 32	RLYTEMP[c]	Relay internal temperature (deg. C)
30, 32	MAXGRP[c]	Maximum number of protection groups
30, 32	I850MOD[c]	IEC 61850 Mode/Behavior status
Event Summary Analog Inputs		
30, 32[e]	FTYPE[c, e]	Fault type
30, 32[e]	FTAR1[c, e]	Fault targets (upper byte is 1st target row, lower byte is 2nd target row)
30, 32[e]	FTAR2[c, e]	Fault targets (upper byte is 3rd target row, lower byte is 0)
30, 32[e]	FGRP[c, e]	Fault settings group
30, 32[e]	FTIMEUH, FTIMEUM, FTIMEUL[c, e]	Fault time (UTC) in DNP3 format—high, middle, and low 16 bits
30, 32[e]	FTIMEH, FTIMEM, FTIMEL[c, e]	Fault time (local) in DNP3 format—high, middle, and low 16 bits
30, 32[e]	FUNR[c, e]	Number of unread fault summaries

Table 10.8 SEL-487B DNP3 Reference Data Map (Sheet 3 of 3)

Object	Label	Description
Analog Outputs		
40, 41	ACTGRP	Active settings group
40, 41	RA001–RA256	Remote Analogs

[a] Default current scaling DECPLA on magnitudes and scale factor of 100 on angles. Dead band ANADBA on magnitudes and ANADBM on angles.
[b] Default voltage scaling DECPLV on magnitudes and scale factor of 100 on angles. Dead band ANADBV on magnitudes and ANADBM on angles.
[c] Default scale factor of 1 and dead band ANADBM.
[d] Default miscellaneous scaling DECPLM and dead band ANADBM.
[e] Event data shall be generated for all Event Summary Analog Inputs if any of them change beyond their dead band after scaling.

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 10.9*. 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.

Table 10.9 SEL-487B Object 12 Control Operations

Label	Close/Any	Trip/Any	NUL/Latch On	NUL/Latch Off	NUL/Pulse On	NUL/Pulse Off
RB01–RB96	Pulse on Remote Bit RB01–RB96	Pulse on Remote Bit RB01–RB96	Set Remote Bit RB01–RB96	Clear Remote Bit RB01–RB96	Pulse on Remote Bit RB01–RB96	Clear Remote Bit RB01–RB96
RB*xx*: RB*yy*	Pulse on RB*yy* RB01–RB96	Pulse on RB*xx* RB01–RB96	Pulse RB*yy*	Pulse RB*xx*	Pulse RB*yy*	Pulse RB*xx*
OC*x*	Open Circuit Breaker *x* (Pulse on OC*x*) *x* = 01–21	Open Circuit Breaker *x* (Pulse on OC*x*) *x* = 01–21	Set OC*x* *x* = 01–21	Clear OC*x* *x* = 01–21	Open Circuit Breaker *x* (Pulse on OC*x*) *x* = 01–21	Clear OC*x* *x* = 01–21
OC*x*: NOOP	No action	Open Circuit Breaker *x* (Pulse on OCx) *x* = 1–21	No action	Pulse On OC*x*	No action	Pulse OC*x*
RST_BAT	Reset battery monitoring	Reset breaker monitoring	Reset battery monitoring	No action	Reset battery monitoring	No action
RSTTRGT	Reset front-panel targets	Reset front-panel targets	Reset front-panel targets	No action	Reset front-panel targets	No action
RSTDNPE	Reset DNP3 event summary	Reset DNP3 event summary	Reset DNP3 event summary	No action	Reset DNP3 event summary	No action
NXTEVE	Load oldest unread relay event summary (FIFO)	Load oldest unread relay event summary (FIFO)	Load oldest unread relay event summary (FIFO)	Load newest relay event (LIFO)	Load oldest unread relay event summary (FIFO)	Load newest event summary (LIFO)

Relay Fault Summary Data

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 DNP. 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 (see *Table 10.8*) will be generated if any of them change beyond their dead-band 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 10.10* for the components of the FTYPE analog input point. The bit asserted in the upper byte indicates the event cause (Trigger, Trip, ER element, etc.). The lower byte of FTYPE is always 0. If no bits are asserted in the upper byte, there is no valid fault summary loaded.

Table 10.10 Object 30, 32, FTYPE Upper Byte-Event Cause

Bit Position								Value	Event Cause
7	6	5	4	3	2	1	0		
								0	No fault summary loaded
							X	1	Trigger command
					X			4	Trip element
				X				8	Event report element
			X					16	Breaker failure trip
		X						32	Differential trip

Default Data Map

Table 10.11 shows the SEL-487B default DNP3 data map. The default data map is an automatically generated subset of the reference map. All data maps are initialized to the default values. If the default maps are not appropriate, you can also 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 required for your application.

Table 10.11 SEL-487B DNP3 Default Data Map (Sheet 1 of 4)

Object	Index	Label	Description
Binary Inputs			
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	SALARM	Software alarm
01, 02	6	HALARM	Hardware alarm
01, 02	7	BADPASS	Invalid password attempt alarm
01, 02	8	UNRDEV	Unread fault summary available
01, 02	9	OPH01	Terminal 1 open-phase detector
01, 02	10	OPH02	Terminal 2 open-phase detector
01, 02	11	OPH03	Terminal 3 open-phase detector
01, 02	12	OPH04	Terminal 4 open-phase detector
01, 02	13	OPH05	Terminal 5 open-phase detector
01, 02	14	OPH06	Terminal 6 open-phase detector
01, 02	15	52A01	Circuit Breaker 1 open status
01, 02	16	52AL01	Circuit Breaker 1 alarm
01, 02	17	52A02	Circuit Breaker 2 open status
01, 02	18	52AL02	Circuit Breaker 2 alarm
01, 02	19	52A03	Circuit Breaker 3 open status

Table 10.11 SEL-487B DNP3 Default Data Map (Sheet 2 of 4)

Object	Index	Label	Description
01, 02	20	52AL03	Circuit Breaker 3 alarm
01, 02	21	52A04	Circuit Breaker 4 open status
01, 02	22	52AL04	Circuit Breaker 4 alarm
01, 02	23	89A01	Disconnect 1 closed status
01, 02	24	89AL01	Disconnect 1 alarm
01, 02	25	89A02	Disconnect 2 closed status
01, 02	26	89AL02	Disconnect 2 alarm
01, 02	27	89A03	Disconnect 3 closed status
01, 02	28	89AL03	Disconnect 3 alarm
01, 02	29	89A04	Disconnect 4 closed status
01, 02	30	89AL04	Disconnect 4 alarm
01, 02	31	89A05	Disconnect 5 closed status
01, 02	32	89AL05	Disconnect 5 alarm
01, 02	33	89A06	Disconnect 6 closed status
01, 02	34	89AL06	Disconnect 6 alarm
01, 02	35	89A07	Disconnect 7 closed status
01, 02	36	89AL07	Disconnect 7 alarm
01, 02	37	89A08	Disconnect 8 closed status
01, 02	38	89AL08	Disconnect 8 alarm
01, 02	39	TLED_1	Target LED 1 on relay front panel
01, 02	40	TLED_2	Target LED 2 on relay front panel
01, 02	41	TLED_3	Target LED 3 on relay front panel
01, 02	42	TLED_4	Target LED 4 on relay front panel
01, 02	43	TLED_5	Target LED 5 on relay front panel
01, 02	44	TLED_6	Target LED 6 on relay front panel
01, 02	45	TLED_7	Target LED 7 on relay front panel
01, 02	46	TLED_8	Target LED 8 on relay front panel
01, 02	47	TLED_9	Target LED 9 on relay front panel
01, 02	48	TLED_10	Target LED 10 on relay front panel
01, 02	49	TLED_11	Target LED 11 on relay front panel
01, 02	50	TLED_12	Target LED 12 on relay front panel
01, 02	51	TLED_13	Target LED 13 on relay front panel
01, 02	52	TLED_14	Target LED 14 on relay front panel
01, 02	53	TLED_15	Target LED 15 on relay front panel
01, 02	54	TLED_16	Target LED 16 on relay front panel
01, 02	55	IN101	Main Board Input 1
01, 02	56	IN102	Main Board Input 2
01, 02	57	IN103	Main Board Input 3
01, 02	58	IN104	Main Board Input 4
01, 02	59	IN105	Main Board Input 5
01, 02	60	IN106	Main Board Input 6

Table 10.11 SEL-487B DNP3 Default Data Map (Sheet 3 of 4)

Object	Index	Label	Description
01, 02	61	IN107	Main Board Input 7
01, 02	62	PSV01	Protection SELOGIC Variable 1
01, 02	63	PSV02	Protection SELOGIC Variable 2
01, 02	64	PSV03	Protection SELOGIC Variable 3
01, 02	65	PSV04	Protection SELOGIC Variable 4
01, 02	66	PSV05	Protection SELOGIC Variable 5
01, 02	67	PSV06	Protection SELOGIC Variable 6
01, 02	68	PSV07	Protection SELOGIC Variable 7
01, 02	69	PSV08	Protection SELOGIC Variable 8
01, 02	70	ASV001	Automation SELOGIC Variable 1
01, 02	71	ASV002	Automation SELOGIC Variable 2
01, 02	72	ASV003	Automation SELOGIC Variable 3
01, 02	73	ASV004	Automation SELOGIC Variable 4
01, 02	74	ASV005	Automation SELOGIC Variable 5
01, 02	75	ASV006	Automation SELOGIC Variable 6
01, 02	76	ASV007	Automation SELOGIC Variable 7
01, 02	77	ASV008	Automation SELOGIC Variable 8
01, 02	78	OUT101	Main Board Output 1
01, 02	79	OUT102	Main Board Output 2
01, 02	80	OUT103	Main Board Output 3
01, 02	81	OUT104	Main Board Output 4
01, 02	82	OUT105	Main Board Output 5
01, 02	83	OUT106	Main Board Output 6
01, 02	84	OUT107	Main Board Output 7
Binary Outputs			
10, 12	0–31	RB01–RB32	Remote bits RB01–RB32
10, 12	32	OC01	Pulse Open Circuit Breaker 1 command
10, 12	33	OC02	Pulse Open Circuit Breaker 2 command
10, 12	34	OC03	Pulse Open Circuit Breaker 3 command
10, 12	35	OC04	Pulse Open Circuit Breaker 4 command
10, 12	36	RST_BAT	Reset battery monitor data
10, 12	37	RSTTRGT	Reset front-panel targets
10, 12	38	RSTDNPE	Reset (clear) DNP3 Event Summary AIs
Binary Counters			
20, 22	0	ACTGRP	Active settings group
Analog Inputs			
30, 32	0	I01FM	1-cycle average Terminal 1 current (magnitude)
30, 32	1	I01FA	1-cycle average Terminal 1 current (angle)
30, 32	2	I02FM	1-cycle average Terminal 2 current (magnitude)
30, 32	3	I02FA	1-cycle average Terminal 2 current (angle)
30, 32	4	I03FM	1-cycle average Terminal 3 current (magnitude)

Table 10.11 SEL-487B DNP3 Default Data Map (Sheet 4 of 4)

Object	Index	Label	Description
30, 32	5	I03FA	1-cycle average Terminal 3 current (angle)
30, 32	6	I04FM	1-cycle average Terminal 4 current (magnitude)
30, 32	7	I04FA	1-cycle average Terminal 4 current (angle)
30, 32	8	I05FM	1-cycle average Terminal 5 current (magnitude)
30, 32	9	I05FA	1-cycle average Terminal 5 current (angle)
30, 32	10	I06FM	1-cycle average Terminal 6 current (magnitude)
30, 32	11	I06FA	1-cycle average Terminal 6 current (angle)
30, 32	12	V01FM	1-cycle average Terminal 1 voltage (magnitude)
30, 32	13	V01FA	1-cycle average Terminal 1 voltage (angle)
30, 32	14	V02FM	1-cycle average Terminal 2 voltage (magnitude)
30, 32	15	V02FA	1-cycle average Terminal 2 voltage (angle)
30, 32	16	V03FM	1-cycle average Terminal 3 voltage (magnitude)
30, 32	17	V03FA	1-cycle average Terminal 3 voltage (angle)
30, 32	18	FTYPE	Fault type
30, 32	19	FTAR1	Fault targets (Upper byte is 1st target row, lower byte is 2nd target row)
30, 32	20	FTAR2	Fault targets (Upper byte is 3rd target row, lower byte is 0)
30, 32	21	FGRP	Fault settings group
30, 32	22	FTIMEUH	Fault time (UTC) in DNP3 format (high 16 bits)
30, 32	23	FTIMEUM	Fault time (UTC) in DNP3 format (middle 16 bits)
30, 32	24	FTIMEUL	Fault time (UTC) in DNP3 format (low 16 bits)
30, 32	25	FUNR	Number of unread fault summaries
30, 32	26	RLYTEMP	Internal box temperature in degrees Celsius
Analog Outputs			
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-487B.

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 10.12 and *Table 10.13* show the logical nodes (LNs) supported in the SEL-487B and the Relay Word bits or Measured Values mapped to those LNs. Additionally, the relay supports the CFG Logical Device logical nodes as described in *Section 17: IEC 61850 Communication in the SEL-400 Series Relays Instruction Manual*.

Table 10.12 shows the LNs associated with protection elements, defined as Logical Device PRO.

Table 10.12 Logical Device: PRO (Protection) (Sheet 1 of 11)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = CO			
BKR01CSWI1	Pos.Oper.ctlVal	OC01:NOOP[a]	Circuit Breaker 1 open command
BKR02CSWI1	Pos.Oper.ctlVal	OC02:NOOP[a]	Circuit Breaker 2 open command
BKR03CSWI1	Pos.Oper.ctlVal	OC03:NOOP[a]	Circuit Breaker 3 open command
BKR04CSWI1	Pos.Oper.ctlVal	OC04:NOOP[a]	Circuit Breaker 4 open command
BKR05CSWI1	Pos.Oper.ctlVal	OC05:NOOP[a]	Circuit Breaker 5 open command
BKR06CSWI1	Pos.Oper.ctlVal	OC06:NOOP[a]	Circuit Breaker 6 open command
BKR07CSWI1	Pos.Oper.ctlVal	OC07:NOOP[a]	Circuit Breaker 7 open command
BKR08CSWI1	Pos.Oper.ctlVal	OC08:NOOP[a]	Circuit Breaker 8 open command
BKR09CSWI1	Pos.Oper.ctlVal	OC09:NOOP[a]	Circuit Breaker 9 open command
BKR10CSWI1	Pos.Oper.ctlVal	OC10:NOOP[a]	Circuit Breaker 10 open command
BKR11CSWI1	Pos.Oper.ctlVal	OC11:NOOP[a]	Circuit Breaker 11 open command
BKR12CSWI1	Pos.Oper.ctlVal	OC12:NOOP[a]	Circuit Breaker 12 open command
BKR13CSWI1	Pos.Oper.ctlVal	OC13:NOOP[a]	Circuit Breaker 13 open command
BKR14CSWI1	Pos.Oper.ctlVal	OC14:NOOP[a]	Circuit Breaker 14 open command
BKR15CSWI1	Pos.Oper.ctlVal	OC15:NOOP[a]	Circuit Breaker 15 open command
BKR16CSWI1	Pos.Oper.ctlVal	OC16:NOOP[a]	Circuit Breaker 16 open command
BKR17CSWI1	Pos.Oper.ctlVal	OC17:NOOP[a]	Circuit Breaker 17 open command
BKR18CSWI1	Pos.Oper.ctlVal	OC18:NOOP[a]	Circuit Breaker 18 open command
BKR19CSWI1	Pos.Oper.ctlVal	OC19:NOOP[a]	Circuit Breaker 19 open command
BKR20CSWI1	Pos.Oper.ctlVal	OC20:NOOP[a]	Circuit Breaker 20 open command
BKR21CSWI1	Pos.Oper.ctlVal	OC21:NOOP[a]	Circuit Breaker 21 open command
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[b]	IEC 61850 mode/behavior status
BFR01RBRF1	Str.general	BFI01	Circuit Breaker 1 breaker failure initiate SELOGIC control equation
BFR01RBRF1	OpEx.general	FBF01	Circuit Breaker 1 failure
BFR01RBRF1	OpIn.general	RT01	Circuit Breaker 1 retrip
BFR02RBRF1	Str.general	BFI02	Circuit Breaker 2 breaker failure initiate SELOGIC control equation
BFR02RBRF1	OpEx.general	FBF02	Circuit Breaker 2 failure
BFR02RBRF1	OpIn.general	RT02	Circuit Breaker 2 retrip
BFR03RBRF1	Str.general	BFI03	Circuit Breaker 3 breaker failure initiate SELOGIC control equation
BFR03RBRF1	OpEx.general	FBF03	Circuit Breaker 3 failure
BFR03RBRF1	OpIn.general	RT03	Circuit Breaker 3 retrip
BFR04RBRF1	Str.general	BFI04	Circuit Breaker 4 breaker failure initiate SELOGIC control equation
BFR04RBRF1	OpEx.general	FBF04	Circuit Breaker 4 failure
BFR04RBRF1	OpIn.general	RT04	Circuit Breaker 4 retrip
BFR05RBRF1	Str.general	BFI05	Circuit Breaker 5 breaker failure initiate SELOGIC control equation

Table 10.12 Logical Device: PRO (Protection) (Sheet 2 of 11)

Logical Node	Attribute	Data Source	Comment
BFR05RBRF1	OpEx.general	FBF05	Circuit Breaker 5 failure
BFR05RBRF1	OpIn.general	RT05	Circuit Breaker 5 retrip
BFR06RBRF1	Str.general	BFI06	Circuit Breaker 6 breaker failure initiate SELOGIC control equation
BFR06RBRF1	OpEx.general	FBF06	Circuit Breaker 6 failure
BFR06RBRF1	OpIn.general	RT06	Circuit Breaker 6 retrip
BFR07RBRF1	Str.general	BFI07	Circuit Breaker 7 breaker failure initiate SELOGIC control equation
BFR07RBRF1	OpEx.general	FBF07	Circuit Breaker 7 failure
BFR07RBRF1	OpIn.general	RT07	Circuit Breaker 7 retrip
BFR08RBRF1	Str.general	BFI08	Circuit Breaker 8 breaker failure initiate SELOGIC control equation
BFR08RBRF1	OpEx.general	FBF08	Circuit Breaker 8 failure
BFR08RBRF1	OpIn.general	RT08	Circuit Breaker 8 retrip
BFR09RBRF1	Str.general	BFI09	Circuit Breaker 9 breaker failure initiate SELOGIC control equation
BFR09RBRF1	OpEx.general	FBF09	Circuit Breaker 9 failure
BFR09RBRF1	OpIn.general	RT09	Circuit Breaker 9 retrip
BFR10RBRF1	Str.general	BFI10	Circuit Breaker 10 breaker failure initiate SELOGIC control equation
BFR10RBRF1	OpEx.general	FBF10	Circuit Breaker 10 failure
BFR10RBRF1	OpIn.general	RT10	Circuit Breaker 10 retrip
BFR11RBRF1	Str.general	BFI11	Circuit Breaker 11 breaker failure initiate SELOGIC control equation
BFR11RBRF1	OpEx.general	FBF11	Circuit Breaker 11 failure
BFR11RBRF1	OpIn.general	RT11	Circuit Breaker 11 retrip
BFR12RBRF1	Str.general	BFI12	Circuit Breaker 12 breaker failure initiate SELOGIC control equation
BFR12RBRF1	OpEx.general	FBF12	Circuit Breaker 12 failure
BFR12RBRF1	OpIn.general	RT12	Circuit Breaker 12 retrip
BFR13RBRF1	Str.general	BFI13	Circuit Breaker 13 breaker failure initiate SELOGIC control equation
BFR13RBRF1	OpEx.general	FBF13	Circuit Breaker 13 failure
BFR13RBRF1	OpIn.general	RT13	Circuit Breaker 13 retrip
BFR14RBRF1	Str.general	BFI14	Circuit Breaker 14 breaker failure initiate SELOGIC control equation
BFR14RBRF1	OpEx.general	FBF14	Circuit Breaker 14 failure
BFR14RBRF1	OpIn.general	RT14	Circuit Breaker 14 retrip
BFR15RBRF1	Str.general	BFI15	Circuit Breaker 15 breaker failure initiate SELOGIC control equation
BFR15RBRF1	OpEx.general	FBF15	Circuit Breaker 15 failure
BFR15RBRF1	OpIn.general	RT15	Circuit Breaker 15 retrip
BFR16RBRF1	Str.general	BFI16	Circuit Breaker 16 breaker failure initiate SELOGIC control equation
BFR16RBRF1	OpEx.general	FBF16	Circuit Breaker 16 failure
BFR16RBRF1	OpIn.general	RT16	Circuit Breaker 16 retrip
BFR17RBRF1	Str.general	BFI17	Circuit Breaker 17 breaker failure initiate SELOGIC control equation
BFR17RBRF1	OpEx.general	FBF17	Circuit Breaker 17 failure
BFR17RBRF1	OpIn.general	RT17	Circuit Breaker 17 retrip
BFR18RBRF1	Str.general	BFI18	Circuit Breaker 18 breaker failure initiate SELOGIC control equation
BFR18RBRF1	OpEx.general	FBF18	Circuit Breaker 18 failure
BFR18RBRF1	OpIn.general	RT18	Circuit Breaker 18 retrip

Table 10.12 Logical Device: PRO (Protection) (Sheet 3 of 11)

Logical Node	Attribute	Data Source	Comment
BFR19RBRF1	Str.general	BFI19	Circuit Breaker 19 breaker failure initiate SELOGIC control equation
BFR19RBRF1	OpEx.general	FBF19	Circuit Breaker 19 failure
BFR19RBRF1	OpIn.general	RT19	Circuit Breaker 19 retrip
BFR20RBRF1	Str.general	BFI20	Circuit Breaker 20 breaker failure initiate SELOGIC control equation
BFR20RBRF1	OpEx.general	FBF20	Circuit Breaker 20 failure
BFR20RBRF1	OpIn.general	RT20	Circuit Breaker 20 retrip
BFR21RBRF1	Str.general	BFI21	Circuit Breaker 21 breaker failure initiate SELOGIC control equation
BFR21RBRF1	OpEx.general	FBF21	Circuit Breaker 21 failure
BFR21RBRF1	OpIn.general	RT21	Circuit Breaker 21 retrip
BKR01CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
BKR01CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
BKR01CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
BKR01CSWI1	OpOpn.general	OC01	Circuit Breaker 1 open command
BKR01CSWI1	Pos.stVal	52CL01?1:2[c]	Circuit Breaker 1 closed
BKR02CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
BKR02CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
BKR02CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
BKR02CSWI1	OpOpn.general	OC02	Circuit Breaker 2 open command
BKR02CSWI1	Pos.stVal	52CL02?1:2[c]	Circuit Breaker 2 closed
BKR03CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
BKR03CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
BKR03CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
BKR03CSWI1	OpOpn.general	OC03	Circuit Breaker 3 open command
BKR03CSWI1	Pos.stVal	52CL03?1:2[c]	Circuit Breaker 3 closed
BKR04CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
BKR04CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
BKR04CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
BKR04CSWI1	OpOpn.general	OC04	Circuit Breaker 4 open command
BKR04CSWI1	Pos.stVal	52CL04?1:2[c]	Circuit Breaker 4 closed
BKR05CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
BKR05CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
BKR05CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
BKR05CSWI1	OpOpn.general	OC05	Circuit Breaker 5 open command
BKR05CSWI1	Pos.stVal	52CL05?1:2[c]	Circuit Breaker 5 closed
BKR06CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
BKR06CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
BKR06CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
BKR06CSWI1	OpOpn.general	OC06	Circuit Breaker 6 open command
BKR06CSWI1	Pos.stVal	52CL06?1:2[c]	Circuit Breaker 6 closed
BKR07CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
BKR07CSWI1	Loc.stVal	LOC	Control authority at local (bay) level

Table 10.12 Logical Device: PRO (Protection) (Sheet 4 of 11)

Logical Node	Attribute	Data Source	Comment
BKR07CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
BKR07CSWI1	OpOpn.general	OC07	Circuit Breaker 7 open command
BKR07CSWI1	Pos.stVal	52CL07?1:2[c]	Circuit Breaker 7 closed
BKR08CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
BKR08CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
BKR08CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
BKR08CSWI1	OpOpn.general	OC08	Circuit Breaker 8 open command
BKR08CSWI1	Pos.stVal	52CL08?1:2[c]	Circuit Breaker 8 closed
BKR09CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
BKR09CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
BKR09CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
BKR09CSWI1	OpOpn.general	OC09	Circuit Breaker 9 open command
BKR09CSWI1	Pos.stVal	52CL09?1:2[c]	Circuit Breaker 9 closed
BKR10CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
BKR10CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
BKR10CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
BKR10CSWI1	OpOpn.general	OC10	Circuit Breaker 10 open command
BKR10CSWI1	Pos.stVal	52CL10?1:2[c]	Circuit Breaker 10 closed
BKR11CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
BKR11CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
BKR11CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
BKR11CSWI1	OpOpn.general	OC11	Circuit Breaker 11 open command
BKR11CSWI1	Pos.stVal	52CL11?1:2[c]	Circuit Breaker 11 closed
BKR12CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
BKR12CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
BKR12CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
BKR12CSWI1	OpOpn.general	OC12	Circuit Breaker 12 open command
BKR12CSWI1	Pos.stVal	52CL12?1:2[c]	Circuit Breaker 12 closed
BKR13CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
BKR13CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
BKR13CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
BKR13CSWI1	OpOpn.general	OC13	Circuit Breaker 13 open command
BKR13CSWI1	Pos.stVal	52CL13?1:2[c]	Circuit Breaker 13 closed
BKR14CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
BKR14CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
BKR14CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
BKR14CSWI1	OpOpn.general	OC14	Circuit Breaker 14 open command
BKR14CSWI1	Pos.stVal	52CL14?1:2[c]	Circuit Breaker 14 closed
BKR15CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
BKR15CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
BKR15CSWI1	LocSta.stVal	LOCSTA	Control authority at station level

Table 10.12 Logical Device: PRO (Protection) (Sheet 5 of 11)

Logical Node	Attribute	Data Source	Comment
BKR15CSWI1	OpOpn.general	OC15	Circuit Breaker 15 open command
BKR15CSWI1	Pos.stVal	52CL15?1:2[c]	Circuit Breaker 15 closed
BKR16CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
BKR16CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
BKR16CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
BKR16CSWI1	OpOpn.general	OC16	Circuit Breaker 16 open command
BKR16CSWI1	Pos.stVal	52CL16?1:2[c]	Circuit Breaker 16 closed
BKR17CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
BKR17CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
BKR17CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
BKR17CSWI1	OpOpn.general	OC17	Circuit Breaker 17 open command
BKR17CSWI1	Pos.stVal	52CL17?1:2[c]	Circuit Breaker 17 closed
BKR18CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
BKR18CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
BKR18CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
BKR18CSWI1	OpOpn.general	OC18	Circuit Breaker 18 open command
BKR18CSWI1	Pos.stVal	52CL18?1:2[c]	Circuit Breaker 18 closed
BKR19CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
BKR19CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
BKR19CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
BKR19CSWI1	OpOpn.general	OC19	Circuit Breaker 19 open command
BKR19CSWI1	Pos.stVal	52CL19?1:2[c]	Circuit Breaker 19 closed
BKR20CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
BKR20CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
BKR20CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
BKR20CSWI1	OpOpn.general	OC20	Circuit Breaker 20 open command
BKR20CSWI1	Pos.stVal	52CL20?1:2[c]	Circuit Breaker 20 closed
BKR21CSWI1	LocKey.stVal	NOOP	Physical key indication for switching LN in local mode
BKR21CSWI1	Loc.stVal	LOC	Control authority at local (bay) level
BKR21CSWI1	LocSta.stVal	LOCSTA	Control authority at station level
BKR21CSWI1	OpOpn.general	OC21	Circuit Breaker 21 open command
BKR21CSWI1	Pos.stVal	52CL21?1:2[c]	Circuit Breaker 21 closed
D87R1PDIF1	Op.general	87R1	Zone 1 restraint differential element picked
D87R1PDIF1	Str.general	P87R1	Zone 1 instantaneous differential element picked
D87R2PDIF1	Op.general	87R2	Zone 2 restraint differential element picked
D87R2PDIF1	Str.general	P87R2	Zone 2 instantaneous differential element picked
D87R3PDIF1	Op.general	87R3	Zone 3 restraint differential element picked
D87R3PDIF1	Str.general	P87R3	Zone 3 instantaneous differential element picked
D87R4PDIF1	Op.general	87R4	Zone 4 restraint differential element picked
D87R4PDIF1	Str.general	P87R4	Zone 4 instantaneous differential element picked
D87R5PDIF1	Op.general	87R5	Zone 5 restraint differential element picked

Table 10.12 Logical Device: PRO (Protection) (Sheet 6 of 11)

Logical Node	Attribute	Data Source	Comment
D87R5PDIF1	Str.general	P87R5	Zone 5 instantaneous differential element picked
D87R6PDIF1	Op.general	87R6	Zone 6 restraint differential element picked
D87R6PDIF1	Str.general	P87R6	Zone 6 instantaneous differential element picked
FLTRRDRE1	FltTyp.stVal	FLTYPE[d]	Affected phases for the latest event
FLTRRDRE1	FltCaus.stVal	FLTCAUS[e]	Event cause for the latest event
FLTRRDRE1	FltNum.stVal	FLRNUM	Event number
FLTRRDRE1	RcdMade.stVal	FLREP	Event report present
PROLPHD1	PhyHealth.stVal	EN?3:1[f]	Relay enabled
T87Z01PTRC1	Tr.general	87Z1	Zone 1 differential element trip
T87Z02PTRC1	Tr.general	87Z2	Zone 2 differential element trip
T87Z03PTRC1	Tr.general	87Z3	Zone 3 differential element trip
T87Z04PTRC1	Tr.general	87Z4	Zone 4 differential element trip
T87Z05PTRC1	Tr.general	87Z5	Zone 5 differential element trip
T87Z06PTRC1	Tr.general	87Z6	Zone 6 differential element trip
TRIP01PTRC1	Tr.general	TRIP01	Terminal 1 trip output
TRIP02PTRC1	Tr.general	TRIP02	Terminal 2 trip output
TRIP03PTRC1	Tr.general	TRIP03	Terminal 3 trip output
TRIP04PTRC1	Tr.general	TRIP04	Terminal 4 trip output
TRIP05PTRC1	Tr.general	TRIP05	Terminal 5 trip output
TRIP06PTRC1	Tr.general	TRIP06	Terminal 6 trip output
TRIP07PTRC1	Tr.general	TRIP07	Terminal 7 trip output
TRIP08PTRC1	Tr.general	TRIP08	Terminal 8 trip output
TRIP09PTRC1	Tr.general	TRIP09	Terminal 9 trip output
TRIP10PTRC1	Tr.general	TRIP10	Terminal 10 trip output
TRIP11PTRC1	Tr.general	TRIP11	Terminal 11 trip output
TRIP12PTRC1	Tr.general	TRIP12	Terminal 12 trip output
TRIP13PTRC1	Tr.general	TRIP13	Terminal 13 trip output
TRIP14PTRC1	Tr.general	TRIP14	Terminal 14 trip output
TRIP15PTRC1	Tr.general	TRIP15	Terminal 15 trip output
TRIP16PTRC1	Tr.general	TRIP16	Terminal 16 trip output
TRIP17PTRC1	Tr.general	TRIP17	Terminal 17 trip output
TRIP18PTRC1	Tr.general	TRIP18	Terminal 18 trip output
TRIP19PTRC1	Tr.general	TRIP19	Terminal 19 trip output
TRIP20PTRC1	Tr.general	TRIP20	Terminal 20 trip output
TRIP21PTRC1	Tr.general	TRIP21	Terminal 21 trip output
X52A01XCBR1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X52A01XCBR1	Loc.stVal	LOC	Control authority at local (bay) level
X52A01XCBR1	Pos.stVal	52CL01?1:2[c]	Circuit Breaker 1 closed
X52A02XCBR1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X52A02XCBR1	Loc.stVal	LOC	Control authority at local (bay) level
X52A02XCBR1	Pos.stVal	52CL02?1:2[c]	Circuit Breaker 2 closed

Table 10.12 Logical Device: PRO (Protection) (Sheet 7 of 11)

Logical Node	Attribute	Data Source	Comment
X52A03XCBR1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X52A03XCBR1	Loc.stVal	LOC	Control authority at local (bay) level
X52A03XCBR1	Pos.stVal	52CL03?1:2[c]	Circuit Breaker 3 closed
X52A04XCBR1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X52A04XCBR1	Loc.stVal	LOC	Control authority at local (bay) level
X52A04XCBR1	Pos.stVal	52CL04?1:2[c]	Circuit Breaker 4 closed
X52A05XCBR1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X52A05XCBR1	Loc.stVal	LOC	Control authority at local (bay) level
X52A05XCBR1	Pos.stVal	52CL05?1:2[c]	Circuit Breaker 5 closed
X52A06XCBR1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X52A06XCBR1	Loc.stVal	LOC	Control authority at local (bay) level
X52A06XCBR1	Pos.stVal	52CL06?1:2[c]	Circuit Breaker 6 closed
X52A07XCBR1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X52A07XCBR1	Loc.stVal	LOC	Control authority at local (bay) level
X52A07XCBR1	Pos.stVal	52CL07?1:2[c]	Circuit Breaker 7 closed
X52A08XCBR1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X52A08XCBR1	Loc.stVal	LOC	Control authority at local (bay) level
X52A08XCBR1	Pos.stVal	52CL08?1:2[c]	Circuit Breaker 8 closed
X52A09XCBR1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X52A09XCBR1	Loc.stVal	LOC	Control authority at local (bay) level
X52A09XCBR1	Pos.stVal	52CL09?1:2[c]	Circuit Breaker 9 closed
X52A10XCBR1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X52A10XCBR1	Loc.stVal	LOC	Control authority at local (bay) level
X52A10XCBR1	Pos.stVal	52CL10?1:2[c]	Circuit Breaker 10 closed
X52A11XCBR1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X52A11XCBR1	Loc.stVal	LOC	Control authority at local (bay) level
X52A11XCBR1	Pos.stVal	52CL11?1:2[c]	Circuit Breaker 11 closed
X52A12XCBR1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X52A12XCBR1	Loc.stVal	LOC	Control authority at local (bay) level
X52A12XCBR1	Pos.stVal	52CL12?1:2[c]	Circuit Breaker 12 closed
X52A13XCBR1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X52A13XCBR1	Loc.stVal	LOC	Control authority at local (bay) level
X52A13XCBR1	Pos.stVal	52CL13?1:2[c]	Circuit Breaker 13 closed
X52A14XCBR1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X52A14XCBR1	Loc.stVal	LOC	Control authority at local (bay) level
X52A14XCBR1	Pos.stVal	52CL14?1:2[c]	Circuit Breaker 14 closed
X52A15XCBR1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X52A15XCBR1	Loc.stVal	LOC	Control authority at local (bay) level
X52A15XCBR1	Pos.stVal	52CL15?1:2[c]	Circuit Breaker 15 closed
X52A16XCBR1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X52A16XCBR1	Loc.stVal	LOC	Control authority at local (bay) level

Table 10.12 Logical Device: PRO (Protection) (Sheet 8 of 11)

Logical Node	Attribute	Data Source	Comment
X52A16XCBR1	Pos.stVal	52CL16?1:2[c]	Circuit Breaker 16 closed
X52AXCBR17	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X52A17XCBR1	Loc.stVal	LOC	Control authority at local (bay) level
X52A17XCBR1	Pos.stVal	52CL17?1:2[c]	Circuit Breaker 17 closed
X52A17XCBR1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X52A18XCBR1	Loc.stVal	LOC	Control authority at local (bay) level
X52A18XCBR1	Pos.stVal	52CL18?1:2[c]	Circuit Breaker 18 closed
X52A18XCBR1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X52A19XCBR1	Loc.stVal	LOC	Control authority at local (bay) level
X52A19XCBR1	Pos.stVal	52CL19?1:2[c]	Circuit Breaker 19 closed
X52A19XCBR1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X52A20XCBR1	Loc.stVal	LOC	Control authority at local (bay) level
X52A20XCBR1	Pos.stVal	52CL20?1:2[c]	Circuit Breaker 20 closed
X52A20XCBR1	LocKey.stVal	NOOP	Physical key indication for switchgear local mode
X52A21XCBR1	Loc.stVal	LOC	Control authority at local (bay) level
X52A21XCBR1	Pos.stVal	52CL21?1:2[c]	Circuit Breaker 21 closed
X89CL01XSWI1	Loc.stVal	LOC	IED local status
X89CL01XSWI1	Pos.stVal	89CL01?1:2[c]	Disconnect 1 closed
X89CL02XSWI1	Loc.stVal	LOC	IED local status
X89CL02XSWI1	Pos.stVal	89CL02?1:2[c]	Disconnect 2 closed
X89CL03XSWI1	Loc.stVal	LOC	IED local status
X89CL03XSWI1	Pos.stVal	89CL03?1:2[c]	Disconnect 3 closed
X89CL04XSWI1	Loc.stVal	LOC	IED local status
X89CL04XSWI1	Pos.stVal	89CL04?1:2[c]	Disconnect 4 closed
X89CL05XSWI1	Loc.stVal	LOC	IED local status
X89CL05XSWI1	Pos.stVal	89CL05?1:2[c]	Disconnect 5 closed
X89CL06XSWI1	Loc.stVal	LOC	IED local status
X89CL06XSWI1	Pos.stVal	89CL06?1:2[c]	Disconnect 6 closed
X89CL07XSWI1	Loc.stVal	LOC	IED local status
X89CL07XSWI1	Pos.stVal	89CL07?1:2[c]	Disconnect 7 closed
X89CL08XSWI1	Loc.stVal	LOC	IED local status
X89CL08XSWI1	Pos.stVal	89CL08?1:2[c]	Disconnect 8 closed
X89CL09XSWI1	Loc.stVal	LOC	IED local status
X89CL09XSWI1	Pos.stVal	89CL09?1:2[c]	Disconnect 9 closed
X89CL10XSWI1	Loc.stVal	LOC	IED local status
X89CL10XSWI1	Pos.stVal	89CL10?1:2[c]	Disconnect 10 closed
X89CL11XSWI1	Loc.stVal	LOC	IED local status
X89CL11XSWI1	Pos.stVal	89CL11?1:2[c]	Disconnect 11 closed
X89CL12XSWI1	Loc.stVal	LOC	IED local status
X89CL12XSWI1	Pos.stVal	89CL12?1:2[c]	Disconnect 12 closed
X89CL13XSWI1	Loc.stVal	LOC	IED local status

Table 10.12 Logical Device: PRO (Protection) (Sheet 9 of 11)

Logical Node	Attribute	Data Source	Comment
X89CL13XSWI1	Pos.stVal	89CL13?1:2[c]	Disconnect 13 closed
X89CL14XSWI1	Loc.stVal	LOC	IED local status
X89CL14XSWI1	Pos.stVal	89CL14?1:2[c]	Disconnect 14 closed
X89CL15XSWI1	Loc.stVal	LOC	IED local status
X89CL15XSWI1	Pos.stVal	89CL15?1:2[c]	Disconnect 15 closed
X89CL16XSWI1	Loc.stVal	LOC	IED local status
X89CL16XSWI1	Pos.stVal	89CL16?1:2[c]	Disconnect 16 closed
X89CL17XSWI1	Loc.stVal	LOC	IED local status
X89CL17XSWI1	Pos.stVal	89CL17?1:2[c]	Disconnect 17 closed
X89CL18XSWI1	Loc.stVal	LOC	IED local status
X89CL18XSWI1	Pos.stVal	89CL18?1:2[c]	Disconnect 18 closed
X89CL19XSWI1	Loc.stVal	LOC	IED local status
X89CL19XSWI1	Pos.stVal	89CL19?1:2[c]	Disconnect 19 closed
X89CL20XSWI1	Loc.stVal	LOC	IED local status
X89CL20XSWI1	Pos.stVal	89CL20?1:2[c]	Disconnect 20 closed
X89CL21XSWI1	Loc.stVal	LOC	IED local status
X89CL21XSWI1	Pos.stVal	89CL21?1:2[c]	Disconnect 21 closed
X89CL22XSWI1	Loc.stVal	LOC	IED local status
X89CL22XSWI1	Pos.stVal	89CL22?1:2[c]	Disconnect 22 closed
X89CL23XSWI1	Loc.stVal	LOC	IED local status
X89CL23XSWI1	Pos.stVal	89CL23?1:2[c]	Disconnect 23 closed
X89CL24XSWI1	Loc.stVal	LOC	IED local status
X89CL24XSWI1	Pos.stVal	89CL24?1:2[c]	Disconnect 24 closed
X89CL25XSWI1	Loc.stVal	LOC	IED local status
X89CL25XSWI1	Pos.stVal	89CL25?1:2[c]	Disconnect 25 closed
X89CL26XSWI1	Loc.stVal	LOC	IED local status
X89CL26XSWI1	Pos.stVal	89CL26?1:2[c]	Disconnect 26 closed
X89CL27XSWI1	Loc.stVal	LOC	IED local status
X89CL27XSWI1	Pos.stVal	89CL27?1:2[c]	Disconnect 27 closed
X89CL28XSWI1	Loc.stVal	LOC	IED local status
X89CL28XSWI1	Pos.stVal	89CL28?1:2[c]	Disconnect 28 closed
X89CL29XSWI1	Loc.stVal	LOC	IED local status
X89CL29XSWI1	Pos.stVal	89CL29?1:2[c]	Disconnect 29 closed
X89CL30XSWI1	Loc.stVal	LOC	IED local status
X89CL30XSWI1	Pos.stVal	89CL30?1:2[c]	Disconnect 30 closed
X89CL31XSWI1	Loc.stVal	LOC	IED local status
X89CL31XSWI1	Pos.stVal	89CL31?1:2[c]	Disconnect 31 closed
X89CL32XSWI1	Loc.stVal	LOC	IED local status
X89CL32XSWI1	Pos.stVal	89CL32?1:2[c]	Disconnect 32 closed
X89CL33XSWI1	Loc.stVal	LOC	IED local status
X89CL33XSWI1	Pos.stVal	89CL33?1:2[c]	Disconnect 33 closed

Table 10.12 Logical Device: PRO (Protection) (Sheet 10 of 11)

Logical Node	Attribute	Data Source	Comment
X89CL34XSWI1	Loc.stVal	LOC	IED local status
X89CL34XSWI1	Pos.stVal	89CL34?1:2[c]	Disconnect 34 closed
X89CL35XSWI1	Loc.stVal	LOC	IED local status
X89CL35XSWI1	Pos.stVal	89CL35?1:2[c]	Disconnect 35 closed
X89CL36XSWI1	Loc.stVal	LOC	IED local status
X89CL36XSWI1	Pos.stVal	89CL36?1:2[c]	Disconnect 36 closed
X89CL37XSWI1	Loc.stVal	LOC	IED local status
X89CL37XSWI1	Pos.stVal	89CL37?1:2[c]	Disconnect 37 closed
X89CL38XSWI1	Loc.stVal	LOC	IED local status
X89CL38XSWI1	Pos.stVal	89CL38?1:2[c]	Disconnect 38 closed
X89CL39XSWI1	Loc.stVal	LOC	IED local status
X89CL39XSWI1	Pos.stVal	89CL39?1:2[c]	Disconnect 39 closed
X89CL40XSWI1	Loc.stVal	LOC	IED local status
X89CL40XSWI1	Pos.stVal	89CL40?1:2[c]	Disconnect 40 closed
X89CL41XSWI1	Loc.stVal	LOC	IED local status
X89CL41XSWI1	Pos.stVal	89CL41?1:2[c]	Disconnect 41 closed
X89CL42XSWI1	Loc.stVal	LOC	IED local status
X89CL42XSWI1	Pos.stVal	89CL42?1:2[c]	Disconnect 42 closed
X89CL43XSWI1	Loc.stVal	LOC	IED local status
X89CL43XSWI1	Pos.stVal	89CL43?1:2[c]	Disconnect 43 closed
X89CL44XSWI1	Loc.stVal	LOC	IED local status
X89CL44XSWI1	Pos.stVal	89CL44?1:2[c]	Disconnect 44 closed
X89CL45XSWI1	Loc.stVal	LOC	IED local status
X89CL45XSWI1	Pos.stVal	89CL45?1:2[c]	Disconnect 45 closed
X89CL46XSWI1	Loc.stVal	LOC	IED local status
X89CL46XSWI1	Pos.stVal	89CL46?1:2[c]	Disconnect 46 closed
X89CL47XSWI1	Loc.stVal	LOC	IED local status
X89CL47XSWI1	Pos.stVal	89CL47?1:2[c]	Disconnect 47 closed
X89CL48XSWI1	Loc.stVal	LOC	IED local status
X89CL48XSWI1	Pos.stVal	89CL48?1:2[c]	Disconnect 48 closed
X89CL49XSWI1	Loc.stVal	LOC	IED local status
X89CL49XSWI1	Pos.stVal	89CL49?1:2[c]	Disconnect 49 closed
X89CL50XSWI1	Loc.stVal	LOC	IED local status
X89CL50XSWI1	Pos.stVal	89CL50?1:2[c]	Disconnect 50 closed
X89CL51XSWI1	Loc.stVal	LOC	IED local status
X89CL51XSWI1	Pos.stVal	89CL51?1:2[c]	Disconnect 51 closed
X89CL52XSWI1	Loc.stVal	LOC	IED local status
X89CL52XSWI1	Pos.stVal	89CL52?1:2[c]	Disconnect 52 closed
X89CL53XSWI1	Loc.stVal	LOC	IED local status
X89CL53XSWI1	Pos.stVal	89CL53?1:2[c]	Disconnect 53 closed
X89CL54XSWI1	Loc.stVal	LOC	IED local status

Table 10.12 Logical Device: PRO (Protection) (Sheet 11 of 11)

Logical Node	Attribute	Data Source	Comment
X89CL54XSWI1	Pos.stVal	89CL54?1:2[c]	Disconnect 54 closed
X89CL55XSWI1	Loc.stVal	LOC	IED local status
X89CL55XSWI1	Pos.stVal	89CL55?1:2[c]	Disconnect 55 closed
X89CL56XSWI1	Loc.stVal	LOC	IED local status
X89CL56XSWI1	Pos.stVal	89CL56?1:2[c]	Disconnect 56 closed
X89CL57XSWI1	Loc.stVal	LOC	IED local status
X89CL57XSWI1	Pos.stVal	89CL57?1:2[c]	Disconnect 57 closed
X89CL58XSWI1	Loc.stVal	LOC	IED local status
X89CL58XSWI1	Pos.stVal	89CL58?1:2[c]	Disconnect 58 closed
X89CL59XSWI1	Loc.stVal	LOC	IED local status
X89CL59XSWI1	Pos.stVal	89CL59?1:2[c]	Disconnect 59 closed
X89CL60XSWI1	Loc.stVal	LOC	IED local status
X89CL60XSWI1	Pos.stVal	89CL60?1:2[c]	Disconnect 60 closed
Functional Constraint = DC			
LLN0	NamPlt.swRev	VERFID	Relay FID string
PROLPHD1	PhyNam.hwRev	HWREV[g]	Hardware version of the relay mainboard
PROLPHD1	PhyNam.model	PARNUM	Relay part number
PROLPHD1	PhyNam.ser-Num	SERNUM	Relay serial number
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 results in no operation.
[b] I60MOD is an internal data source derived from the I850MOD analog quantity and is not available to the user.
[c] If closed, value = 2. If open, value = 1.
[d] FLTYPE is an internal data source derived from the event summary and is not available to the user. Refer to Table 10.14 for more details.
[e] FLTCAUS is an internal data source derived from the event summary and is not available to the user. Refer to Table 10.15 for more details.
[f] If enabled, value = 1. If disabled, value = 3.
[g] HWREV is an internal data source and is not available to the user.

Table 10.13 shows the LNs associated with measuring elements, defined as Logical Device MET.

Table 10.13 Logical Device: MET (Metering) (Sheet 1 of 3)

Logical Node	Attribute	Data Source	Comment	Relay Word Bit
Functional Constraint = ST				
LLN0	LocKey.stVal	NOOP	Physical key indication for switching LD in local mode	NOOP
LLN0	Loc.stVal	LOC	Control authority at local (bay) level	LOC
LLN0	LocSta.stVal	LOCSTA	Control authority at station level	LOCSTA
LLN0	Mod.stVal	I60MOD[a]	IEC 61850 mode/behavior status	I60MOD
DC1ZBAT1	BatWrn.stVal	DC1W	DC monitor warning alarm	DC1W
DC1ZBAT1	BatFail.stVal	DC1F	DC monitor fail alarm	DC1F
DC1ZBAT1	BatGndFlt.st.Val	DC1G	DC monitor ground fault alarm	DC1G

Table 10.13 Logical Device: MET (Metering) (Sheet 2 of 3)

Logical Node	Attribute	Data Source	Comment	Relay Word Bit
DC1ZBAT1	BatDvAlm.stVal	DC1R	DC monitor alarm for ac ripple	DC1R
METLPHD1	PhyHealth.stVal	EN?3:1[b]	Relay enabled	EN?3:1
Functional Constraint = MX				
DC1ZBAT1	Vol.instMag.f	DC1	Station battery dc voltage	DC1
IOPZ1MMXN1	Amp.instMag.f	IOP1F	1-cycle average Zone 1 operating current	IOP1F
IOPZ2MMXN1	Amp.instMag.f	IOP2F	1-cycle average Zone 2 operating current	IOP2F
IOPZ3MMXN1	Amp.instMag.f	IOP3F	1-cycle average Zone 3 operating current	IOP3F
IOPZ4MMXN1	Amp.instMag.f	IOP4F	1-cycle average Zone 4 operating current	IOP4F
IOPZ5MMXN1	Amp.instMag.f	IOP5F	1-cycle average Zone 5 operating current	IOP5F
IOPZ6MMXN1	Amp.instMag.f	IOP6F	1-cycle average Zone 6 operating current	IOP6F
IRTZ1MMXN1	Amp.instMag.f	IRT1F	1-cycle average Zone 1 restraint current	IRT1F
IRTZ2MMXN1	Amp.instMag.f	IRT2F	1-cycle average Zone 2 restraint current	IRT2F
IRTZ3MMXN1	Amp.instMag.f	IRT3F	1-cycle average Zone 3 restraint current	IRT3F
IRTZ4MMXN1	Amp.instMag.f	IRT4F	1-cycle average Zone 4 restraint current	IRT4F
IRTZ5MMXN1	Amp.instMag.f	IRT5F	1-cycle average Zone 5 restraint current	IRT5F
IRTZ6MMXN1	Amp.instMag.f	IRT6F	1-cycle average Zone 6 restraint current	IRT6F
METI01MMXN1	Amp.instMag.f	I01FM	1-cycle average Phase 01 current (magnitude)	I01FM
METI02MMXN1	Amp.instMag.f	I02FM	1-cycle average Phase 02 current (magnitude)	I02FM
METI03MMXN1	Amp.instMag.f	I03FM	1-cycle average Phase 03 current (magnitude)	I03FM
METI04MMXN1	Amp.instMag.f	I04FM	1-cycle average Phase 04 current (magnitude)	I04FM
METI05MMXN1	Amp.instMag.f	I05FM	1-cycle average Phase 05 current (magnitude)	I05FM
METI06MMXN1	Amp.instMag.f	I06FM	1-cycle average Phase 06 current (magnitude)	I06FM
METI07MMXN1	Amp.instMag.f	I07FM	1-cycle average Phase 07 current (magnitude)	I07FM
METI08MMXN1	Amp.instMag.f	I08FM	1-cycle average Phase 08 current (magnitude)	I08FM
METI09MMXN1	Amp.instMag.f	I09FM	1-cycle average Phase 09 current (magnitude)	I09FM
METI10MMXN1	Amp.instMag.f	I10FM	1-cycle average Phase 10 current (magnitude)	I10FM
METI11MMXN1	Amp.instMag.f	I11FM	1-cycle average Phase 11 current (magnitude)	I11FM
METI12MMXN1	Amp.instMag.f	I12FM	1-cycle average Phase 12 current (magnitude)	I12FM
METI13MMXN1	Amp.instMag.f	I13FM	1-cycle average Phase 13 current (magnitude)	I13FM
METI14MMXN1	Amp.instMag.f	I14FM	1-cycle average Phase 14 current (magnitude)	I14FM
METI15MMXN1	Amp.instMag.f	I15FM	1-cycle average Phase 15 current (magnitude)	I15FM
METI16MMXN1	Amp.instMag.f	I16FM	1-cycle average Phase 16 current (magnitude)	I16FM
METI17MMXN1	Amp.instMag.f	I17FM	1-cycle average Phase 17 current (magnitude)	I17FM
METI18MMXN1	Amp.instMag.f	I18FM	1-cycle average Phase 18 current (magnitude)	I18FM
METI19MMXN1	Amp.instMag.f	I19FM	1-cycle average Phase 19 current (magnitude)	I19FM
METI20MMXN1	Amp.instMag.f	I20FM	1-cycle average Phase 20 current (magnitude)	I20FM
METI21MMXN1	Amp.instMag.f	I21FM	1-cycle average Phase 21 current (magnitude)	I21FM
METV01MMXN1	Vol.instMag.f	V01FM	1-cycle average Phase 01 voltage (magnitude)	V01FM
METV02MMXN1	Vol.instMag.f	V02FM	1-cycle average Phase 02 voltage (magnitude)	V02FM
METV03MMXN1	Vol.instMag.f	V03FM	1-cycle average Phase 03 voltage (magnitude)	V03FM

Table 10.13 Logical Device: MET (Metering) (Sheet 3 of 3)

Logical Node	Attribute	Data Source	Comment	Relay Word Bit
Functional Constraint = DC				
LLN0	NamPlt.swRev	VERFID	Relay FID string	VERFID
METLPHD1	PhyNam.hwRev	HWREV[c]	Hardware version of the relay mainboard	HWREV
METLPHD1	PhyNam.model	PARNUM	Relay part number	PARNUM
METLPHD1	PhyNam.serNum	SERNUM	Relay serial number	SERNUM
Functional Constraint = DC				
LLN0	GrRef.setSrcRef	IdName	Functional name	IdNam
LLN0	MltLev.setVal	MLTLEV	Multi-level control authority	MLTLEV

[a] I60MOD is an internal data source derived from the I850MOD analog quantity and is not available to the user.
[b] b If enabled, value = 1. If disabled, value = 3.
[c] HWREV is an internal data source and is not available to the user.

Table 10.14 FLTYPE—Fault Type

Value	Fault Type
0	No fault type identified/present

Table 10.15 FLTCAUS—Fault Cause

Value	Fault Cause
0	No fault summary loaded
1	Trigger command
2	Trip element
3	Event report element
4	Differential trip
5	Breaker failure trip

SECTION 11

Relay Word Bits

This section contains tables of the Relay Word bits available in the SEL-487B relay. *Table 11.1* lists the Relay Word bits in alphabetical order; *Table 11.2* lists every Relay Word bit row and the bits contained within each row.

Alphabetical List

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 1 of 79)

Name	Bit Description	Row
271P1	Undervoltage Element 1, Level 1 asserted	221
271P1T	Undervoltage Element 1, Level 1 timed out	221
271P2	Undervoltage Element 1, Level 2 asserted	221
272P1	Undervoltage Element 2, Level 1 asserted	221
272P1T	Undervoltage Element 2, Level 1 timed out	221
272P2	Undervoltage Element 2, Level 2 asserted	221
273P1	Undervoltage Element 3, Level 1 asserted	222
273P1T	Undervoltage Element 3, Level 1 timed out	222
273P2	Undervoltage Element 3, Level 2 asserted	222
274P1	Undervoltage Element 4, Level 1 asserted	222
274P1T	Undervoltage Element 4, Level 1 timed out	222
274P2	Undervoltage Element 4, Level 2 asserted	222
275P1	Undervoltage Element 5, Level 1 asserted	223
275P1T	Undervoltage Element 5, Level 1 timed out	223
275P2	Undervoltage Element 5, Level 2 asserted	223
276P1	Undervoltage Element 6, Level 1 asserted	223
276P1T	Undervoltage Element 6, Level 1 timed out	223
276P2	Undervoltage Element 6, Level 2 asserted	223
27TC1	Undervoltage Element 1, torque control	221
27TC2	Undervoltage Element 2, torque control	221
27TC3	Undervoltage Element 3, torque control	222
27TC4	Undervoltage Element 4, torque control	222
27TC5	Undervoltage Element 5, torque control	223
27TC6	Undervoltage Element 6, torque control	223
50DS01	Terminal 01 directional element current threshold exceeded	173
50DS02	Terminal 02 directional element current threshold exceeded	173
50DS03	Terminal 03 directional element current threshold exceeded	173
50DS04	Terminal 04 directional element current threshold exceeded	173

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 2 of 79)

Name	Bit Description	Row
50DS05	Terminal 05 directional element current threshold exceeded	173
50DS06	Terminal 06 directional element current threshold exceeded	173
50DS07	Terminal 07 directional element current threshold exceeded	173
50DS08	Terminal 08 directional element current threshold exceeded	173
50DS09	Terminal 09 directional element current threshold exceeded	174
50DS10	Terminal 10 directional element current threshold exceeded	174
50DS11	Terminal 11 directional element current threshold exceeded	174
50DS12	Terminal 12 directional element current threshold exceeded	174
50DS13	Terminal 13 directional element current threshold exceeded	174
50DS14	Terminal 14 directional element current threshold exceeded	174
50DS15	Terminal 15 directional element current threshold exceeded	174
50DS16	Terminal 16 directional element current threshold exceeded	174
50DS17	Terminal 17 directional element current threshold exceeded	175
50DS18	Terminal 18 directional element current threshold exceeded	175
50DS19	Terminal 19 directional element current threshold exceeded	175
50DS20	Terminal 20 directional element current threshold exceeded	175
50DS21	Terminal 21 directional element current threshold exceeded	175
50F01	Circuit Breaker 1 breaker failure current threshold exceeded	183
50F02	Circuit Breaker 2 breaker failure current threshold exceeded	184
50F03	Circuit Breaker 3 breaker failure current threshold exceeded	185
50F04	Circuit Breaker 4 breaker failure current threshold exceeded	186
50F05	Circuit Breaker 5 breaker failure current threshold exceeded	187
50F06	Circuit Breaker 6 breaker failure current threshold exceeded	188
50F07	Circuit Breaker 7 breaker failure current threshold exceeded	189
50F08	Circuit Breaker 8 breaker failure current threshold exceeded	190
50F09	Circuit Breaker 9 breaker failure current threshold exceeded	191
50F10	Circuit Breaker 10 breaker failure current threshold exceeded	192
50F11	Circuit Breaker 11 breaker failure current threshold exceeded	193
50F12	Circuit Breaker 12 breaker failure current threshold exceeded	194
50F13	Circuit Breaker 13 breaker failure current threshold exceeded	195
50F14	Circuit Breaker 14 breaker failure current threshold exceeded	196
50F15	Circuit Breaker 15 breaker failure current threshold exceeded	197
50F16	Circuit Breaker 16 breaker failure current threshold exceeded	198
50F17	Circuit Breaker 17 breaker failure current threshold exceeded	199
50F18	Circuit Breaker 18 breaker failure current threshold exceeded	200
50F19	Circuit Breaker 19 breaker failure current threshold exceeded	201
50F20	Circuit Breaker 20 breaker failure current threshold exceeded	202
50F21	Circuit Breaker 21 breaker failure current threshold exceeded	203
50P01	Terminal 01 instantaneous overcurrent element	207
50P01T	Terminal 01 definite-time overcurrent element timed out	207
50P02	Terminal 02 instantaneous overcurrent element	207

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 3 of 79)

Name	Bit Description	Row
50P02T	Terminal 02 definite-time overcurrent element timed out	207
50P03	Terminal 03 instantaneous overcurrent element	207
50P03T	Terminal 03 definite-time overcurrent element timed out	207
50P04	Terminal 04 instantaneous overcurrent element	207
50P04T	Terminal 04 definite-time overcurrent element timed out	207
50P05	Terminal 05 instantaneous overcurrent element	208
50P05T	Terminal 05 definite-time overcurrent element timed out	208
50P06	Terminal 06 instantaneous overcurrent element	208
50P06T	Terminal 06 definite-time overcurrent element timed out	208
50P07	Terminal 07 instantaneous overcurrent element	208
50P07T	Terminal 07 definite-time overcurrent element timed out	208
50P08	Terminal 08 instantaneous overcurrent element	208
50P08T	Terminal 08 definite-time overcurrent element timed out	208
50P09	Terminal 09 instantaneous overcurrent element	209
50P09T	Terminal 09 definite-time overcurrent element timed out	209
50P10	Terminal 10 instantaneous overcurrent element	209
50P10T	Terminal 10 definite-time overcurrent element timed out	209
50P11	Terminal 11 instantaneous overcurrent element	209
50P11T	Terminal 11 definite-time overcurrent element timed out	209
50P12	Terminal 12 instantaneous overcurrent element	209
50P12T	Terminal 12 definite-time overcurrent element timed out	209
50P13	Terminal 13 instantaneous overcurrent element	210
50P13T	Terminal 13 definite-time overcurrent element timed out	210
50P14	Terminal 14 instantaneous overcurrent element	210
50P14T	Terminal 14 definite-time overcurrent element timed out	210
50P15	Terminal 15 instantaneous overcurrent element	210
50P15T	Terminal 15 definite-time overcurrent element timed out	210
50P16	Terminal 16 instantaneous overcurrent element	210
50P16T	Terminal 16 definite-time overcurrent element timed out	210
50P17	Terminal 17 instantaneous overcurrent element	211
50P17T	Terminal 17 definite-time overcurrent element timed out	211
50P18	Terminal 18 instantaneous overcurrent element	211
50P18T	Terminal 18 definite-time overcurrent element timed out	211
50P19	Terminal 19 instantaneous overcurrent element	211
50P19T	Terminal 19 definite-time overcurrent element timed out	211
50P20	Terminal 20 instantaneous overcurrent element	211
50P20T	Terminal 20 definite-time overcurrent element timed out	211
50P21	Terminal 21 instantaneous overcurrent element	212
50P21T	Terminal 21 definite-time overcurrent element timed out	212
51MM01	Inverse-time Element 01 pickup setting outside of specified limits	219
51MM02	Inverse-time Element 02 pickup setting outside of specified limits	219

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 4 of 79)

Name	Bit Description	Row
51MM03	Inverse-time Element 03 pickup setting outside of specified limits	219
51MM04	Inverse-time Element 04 pickup setting outside of specified limits	219
51MM05	Inverse-time Element 05 pickup setting outside of specified limits	220
51MM06	Inverse-time Element 06 pickup setting outside of specified limits	220
51MM07	Inverse-time Element 07 pickup setting outside of specified limits	220
51MM08	Inverse-time Element 08 pickup setting outside of specified limits	220
51MM09	Inverse-time Element 09 pickup setting outside of specified limits	232
51MM10	Inverse-time Element 10 pickup setting outside of specified limits	232
51MM11	Inverse-time Element 11 pickup setting outside of specified limits	232
51MM12	Inverse-time Element 12 pickup setting outside of specified limits	232
51MM13	Inverse-time Element 13 pickup setting outside of specified limits	233
51MM14	Inverse-time Element 14 pickup setting outside of specified limits	233
51MM15	Inverse-time Element 15 pickup setting outside of specified limits	233
51MM16	Inverse-time Element 16 pickup setting outside of specified limits	233
51MM17	Inverse-time Element 17 pickup setting outside of specified limits	234
51MM18	Inverse-time Element 18 pickup setting outside of specified limits	234
51MM19	Inverse-time Element 19 pickup setting outside of specified limits	234
51MM20	Inverse-time Element 20 pickup setting outside of specified limits	234
51MM21	Inverse-time Element 21 pickup setting outside of specified limits	252
51R01	Inverse-time Element 01 reset	254
51R02	Inverse-time Element 02 reset	254
51R03	Inverse-time Element 03 reset	254
51R04	Inverse-time Element 04 reset	254
51R05	Inverse-time Element 05 reset	254
51R06	Inverse-time Element 06 reset	254
51R07	Inverse-time Element 07 reset	254
51R08	Inverse-time Element 08 reset	254
51R09	Inverse-time Element 09 reset	253
51R10	Inverse-time Element 10 reset	253
51R11	Inverse-time Element 11 reset	253
51R12	Inverse-time Element 12 reset	253
51R13	Inverse-time Element 13 reset	253
51R14	Inverse-time Element 14 reset	253
51R15	Inverse-time Element 15 reset	253
51R16	Inverse-time Element 16 reset	253
51R17	Inverse-time Element 17 reset	381
51R18	Inverse-time Element 18 reset	381
51R19	Inverse-time Element 19 reset	381
51R20	Inverse-time Element 20 reset	381
51R21	Inverse-time Element 21 reset	381
51S01	Inverse-time Element 01 picked up	213

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 5 of 79)

Name	Bit Description	Row
51S02	Inverse-time Element 02 picked up	213
51S03	Inverse-time Element 03 picked up	213
51S04	Inverse-time Element 04 picked up	213
51S05	Inverse-time Element 05 picked up	214
51S06	Inverse-time Element 06 picked up	214
51S07	Inverse-time Element 07 picked up	214
51S08	Inverse-time Element 08 picked up	214
51S09	Inverse-time Element 09 picked up	215
51S10	Inverse-time Element 10 picked up	215
51S11	Inverse-time Element 11 picked up	215
51S12	Inverse-time Element 12 picked up	215
51S13	Inverse-time Element 13 picked up	216
51S14	Inverse-time Element 14 picked up	216
51S15	Inverse-time Element 15 picked up	216
51S16	Inverse-time Element 16 picked up	216
51S17	Inverse-time Element 17 picked up	217
51S18	Inverse-time Element 18 picked up	217
51S19	Inverse-time Element 19 picked up	217
51S20	Inverse-time Element 20 picked up	217
51S21	Inverse-time Element 21 picked up	218
51T01	Inverse-time Element 01 timed out	213
51T02	Inverse-time Element 02 timed out	213
51T03	Inverse-time Element 03 timed out	213
51T04	Inverse-time Element 04 timed out	213
51T05	Inverse-time Element 05 timed out	214
51T06	Inverse-time Element 06 timed out	214
51T07	Inverse-time Element 07 timed out	214
51T08	Inverse-time Element 08 timed out	214
51T09	Inverse-time Element 09 timed out	215
51T10	Inverse-time Element 10 timed out	215
51T11	Inverse-time Element 11 timed out	215
51T12	Inverse-time Element 12 timed out	215
51T13	Inverse-time Element 13 timed out	216
51T14	Inverse-time Element 14 timed out	216
51T15	Inverse-time Element 15 timed out	216
51T16	Inverse-time Element 16 timed out	216
51T17	Inverse-time Element 17 timed out	217
51T18	Inverse-time Element 18 timed out	217
51T19	Inverse-time Element 19 timed out	217
51T20	Inverse-time Element 20 timed out	217
51T21	Inverse-time Element 21 timed out	218

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 6 of 79)

Name	Bit Description	Row
51TM01	Inverse-time Element 01 time-dial setting outside of specified limits	219
51TM02	Inverse-time Element 02 time-dial setting outside of specified limits	219
51TM03	Inverse-time Element 03 time-dial setting outside of specified limits	219
51TM04	Inverse-time Element 04 time-dial setting outside of specified limits	219
51TM05	Inverse-time Element 05 time-dial setting outside of specified limits	220
51TM06	Inverse-time Element 06 time-dial setting outside of specified limits	220
51TM07	Inverse-time Element 07 time-dial setting outside of specified limits	220
51TM08	Inverse-time Element 08 time-dial setting outside of specified limits	220
51TM09	Inverse-time Element 09 time-dial setting outside of specified limits	232
51TM10	Inverse-time Element 10 time-dial setting outside of specified limits	232
51TM11	Inverse-time Element 11 time-dial setting outside of specified limits	232
51TM12	Inverse-time Element 12 time-dial setting outside of specified limits	232
51TM13	Inverse-time Element 13 time-dial setting outside of specified limits	233
51TM14	Inverse-time Element 14 time-dial setting outside of specified limits	233
51TM15	Inverse-time Element 15 time-dial setting outside of specified limits	233
51TM16	Inverse-time Element 16 time-dial setting outside of specified limits	233
51TM17	Inverse-time Element 17 time-dial setting outside of specified limits	234
51TM18	Inverse-time Element 18 time-dial setting outside of specified limits	234
51TM19	Inverse-time Element 19 time-dial setting outside of specified limits	234
51TM20	Inverse-time Element 20 time-dial setting outside of specified limits	234
51TM21	Inverse-time Element 21 time-dial setting outside of specified limits	252
52A01	Circuit Breaker 01 status	7
52A02	Circuit Breaker 02 status	7
52A03	Circuit Breaker 03 status	7
52A04	Circuit Breaker 04 status	8
52A05	Circuit Breaker 05 status	8
52A06	Circuit Breaker 06 status	8
52A07	Circuit Breaker 07 status	9
52A08	Circuit Breaker 08 status	9
52A09	Circuit Breaker 09 status	10
52A10	Circuit Breaker 10 status	10
52A11	Circuit Breaker 11 status	10
52A12	Circuit Breaker 12 status	11
52A13	Circuit Breaker 13 status	11
52A14	Circuit Breaker 14 status	11
52A15	Circuit Breaker 15 status	12
52A16	Circuit Breaker 16 status	12
52A17	Circuit Breaker 17 status	13
52A18	Circuit Breaker 18 status	13
52A19	Circuit Breaker 19 status	13
52A20	Circuit Breaker 20 status	14

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 7 of 79)

Name	Bit Description	Row
52A21	Circuit Breaker 21 status	14
52AL	Any circuit breaker alarm	14
52AL01	Circuit Breaker 01 alarm	7
52AL02	Circuit Breaker 02 alarm	7
52AL03	Circuit Breaker 03 alarm	7
52AL04	Circuit Breaker 04 alarm	8
52AL05	Circuit Breaker 05 alarm	8
52AL06	Circuit Breaker 06 alarm	9
52AL07	Circuit Breaker 07 alarm	9
52AL08	Circuit Breaker 08 alarm	9
52AL09	Circuit Breaker 09 alarm	10
52AL10	Circuit Breaker 10 alarm	10
52AL11	Circuit Breaker 11 alarm	10
52AL12	Circuit Breaker 12 alarm	11
52AL13	Circuit Breaker 13 alarm	11
52AL14	Circuit Breaker 14 alarm	12
52AL15	Circuit Breaker 15 alarm	12
52AL16	Circuit Breaker 16 alarm	12
52AL17	Circuit Breaker 17 alarm	13
52AL18	Circuit Breaker 18 alarm	13
52AL19	Circuit Breaker 19 alarm	13
52AL20	Circuit Breaker 20 alarm	14
52AL21	Circuit Breaker 21 alarm	14
52CL01	Circuit Breaker 01 closed	7
52CL02	Circuit Breaker 02 closed	7
52CL03	Circuit Breaker 03 closed	8
52CL04	Circuit Breaker 04 closed	8
52CL05	Circuit Breaker 05 closed	8
52CL06	Circuit Breaker 06 closed	9
52CL07	Circuit Breaker 07 closed	9
52CL08	Circuit Breaker 08 closed	9
52CL09	Circuit Breaker 09 closed	10
52CL10	Circuit Breaker 10 closed	10
52CL11	Circuit Breaker 11 closed	11
52CL12	Circuit Breaker 12 closed	11
52CL13	Circuit Breaker 13 closed	11
52CL14	Circuit Breaker 14 closed	12
52CL15	Circuit Breaker 15 closed	12
52CL16	Circuit Breaker 16 closed	12
52CL17	Circuit Breaker 17 closed	13
52CL18	Circuit Breaker 18 closed	13

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 8 of 79)

Name	Bit Description	Row
52CL19	Circuit Breaker 19 closed	14
52CL20	Circuit Breaker 20 closed	14
52CL21	Circuit Breaker 21 closed	14
591P1	Overvoltage Element 1, Level 1 asserted	224
591P1T	Overvoltage Element 1, Level 1 timed out	224
591P2	Overvoltage Element 1, Level 2 asserted	224
592P1	Overvoltage Element 2, Level 1 asserted	224
592P1T	Overvoltage Element 2, Level 1 timed out	224
592P2	Overvoltage Element 2, Level 2 asserted	224
593P1	Overvoltage Element 3, Level 1 asserted	225
593P1T	Overvoltage Element 3, Level 1 timed out	225
593P2	Overvoltage Element 3, Level 2 asserted	225
594P1	Overvoltage Element 4, Level 1 asserted	225
594P1T	Overvoltage Element 4, Level 1 timed out	225
594P2	Overvoltage Element 4, Level 2 asserted	225
595P1	Overvoltage Element 5, Level 1 asserted	226
595P1T	Overvoltage Element 5, Level 1 timed out	226
595P2	Overvoltage Element 5, Level 2 asserted	226
596P1	Overvoltage Element 6, Level 1 asserted	226
596P1T	Overvoltage Element 6, Level 1 timed out	226
596P2	Overvoltage Element 6, Level 2 asserted	226
59TC1	Overvoltage Element 1, torque control	224
59TC2	Overvoltage Element 2, torque control	224
59TC3	Overvoltage Element 3, torque control	225
59TC4	Overvoltage Element 4, torque control	225
59TC5	Overvoltage Element 5, torque control	226
59TC6	Overvoltage Element 6, torque control	226
87BTR	Any terminal bus-zone differential trip asserted	231
87BTR01	Terminal 01 bus-zone differential trip asserted	228
87BTR02	Terminal 02 bus-zone differential trip asserted	228
87BTR03	Terminal 03 bus-zone differential trip asserted	228
87BTR04	Terminal 04 bus-zone differential trip asserted	228
87BTR05	Terminal 05 bus-zone differential trip asserted	228
87BTR06	Terminal 06 bus-zone differential trip asserted	228
87BTR07	Terminal 07 bus-zone differential trip asserted	228
87BTR08	Terminal 08 bus-zone differential trip asserted	228
87BTR09	Terminal 09 bus-zone differential trip asserted	229
87BTR10	Terminal 10 bus-zone differential trip asserted	229
87BTR11	Terminal 11 bus-zone differential trip asserted	229
87BTR12	Terminal 12 bus-zone differential trip asserted	229
87BTR13	Terminal 13 bus-zone differential trip asserted	229

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 9 of 79)

Name	Bit Description	Row
87BTR14	Terminal 14 bus-zone differential trip asserted	229
87BTR15	Terminal 15 bus-zone differential trip asserted	229
87BTR16	Terminal 16 bus-zone differential trip asserted	229
87BTR17	Terminal 17 bus-zone differential trip asserted	230
87BTR18	Terminal 18 bus-zone differential trip asserted	230
87BTR19	Terminal 19 bus-zone differential trip asserted	230
87BTR20	Terminal 20 bus-zone differential trip asserted	230
87BTR21	Terminal 21 bus-zone differential trip asserted	230
87CZ1	Check Zone 1 differential element trip	447
87CZ2	Check Zone 2 differential element trip	447
87CZ3	Check Zone 3 differential element trip	447
87O1	Zone 1 restraint differential operating current above O87P	159
87O2	Zone 2 restraint differential operating current above O87P	161
87O3	Zone 3 restraint differential operating current above O87P	163
87O4	Zone 4 restraint differential operating current above O87P	165
87O5	Zone 5 restraint differential operating current above O87P	167
87O6	Zone 6 restraint differential operating current above O87P	169
87OCZ1	Check Zone 1 restraint differential operating current above CZO87P	450
87OCZ2	Check Zone 2 restraint differential operating current above CZO87P	452
87OCZ3	Check Zone 3 restraint differential operating current above CZO87P	454
87R1	Zone 1 restraint differential element picked up	159
87R2	Zone 2 restraint differential element picked up	161
87R3	Zone 3 restraint differential element picked up	163
87R4	Zone 4 restraint differential element picked up	165
87R5	Zone 5 restraint differential element picked up	167
87R6	Zone 6 restraint differential element picked up	169
87RCZ1	Check Zone 1 restraint differential element picked up	450
87RCZ2	Check Zone 2 restraint differential element picked up	452
87RCZ3	Check Zone 3 restraint differential element picked up	454
87S1	Zone 1 sensitive differential element picked up	157
87S2	Zone 2 sensitive differential element picked up	157
87S3	Zone 3 sensitive differential element picked up	157
87S4	Zone 4 sensitive differential element picked up	157
87S5	Zone 5 sensitive differential element picked up	157
87S6	Zone 6 sensitive differential element picked up	157
87SCZ1	Check Zone 1 sensitive differential element picked up	448
87SCZ2	Check Zone 2 sensitive differential element picked up	448
87SCZ3	Check Zone 3 sensitive differential element picked up	448
87ST	Any sensitive differential element timer timed out	158
87ST1	Zone 1 sensitive differential element timed out	158
87ST2	Zone 2 sensitive differential element timed out	158

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 10 of 79)

Name	Bit Description	Row
87ST3	Zone 3 sensitive differential element timed out	158
87ST4	Zone 4 sensitive differential element timed out	158
87ST5	Zone 5 sensitive differential element timed out	158
87ST6	Zone 6 sensitive differential element timed out	158
87STCZ1	Check Zone 1 sensitive differential element timed out	449
87STCZ2	Check Zone 2 sensitive differential element timed out	449
87STCZ3	Check Zone 3 sensitive differential element timed out	449
87Z1	Zone 1 differential element trip	235
87Z2	Zone 2 differential element trip	235
87Z3	Zone 3 differential element trip	235
87Z4	Zone 4 differential element trip	235
87Z5	Zone 5 differential element trip	235
87Z6	Zone 6 differential element trip	235
89A01	Disconnect 01 A auxiliary contact closed	17
89A02	Disconnect 02 A auxiliary contact closed	17
89A03	Disconnect 03 A auxiliary contact closed	18
89A04	Disconnect 04 A auxiliary contact closed	18
89A05	Disconnect 05 A auxiliary contact closed	19
89A06	Disconnect 06 A auxiliary contact closed	20
89A07	Disconnect 07 A auxiliary contact closed	20
89A08	Disconnect 08 A auxiliary contact closed	21
89A09	Disconnect 09 A auxiliary contact closed	22
89A10	Disconnect 10 A auxiliary contact closed	22
89A11	Disconnect 11 A auxiliary contact closed	23
89A12	Disconnect 12 A auxiliary contact closed	23
89A13	Disconnect 13 A auxiliary contact closed	24
89A14	Disconnect 14 A auxiliary contact closed	25
89A15	Disconnect 15 A auxiliary contact closed	25
89A16	Disconnect 16 A auxiliary contact closed	26
89A17	Disconnect 17 A auxiliary contact closed	27
89A18	Disconnect 18 A auxiliary contact closed	27
89A19	Disconnect 19 A auxiliary contact closed	28
89A20	Disconnect 20 A auxiliary contact closed	28
89A21	Disconnect 21 A auxiliary contact closed	29
89A22	Disconnect 22 A auxiliary contact closed	30
89A23	Disconnect 23 A auxiliary contact closed	30
89A24	Disconnect 24 A auxiliary contact closed	31
89A25	Disconnect 25 A auxiliary contact closed	32
89A26	Disconnect 26 A auxiliary contact closed	32
89A27	Disconnect 27 A auxiliary contact closed	33
89A28	Disconnect 28 A auxiliary contact closed	33

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 11 of 79)

Name	Bit Description	Row
89A29	Disconnect 29 A auxiliary contact closed	34
89A30	Disconnect 30 A auxiliary contact closed	35
89A31	Disconnect 31 A auxiliary contact closed	35
89A32	Disconnect 32 A auxiliary contact closed	36
89A33	Disconnect 33 A auxiliary contact closed	37
89A34	Disconnect 34 A auxiliary contact closed	37
89A35	Disconnect 35 A auxiliary contact closed	38
89A36	Disconnect 36 A auxiliary contact closed	38
89A37	Disconnect 37 A auxiliary contact closed	39
89A38	Disconnect 38 A auxiliary contact closed	40
89A39	Disconnect 39 A auxiliary contact closed	40
89A40	Disconnect 40 A auxiliary contact closed	41
89A41	Disconnect 41 A auxiliary contact closed	42
89A42	Disconnect 42 A auxiliary contact closed	42
89A43	Disconnect 43 A auxiliary contact closed	43
89A44	Disconnect 44 A auxiliary contact closed	43
89A45	Disconnect 45 A auxiliary contact closed	44
89A46	Disconnect 46 A auxiliary contact closed	45
89A47	Disconnect 47 A auxiliary contact closed	45
89A48	Disconnect 48 A auxiliary contact closed	46
89A49	Disconnect 49 A auxiliary contact closed	47
89A50	Disconnect 50 A auxiliary contact closed	47
89A51	Disconnect 51 A auxiliary contact closed	48
89A52	Disconnect 52 A auxiliary contact closed	48
89A53	Disconnect 53 A auxiliary contact closed	49
89A54	Disconnect 54 A auxiliary contact closed	50
89A55	Disconnect 55 A auxiliary contact closed	50
89A56	Disconnect 56 A auxiliary contact closed	51
89A57	Disconnect 57 A auxiliary contact closed	52
89A58	Disconnect 58 A auxiliary contact closed	52
89A59	Disconnect 59 A auxiliary contact closed	53
89A60	Disconnect 60 A auxiliary contact closed	53
89AL	Any disconnect auxiliary contact discrepancy alarm	55
89AL01	Disconnect 01 auxiliary contact discrepancy alarm	17
89AL02	Disconnect 02 auxiliary contact discrepancy alarm	18
89AL03	Disconnect 03 auxiliary contact discrepancy alarm	18
89AL04	Disconnect 04 auxiliary contact discrepancy alarm	19
89AL05	Disconnect 05 auxiliary contact discrepancy alarm	20
89AL06	Disconnect 06 auxiliary contact discrepancy alarm	20
89AL07	Disconnect 07 auxiliary contact discrepancy alarm	21
89AL08	Disconnect 08 auxiliary contact discrepancy alarm	21

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 12 of 79)

Name	Bit Description	Row
89AL09	Disconnect 09 auxiliary contact discrepancy alarm	22
89AL10	Disconnect 10 auxiliary contact discrepancy alarm	23
89AL11	Disconnect 11 auxiliary contact discrepancy alarm	23
89AL12	Disconnect 12 auxiliary contact discrepancy alarm	24
89AL13	Disconnect 13 auxiliary contact discrepancy alarm	25
89AL14	Disconnect 14 auxiliary contact discrepancy alarm	25
89AL15	Disconnect 15 auxiliary contact discrepancy alarm	26
89AL16	Disconnect 16 auxiliary contact discrepancy alarm	26
89AL17	Disconnect 17 auxiliary contact discrepancy alarm	27
89AL18	Disconnect 18 auxiliary contact discrepancy alarm	28
89AL19	Disconnect 19 auxiliary contact discrepancy alarm	28
89AL20	Disconnect 20 auxiliary contact discrepancy alarm	29
89AL21	Disconnect 21 auxiliary contact discrepancy alarm	30
89AL22	Disconnect 22 auxiliary contact discrepancy alarm	30
89AL23	Disconnect 23 auxiliary contact discrepancy alarm	31
89AL24	Disconnect 24 auxiliary contact discrepancy alarm	31
89AL25	Disconnect 25 auxiliary contact discrepancy alarm	32
89AL26	Disconnect 26 auxiliary contact discrepancy alarm	33
89AL27	Disconnect 27 auxiliary contact discrepancy alarm	33
89AL28	Disconnect 28 auxiliary contact discrepancy alarm	34
89AL29	Disconnect 29 auxiliary contact discrepancy alarm	35
89AL30	Disconnect 30 auxiliary contact discrepancy alarm	35
89AL31	Disconnect 31 auxiliary contact discrepancy alarm	36
89AL32	Disconnect 32 auxiliary contact discrepancy alarm	36
89AL33	Disconnect 33 auxiliary contact discrepancy alarm	37
89AL34	Disconnect 34 auxiliary contact discrepancy alarm	38
89AL35	Disconnect 35 auxiliary contact discrepancy alarm	38
89AL36	Disconnect 36 auxiliary contact discrepancy alarm	39
89AL37	Disconnect 37 auxiliary contact discrepancy alarm	40
89AL38	Disconnect 38 auxiliary contact discrepancy alarm	40
89AL39	Disconnect 39 auxiliary contact discrepancy alarm	41
89AL40	Disconnect 40 auxiliary contact discrepancy alarm	41
89AL41	Disconnect 41 auxiliary contact discrepancy alarm	42
89AL42	Disconnect 42 auxiliary contact discrepancy alarm	43
89AL43	Disconnect 43 auxiliary contact discrepancy alarm	43
89AL44	Disconnect 44 auxiliary contact discrepancy alarm	44
89AL45	Disconnect 45 auxiliary contact discrepancy alarm	45
89AL46	Disconnect 46 auxiliary contact discrepancy alarm	45
89AL47	Disconnect 47 auxiliary contact discrepancy alarm	46
89AL48	Disconnect 48 auxiliary contact discrepancy alarm	46
89AL49	Disconnect 49 auxiliary contact discrepancy alarm	47

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 13 of 79)

Name	Bit Description	Row
89AL50	Disconnect 50 auxiliary contact discrepancy alarm	48
89AL51	Disconnect 51 auxiliary contact discrepancy alarm	48
89AL52	Disconnect 52 auxiliary contact discrepancy alarm	49
89AL53	Disconnect 53 auxiliary contact discrepancy alarm	50
89AL54	Disconnect 54 auxiliary contact discrepancy alarm	50
89AL55	Disconnect 55 auxiliary contact discrepancy alarm	51
89AL56	Disconnect 56 auxiliary contact discrepancy alarm	51
89AL57	Disconnect 57 auxiliary contact discrepancy alarm	52
89AL58	Disconnect 58 auxiliary contact discrepancy alarm	53
89AL59	Disconnect 59 auxiliary contact discrepancy alarm	53
89AL60	Disconnect 60 auxiliary contact discrepancy alarm	54
89B01	Disconnect 01 B auxiliary contact closed	17
89B02	Disconnect 02 B auxiliary contact closed	17
89B03	Disconnect 03 B auxiliary contact closed	18
89B04	Disconnect 04 B auxiliary contact closed	19
89B05	Disconnect 05 B auxiliary contact closed	19
89B06	Disconnect 06 B auxiliary contact closed	20
89B07	Disconnect 07 B auxiliary contact closed	20
89B08	Disconnect 08 B auxiliary contact closed	21
89B09	Disconnect 09 B auxiliary contact closed	22
89B10	Disconnect 10 B auxiliary contact closed	22
89B11	Disconnect 11 B auxiliary contact closed	23
89B12	Disconnect 12 B auxiliary contact closed	24
89B13	Disconnect 13 B auxiliary contact closed	24
89B14	Disconnect 14 B auxiliary contact closed	25
89B15	Disconnect 15 B auxiliary contact closed	25
89B16	Disconnect 16 B auxiliary contact closed	26
89B17	Disconnect 17 B auxiliary contact closed	27
89B18	Disconnect 18 B auxiliary contact closed	27
89B19	Disconnect 19 B auxiliary contact closed	28
89B20	Disconnect 20 B auxiliary contact closed	29
89B21	Disconnect 21 B auxiliary contact closed	29
89B22	Disconnect 22 B auxiliary contact closed	30
89B23	Disconnect 23 B auxiliary contact closed	30
89B24	Disconnect 24 B auxiliary contact closed	31
89B25	Disconnect 25 B auxiliary contact closed	32
89B26	Disconnect 26 B auxiliary contact closed	32
89B27	Disconnect 27 B auxiliary contact closed	33
89B28	Disconnect 28 B auxiliary contact closed	34
89B29	Disconnect 29 B auxiliary contact closed	34
89B30	Disconnect 30 B auxiliary contact closed	35

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 14 of 79)

Name	Bit Description	Row
89B31	Disconnect 31 B auxiliary contact closed	35
89B32	Disconnect 32 B auxiliary contact closed	36
89B33	Disconnect 33 B auxiliary contact closed	37
89B34	Disconnect 34 B auxiliary contact closed	37
89B35	Disconnect 35 B auxiliary contact closed	38
89B36	Disconnect 36 B auxiliary contact closed	39
89B37	Disconnect 37 B auxiliary contact closed	39
89B38	Disconnect 38 B auxiliary contact closed	40
89B39	Disconnect 39 B auxiliary contact closed	40
89B40	Disconnect 40 B auxiliary contact closed	41
89B41	Disconnect 41 B auxiliary contact closed	42
89B42	Disconnect 42 B auxiliary contact closed	42
89B43	Disconnect 43 B auxiliary contact closed	43
89B44	Disconnect 44 B auxiliary contact closed	44
89B45	Disconnect 45 B auxiliary contact closed	44
89B46	Disconnect 46 B auxiliary contact closed	45
89B47	Disconnect 47 B auxiliary contact closed	45
89B48	Disconnect 48 B auxiliary contact closed	46
89B49	Disconnect 49 B auxiliary contact closed	47
89B50	Disconnect 50 B auxiliary contact closed	47
89B51	Disconnect 51 B auxiliary contact closed	48
89B52	Disconnect 52 B auxiliary contact closed	49
89B53	Disconnect 53 B auxiliary contact closed	49
89B54	Disconnect 54 B auxiliary contact closed	50
89B55	Disconnect 55 B auxiliary contact closed	50
89B56	Disconnect 56 B auxiliary contact closed	51
89B57	Disconnect 57 B auxiliary contact closed	52
89B58	Disconnect 58 B auxiliary contact closed	52
89B59	Disconnect 59 B auxiliary contact closed	53
89B60	Disconnect 60 B auxiliary contact closed	54
89CL01	Disconnect 01 closed	17
89CL02	Disconnect 02 closed	17
89CL03	Disconnect 03 closed	18
89CL04	Disconnect 04 closed	19
89CL05	Disconnect 05 closed	19
89CL06	Disconnect 06 closed	20
89CL07	Disconnect 07 closed	21
89CL08	Disconnect 08 closed	21
89CL09	Disconnect 09 closed	22
89CL10	Disconnect 10 closed	22
89CL11	Disconnect 11 closed	23

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 15 of 79)

Name	Bit Description	Row
89CL12	Disconnect 12 closed	24
89CL13	Disconnect 13 closed	24
89CL14	Disconnect 14 closed	25
89CL15	Disconnect 15 closed	26
89CL16	Disconnect 16 closed	26
89CL17	Disconnect 17 closed	27
89CL18	Disconnect 18 closed	27
89CL19	Disconnect 19 closed	28
89CL20	Disconnect 20 closed	29
89CL21	Disconnect 21 closed	29
89CL22	Disconnect 22 closed	30
89CL23	Disconnect 23 closed	31
89CL24	Disconnect 24 closed	31
89CL25	Disconnect 25 closed	32
89CL26	Disconnect 26 closed	32
89CL27	Disconnect 27 closed	33
89CL28	Disconnect 28 closed	34
89CL29	Disconnect 29 closed	34
89CL30	Disconnect 30 closed	35
89CL31	Disconnect 31 closed	36
89CL32	Disconnect 32 closed	36
89CL33	Disconnect 33 closed	37
89CL34	Disconnect 34 closed	37
89CL35	Disconnect 35 closed	38
89CL36	Disconnect 36 closed	39
89CL37	Disconnect 37 closed	39
89CL38	Disconnect 38 closed	40
89CL39	Disconnect 39 closed	41
89CL40	Disconnect 40 closed	41
89CL41	Disconnect 41 closed	42
89CL42	Disconnect 42 closed	42
89CL43	Disconnect 43 closed	43
89CL44	Disconnect 44 closed	44
89CL45	Disconnect 45 closed	44
89CL46	Disconnect 46 closed	45
89CL47	Disconnect 47 closed	46
89CL48	Disconnect 48 closed	46
89CL49	Disconnect 49 closed	47
89CL50	Disconnect 50 closed	47
89CL51	Disconnect 51 closed	48
89CL52	Disconnect 52 closed	49

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 16 of 79)

Name	Bit Description	Row
89CL53	Disconnect 53 closed	49
89CL54	Disconnect 54 closed	50
89CL55	Disconnect 55 closed	51
89CL56	Disconnect 56 closed	51
89CL57	Disconnect 57 closed	52
89CL58	Disconnect 58 closed	52
89CL59	Disconnect 59 closed	53
89CL60	Disconnect 60 closed	54
89OIP	Any disconnect operation in progress	55
89OIP01	Disconnect 01 operation in progress	17
89OIP02	Disconnect 02 operation in progress	18
89OIP03	Disconnect 03 operation in progress	18
89OIP04	Disconnect 04 operation in progress	19
89OIP05	Disconnect 05 operation in progress	19
89OIP06	Disconnect 06 operation in progress	20
89OIP07	Disconnect 07 operation in progress	21
89OIP08	Disconnect 08 operation in progress	21
89OIP09	Disconnect 09 operation in progress	22
89OIP10	Disconnect 10 operation in progress	23
89OIP11	Disconnect 11 operation in progress	23
89OIP12	Disconnect 12 operation in progress	24
89OIP13	Disconnect 13 operation in progress	24
89OIP14	Disconnect 14 operation in progress	25
89OIP15	Disconnect 15 operation in progress	26
89OIP16	Disconnect 16 operation in progress	26
89OIP17	Disconnect 17 operation in progress	27
89OIP18	Disconnect 18 operation in progress	28
89OIP19	Disconnect 19 operation in progress	28
89OIP20	Disconnect 20 operation in progress	29
89OIP21	Disconnect 21 operation in progress	29
89OIP22	Disconnect 22 operation in progress	30
89OIP23	Disconnect 23 operation in progress	31
89OIP24	Disconnect 24 operation in progress	31
89OIP25	Disconnect 25 operation in progress	32
89OIP26	Disconnect 26 operation in progress	33
89OIP27	Disconnect 27 operation in progress	33
89OIP28	Disconnect 28 operation in progress	34
89OIP29	Disconnect 29 operation in progress	34
89OIP30	Disconnect 30 operation in progress	35
89OIP31	Disconnect 31 operation in progress	36
89OIP32	Disconnect 32 operation in progress	36

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 17 of 79)

Name	Bit Description	Row
89OIP33	Disconnect 33 operation in progress	37
89OIP34	Disconnect 34 operation in progress	38
89OIP35	Disconnect 35 operation in progress	38
89OIP36	Disconnect 36 operation in progress	39
89OIP37	Disconnect 37 operation in progress	39
89OIP38	Disconnect 38 operation in progress	40
89OIP39	Disconnect 39 operation in progress	41
89OIP40	Disconnect 40 operation in progress	41
89OIP41	Disconnect 41 operation in progress	42
89OIP42	Disconnect 42 operation in progress	43
89OIP43	Disconnect 43 operation in progress	43
89OIP44	Disconnect 44 operation in progress	44
89OIP45	Disconnect 45 operation in progress	44
89OIP46	Disconnect 46 operation in progress	45
89OIP47	Disconnect 47 operation in progress	46
89OIP48	Disconnect 48 operation in progress	46
89OIP49	Disconnect 49 operation in progress	47
89OIP50	Disconnect 50 operation in progress	48
89OIP51	Disconnect 51 operation in progress	48
89OIP52	Disconnect 52 operation in progress	49
89OIP53	Disconnect 53 operation in progress	49
89OIP54	Disconnect 54 operation in progress	50
89OIP55	Disconnect 55 operation in progress	51
89OIP56	Disconnect 56 operation in progress	51
89OIP57	Disconnect 57 operation in progress	52
89OIP58	Disconnect 58 operation in progress	53
89OIP59	Disconnect 59 operation in progress	53
89OIP60	Disconnect 60 operation in progress	54
ABFIT01	Circuit Breaker 1 alternate circuit breaker failure initiate	183
ABFIT02	Circuit Breaker 2 alternate circuit breaker failure initiate	184
ABFIT03	Circuit Breaker 3 alternate circuit breaker failure initiate	185
ABFIT04	Circuit Breaker 4 alternate circuit breaker failure initiate	186
ABFIT05	Circuit Breaker 5 alternate circuit breaker failure initiate	187
ABFIT06	Circuit Breaker 6 alternate circuit breaker failure initiate	188
ABFIT07	Circuit Breaker 7 alternate circuit breaker failure initiate	189
ABFIT08	Circuit Breaker 8 alternate circuit breaker failure initiate	190
ABFIT09	Circuit Breaker 9 alternate circuit breaker failure initiate	191
ABFIT10	Circuit Breaker 10 alternate circuit breaker failure initiate	192
ABFIT11	Circuit Breaker 11 alternate circuit breaker failure initiate	193
ABFIT12	Circuit Breaker 12 alternate circuit breaker failure initiate	194
ABFIT13	Circuit Breaker 13 alternate circuit breaker failure initiate	195

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 18 of 79)

Name	Bit Description	Row
ABFIT14	Circuit Breaker 14 alternate circuit breaker failure initiate	196
ABFIT15	Circuit Breaker 15 alternate circuit breaker failure initiate	197
ABFIT16	Circuit Breaker 16 alternate circuit breaker failure initiate	198
ABFIT17	Circuit Breaker 17 alternate circuit breaker failure initiate	199
ABFIT18	Circuit Breaker 18 alternate circuit breaker failure initiate	200
ABFIT19	Circuit Breaker 19 alternate circuit breaker failure initiate	201
ABFIT20	Circuit Breaker 20 alternate circuit breaker failure initiate	202
ABFIT21	Circuit Breaker 21 alternate circuit breaker failure initiate	203
ACCESS	A user is connected at Access Level B or higher	377
ACCESSP	Pulsed when higher level access achieved	377
ACN01Q	Automation counter Output 1	366
ACN01R	Automation counter Reset 1	370
ACN02Q	Automation counter Output 2	366
ACN02R	Automation counter Reset 2	370
ACN03Q	Automation counter Output 3	366
ACN03R	Automation counter Reset 3	370
ACN04Q	Automation counter Output 4	366
ACN04R	Automation counter Reset 4	370
ACN05Q	Automation counter Output 5	366
ACN05R	Automation counter Reset 5	370
ACN06Q	Automation counter Output 6	366
ACN06R	Automation counter Reset 6	370
ACN07Q	Automation counter Output 7	366
ACN07R	Automation counter Reset 7	370
ACN08Q	Automation counter Output 8	366
ACN08R	Automation counter Reset 8	370
ACN09Q	Automation counter Output 9	367
ACN09R	Automation counter Reset 9	371
ACN10Q	Automation counter Output 10	367
ACN10R	Automation counter Reset 10	371
ACN11Q	Automation counter Output 11	367
ACN11R	Automation counter Reset 11	371
ACN12Q	Automation counter Output 12	367
ACN12R	Automation counter Reset 12	371
ACN13Q	Automation counter Output 13	367
ACN13R	Automation counter Reset 13	371
ACN14Q	Automation counter Output 14	367
ACN14R	Automation counter Reset 14	371
ACN15Q	Automation counter Output 15	367
ACN15R	Automation counter Reset 15	371
ACN16Q	Automation counter Output 16	367

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 19 of 79)

Name	Bit Description	Row
ACN16R	Automation counter Reset 16	371
ACN17Q	Automation counter Output 17	368
ACN17R	Automation counter Reset 17	372
ACN18Q	Automation counter Output 18	368
ACN18R	Automation counter Reset 18	372
ACN19Q	Automation counter Output 19	368
ACN19R	Automation counter Reset 19	372
ACN20Q	Automation counter Output 20	368
ACN20R	Automation counter Reset 20	372
ACN21Q	Automation counter Output 21	368
ACN21R	Automation counter Reset 21	372
ACN22Q	Automation counter Output 22	368
ACN22R	Automation counter Reset 22	372
ACN23Q	Automation counter Output 23	368
ACN23R	Automation counter Reset 23	372
ACN24Q	Automation counter Output 24	368
ACN24R	Automation counter Reset 24	372
ACN25Q	Automation counter Output 25	369
ACN25R	Automation counter Reset 25	373
ACN26Q	Automation counter Output 26	369
ACN26R	Automation counter Reset 26	373
ACN27Q	Automation counter Output 27	369
ACN27R	Automation counter Reset 27	373
ACN28Q	Automation counter Output 28	369
ACN28R	Automation counter Reset 28	373
ACN29Q	Automation counter Output 29	369
ACN29R	Automation counter Reset 29	373
ACN30Q	Automation counter Output 30	369
ACN30R	Automation counter Reset 30	373
ACN31Q	Automation counter Output 31	369
ACN31R	Automation counter Reset 31	373
ACN32Q	Automation counter Output 32	369
ACN32R	Automation counter Reset 32	373
ACT01Q	Automation conditioning timer Output 01	484
ACT02Q	Automation conditioning timer Output 02	484
ACT03Q	Automation conditioning timer Output 03	484
ACT04Q	Automation conditioning timer Output 04	484
ACT05Q	Automation conditioning timer Output 05	484
ACT06Q	Automation conditioning timer Output 06	484
ACT07Q	Automation conditioning timer Output 07	484
ACT08Q	Automation conditioning timer Output 08	484

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 20 of 79)

Name	Bit Description	Row
ACT09Q	Automation conditioning timer Output 09	485
ACT10Q	Automation conditioning timer Output 10	485
ACT11Q	Automation conditioning timer Output 11	485
ACT12Q	Automation conditioning timer Output 12	485
ACT13Q	Automation conditioning timer Output 13	485
ACT14Q	Automation conditioning timer Output 14	485
ACT15Q	Automation conditioning timer Output 15	485
ACT16Q	Automation conditioning timer Output 16	485
ACT17Q	Automation conditioning timer Output 17	486
ACT18Q	Automation conditioning timer Output 18	486
ACT19Q	Automation conditioning timer Output 19	486
ACT20Q	Automation conditioning timer Output 20	486
ACT21Q	Automation conditioning timer Output 21	486
ACT22Q	Automation conditioning timer Output 22	486
ACT23Q	Automation conditioning timer Output 23	486
ACT24Q	Automation conditioning timer Output 24	486
ACT25Q	Automation conditioning timer Output 25	487
ACT26Q	Automation conditioning timer Output 26	487
ACT27Q	Automation conditioning timer Output 27	487
ACT28Q	Automation conditioning timer Output 28	487
ACT29Q	Automation conditioning timer Output 29	487
ACT30Q	Automation conditioning timer Output 30	487
ACT31Q	Automation conditioning timer Output 31	487
ACT32Q	Automation conditioning timer Output 32	487
ACTRP1	Coupler 1 accelerated trip SELOGIC control equation	176
ACTRP2	Coupler 2 accelerated trip SELOGIC control equation	177
ACTRP3	Coupler 3 accelerated trip SELOGIC control equation	178
ACTRP4	Coupler 4 accelerated trip SELOGIC control equation	179
ACTRPT1	Coupler 1 accelerated trip timed out	176
ACTRPT2	Coupler 2 accelerated trip timed out	177
ACTRPT3	Coupler 3 accelerated trip timed out	178
ACTRPT4	Coupler 4 accelerated trip timed out	179
AFRTEXA	Automation SELOGIC control equation first execution automation	375
AFRTEXP	Automation SELOGIC control equation first execution protection	375
ALT01	Automation Latch 1	354
ALT02	Automation Latch 2	354
ALT03	Automation Latch 3	354
ALT04	Automation Latch 4	354
ALT05	Automation Latch 5	354
ALT06	Automation Latch 6	354
ALT07	Automation Latch 7	354

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 21 of 79)

Name	Bit Description	Row
ALT08	Automation Latch 8	354
ALT09	Automation Latch 9	355
ALT10	Automation Latch 10	355
ALT11	Automation Latch 11	355
ALT12	Automation Latch 12	355
ALT13	Automation Latch 13	355
ALT14	Automation Latch 14	355
ALT15	Automation Latch 15	355
ALT16	Automation Latch 16	355
ALT17	Automation Latch 17	356
ALT18	Automation Latch 18	356
ALT19	Automation Latch 19	356
ALT20	Automation Latch 20	356
ALT21	Automation Latch 21	356
ALT22	Automation Latch 22	356
ALT23	Automation Latch 23	356
ALT24	Automation Latch 24	356
ALT25	Automation Latch 25	357
ALT26	Automation Latch 26	357
ALT27	Automation Latch 27	357
ALT28	Automation Latch 28	357
ALT29	Automation Latch 29	357
ALT30	Automation Latch 30	357
ALT31	Automation Latch 31	357
ALT32	Automation Latch 32	357
ANOKA	Channel A MIRRORED BITS analog transfer OK	404
ANOKB	Channel B MIRRORED BITS analog transfer OK	405
AST01Q	Automation sequencing timer Output 1	358
AST01R	Automation sequencing timer Reset 1	362
AST02Q	Automation sequencing timer Output 2	358
AST02R	Automation sequencing timer Reset 2	362
AST03Q	Automation sequencing timer Output 3	358
AST03R	Automation sequencing timer Reset 3	362
AST04Q	Automation sequencing timer Output 4	358
AST04R	Automation sequencing timer Reset 4	362
AST05Q	Automation sequencing timer Output 5	358
AST05R	Automation sequencing timer Reset 5	362
AST06Q	Automation sequencing timer Output 6	358
AST06R	Automation sequencing timer Reset 6	362
AST07Q	Automation sequencing timer Output 7	358
AST07R	Automation sequencing timer Reset 7	362

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 22 of 79)

Name	Bit Description	Row
AST08Q	Automation sequencing timer Output 8	358
AST08R	Automation sequencing timer Reset 8	362
AST09Q	Automation sequencing timer Output 9	359
AST09R	Automation sequencing timer Reset 9	363
AST10Q	Automation sequencing timer Output 10	359
AST10R	Automation sequencing timer Reset 10	363
AST11Q	Automation sequencing timer Output 11	359
AST11R	Automation sequencing timer Reset 11	363
AST12Q	Automation sequencing timer Output 12	359
AST12R	Automation sequencing timer Reset 12	363
AST13Q	Automation sequencing timer Output 13	359
AST13R	Automation sequencing timer Reset 13	363
AST14Q	Automation sequencing timer Output 14	359
AST14R	Automation sequencing timer Reset 14	363
AST15Q	Automation sequencing timer Output 15	359
AST15R	Automation sequencing timer Reset 15	363
AST16Q	Automation sequencing timer Output 16	359
AST16R	Automation sequencing timer Reset 16	363
AST17Q	Automation sequencing timer Output 17	360
AST17R	Automation sequencing timer Reset 17	364
AST18Q	Automation sequencing timer Output 18	360
AST18R	Automation sequencing timer Reset 18	364
AST19Q	Automation sequencing timer Output 19	360
AST19R	Automation sequencing timer Reset 19	364
AST20Q	Automation sequencing timer Output 20	360
AST20R	Automation sequencing timer Reset 20	364
AST21Q	Automation sequencing timer Output 21	360
AST21R	Automation sequencing timer Reset 21	364
AST22Q	Automation sequencing timer Output 22	360
AST22R	Automation sequencing timer Reset 22	364
AST23Q	Automation sequencing timer Output 23	360
AST23R	Automation sequencing timer Reset 23	364
AST24Q	Automation sequencing timer Output 24	360
AST24R	Automation sequencing timer Reset 24	364
AST25Q	Automation sequencing timer Output 25	361
AST25R	Automation sequencing timer Reset 25	365
AST26Q	Automation sequencing timer Output 26	361
AST26R	Automation sequencing timer Reset 26	365
AST27Q	Automation sequencing timer Output 27	361
AST27R	Automation sequencing timer Reset 27	365
AST28Q	Automation sequencing timer Output 28	361

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 23 of 79)

Name	Bit Description	Row
AST28R	Automation sequencing timer Reset 28	365
AST29Q	Automation sequencing timer Output 29	361
AST29R	Automation sequencing timer Reset 29	365
AST30Q	Automation sequencing timer Output 30	361
AST30R	Automation sequencing timer Reset 30	365
AST31Q	Automation sequencing timer Output 31	361
AST31R	Automation sequencing timer Reset 31	365
AST32Q	Automation sequencing timer Output 32	361
AST32R	Automation sequencing timer Reset 32	365
ASV001	Automation SELOGIC control equation Variable 1	322
ASV002	Automation SELOGIC control equation Variable 2	322
ASV003	Automation SELOGIC control equation Variable 3	322
ASV004	Automation SELOGIC control equation Variable 4	322
ASV005	Automation SELOGIC control equation Variable 5	322
ASV006	Automation SELOGIC control equation Variable 6	322
ASV007	Automation SELOGIC control equation Variable 7	322
ASV008	Automation SELOGIC control equation Variable 8	322
ASV009	Automation SELOGIC control equation Variable 9	323
ASV010	Automation SELOGIC control equation Variable 10	323
ASV011	Automation SELOGIC control equation Variable 11	323
ASV012	Automation SELOGIC control equation Variable 12	323
ASV013	Automation SELOGIC control equation Variable 13	323
ASV014	Automation SELOGIC control equation Variable 14	323
ASV015	Automation SELOGIC control equation Variable 15	323
ASV016	Automation SELOGIC control equation Variable 16	323
ASV017	Automation SELOGIC control equation Variable 17	324
ASV018	Automation SELOGIC control equation Variable 18	324
ASV019	Automation SELOGIC control equation Variable 19	324
ASV020	Automation SELOGIC control equation Variable 20	324
ASV021	Automation SELOGIC control equation Variable 21	324
ASV022	Automation SELOGIC control equation Variable 22	324
ASV023	Automation SELOGIC control equation Variable 23	324
ASV024	Automation SELOGIC control equation Variable 24	324
ASV025	Automation SELOGIC control equation Variable 25	325
ASV026	Automation SELOGIC control equation Variable 26	325
ASV027	Automation SELOGIC control equation Variable 27	325
ASV028	Automation SELOGIC control equation Variable 28	325
ASV029	Automation SELOGIC control equation Variable 29	325
ASV030	Automation SELOGIC control equation Variable 30	325
ASV031	Automation SELOGIC control equation Variable 31	325
ASV032	Automation SELOGIC control equation Variable 32	325

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 24 of 79)

Name	Bit Description	Row
ASV033	Automation SELOGIC control equation Variable 33	326
ASV034	Automation SELOGIC control equation Variable 34	326
ASV035	Automation SELOGIC control equation Variable 35	326
ASV036	Automation SELOGIC control equation Variable 36	326
ASV037	Automation SELOGIC control equation Variable 37	326
ASV038	Automation SELOGIC control equation Variable 38	326
ASV039	Automation SELOGIC control equation Variable 39	326
ASV040	Automation SELOGIC control equation Variable 40	326
ASV041	Automation SELOGIC control equation Variable 41	327
ASV042	Automation SELOGIC control equation Variable 42	327
ASV043	Automation SELOGIC control equation Variable 43	327
ASV044	Automation SELOGIC control equation Variable 44	327
ASV045	Automation SELOGIC control equation Variable 45	327
ASV046	Automation SELOGIC control equation Variable 46	327
ASV047	Automation SELOGIC control equation Variable 47	327
ASV048	Automation SELOGIC control equation Variable 48	327
ASV049	Automation SELOGIC control equation Variable 49	328
ASV050	Automation SELOGIC control equation Variable 50	328
ASV051	Automation SELOGIC control equation Variable 51	328
ASV052	Automation SELOGIC control equation Variable 52	328
ASV053	Automation SELOGIC control equation Variable 53	328
ASV054	Automation SELOGIC control equation Variable 54	328
ASV055	Automation SELOGIC control equation Variable 55	328
ASV056	Automation SELOGIC control equation Variable 56	328
ASV057	Automation SELOGIC control equation Variable 57	329
ASV058	Automation SELOGIC control equation Variable 58	329
ASV059	Automation SELOGIC control equation Variable 59	329
ASV060	Automation SELOGIC control equation Variable 60	329
ASV061	Automation SELOGIC control equation Variable 61	329
ASV062	Automation SELOGIC control equation Variable 62	329
ASV063	Automation SELOGIC control equation Variable 63	329
ASV064	Automation SELOGIC control equation Variable 64	329
ASV065	Automation SELOGIC control equation Variable 65	330
ASV066	Automation SELOGIC control equation Variable 66	330
ASV067	Automation SELOGIC control equation Variable 67	330
ASV068	Automation SELOGIC control equation Variable 68	330
ASV069	Automation SELOGIC control equation Variable 69	330
ASV070	Automation SELOGIC control equation Variable 70	330
ASV071	Automation SELOGIC control equation Variable 71	330
ASV072	Automation SELOGIC control equation Variable 72	330
ASV073	Automation SELOGIC control equation Variable 73	331

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 25 of 79)

Name	Bit Description	Row
ASV074	Automation SELOGIC control equation Variable 74	331
ASV075	Automation SELOGIC control equation Variable 75	331
ASV076	Automation SELOGIC control equation Variable 76	331
ASV077	Automation SELOGIC control equation Variable 77	331
ASV078	Automation SELOGIC control equation Variable 78	331
ASV079	Automation SELOGIC control equation Variable 79	331
ASV080	Automation SELOGIC control equation Variable 80	331
ASV081	Automation SELOGIC control equation Variable 81	332
ASV082	Automation SELOGIC control equation Variable 82	332
ASV083	Automation SELOGIC control equation Variable 83	332
ASV084	Automation SELOGIC control equation Variable 84	332
ASV085	Automation SELOGIC control equation Variable 85	332
ASV086	Automation SELOGIC control equation Variable 86	332
ASV087	Automation SELOGIC control equation Variable 87	332
ASV088	Automation SELOGIC control equation Variable 88	332
ASV089	Automation SELOGIC control equation Variable 89	333
ASV090	Automation SELOGIC control equation Variable 90	333
ASV091	Automation SELOGIC control equation Variable 91	333
ASV092	Automation SELOGIC control equation Variable 92	333
ASV093	Automation SELOGIC control equation Variable 93	333
ASV094	Automation SELOGIC control equation Variable 94	333
ASV095	Automation SELOGIC control equation Variable 95	333
ASV096	Automation SELOGIC control equation Variable 96	333
ASV097	Automation SELOGIC control equation Variable 097	334
ASV098	Automation SELOGIC control equation Variable 098	334
ASV099	Automation SELOGIC control equation Variable 099	334
ASV100	Automation SELOGIC control equation Variable 100	334
ASV101	Automation SELOGIC control equation Variable 101	334
ASV102	Automation SELOGIC control equation Variable 102	334
ASV103	Automation SELOGIC control equation Variable 103	334
ASV104	Automation SELOGIC control equation Variable 104	334
ASV105	Automation SELOGIC control equation Variable 105	335
ASV106	Automation SELOGIC control equation Variable 106	335
ASV107	Automation SELOGIC control equation Variable 107	335
ASV108	Automation SELOGIC control equation Variable 108	335
ASV109	Automation SELOGIC control equation Variable 109	335
ASV110	Automation SELOGIC control equation Variable 110	335
ASV111	Automation SELOGIC control equation Variable 111	335
ASV112	Automation SELOGIC control equation Variable 112	335
ASV113	Automation SELOGIC control equation Variable 113	336
ASV114	Automation SELOGIC control equation Variable 114	336

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 26 of 79)

Name	Bit Description	Row
ASV115	Automation SELOGIC control equation Variable 115	336
ASV116	Automation SELOGIC control equation Variable 116	336
ASV117	Automation SELOGIC control equation Variable 117	336
ASV118	Automation SELOGIC control equation Variable 118	336
ASV119	Automation SELOGIC control equation Variable 119	336
ASV120	Automation SELOGIC control equation Variable 120	336
ASV121	Automation SELOGIC control equation Variable 121	337
ASV122	Automation SELOGIC control equation Variable 122	337
ASV123	Automation SELOGIC control equation Variable 123	337
ASV124	Automation SELOGIC control equation Variable 124	337
ASV125	Automation SELOGIC control equation Variable 125	337
ASV126	Automation SELOGIC control equation Variable 126	337
ASV127	Automation SELOGIC control equation Variable 127	337
ASV128	Automation SELOGIC control equation Variable 128	337
ASV129	Automation SELOGIC control equation Variable 129	338
ASV130	Automation SELOGIC control equation Variable 130	338
ASV131	Automation SELOGIC control equation Variable 131	338
ASV132	Automation SELOGIC control equation Variable 132	338
ASV133	Automation SELOGIC control equation Variable 133	338
ASV134	Automation SELOGIC control equation Variable 134	338
ASV135	Automation SELOGIC control equation Variable 135	338
ASV136	Automation SELOGIC control equation Variable 136	338
ASV137	Automation SELOGIC control equation Variable 137	339
ASV138	Automation SELOGIC control equation Variable 138	339
ASV139	Automation SELOGIC control equation Variable 139	339
ASV140	Automation SELOGIC control equation Variable 140	339
ASV141	Automation SELOGIC control equation Variable 141	339
ASV142	Automation SELOGIC control equation Variable 142	339
ASV143	Automation SELOGIC control equation Variable 143	339
ASV144	Automation SELOGIC control equation Variable 144	339
ASV145	Automation SELOGIC control equation Variable 145	340
ASV146	Automation SELOGIC control equation Variable 146	340
ASV147	Automation SELOGIC control equation Variable 147	340
ASV148	Automation SELOGIC control equation Variable 148	340
ASV149	Automation SELOGIC control equation Variable 149	340
ASV150	Automation SELOGIC control equation Variable 150	340
ASV151	Automation SELOGIC control equation Variable 151	340
ASV152	Automation SELOGIC control equation Variable 152	340
ASV153	Automation SELOGIC control equation Variable 153	341
ASV154	Automation SELOGIC control equation Variable 154	341
ASV155	Automation SELOGIC control equation Variable 155	341

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 27 of 79)

Name	Bit Description	Row
ASV156	Automation SELOGIC control equation Variable 156	341
ASV157	Automation SELOGIC control equation Variable 157	341
ASV158	Automation SELOGIC control equation Variable 158	341
ASV159	Automation SELOGIC control equation Variable 159	341
ASV160	Automation SELOGIC control equation Variable 160	341
ASV161	Automation SELOGIC control equation Variable 161	342
ASV162	Automation SELOGIC control equation Variable 162	342
ASV163	Automation SELOGIC control equation Variable 163	342
ASV164	Automation SELOGIC control equation Variable 164	342
ASV165	Automation SELOGIC control equation Variable 165	342
ASV166	Automation SELOGIC control equation Variable 166	342
ASV167	Automation SELOGIC control equation Variable 167	342
ASV168	Automation SELOGIC control equation Variable 168	342
ASV169	Automation SELOGIC control equation Variable 169	343
ASV170	Automation SELOGIC control equation Variable 170	343
ASV171	Automation SELOGIC control equation Variable 171	343
ASV172	Automation SELOGIC control equation Variable 172	343
ASV173	Automation SELOGIC control equation Variable 173	343
ASV174	Automation SELOGIC control equation Variable 174	343
ASV175	Automation SELOGIC control equation Variable 175	343
ASV176	Automation SELOGIC control equation Variable 176	343
ASV177	Automation SELOGIC control equation Variable 177	344
ASV178	Automation SELOGIC control equation Variable 178	344
ASV179	Automation SELOGIC control equation Variable 179	344
ASV180	Automation SELOGIC control equation Variable 180	344
ASV181	Automation SELOGIC control equation Variable 181	344
ASV182	Automation SELOGIC control equation Variable 182	344
ASV183	Automation SELOGIC control equation Variable 183	344
ASV184	Automation SELOGIC control equation Variable 184	344
ASV185	Automation SELOGIC control equation Variable 185	345
ASV186	Automation SELOGIC control equation Variable 186	345
ASV187	Automation SELOGIC control equation Variable 187	345
ASV188	Automation SELOGIC control equation Variable 188	345
ASV189	Automation SELOGIC control equation Variable 189	345
ASV190	Automation SELOGIC control equation Variable 190	345
ASV191	Automation SELOGIC control equation Variable 191	345
ASV192	Automation SELOGIC control equation Variable 192	345
ASV193	Automation SELOGIC control equation Variable 193	346
ASV194	Automation SELOGIC control equation Variable 194	346
ASV195	Automation SELOGIC control equation Variable 195	346
ASV196	Automation SELOGIC control equation Variable 196	346

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 28 of 79)

Name	Bit Description	Row
ASV197	Automation SELOGIC control equation Variable 197	346
ASV198	Automation SELOGIC control equation Variable 198	346
ASV199	Automation SELOGIC control equation Variable 199	346
ASV200	Automation SELOGIC control equation Variable 200	346
ASV201	Automation SELOGIC control equation Variable 201	347
ASV202	Automation SELOGIC control equation Variable 202	347
ASV203	Automation SELOGIC control equation Variable 203	347
ASV204	Automation SELOGIC control equation Variable 204	347
ASV205	Automation SELOGIC control equation Variable 205	347
ASV206	Automation SELOGIC control equation Variable 206	347
ASV207	Automation SELOGIC control equation Variable 207	347
ASV208	Automation SELOGIC control equation Variable 208	347
ASV209	Automation SELOGIC control equation Variable 209	348
ASV210	Automation SELOGIC control equation Variable 210	348
ASV211	Automation SELOGIC control equation Variable 211	348
ASV212	Automation SELOGIC control equation Variable 212	348
ASV213	Automation SELOGIC control equation Variable 213	348
ASV214	Automation SELOGIC control equation Variable 214	348
ASV215	Automation SELOGIC control equation Variable 215	348
ASV216	Automation SELOGIC control equation Variable 216	348
ASV217	Automation SELOGIC control equation Variable 217	349
ASV218	Automation SELOGIC control equation Variable 218	349
ASV219	Automation SELOGIC control equation Variable 219	349
ASV220	Automation SELOGIC control equation Variable 220	349
ASV221	Automation SELOGIC control equation Variable 221	349
ASV222	Automation SELOGIC control equation Variable 222	349
ASV223	Automation SELOGIC control equation Variable 223	349
ASV224	Automation SELOGIC control equation Variable 224	349
ASV225	Automation SELOGIC control equation Variable 225	350
ASV226	Automation SELOGIC control equation Variable 226	350
ASV227	Automation SELOGIC control equation Variable 227	350
ASV228	Automation SELOGIC control equation Variable 228	350
ASV229	Automation SELOGIC control equation Variable 229	350
ASV230	Automation SELOGIC control equation Variable 230	350
ASV231	Automation SELOGIC control equation Variable 231	350
ASV232	Automation SELOGIC control equation Variable 232	350
ASV233	Automation SELOGIC control equation Variable 233	351
ASV234	Automation SELOGIC control equation Variable 234	351
ASV235	Automation SELOGIC control equation Variable 235	351
ASV236	Automation SELOGIC control equation Variable 236	351
ASV237	Automation SELOGIC control equation Variable 237	351

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 29 of 79)

Name	Bit Description	Row
ASV238	Automation SELOGIC control equation Variable 238	351
ASV239	Automation SELOGIC control equation Variable 239	351
ASV240	Automation SELOGIC control equation Variable 240	351
ASV241	Automation SELOGIC control equation Variable 241	352
ASV242	Automation SELOGIC control equation Variable 242	352
ASV243	Automation SELOGIC control equation Variable 243	352
ASV244	Automation SELOGIC control equation Variable 244	352
ASV245	Automation SELOGIC control equation Variable 245	352
ASV246	Automation SELOGIC control equation Variable 246	352
ASV247	Automation SELOGIC control equation Variable 247	352
ASV248	Automation SELOGIC control equation Variable 248	352
ASV249	Automation SELOGIC control equation Variable 249	353
ASV250	Automation SELOGIC control equation Variable 250	353
ASV251	Automation SELOGIC control equation Variable 251	353
ASV252	Automation SELOGIC control equation Variable 252	353
ASV253	Automation SELOGIC control equation Variable 253	353
ASV254	Automation SELOGIC control equation Variable 254	353
ASV255	Automation SELOGIC control equation Variable 255	353
ASV256	Automation SELOGIC control equation Variable 256	353
ATBFI01	Circuit Breaker 1 alternate breaker failure initiate SELOGIC control equation	183
ATBFI02	Circuit Breaker 2 alternate breaker failure initiate SELOGIC control equation	184
ATBFI03	Circuit Breaker 3 alternate breaker failure initiate SELOGIC control equation	185
ATBFI04	Circuit Breaker 4 alternate breaker failure initiate SELOGIC control equation	186
ATBFI05	Circuit Breaker 5 alternate breaker failure initiate SELOGIC control equation	187
ATBFI06	Circuit Breaker 6 alternate breaker failure initiate SELOGIC control equation	188
ATBFI07	Circuit Breaker 7 alternate breaker failure initiate SELOGIC control equation	189
ATBFI08	Circuit Breaker 8 alternate breaker failure initiate SELOGIC control equation	190
ATBFI09	Circuit Breaker 9 alternate breaker failure initiate SELOGIC control equation	191
ATBFI10	Circuit Breaker 10 alternate breaker failure initiate SELOGIC control equation	192
ATBFI11	Circuit Breaker 11 alternate breaker failure initiate SELOGIC control equation	193
ATBFI12	Circuit Breaker 12 alternate breaker failure initiate SELOGIC control equation	194
ATBFI13	Circuit Breaker 13 alternate breaker failure initiate SELOGIC control equation	195
ATBFI14	Circuit Breaker 14 alternate breaker failure initiate SELOGIC control equation	196
ATBFI15	Circuit Breaker 15 alternate breaker failure initiate SELOGIC control equation	197
ATBFI16	Circuit Breaker 16 alternate breaker failure initiate SELOGIC control equation	198
ATBFI17	Circuit Breaker 17 alternate breaker failure initiate SELOGIC control equation	199
ATBFI18	Circuit Breaker 18 alternate breaker failure initiate SELOGIC control equation	200
ATBFI19	Circuit Breaker 19 alternate breaker failure initiate SELOGIC control equation	201
ATBFI20	Circuit Breaker 20 alternate breaker failure initiate SELOGIC control equation	202
ATBFI21	Circuit Breaker 21 alternate breaker failure initiate SELOGIC control equation	203
AUNRLBL	Automation SELOGIC control equation unresolved label	375

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 30 of 79)

Name	Bit Description	Row
BADPASS	Pulsed when user enters three successive bad passwords	376
BFI01	Circuit Breaker 1 breaker failure initiate SELOGIC control equation	183
BFI02	Circuit Breaker 2 breaker failure initiate SELOGIC control equation	184
BFI03	Circuit Breaker 3 breaker failure initiate SELOGIC control equation	185
BFI04	Circuit Breaker 4 breaker failure initiate SELOGIC control equation	186
BFI05	Circuit Breaker 5 breaker failure initiate SELOGIC control equation	187
BFI06	Circuit Breaker 6 breaker failure initiate SELOGIC control equation	188
BFI07	Circuit Breaker 7 breaker failure initiate SELOGIC control equation	189
BFI08	Circuit Breaker 8 breaker failure initiate SELOGIC control equation	190
BFI09	Circuit Breaker 9 breaker failure initiate SELOGIC control equation	191
BFI10	Circuit Breaker 10 breaker failure initiate SELOGIC control equation	192
BFI11	Circuit Breaker 11 breaker failure initiate SELOGIC control equation	193
BFI12	Circuit Breaker 12 breaker failure initiate SELOGIC control equation	194
BFI13	Circuit Breaker 13 breaker failure initiate SELOGIC control equation	195
BFI14	Circuit Breaker 14 breaker failure initiate SELOGIC control equation	196
BFI15	Circuit Breaker 15 breaker failure initiate SELOGIC control equation	197
BFI16	Circuit Breaker 16 breaker failure initiate SELOGIC control equation	198
BFI17	Circuit Breaker 17 breaker failure initiate SELOGIC control equation	199
BFI18	Circuit Breaker 18 breaker failure initiate SELOGIC control equation	200
BFI19	Circuit Breaker 19 breaker failure initiate SELOGIC control equation	201
BFI20	Circuit Breaker 20 breaker failure initiate SELOGIC control equation	202
BFI21	Circuit Breaker 21 breaker failure initiate SELOGIC control equation	203
BFIT01	Circuit Breaker 1 breaker failure timed out	183
BFIT02	Circuit Breaker 2 breaker failure timed out	184
BFIT03	Circuit Breaker 3 breaker failure timed out	185
BFIT04	Circuit Breaker 4 breaker failure timed out	186
BFIT05	Circuit Breaker 5 breaker failure timed out	187
BFIT06	Circuit Breaker 6 breaker failure timed out	188
BFIT07	Circuit Breaker 7 breaker failure timed out	189
BFIT08	Circuit Breaker 8 breaker failure timed out	190
BFIT09	Circuit Breaker 9 breaker failure timed out	191
BFIT10	Circuit Breaker 10 breaker failure timed out	192
BFIT11	Circuit Breaker 11 breaker failure timed out	193
BFIT12	Circuit Breaker 12 breaker failure timed out	194
BFIT13	Circuit Breaker 13 breaker failure timed out	195
BFIT14	Circuit Breaker 14 breaker failure timed out	196
BFIT15	Circuit Breaker 15 breaker failure timed out	197
BFIT16	Circuit Breaker 16 breaker failure timed out	198
BFIT17	Circuit Breaker 17 breaker failure timed out	199
BFIT18	Circuit Breaker 18 breaker failure timed out	200
BFIT19	Circuit Breaker 19 breaker failure timed out	201

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 31 of 79)

Name	Bit Description	Row
BFIT20	Circuit Breaker 20 breaker failure timed out	202
BFIT21	Circuit Breaker 21 breaker failure timed out	203
BFZ1	Zone 1 breaker failure	240
BFZ2	Zone 2 breaker failure	240
BFZ3	Zone 3 breaker failure	240
BFZ4	Zone 4 breaker failure	240
BFZ5	Zone 5 breaker failure	240
BFZ6	Zone 6 breaker failure	240
BLKLPTS	Block low-priority source from updating relay time	379
BNC_BNP	Bad jitter on BNC port and the IRIG-B signal is lost afterwards	472
BNC_OK	IRIG-B signal from BNC port is available and has sufficient quality	472
BNC_RST	Disqualify BNC IRIG-B time source	472
BNC_SET	Qualify BNC IRIG-B time source	472
BNC_TIM	A valid IRIG-B time source is detected on BNC port	473
BNCSYNC	Synchronized to a high-quality BNC IRIG source	474
BRKENAB	Asserts to indicate breaker control enable jumper is installed	377
BZ1BZ2R	A connection exists between BZ1 and BZ2 and a coupler is removed	136
BZ1BZ2V	A connection exists between BZ1 and BZ2	128
BZ1BZ3R	A connection exists between BZ1 and BZ3 and a coupler is removed	136
BZ1BZ3V	A connection exists between BZ1 and BZ3	128
BZ1BZ4R	A connection exists between BZ1 and BZ4 and a coupler is removed	136
BZ1BZ4V	A connection exists between BZ1 and BZ4	128
BZ1BZ5R	A connection exists between BZ1 and BZ5 and a coupler is removed	136
BZ1BZ5V	A connection exists between BZ1 and BZ5	128
BZ1BZ6R	A connection exists between BZ1 and BZ6 and a coupler is removed	136
BZ1BZ6V	A connection exists between BZ1 and BZ6	128
BZ2BZ3R	A connection exists between BZ2 and BZ3 and a coupler is removed	137
BZ2BZ3V	A connection exists between BZ2 and BZ3	129
BZ2BZ4R	A connection exists between BZ2 and BZ4 and a coupler is removed	137
BZ2BZ4V	A connection exists between BZ2 and BZ4	129
BZ2BZ5R	A connection exists between BZ2 and BZ5 and a coupler is removed	137
BZ2BZ5V	A connection exists between BZ2 and BZ5	129
BZ2BZ6R	A connection exists between BZ2 and BZ6 and a coupler is removed	137
BZ2BZ6V	A connection exists between BZ2 and BZ6	129
BZ3BZ4R	A connection exists between BZ3 and BZ4 and a coupler is removed	138
BZ3BZ4V	A connection exists between BZ3 and BZ4	130
BZ3BZ5R	A connection exists between BZ3 and BZ5 and a coupler is removed	138
BZ3BZ5V	A connection exists between BZ3 and BZ5	130
BZ3BZ6R	A connection exists between BZ3 and BZ6 and a coupler is removed	138
BZ3BZ6V	A connection exists between BZ3 and BZ6	130
BZ4BZ5R	A connection exists between BZ4 and BZ5 and a coupler is removed	139

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 32 of 79)

Name	Bit Description	Row
BZ4BZ5V	A connection exists between BZ4 and BZ5	131
BZ4BZ6R	A connection exists between BZ4 and BZ6 and a coupler is removed	139
BZ4BZ6V	A connection exists between BZ4 and BZ6	131
BZ5BZ6R	A connection exists between BZ5 and BZ6 and a coupler is removed	140
BZ5BZ6V	A connection exists between BZ5 and BZ6	132
CB52A1	Coupler 1 status SELOGIC control equation	176
CB52A2	Coupler 2 status SELOGIC control equation	177
CB52A3	Coupler 3 status SELOGIC control equation	178
CB52A4	Coupler 4 status SELOGIC control equation	179
CB52T1	Coupler 1 status timed out	176
CB52T2	Coupler 2 status timed out	177
CB52T3	Coupler 3 status timed out	178
CB52T4	Coupler 4 status timed out	179
CBADA	Channel A MIRRORED BITS unavailability	404
CBADB	Channel B MIRRORED BITS unavailability	405
CBCLS1	Coupler 1 close command SELOGIC control equation	176
CBCLS2	Coupler 2 close command SELOGIC control equation	177
CBCLS3	Coupler 3 close command SELOGIC control equation	178
CBCLS4	Coupler 4 close command SELOGIC control equation	179
CBCLST1	Coupler 1 close command timed out	176
CBCLST2	Coupler 2 close command timed out	177
CBCLST3	Coupler 3 close command timed out	178
CBCLST4	Coupler 4 close command timed out	179
CHSG	Asserted during settings group change	255
CON1	Zone 1 in high-security mode	159
CON2	Zone 2 in high-security mode	161
CON3	Zone 3 in high-security mode	163
CON4	Zone 4 in high-security mode	165
CON5	Zone 5 in high-security mode	167
CON6	Zone 6 in high-security mode	169
CONCZ1	Check Zone 1 in high-security mode	450
CONCZ2	Check Zone 2 in high-security mode	452
CONCZ3	Check Zone 3 in high-security mode	454
CSL1	Coupler 1 security logic picked up	176
CSL2	Coupler 2 security logic picked up	177
CSL3	Coupler 3 security logic picked up	178
CSL4	Coupler 4 security logic picked up	179
CZ11R	Include Bus Coupler 1 in Check Zone 1	407
CZ12R	Include Bus Coupler 2 in Check Zone 1	407
CZ13R	Include Bus Coupler 3 in Check Zone 1	407
CZ14R	Include Bus Coupler 4 in Check Zone 1	407

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 33 of 79)

Name	Bit Description	Row
CZ1S	Check Zone 1 supervision asserted	446
CZ21R	Include Bus Coupler 1 in Check Zone 2	407
CZ22R	Include Bus Coupler 2 in Check Zone 2	407
CZ23R	Include Bus Coupler 3 in Check Zone 2	407
CZ24R	Include Bus Coupler 4 in Check Zone 2	407
CZ2S	Check Zone 2 supervision asserted	446
CZ31R	Include Bus Coupler 1 in Check Zone 3	443
CZ32R	Include Bus Coupler 2 in Check Zone 3	443
CZ33R	Include Bus Coupler 3 in Check Zone 3	443
CZ34R	Include Bus Coupler 4 in Check Zone 3	443
CZ3S	Check Zone 3 supervision asserted	446
CZONE1	Check Zone 1 is active	445
CZONE2	Check Zone 2 is active	445
CZONE3	Check Zone 3 is active	445
DC1F	DC monitor fail alarm	227
DC1G	DC monitor ground fault alarm	227
DC1R	DC monitor alarm for ac ripple	227
DC1W	DC monitor warning alarm	227
DE1F	Zone 1 forward directional element picked up	172
DE2F	Zone 2 forward directional element picked up	172
DE3F	Zone 3 forward directional element picked up	172
DE4F	Zone 4 forward directional element picked up	172
DE5F	Zone 5 forward directional element picked up	172
DE6F	Zone 6 forward directional element picked up	172
DECZ1F	Check Zone 1 forward directional element picked up	456
DECZ2F	Check Zone 2 forward directional element picked up	456
DECZ3F	Check Zone 3 forward directional element picked up	456
DOKA	Channel A MIRRORED BITS communications normal status	404
DOKB	Channel B MIRRORED BITS communications normal status	405
DOP1	Zone 1 incremental operating current picked up	159
DOP2	Zone 2 incremental operating current picked up	161
DOP3	Zone 3 incremental operating current picked up	163
DOP4	Zone 4 incremental operating current picked up	165
DOP5	Zone 5 incremental operating current picked up	167
DOP6	Zone 6 incremental operating current picked up	169
DOPCZ1	Check Zone 1 incremental operating current picked up	450
DOPCZ2	Check Zone 2 incremental operating current picked up	452
DOPCZ3	Check Zone 3 incremental operating current picked up	454
DRT1	Zone 1 incremental restraint current picked up	159
DRT2	Zone 2 incremental restraint current picked up	161
DRT3	Zone 3 incremental restraint current picked up	163

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 34 of 79)

Name	Bit Description	Row
DRT4	Zone 4 incremental restraint current picked up	165
DRT5	Zone 5 incremental restraint current picked up	167
DRT6	Zone 6 incremental restraint current picked up	169
DRTCZ1	Check Zone 1 incremental restraint current picked up	450
DRTCZ2	Check Zone 2 incremental restraint current picked up	452
DRTCZ3	Check Zone 3 incremental restraint current picked up	454
DST	Daylight-saving time	470
DSTP	IRIG-B daylight-saving time pending	470
DUMMY	0	471
E2AC	Enable Levels 1–2 access (SELOGIC control equation)	377
EACC	Enable Level 1 access (SELOGIC control equation)	377
EN	Relay enabled	0
ER	Event report trigger equation (SELOGIC control equation)	241
EVELOCK	Event summary lock period	241
EXT1	Zone 1 external fault declaration	159
EXT2	Zone 2 external fault declaration	161
EXT3	Zone 3 external fault declaration	163
EXT4	Zone 4 external fault declaration	165
EXT5	Zone 5 external fault declaration	167
EXT6	Zone 6 external fault declaration	169
EXTCZ1	Check Zone 1 external fault declaration	450
EXTCZ2	Check Zone 2 external fault declaration	452
EXTCZ3	Check Zone 3 external fault declaration	454
FAULT	Busbar fault in any zone	171
FAULT1	Zone 1 fault detector picked up	159
FAULT2	Zone 2 fault detector picked up	161
FAULT3	Zone 3 fault detector picked up	163
FAULT4	Zone 4 fault detector picked up	165
FAULT5	Zone 5 fault detector picked up	167
FAULT6	Zone 6 fault detector picked up	169
FBF01	Circuit Breaker 1 failure	183
FBF02	Circuit Breaker 2 failure	184
FBF03	Circuit Breaker 3 failure	185
FBF04	Circuit Breaker 4 failure	186
FBF05	Circuit Breaker 5 failure	187
FBF06	Circuit Breaker 6 failure	188
FBF07	Circuit Breaker 7 failure	189
FBF08	Circuit Breaker 8 failure	190
FBF09	Circuit Breaker 9 failure	191
FBF10	Circuit Breaker 10 failure	192
FBF11	Circuit Breaker 11 failure	193

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 35 of 79)

Name	Bit Description	Row
FBF12	Circuit Breaker 12 failure	194
FBF13	Circuit Breaker 13 failure	195
FBF14	Circuit Breaker 14 failure	196
FBF15	Circuit Breaker 15 failure	197
FBF16	Circuit Breaker 16 failure	198
FBF17	Circuit Breaker 17 failure	199
FBF18	Circuit Breaker 18 failure	200
FBF19	Circuit Breaker 19 failure	201
FBF20	Circuit Breaker 20 failure	202
FBF21	Circuit Breaker 21 failure	203
FDIF1	Zone 1 filtered restrained differential element picked up	160
FDIF2	Zone 2 filtered restrained differential element picked up	162
FDIF3	Zone 3 filtered restrained differential element picked up	164
FDIF4	Zone 4 filtered restrained differential element picked up	166
FDIF5	Zone 5 filtered restrained differential element picked up	168
FDIF6	Zone 6 filtered restrained differential element picked up	170
FDIFCZ1	Check Zone 1 filtered restrained differential element picked up	451
FDIFCZ2	Check Zone 2 filtered restrained differential element picked up	453
FDIFCZ3	Check Zone 3 filtered restrained differential element picked up	455
FLTCZ1	Check Zone 1 fault detector picked up	450
FLTCZ2	Check Zone 2 fault detector picked up	452
FLTCZ3	Check Zone 3 fault detector picked up	454
FSERP1	Fast SER enabled for Serial Port 1	444
FSERP2	Fast SER enabled for Serial Port 2	444
FSERP3	Fast SER enabled for Serial Port 3	444
FSERP5	Fast SER enabled for Serial Port 5	444
FSERPF	Fast SER enabled for Serial Port F	444
GFAULT1	Zone 1 fast fault detection	160
GFAULT2	Zone 2 fast fault detection	162
GFAULT3	Zone 3 fast fault detection	164
GFAULT4	Zone 4 fast fault detection	166
GFAULT5	Zone 5 fast fault detection	168
GFAULT6	Zone 6 fast fault detection	170
GFLTCZ1	Check Zone 1 fast fault detection	451
GFLTCZ2	Check Zone 2 fast fault detection	453
GFLTCZ3	Check Zone 3 fast fault detection	455
GRPSW	Pulsed when settings group changes	376
HALARM	Relay diagnostic failure or warning	376
HALARMA	Relay warning periodic alarm	376
HALARML	Latching relay failure alarm	376
HALARMP	Relay warning alarm pulse	376

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 36 of 79)

Name	Bit Description	Row
I01BZ1V	Terminal I01 connected to BZ1	56
I01BZ2V	Terminal I01 connected to BZ2	60
I01BZ3V	Terminal I01 connected to BZ3	64
I01BZ4V	Terminal I01 connected to BZ4	68
I01BZ5V	Terminal I01 connected to BZ5	72
I01BZ6V	Terminal I01 connected to BZ6	76
I02BZ1V	Terminal I02 connected to BZ1	56
I02BZ2V	Terminal I02 connected to BZ2	60
I02BZ3V	Terminal I02 connected to BZ3	64
I02BZ4V	Terminal I02 connected to BZ4	68
I02BZ5V	Terminal I02 connected to BZ5	72
I02BZ6V	Terminal I02 connected to BZ6	76
I03BZ1V	Terminal I03 connected to BZ1	56
I03BZ2V	Terminal I03 connected to BZ2	60
I03BZ3V	Terminal I03 connected to BZ3	64
I03BZ4V	Terminal I03 connected to BZ4	68
I03BZ5V	Terminal I03 connected to BZ5	72
I03BZ6V	Terminal I03 connected to BZ6	76
I04BZ1V	Terminal I04 connected to BZ1	56
I04BZ2V	Terminal I04 connected to BZ2	60
I04BZ3V	Terminal I04 connected to BZ3	64
I04BZ4V	Terminal I04 connected to BZ4	68
I04BZ5V	Terminal I04 connected to BZ5	72
I04BZ6V	Terminal I04 connected to BZ6	76
I05BZ1V	Terminal I05 connected to BZ1	56
I05BZ2V	Terminal I05 connected to BZ2	60
I05BZ3V	Terminal I05 connected to BZ3	64
I05BZ4V	Terminal I05 connected to BZ4	68
I05BZ5V	Terminal I05 connected to BZ5	72
I05BZ6V	Terminal I05 connected to BZ6	76
I06BZ1V	Terminal I06 connected to BZ1	56
I06BZ2V	Terminal I06 connected to BZ2	60
I06BZ3V	Terminal I06 connected to BZ3	64
I06BZ4V	Terminal I06 connected to BZ4	68
I06BZ5V	Terminal I06 connected to BZ5	72
I06BZ6V	Terminal I06 connected to BZ6	76
I07BZ1V	Terminal I07 connected to BZ1	56
I07BZ2V	Terminal I07 connected to BZ2	60
I07BZ3V	Terminal I07 connected to BZ3	64
I07BZ4V	Terminal I07 connected to BZ4	68
I07BZ5V	Terminal I07 connected to BZ5	72

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 37 of 79)

Name	Bit Description	Row
I07BZ6V	Terminal I07 connected to BZ6	76
I08BZ1V	Terminal I08 connected to BZ1	56
I08BZ2V	Terminal I08 connected to BZ2	60
I08BZ3V	Terminal I08 connected to BZ3	64
I08BZ4V	Terminal I08 connected to BZ4	68
I08BZ5V	Terminal I08 connected to BZ5	72
I08BZ6V	Terminal I08 connected to BZ6	76
I09BZ1V	Terminal I09 connected to BZ1	57
I09BZ2V	Terminal I09 connected to BZ2	61
I09BZ3V	Terminal I09 connected to BZ3	65
I09BZ4V	Terminal I09 connected to BZ4	69
I09BZ5V	Terminal I09 connected to BZ5	73
I09BZ6V	Terminal I09 connected to BZ6	77
I10BZ1V	Terminal I10 connected to BZ1	57
I10BZ2V	Terminal I10 connected to BZ2	61
I10BZ3V	Terminal I10 connected to BZ3	65
I10BZ4V	Terminal I10 connected to BZ4	69
I10BZ5V	Terminal I10 connected to BZ5	73
I10BZ6V	Terminal I10 connected to BZ6	77
I11BZ1V	Terminal I11 connected to BZ1	57
I11BZ2V	Terminal I11 connected to BZ2	61
I11BZ3V	Terminal I11 connected to BZ3	65
I11BZ4V	Terminal I11 connected to BZ4	69
I11BZ5V	Terminal I11 connected to BZ5	73
I11BZ6V	Terminal I11 connected to BZ6	77
I12BZ1V	Terminal I12 connected to BZ1	57
I12BZ2V	Terminal I12 connected to BZ2	61
I12BZ3V	Terminal I12 connected to BZ3	65
I12BZ4V	Terminal I12 connected to BZ4	69
I12BZ5V	Terminal I12 connected to BZ5	73
I12BZ6V	Terminal I12 connected to BZ6	77
I13BZ1V	Terminal I13 connected to BZ1	57
I13BZ2V	Terminal I13 connected to BZ2	61
I13BZ3V	Terminal I13 connected to BZ3	65
I13BZ4V	Terminal I13 connected to BZ4	69
I13BZ5V	Terminal I13 connected to BZ5	73
I13BZ6V	Terminal I13 connected to BZ6	77
I14BZ1V	Terminal I14 connected to BZ1	57
I14BZ2V	Terminal I14 connected to BZ2	61
I14BZ3V	Terminal I14 connected to BZ3	65
I14BZ4V	Terminal I14 connected to BZ4	69

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 38 of 79)

Name	Bit Description	Row
I14BZ5V	Terminal I14 connected to BZ5	73
I14BZ6V	Terminal I14 connected to BZ6	77
I15BZ1V	Terminal I15 connected to BZ1	57
I15BZ2V	Terminal I15 connected to BZ2	61
I15BZ3V	Terminal I15 connected to BZ3	65
I15BZ4V	Terminal I15 connected to BZ4	69
I15BZ5V	Terminal I15 connected to BZ5	73
I15BZ6V	Terminal I15 connected to BZ6	77
I16BZ1V	Terminal I16 connected to BZ1	57
I16BZ2V	Terminal I16 connected to BZ2	61
I16BZ3V	Terminal I16 connected to BZ3	65
I16BZ4V	Terminal I16 connected to BZ4	69
I16BZ5V	Terminal I16 connected to BZ5	73
I16BZ6V	Terminal I16 connected to BZ6	77
I17BZ1V	Terminal I17 connected to BZ1	58
I17BZ2V	Terminal I17 connected to BZ2	62
I17BZ3V	Terminal I17 connected to BZ3	66
I17BZ4V	Terminal I17 connected to BZ4	70
I17BZ5V	Terminal I17 connected to BZ5	74
I17BZ6V	Terminal I17 connected to BZ6	78
I18BZ1V	Terminal I18 connected to BZ1	58
I18BZ2V	Terminal I18 connected to BZ2	62
I18BZ3V	Terminal I18 connected to BZ3	66
I18BZ4V	Terminal I18 connected to BZ4	70
I18BZ5V	Terminal I18 connected to BZ5	74
I18BZ6V	Terminal I18 connected to BZ6	78
I19BZ1V	Terminal I19 connected to BZ1	58
I19BZ2V	Terminal I19 connected to BZ2	62
I19BZ3V	Terminal I19 connected to BZ3	66
I19BZ4V	Terminal I19 connected to BZ4	70
I19BZ5V	Terminal I19 connected to BZ5	74
I19BZ6V	Terminal I19 connected to BZ6	78
I20BZ1V	Terminal I20 connected to BZ1	58
I20BZ2V	Terminal I20 connected to BZ2	62
I20BZ3V	Terminal I20 connected to BZ3	66
I20BZ4V	Terminal I20 connected to BZ4	70
I20BZ5V	Terminal I20 connected to BZ5	74
I20BZ6V	Terminal I20 connected to BZ6	78
I21BZ1V	Terminal I21 connected to BZ1	58
I21BZ2V	Terminal I21 connected to BZ2	62
I21BZ3V	Terminal I21 connected to BZ3	66

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 39 of 79)

Name	Bit Description	Row
I21BZ4V	Terminal I21 connected to BZ4	70
I21BZ5V	Terminal I21 connected to BZ5	74
I21BZ6V	Terminal I21 connected to BZ6	78
IFAULT1	Zone 1 fault detection	160
IFAULT2	Zone 2 fault detection	162
IFAULT3	Zone 3 fault detection	164
IFAULT4	Zone 4 fault detection	166
IFAULT5	Zone 5 fault detection	168
IFAULT6	Zone 6 fault detection	170
IFLTCZ1	Check Zone 1 fault detection	451
IFLTCZ2	Check Zone 2 fault detection	453
IFLTCZ3	Check Zone 3 fault detection	455
IN101	Main board Input 01	272
IN102	Main board Input 02	272
IN103	Main board Input 03	272
IN104	Main board Input 04	272
IN105	Main board Input 05	272
IN106	Main board Input 06	272
IN107	Main board Input 07	272
IN201	Optional I/O Board 1 Input 01	276
IN202	Optional I/O Board 1 Input 02	276
IN203	Optional I/O Board 1 Input 03	276
IN204	Optional I/O Board 1 Input 04	276
IN205	Optional I/O Board 1 Input 05	276
IN206	Optional I/O Board 1 Input 06	276
IN207	Optional I/O Board 1 Input 07	276
IN208	Optional I/O Board 1 Input 08	276
IN209	Optional I/O Board 1 Input 09	277
IN210	Optional I/O Board 1 Input 10	277
IN211	Optional I/O Board 1 Input 11	277
IN212	Optional I/O Board 1 Input 12	277
IN213	Optional I/O Board 1 Input 13	277
IN214	Optional I/O Board 1 Input 14	277
IN215	Optional I/O Board 1 Input 15	277
IN216	Optional I/O Board 1 Input 16	277
IN217	Optional I/O Board 1 Input 17	278
IN218	Optional I/O Board 1 Input 18	278
IN219	Optional I/O Board 1 Input 19	278
IN220	Optional I/O Board 1 Input 20	278
IN221	Optional I/O Board 1 Input 21	278
IN222	Optional I/O Board 1 Input 22	278

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 40 of 79)

Name	Bit Description	Row
IN223	Optional I/O Board 1 Input 23	278
IN224	Optional I/O Board 1 Input 24	278
IN301	Optional I/O Board 2 Input 01	280
IN302	Optional I/O Board 2 Input 02	280
IN303	Optional I/O Board 2 Input 03	280
IN304	Optional I/O Board 2 Input 04	280
IN305	Optional I/O Board 2 Input 05	280
IN306	Optional I/O Board 2 Input 06	280
IN307	Optional I/O Board 2 Input 07	280
IN308	Optional I/O Board 2 Input 08	280
IN309	Optional I/O Board 2 Input 09	281
IN310	Optional I/O Board 2 Input 10	281
IN311	Optional I/O Board 2 Input 11	281
IN312	Optional I/O Board 2 Input 12	281
IN313	Optional I/O Board 2 Input 13	281
IN314	Optional I/O Board 2 Input 14	281
IN315	Optional I/O Board 2 Input 15	281
IN316	Optional I/O Board 2 Input 16	281
IN317	Optional I/O Board 2 Input 17	282
IN318	Optional I/O Board 2 Input 18	282
IN319	Optional I/O Board 2 Input 19	282
IN320	Optional I/O Board 2 Input 20	282
IN321	Optional I/O Board 2 Input 21	282
IN322	Optional I/O Board 2 Input 22	282
IN323	Optional I/O Board 2 Input 23	282
IN324	Optional I/O Board 2 Input 24	282
IN401	Optional I/O Board 3 Input 01	284
IN402	Optional I/O Board 3 Input 02	284
IN403	Optional I/O Board 3 Input 03	284
IN404	Optional I/O Board 3 Input 04	284
IN405	Optional I/O Board 3 Input 05	284
IN406	Optional I/O Board 3 Input 06	284
IN407	Optional I/O Board 3 Input 07	284
IN408	Optional I/O Board 3 Input 08	284
IN409	Optional I/O Board 3 Input 09	285
IN410	Optional I/O Board 3 Input 10	285
IN411	Optional I/O Board 3 Input 11	285
IN412	Optional I/O Board 3 Input 12	285
IN413	Optional I/O Board 3 Input 13	285
IN414	Optional I/O Board 3 Input 14	285
IN415	Optional I/O Board 3 Input 15	285

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 41 of 79)

Name	Bit Description	Row
IN416	Optional I/O Board 3 Input 16	285
IN417	Optional I/O Board 3 Input 17	286
IN418	Optional I/O Board 3 Input 18	286
IN419	Optional I/O Board 3 Input 19	286
IN420	Optional I/O Board 3 Input 20	286
IN421	Optional I/O Board 3 Input 21	286
IN422	Optional I/O Board 3 Input 22	286
IN423	Optional I/O Board 3 Input 23	286
IN424	Optional I/O Board 3 Input 24	286
IN501	Optional I/O Board 4 Input 01	288
IN502	Optional I/O Board 4 Input 02	288
IN503	Optional I/O Board 4 Input 03	288
IN504	Optional I/O Board 4 Input 04	288
IN505	Optional I/O Board 4 Input 05	288
IN506	Optional I/O Board 4 Input 06	288
IN507	Optional I/O Board 4 Input 07	288
IN508	Optional I/O Board 4 Input 08	288
IN509	Optional I/O Board 4 Input 09	289
IN510	Optional I/O Board 4 Input 10	289
IN511	Optional I/O Board 4 Input 11	289
IN512	Optional I/O Board 4 Input 12	289
IN513	Optional I/O Board 4 Input 13	289
IN514	Optional I/O Board 4 Input 14	289
IN515	Optional I/O Board 4 Input 15	289
IN516	Optional I/O Board 4 Input 16	289
IN517	Optional I/O Board 4 Input 17	290
IN518	Optional I/O Board 4 Input 18	290
IN519	Optional I/O Board 4 Input 19	290
IN520	Optional I/O Board 4 Input 20	290
IN521	Optional I/O Board 4 Input 21	290
IN522	Optional I/O Board 4 Input 22	290
IN523	Optional I/O Board 4 Input 23	290
IN524	Optional I/O Board 4 Input 24	290
IO300OK	Communications status of Interface Board 300 when installed or commissioned	475
IO400OK	Communications status of Interface Board 400 when installed or commissioned	475
IO500OK	Communications status of Interface Board 400 when installed or commissioned	475
LB_DP01	Local Bit 01 status display (SELOGIC control equation)	461
LB_DP02	Local Bit 02 status display (SELOGIC control equation)	461
LB_DP03	Local Bit 03 status display (SELOGIC control equation)	461
LB_DP04	Local Bit 04 status display (SELOGIC control equation)	461
LB_DP05	Local Bit 05 status display (SELOGIC control equation)	461

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Name	Bit Description	Row
LB_DP06	Local Bit 06 status display (SELOGIC control equation)	461
LB_DP07	Local Bit 07 status display (SELOGIC control equation)	461
LB_DP08	Local Bit 08 status display (SELOGIC control equation)	461
LB_DP09	Local Bit 09 status display (SELOGIC control equation)	462
LB_DP10	Local Bit 10 status display (SELOGIC control equation)	462
LB_DP11	Local Bit 11 status display (SELOGIC control equation)	462
LB_DP12	Local Bit 12 status display (SELOGIC control equation)	462
LB_DP13	Local Bit 13 status display (SELOGIC control equation)	462
LB_DP14	Local Bit 14 status display (SELOGIC control equation)	462
LB_DP15	Local Bit 15 status display (SELOGIC control equation)	462
LB_DP16	Local Bit 16 status display (SELOGIC control equation)	462
LB_DP17	Local Bit 17 status display (SELOGIC control equation)	463
LB_DP18	Local Bit 18 status display (SELOGIC control equation)	463
LB_DP19	Local Bit 19 status display (SELOGIC control equation)	463
LB_DP20	Local Bit 20 status display (SELOGIC control equation)	463
LB_DP21	Local Bit 21 status display (SELOGIC control equation)	463
LB_DP22	Local Bit 22 status display (SELOGIC control equation)	463
LB_DP23	Local Bit 23 status display (SELOGIC control equation)	463
LB_DP24	Local Bit 24 status display (SELOGIC control equation)	463
LB_DP25	Local Bit 25 status display (SELOGIC control equation)	464
LB_DP26	Local Bit 26 status display (SELOGIC control equation)	464
LB_DP27	Local Bit 27 status display (SELOGIC control equation)	464
LB_DP28	Local Bit 28 status display (SELOGIC control equation)	464
LB_DP29	Local Bit 29 status display (SELOGIC control equation)	464
LB_DP30	Local Bit 30 status display (SELOGIC control equation)	464
LB_DP31	Local Bit 31 status display (SELOGIC control equation)	464
LB_DP32	Local Bit 32 status display (SELOGIC control equation)	464
LB_DP33	Local Bit 33 status display (SELOGIC control equation)	496
LB_DP34	Local Bit 34 status display (SELOGIC control equation)	496
LB_DP35	Local Bit 35 status display (SELOGIC control equation)	496
LB_DP36	Local Bit 36 status display (SELOGIC control equation)	496
LB_DP37	Local Bit 37 status display (SELOGIC control equation)	496
LB_DP38	Local Bit 38 status display (SELOGIC control equation)	496
LB_DP39	Local Bit 39 status display (SELOGIC control equation)	496
LB_DP40	Local Bit 40 status display (SELOGIC control equation)	496
LB_DP41	Local Bit 41 status display (SELOGIC control equation)	497
LB_DP42	Local Bit 42 status display (SELOGIC control equation)	497
LB_DP43	Local Bit 43 status display (SELOGIC control equation)	497
LB_DP44	Local Bit 44 status display (SELOGIC control equation)	497
LB_DP45	Local Bit 45 status display (SELOGIC control equation)	497
LB_DP46	Local Bit 46 status display (SELOGIC control equation)	497

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 43 of 79)

Name	Bit Description	Row
LB_DP47	Local Bit 47 status display (SELOGIC control equation)	497
LB_DP48	Local Bit 48 status display (SELOGIC control equation)	497
LB_DP49	Local Bit 49 status display (SELOGIC control equation)	498
LB_DP50	Local Bit 50 status display (SELOGIC control equation)	498
LB_DP51	Local Bit 51 status display (SELOGIC control equation)	498
LB_DP52	Local Bit 52 status display (SELOGIC control equation)	498
LB_DP53	Local Bit 53 status display (SELOGIC control equation)	498
LB_DP54	Local Bit 54 status display (SELOGIC control equation)	498
LB_DP55	Local Bit 55 status display (SELOGIC control equation)	498
LB_DP56	Local Bit 56 status display (SELOGIC control equation)	498
LB_DP57	Local Bit 57 status display (SELOGIC control equation)	498
LB_DP58	Local Bit 58 status display (SELOGIC control equation)	499
LB_DP59	Local Bit 59 status display (SELOGIC control equation)	499
LB_DP60	Local Bit 60 status display (SELOGIC control equation)	499
LB_DP61	Local Bit 61 status display (SELOGIC control equation)	499
LB_DP62	Local Bit 62 status display (SELOGIC control equation)	499
LB_DP63	Local Bit 63 status display (SELOGIC control equation)	499
LB_DP64	Local Bit 64 status display (SELOGIC control equation)	499
LB_SP01	Local Bit 01 supervision (SELOGIC control equation)	457
LB_SP02	Local Bit 02 supervision (SELOGIC control equation)	457
LB_SP03	Local Bit 03 supervision (SELOGIC control equation)	457
LB_SP04	Local Bit 04 supervision (SELOGIC control equation)	457
LB_SP05	Local Bit 05 supervision (SELOGIC control equation)	457
LB_SP06	Local Bit 06 supervision (SELOGIC control equation)	457
LB_SP07	Local Bit 07 supervision (SELOGIC control equation)	457
LB_SP08	Local Bit 08 supervision (SELOGIC control equation)	457
LB_SP09	Local Bit 09 supervision (SELOGIC control equation)	458
LB_SP10	Local Bit 10 supervision (SELOGIC control equation)	458
LB_SP11	Local Bit 11 supervision (SELOGIC control equation)	458
LB_SP12	Local Bit 12 supervision (SELOGIC control equation)	458
LB_SP13	Local Bit 13 supervision (SELOGIC control equation)	458
LB_SP14	Local Bit 14 supervision (SELOGIC control equation)	458
LB_SP15	Local Bit 15 supervision (SELOGIC control equation)	458
LB_SP16	Local Bit 16 supervision (SELOGIC control equation)	458
LB_SP17	Local Bit 17 supervision (SELOGIC control equation)	459
LB_SP18	Local Bit 18 supervision (SELOGIC control equation)	459
LB_SP19	Local Bit 19 supervision (SELOGIC control equation)	459
LB_SP20	Local Bit 20 supervision (SELOGIC control equation)	459
LB_SP21	Local Bit 21 supervision (SELOGIC control equation)	459
LB_SP22	Local Bit 22 supervision (SELOGIC control equation)	459
LB_SP23	Local Bit 23 supervision (SELOGIC control equation)	459

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 44 of 79)

Name	Bit Description	Row
LB_SP24	Local Bit 24 supervision (SELOGIC control equation)	459
LB_SP25	Local Bit 25 supervision (SELOGIC control equation)	460
LB_SP26	Local Bit 26 supervision (SELOGIC control equation)	460
LB_SP27	Local Bit 27 supervision (SELOGIC control equation)	460
LB_SP28	Local Bit 28 supervision (SELOGIC control equation)	460
LB_SP29	Local Bit 29 supervision (SELOGIC control equation)	460
LB_SP30	Local Bit 30 supervision (SELOGIC control equation)	460
LB_SP31	Local Bit 31 supervision (SELOGIC control equation)	460
LB_SP32	Local Bit 32 supervision (SELOGIC control equation)	460
LB_SP33	Local Bit 33 supervision (SELOGIC control equation)	492
LB_SP34	Local Bit 34 supervision (SELOGIC control equation)	492
LB_SP35	Local Bit 35 supervision (SELOGIC control equation)	492
LB_SP36	Local Bit 36 supervision (SELOGIC control equation)	492
LB_SP37	Local Bit 37 supervision (SELOGIC control equation)	492
LB_SP38	Local Bit 38 supervision (SELOGIC control equation)	492
LB_SP39	Local Bit 39 supervision (SELOGIC control equation)	492
LB_SP40	Local Bit 40 supervision (SELOGIC control equation)	492
LB_SP41	Local Bit 41 supervision (SELOGIC control equation)	493
LB_SP42	Local Bit 42 supervision (SELOGIC control equation)	493
LB_SP43	Local Bit 43 supervision (SELOGIC control equation)	493
LB_SP44	Local Bit 44 supervision (SELOGIC control equation)	493
LB_SP45	Local Bit 45 supervision (SELOGIC control equation)	493
LB_SP46	Local Bit 46 supervision (SELOGIC control equation)	493
LB_SP47	Local Bit 47 supervision (SELOGIC control equation)	493
LB_SP48	Local Bit 48 supervision (SELOGIC control equation)	493
LB_SP49	Local Bit 49 supervision (SELOGIC control equation)	494
LB_SP50	Local Bit 50 supervision (SELOGIC control equation)	494
LB_SP51	Local Bit 51 supervision (SELOGIC control equation)	494
LB_SP52	Local Bit 52 supervision (SELOGIC control equation)	494
LB_SP53	Local Bit 53 supervision (SELOGIC control equation)	494
LB_SP54	Local Bit 54 supervision (SELOGIC control equation)	494
LB_SP55	Local Bit 55 supervision (SELOGIC control equation)	494
LB_SP56	Local Bit 56 supervision (SELOGIC control equation)	494
LB_SP57	Local Bit 57 supervision (SELOGIC control equation)	495
LB_SP58	Local Bit 58 supervision (SELOGIC control equation)	495
LB_SP59	Local Bit 59 supervision (SELOGIC control equation)	495
LB_SP60	Local Bit 60 supervision (SELOGIC control equation)	495
LB_SP61	Local Bit 61 supervision (SELOGIC control equation)	495
LB_SP62	Local Bit 62 supervision (SELOGIC control equation)	495
LB_SP63	Local Bit 63 supervision (SELOGIC control equation)	495
LB_SP64	Local Bit 64 supervision (SELOGIC control equation)	495

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 45 of 79)

Name	Bit Description	Row
LB01	Local Bit 01	256
LB02	Local Bit 02	256
LB03	Local Bit 03	256
LB04	Local Bit 04	256
LB05	Local Bit 05	256
LB06	Local Bit 06	256
LB07	Local Bit 07	256
LB08	Local Bit 08	256
LB09	Local Bit 09	257
LB10	Local Bit 10	257
LB11	Local Bit 11	257
LB12	Local Bit 12	257
LB13	Local Bit 13	257
LB14	Local Bit 14	257
LB15	Local Bit 15	257
LB16	Local Bit 16	257
LB17	Local Bit 17	258
LB18	Local Bit 18	258
LB19	Local Bit 19	258
LB20	Local Bit 20	258
LB21	Local Bit 21	258
LB22	Local Bit 22	258
LB23	Local Bit 23	258
LB24	Local Bit 24	258
LB25	Local Bit 25	259
LB26	Local Bit 26	259
LB27	Local Bit 27	259
LB28	Local Bit 28	259
LB29	Local Bit 29	259
LB30	Local Bit 30	259
LB31	Local Bit 31	259
LB32	Local Bit 32	259
LB33	Local Bit 33	488
LB34	Local Bit 34	488
LB35	Local Bit 35	488
LB36	Local Bit 36	488
LB37	Local Bit 37	488
LB38	Local Bit 38	488
LB39	Local Bit 39	488
LB40	Local Bit 40	488
LB41	Local Bit 41	489

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 46 of 79)

Name	Bit Description	Row
LB42	Local Bit 42	489
LB43	Local Bit 43	489
LB44	Local Bit 44	489
LB45	Local Bit 45	489
LB46	Local Bit 46	489
LB47	Local Bit 47	489
LB48	Local Bit 48	489
LB49	Local Bit 49	490
LB50	Local Bit 50	490
LB51	Local Bit 51	490
LB52	Local Bit 52	490
LB53	Local Bit 53	490
LB54	Local Bit 54	490
LB55	Local Bit 55	490
LB56	Local Bit 56	490
LB57	Local Bit 57	491
LB58	Local Bit 58	491
LB59	Local Bit 59	491
LB60	Local Bit 60	491
LB61	Local Bit 61	491
LB62	Local Bit 62	491
LB63	Local Bit 63	491
LB64	Local Bit 64	491
LBOKA	Channel A MIRRORED BITS normal status (loopback)	404
LBOKB	Channel B MIRRORED BITS normal status (loopback mode)	405
LINK5A	Link status of Port 5A connection	441
LINK5B	Link status of Port 5B connection	441
LINK5C	Link status of Port 5C connection	441
LINK5D	Link status of Port 5D connection	441
LNKFAIL	Link status of the active port	441
LOC	Control authority at local (bay) level	480
LOCSTA	Control authority at station level	480
LPHDSIM	61850 Logical Node for Physical Device Simulation	406
LPSEC	Direction of the upcoming leap second. During the time that LPSECP is asserted, if LPSEC is asserted, the upcoming leap second is deleted; otherwise, the leap second is added.	470
LPSECP	Leap second pending	470
MATHERR	SELOGIC control equation math error	374
MLTLEV	Multi-level control authority	480
OC01	Circuit Breaker 01 open command	249
OC02	Circuit Breaker 02 open command	249
OC03	Circuit Breaker 03 open command	249

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 47 of 79)

Name	Bit Description	Row
OC04	Circuit Breaker 04 open command	249
OC05	Circuit Breaker 05 open command	249
OC06	Circuit Breaker 06 open command	249
OC07	Circuit Breaker 07 open command	249
OC08	Circuit Breaker 08 open command	249
OC09	Circuit Breaker 09 open command	250
OC10	Circuit Breaker 10 open command	250
OC11	Circuit Breaker 11 open command	250
OC12	Circuit Breaker 12 open command	250
OC13	Circuit Breaker 13 open command	250
OC14	Circuit Breaker 14 open command	250
OC15	Circuit Breaker 15 open command	250
OC16	Circuit Breaker 16 open command	250
OC17	Circuit Breaker 17 open command	251
OC18	Circuit Breaker 18 open command	251
OC19	Circuit Breaker 19 open command	251
OC20	Circuit Breaker 20 open command	251
OC21	Circuit Breaker 21 open command	251
OCTZ1	Zone 1 open CT detection	155
OCTZ2	Zone 2 open CT detection	155
OCTZ3	Zone 3 open CT detection	155
OCTZ4	Zone 4 open CT detection	155
OCTZ5	Zone 5 open CT detection	155
OCTZ6	Zone 6 open CT detection	155
OPH01	Terminal 01 open phase detected	4
OPH02	Terminal 02 open phase detected	4
OPH03	Terminal 03 open phase detected	4
OPH04	Terminal 04 open phase detected	4
OPH05	Terminal 05 open phase detected	4
OPH06	Terminal 06 open phase detected	4
OPH07	Terminal 07 open phase detected	4
OPH08	Terminal 08 open phase detected	4
OPH09	Terminal 09 open phase detected	5
OPH10	Terminal 10 open phase detected	5
OPH11	Terminal 11 open phase detected	5
OPH12	Terminal 12 open phase detected	5
OPH13	Terminal 13 open phase detected	5
OPH14	Terminal 14 open phase detected	5
OPH15	Terminal 15 open phase detected	5
OPH16	Terminal 16 open phase detected	5
OPH17	Terminal 17 open phase detected	6

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 48 of 79)

Name	Bit Description	Row
OPH18	Terminal 18 open phase detected	6
OPH19	Terminal 19 open phase detected	6
OPH20	Terminal 20 open phase detected	6
OPH21	Terminal 21 open phase detected	6
OUT101	Main board Output 1	384
OUT102	Main board Output 2	384
OUT103	Main board Output 3	384
OUT104	Main board Output 4	384
OUT105	Main board Output 5	384
OUT106	Main board Output 6	384
OUT107	Main board Output 7	384
OUT108	Main board Output 8	384
OUT201	Optional I/O Board 1 Output 1	388
OUT202	Optional I/O Board 1 Output 2	388
OUT203	Optional I/O Board 1 Output 3	388
OUT204	Optional I/O Board 1 Output 4	388
OUT205	Optional I/O Board 1 Output 5	388
OUT206	Optional I/O Board 1 Output 6	388
OUT207	Optional I/O Board 1 Output 7	388
OUT208	Optional I/O Board 1 Output 8	388
OUT209	Optional I/O Board 1 Output 9	389
OUT210	Optional I/O Board 1 Output 10	389
OUT211	Optional I/O Board 1 Output 11	389
OUT212	Optional I/O Board 1 Output 12	389
OUT213	Optional I/O Board 1 Output 13	389
OUT214	Optional I/O Board 1 Output 14	389
OUT215	Optional I/O Board 1 Output 15	389
OUT216	Optional I/O Board 1 Output 16	389
OUT301	Optional I/O Board 2 Output 1	390
OUT302	Optional I/O Board 2 Output 2	390
OUT303	Optional I/O Board 2 Output 3	390
OUT304	Optional I/O Board 2 Output 4	390
OUT305	Optional I/O Board 2 Output 5	390
OUT306	Optional I/O Board 2 Output 6	390
OUT307	Optional I/O Board 2 Output 7	390
OUT308	Optional I/O Board 2 Output 8	390
OUT309	Optional I/O Board 2 Output 9	391
OUT310	Optional I/O Board 2 Output 10	391
OUT311	Optional I/O Board 2 Output 11	391
OUT312	Optional I/O Board 2 Output 12	391
OUT313	Optional I/O Board 2 Output 13	391

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 49 of 79)

Name	Bit Description	Row
OUT314	Optional I/O Board 2 Output 14	391
OUT315	Optional I/O Board 2 Output 15	391
OUT316	Optional I/O Board 2 Output 16	391
OUT401	Optional I/O Board 3 Output 1	392
OUT402	Optional I/O Board 3 Output 2	392
OUT403	Optional I/O Board 3 Output 3	392
OUT404	Optional I/O Board 3 Output 4	392
OUT405	Optional I/O Board 3 Output 5	392
OUT406	Optional I/O Board 3 Output 6	392
OUT407	Optional I/O Board 3 Output 7	392
OUT408	Optional I/O Board 3 Output 8	392
OUT409	Optional I/O Board 3 Output 9	393
OUT410	Optional I/O Board 3 Output 10	393
OUT411	Optional I/O Board 3 Output 11	393
OUT412	Optional I/O Board 3 Output 12	393
OUT413	Optional I/O Board 3 Output 13	393
OUT414	Optional I/O Board 3 Output 14	393
OUT415	Optional I/O Board 3 Output 15	393
OUT416	Optional I/O Board 3 Output 16	393
OUT501	Optional I/O Board 4 Output 1	394
OUT502	Optional I/O Board 4 Output 2	394
OUT503	Optional I/O Board 4 Output 3	394
OUT504	Optional I/O Board 4 Output 4	394
OUT505	Optional I/O Board 4 Output 5	394
OUT506	Optional I/O Board 4 Output 6	394
OUT507	Optional I/O Board 4 Output 7	394
OUT508	Optional I/O Board 4 Output 8	394
OUT509	Optional I/O Board 4 Output 9	395
OUT510	Optional I/O Board 4 Output 10	395
OUT511	Optional I/O Board 4 Output 11	395
OUT512	Optional I/O Board 4 Output 12	395
OUT513	Optional I/O Board 4 Output 13	395
OUT514	Optional I/O Board 4 Output 14	395
OUT515	Optional I/O Board 4 Output 15	395
OUT516	Optional I/O Board 4 Output 16	395
P5ABSW	Port 5A or 5B has just become active	473
P5ASEL	Port 5A active/inactive	442
P5BSEL	Port 5B active/inactive	442
P5CSEL	Port 5C active/inactive	442
P5DSEL	Port 5D active/inactive	442
P87R1	Zone 1 instantaneous differential element picked up	159

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 50 of 79)

Name	Bit Description	Row
P87R2	Zone 2 instantaneous differential element picked up	161
P87R3	Zone 3 instantaneous differential element picked up	163
P87R4	Zone 4 instantaneous differential element picked up	165
P87R5	Zone 5 instantaneous differential element picked up	167
P87R6	Zone 6 instantaneous differential element picked up	169
P87RCZ1	Check Zone 1 instantaneous differential element picked up	450
P87RCZ2	Check Zone 2 instantaneous differential element picked up	452
P87RCZ3	Check Zone 3 instantaneous differential element picked up	454
PASSDIS	Asserts to indicate password disable jumper is installed	377
PB1	Pushbutton 1	382
PB1_LED	Pushbutton 1 LED	398
PB1_PUL	Pushbutton 1 pulse input	396
PB10	Pushbutton 10	383
PB10LED	Pushbutton 10 LED	399
PB10PUL	Pushbutton 10 pulse input	397
PB11	Pushbutton 11	383
PB11LED	Pushbutton 11 LED	399
PB11PUL	Pushbutton 11 pulse input	397
PB12	Pushbutton 12	383
PB12LED	Pushbutton 12 LED	399
PB12PUL	Pushbutton 12 pulse input	397
PB2	Pushbutton 2	382
PB2_LED	Pushbutton 2 LED	398
PB2_PUL	Pushbutton 2 pulse input	396
PB3	Pushbutton 3	382
PB3_LED	Pushbutton 3 LED	398
PB3_PUL	Pushbutton 3 pulse input	396
PB4	Pushbutton 4	382
PB4_LED	Pushbutton 4 LED	398
PB4_PUL	Pushbutton 4 pulse input	396
PB5	Pushbutton 5	382
PB5_LED	Pushbutton 5 LED	398
PB5_PUL	Pushbutton 5 pulse input	396
PB6	Pushbutton 6	382
PB6_LED	Pushbutton 6 LED	398
PB6_PUL	Pushbutton 6 pulse input	396
PB7	Pushbutton 7	382
PB7_LED	Pushbutton 7 LED	398
PB7_PUL	Pushbutton 7 pulse input	396
PB8	Pushbutton 8	382
PB8_LED	Pushbutton 8 LED	398

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 51 of 79)

Name	Bit Description	Row
PB8_PUL	Pushbutton 8 pulse input	396
PB9	Pushbutton 9	383
PB9_LED	Pushbutton 9 LED	399
PB9_PUL	Pushbutton 9 pulse input	397
PCN01Q	Protection counter Output 01	314
PCN01R	Protection counter Reset 01	318
PCN02Q	Protection counter Output 02	314
PCN02R	Protection counter Reset 02	318
PCN03Q	Protection counter Output 03	314
PCN03R	Protection counter Reset 03	318
PCN04Q	Protection counter Output 04	314
PCN04R	Protection counter Reset 04	318
PCN05Q	Protection counter Output 05	314
PCN05R	Protection counter Reset 05	318
PCN06Q	Protection counter Output 06	314
PCN06R	Protection counter Reset 06	318
PCN07Q	Protection counter Output 07	314
PCN07R	Protection counter Reset 07	318
PCN08Q	Protection counter Output 08	314
PCN08R	Protection counter Reset 08	318
PCN09Q	Protection counter Output 09	315
PCN09R	Protection counter Reset 09	319
PCN10Q	Protection counter Output 10	315
PCN10R	Protection counter Reset 10	319
PCN11Q	Protection counter Output 11	315
PCN11R	Protection counter Reset 11	319
PCN12Q	Protection counter Output 12	315
PCN12R	Protection counter Reset 12	319
PCN13Q	Protection counter Output 13	315
PCN13R	Protection counter Reset 13	319
PCN14Q	Protection counter Output 14	315
PCN14R	Protection counter Reset 14	319
PCN15Q	Protection counter Output 15	315
PCN15R	Protection counter Reset 15	319
PCN16Q	Protection counter Output 16	315
PCN16R	Protection counter Reset 16	319
PCN17Q	Protection counter Output 17	316
PCN17R	Protection counter Reset 17	320
PCN18Q	Protection counter Output 18	316
PCN18R	Protection counter Reset 18	320
PCN19Q	Protection counter Output 19	316

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 52 of 79)

Name	Bit Description	Row
PCN19R	Protection counter Reset 19	320
PCN20Q	Protection counter Output 20	316
PCN20R	Protection counter Reset 20	320
PCN21Q	Protection counter Output 21	316
PCN21R	Protection counter Reset 21	320
PCN22Q	Protection counter Output 22	316
PCN22R	Protection counter Reset 22	320
PCN23Q	Protection counter Output 23	316
PCN23R	Protection counter Reset 23	320
PCN24Q	Protection counter Output 24	316
PCN24R	Protection counter Reset 24	320
PCN25Q	Protection counter Output 25	317
PCN25R	Protection counter Reset 25	321
PCN26Q	Protection counter Output 26	317
PCN26R	Protection counter Reset 26	321
PCN27Q	Protection counter Output 27	317
PCN27R	Protection counter Reset 27	321
PCN28Q	Protection counter Output 28	317
PCN28R	Protection counter Reset 28	321
PCN29Q	Protection counter Output 29	317
PCN29R	Protection counter Reset 29	321
PCN30Q	Protection counter Output 30	317
PCN30R	Protection counter Reset 30	321
PCN31Q	Protection counter Output 31	317
PCN31R	Protection counter Reset 31	321
PCN32Q	Protection counter Output 32	317
PCN32R	Protection counter Reset 32	321
PCT01Q	Protection conditioning timer Output 01	304
PCT02Q	Protection conditioning timer Output 02	304
PCT03Q	Protection conditioning timer Output 03	304
PCT04Q	Protection conditioning timer Output 04	304
PCT05Q	Protection conditioning timer Output 05	304
PCT06Q	Protection conditioning timer Output 06	304
PCT07Q	Protection conditioning timer Output 07	304
PCT08Q	Protection conditioning timer Output 08	304
PCT09Q	Protection conditioning timer Output 09	305
PCT10Q	Protection conditioning timer Output 10	305
PCT11Q	Protection conditioning timer Output 11	305
PCT12Q	Protection conditioning timer Output 12	305
PCT13Q	Protection conditioning timer Output 13	305
PCT14Q	Protection conditioning timer Output 14	305

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 53 of 79)

Name	Bit Description	Row
PCT15Q	Protection conditioning timer Output 15	305
PCT16Q	Protection conditioning timer Output 16	305
PFRTEX	Protection SELOGIC control equation first execution	374
PLT01	Protection Latch 01	300
PLT02	Protection Latch 02	300
PLT03	Protection Latch 03	300
PLT04	Protection Latch 04	300
PLT05	Protection Latch 05	300
PLT06	Protection Latch 06	300
PLT07	Protection Latch 07	300
PLT08	Protection Latch 08	300
PLT09	Protection Latch 09	301
PLT10	Protection Latch 10	301
PLT11	Protection Latch 11	301
PLT12	Protection Latch 12	301
PLT13	Protection Latch 13	301
PLT14	Protection Latch 14	301
PLT15	Protection Latch 15	301
PLT16	Protection Latch 16	301
PLT17	Protection Latch 17	302
PLT18	Protection Latch 18	302
PLT19	Protection Latch 19	302
PLT20	Protection Latch 20	302
PLT21	Protection Latch 21	302
PLT22	Protection Latch 22	302
PLT23	Protection Latch 23	302
PLT24	Protection Latch 24	302
PLT25	Protection Latch 25	303
PLT26	Protection Latch 26	303
PLT27	Protection Latch 27	303
PLT28	Protection Latch 28	303
PLT29	Protection Latch 29	303
PLT30	Protection Latch 30	303
PLT31	Protection Latch 31	303
PLT32	Protection Latch 32	303
PST01Q	Protection sequencing timer Output 01	306
PST01R	Protection sequencing timer Reset 01	310
PST02Q	Protection sequencing timer Output 02	306
PST02R	Protection sequencing timer Reset 02	310
PST03Q	Protection sequencing timer Output 03	306
PST03R	Protection sequencing timer Reset 03	310

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 54 of 79)

Name	Bit Description	Row
PST04Q	Protection sequencing timer Output 04	306
PST04R	Protection sequencing timer Reset 04	310
PST05Q	Protection sequencing timer Output 05	306
PST05R	Protection sequencing timer Reset 05	310
PST06Q	Protection sequencing timer Output 06	306
PST06R	Protection sequencing timer Reset 06	310
PST07Q	Protection sequencing timer Output 07	306
PST07R	Protection sequencing timer Reset 07	310
PST08Q	Protection sequencing timer Output 08	306
PST08R	Protection sequencing timer Reset 08	310
PST09Q	Protection sequencing timer Output 09	307
PST09R	Protection sequencing timer Reset 09	311
PST10Q	Protection sequencing timer Output 10	307
PST10R	Protection sequencing timer Reset 10	311
PST11Q	Protection sequencing timer Output 11	307
PST11R	Protection sequencing timer Reset 11	311
PST12Q	Protection sequencing timer Output 12	307
PST12R	Protection sequencing timer Reset 12	311
PST13Q	Protection sequencing timer Output 13	307
PST13R	Protection sequencing timer Reset 13	311
PST14Q	Protection sequencing timer Output 14	307
PST14R	Protection sequencing timer Reset 14	311
PST15Q	Protection sequencing timer Output 15	307
PST15R	Protection sequencing timer Reset 15	311
PST16Q	Protection sequencing timer Output 16	307
PST16R	Protection sequencing timer Reset 16	311
PST17Q	Protection sequencing timer Output 17	308
PST17R	Protection sequencing timer Reset 17	312
PST18Q	Protection sequencing timer Output 18	308
PST18R	Protection sequencing timer Reset 18	312
PST19Q	Protection sequencing timer Output 19	308
PST19R	Protection sequencing timer Reset 19	312
PST20Q	Protection sequencing timer Output 20	308
PST20R	Protection sequencing timer Reset 20	312
PST21Q	Protection sequencing timer Output 21	308
PST21R	Protection sequencing timer Reset 21	312
PST22Q	Protection sequencing timer Output 22	308
PST22R	Protection sequencing timer Reset 22	312
PST23Q	Protection sequencing timer Output 23	308
PST23R	Protection sequencing timer Reset 23	312
PST24Q	Protection sequencing timer Output 24	308

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 55 of 79)

Name	Bit Description	Row
PST24R	Protection sequencing timer Reset 24	312
PST25Q	Protection sequencing timer Output 25	309
PST25R	Protection sequencing timer Reset 25	313
PST26Q	Protection sequencing timer Output 26	309
PST26R	Protection sequencing timer Reset 26	313
PST27Q	Protection sequencing timer Output 27	309
PST27R	Protection sequencing timer Reset 27	313
PST28Q	Protection sequencing timer Output 28	309
PST28R	Protection sequencing timer Reset 28	313
PST29Q	Protection sequencing timer Output 29	309
PST29R	Protection sequencing timer Reset 29	313
PST30Q	Protection sequencing timer Output 30	309
PST30R	Protection sequencing timer Reset 30	313
PST31Q	Protection sequencing timer Output 31	309
PST31R	Protection sequencing timer Reset 31	313
PST32Q	Protection sequencing timer Output 32	309
PST32R	Protection sequencing timer Reset 32	313
PSV01	Protection SELOGIC control equation Variable 01	292
PSV02	Protection SELOGIC control equation Variable 02	292
PSV03	Protection SELOGIC control equation Variable 03	292
PSV04	Protection SELOGIC control equation Variable 04	292
PSV05	Protection SELOGIC control equation Variable 05	292
PSV06	Protection SELOGIC control equation Variable 06	292
PSV07	Protection SELOGIC control equation Variable 07	292
PSV08	Protection SELOGIC control equation Variable 08	292
PSV09	Protection SELOGIC control equation Variable 09	293
PSV10	Protection SELOGIC control equation Variable 10	293
PSV11	Protection SELOGIC control equation Variable 11	293
PSV12	Protection SELOGIC control equation Variable 12	293
PSV13	Protection SELOGIC control equation Variable 13	293
PSV14	Protection SELOGIC control equation Variable 14	293
PSV15	Protection SELOGIC control equation Variable 15	293
PSV16	Protection SELOGIC control equation Variable 16	293
PSV17	Protection SELOGIC control equation Variable 17	294
PSV18	Protection SELOGIC control equation Variable 18	294
PSV19	Protection SELOGIC control equation Variable 19	294
PSV20	Protection SELOGIC control equation Variable 20	294
PSV21	Protection SELOGIC control equation Variable 21	294
PSV22	Protection SELOGIC control equation Variable 22	294
PSV23	Protection SELOGIC control equation Variable 23	294
PSV24	Protection SELOGIC control equation Variable 24	294

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 56 of 79)

Name	Bit Description	Row
PSV25	Protection SELOGIC control equation Variable 25	295
PSV26	Protection SELOGIC control equation Variable 26	295
PSV27	Protection SELOGIC control equation Variable 27	295
PSV28	Protection SELOGIC control equation Variable 28	295
PSV29	Protection SELOGIC control equation Variable 29	295
PSV30	Protection SELOGIC control equation Variable 30	295
PSV31	Protection SELOGIC control equation Variable 31	295
PSV32	Protection SELOGIC control equation Variable 32	295
PSV33	Protection SELOGIC control equation Variable 33	296
PSV34	Protection SELOGIC control equation Variable 34	296
PSV35	Protection SELOGIC control equation Variable 35	296
PSV36	Protection SELOGIC control equation Variable 36	296
PSV37	Protection SELOGIC control equation Variable 37	296
PSV38	Protection SELOGIC control equation Variable 38	296
PSV39	Protection SELOGIC control equation Variable 39	296
PSV40	Protection SELOGIC control equation Variable 40	296
PSV41	Protection SELOGIC control equation Variable 41	297
PSV42	Protection SELOGIC control equation Variable 42	297
PSV43	Protection SELOGIC control equation Variable 43	297
PSV44	Protection SELOGIC control equation Variable 44	297
PSV45	Protection SELOGIC control equation Variable 45	297
PSV46	Protection SELOGIC control equation Variable 46	297
PSV47	Protection SELOGIC control equation Variable 47	297
PSV48	Protection SELOGIC control equation Variable 48	297
PSV49	Protection SELOGIC control equation Variable 49	298
PSV50	Protection SELOGIC control equation Variable 50	298
PSV51	Protection SELOGIC control equation Variable 51	298
PSV52	Protection SELOGIC control equation Variable 52	298
PSV53	Protection SELOGIC control equation Variable 53	298
PSV54	Protection SELOGIC control equation Variable 54	298
PSV55	Protection SELOGIC control equation Variable 55	298
PSV56	Protection SELOGIC control equation Variable 56	298
PSV57	Protection SELOGIC control equation Variable 57	299
PSV58	Protection SELOGIC control equation Variable 58	299
PSV59	Protection SELOGIC control equation Variable 59	299
PSV60	Protection SELOGIC control equation Variable 60	299
PSV61	Protection SELOGIC control equation Variable 61	299
PSV62	Protection SELOGIC control equation Variable 62	299
PSV63	Protection SELOGIC control equation Variable 63	299
PSV64	Protection SELOGIC control equation Variable 64	299
PTP_BNP	Bad jitter on PTP signals and the PTP signal is lost afterwards	474

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 57 of 79)

Name	Bit Description	Row
PTP_OK	PTP is available and has sufficient quality	473
PTP_RST	Disqualify PTP time source	473
PTP_SET	Qualify PTP time source	473
PTP_TIM	A valid PTP time source is detected	473
PTPSYNC	Synchronized to a high-quality PTP source	474
PUNRLBL	Protection SELOGIC control equation unresolved label	374
RB01	Remote Bit 01	271
RB02	Remote Bit 02	271
RB03	Remote Bit 03	271
RB04	Remote Bit 04	271
RB05	Remote Bit 05	271
RB06	Remote Bit 06	271
RB07	Remote Bit 07	271
RB08	Remote Bit 08	271
RB09	Remote Bit 09	270
RB10	Remote Bit 10	270
RB11	Remote Bit 11	270
RB12	Remote Bit 12	270
RB13	Remote Bit 13	270
RB14	Remote Bit 14	270
RB15	Remote Bit 15	270
RB16	Remote Bit 16	270
RB17	Remote Bit 17	269
RB18	Remote Bit 18	269
RB19	Remote Bit 19	269
RB20	Remote Bit 20	269
RB21	Remote Bit 21	269
RB22	Remote Bit 22	269
RB23	Remote Bit 23	269
RB24	Remote Bit 24	269
RB25	Remote Bit 25	268
RB26	Remote Bit 26	268
RB27	Remote Bit 27	268
RB28	Remote Bit 28	268
RB29	Remote Bit 29	268
RB30	Remote Bit 30	268
RB31	Remote Bit 31	268
RB32	Remote Bit 32	268
RB33	Remote Bit 33	267
RB34	Remote Bit 34	267
RB35	Remote Bit 35	267

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 58 of 79)

Name	Bit Description	Row
RB36	Remote Bit 36	267
RB37	Remote Bit 37	267
RB38	Remote Bit 38	267
RB39	Remote Bit 39	267
RB40	Remote Bit 40	267
RB41	Remote Bit 41	266
RB42	Remote Bit 42	266
RB43	Remote Bit 43	266
RB44	Remote Bit 44	266
RB45	Remote Bit 45	266
RB46	Remote Bit 46	266
RB47	Remote Bit 47	266
RB48	Remote Bit 48	266
RB49	Remote Bit 49	265
RB50	Remote Bit 50	265
RB51	Remote Bit 51	265
RB52	Remote Bit 52	265
RB53	Remote Bit 53	265
RB54	Remote Bit 54	265
RB55	Remote Bit 55	265
RB56	Remote Bit 56	265
RB57	Remote Bit 57	264
RB58	Remote Bit 58	264
RB59	Remote Bit 59	264
RB60	Remote Bit 60	264
RB61	Remote Bit 61	264
RB62	Remote Bit 62	264
RB63	Remote Bit 63	264
RB64	Remote Bit 64	264
RB65	Remote Bit 65	263
RB66	Remote Bit 66	263
RB67	Remote Bit 67	263
RB68	Remote Bit 68	263
RB69	Remote Bit 69	263
RB70	Remote Bit 70	263
RB71	Remote Bit 71	263
RB72	Remote Bit 72	263
RB73	Remote Bit 73	262
RB74	Remote Bit 74	262
RB75	Remote Bit 75	262
RB76	Remote Bit 76	262

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 59 of 79)

Name	Bit Description	Row
RB77	Remote Bit 77	262
RB78	Remote Bit 78	262
RB79	Remote Bit 79	262
RB80	Remote Bit 80	262
RB81	Remote Bit 81	261
RB82	Remote Bit 82	261
RB83	Remote Bit 83	261
RB84	Remote Bit 84	261
RB85	Remote Bit 85	261
RB86	Remote Bit 86	261
RB87	Remote Bit 87	261
RB88	Remote Bit 88	261
RB89	Remote Bit 89	260
RB90	Remote Bit 90	260
RB91	Remote Bit 91	260
RB92	Remote Bit 92	260
RB93	Remote Bit 93	260
RB94	Remote Bit 94	260
RB95	Remote Bit 95	260
RB96	Remote Bit 96	260
RBADA	Channel A MIRRORED BITS outage too long	404
RBADB	Channel B MIRRORED BITS outage too long	405
RDIF1	Zone 1 unfiltered restrained differential element picked up	160
RDIF2	Zone 2 unfiltered restrained differential element picked up	162
RDIF3	Zone 3 unfiltered restrained differential element picked up	164
RDIF4	Zone 4 unfiltered restrained differential element picked up	166
RDIF5	Zone 5 unfiltered restrained differential element picked up	168
RDIF6	Zone 6 unfiltered restrained differential element picked up	170
RDIFCZ1	Check Zone 1 unfiltered restrained differential element picked up	451
RDIFCZ2	Check Zone 2 unfiltered restrained differential element picked up	453
RDIFCZ3	Check Zone 3 unfiltered restrained differential element picked up	455
RMB1A	Channel A receive MIRRORED BIT 1	400
RMB1B	Channel B receive MIRRORED BIT 1	402
RMB2A	Channel A receive MIRRORED BIT 2	400
RMB2B	Channel B receive MIRRORED BIT 2	402
RMB3A	Channel A receive MIRRORED BIT 3	400
RMB3B	Channel B receive MIRRORED BIT 3	402
RMB4A	Channel A receive MIRRORED BIT 4	400
RMB4B	Channel B receive MIRRORED BIT 4	402
RMB5A	Channel A receive MIRRORED BIT 5	400
RMB5B	Channel B receive MIRRORED BIT 5	402

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 60 of 79)

Name	Bit Description	Row
RMB6A	Channel A receive MIRRORED BIT 6	400
RMB6B	Channel B receive MIRRORED BIT 6	402
RMB7A	Channel A receive MIRRORED BIT 7	400
RMB7B	Channel B receive MIRRORED BIT 7	402
RMB8A	Channel A receive MIRRORED BIT 8	400
RMB8B	Channel B receive MIRRORED BIT 8	402
ROCTZ1	Zone 1 open CT logic reset	154
ROCTZ2	Zone 2 open CT logic reset	154
ROCTZ3	Zone 3 open CT logic reset	154
ROCTZ4	Zone 4 open CT logic reset	154
ROCTZ5	Zone 5 open CT logic reset	154
ROCTZ6	Zone 6 open CT logic reset	154
ROKA	Channel A MIRRORED BITS normal status (non-loopback)	404
ROKB	Channel B MIRRORED BITS normal status (non-loopback mode)	405
RST_BAT	Reset battery monitoring	440
RST_HAL	Reset HALARMA	440
RSTDNPE	Reset DNP fault summary data	440
RSTOCT1	Zone 1 open CT detection reset	156
RSTOCT2	Zone 2 open CT detection reset	156
RSTOCT3	Zone 3 open CT detection reset	156
RSTOCT4	Zone 4 open CT detection reset	156
RSTOCT5	Zone 5 open CT detection reset	156
RSTOCT6	Zone 6 open CT detection reset	156
RSTTRGT	Target reset (SELOGIC control equation)	440
RT01	Circuit Breaker 1 retrip	183
RT02	Circuit Breaker 2 retrip	184
RT03	Circuit Breaker 3 retrip	185
RT04	Circuit Breaker 4 retrip	186
RT05	Circuit Breaker 5 retrip	187
RT06	Circuit Breaker 6 retrip	188
RT07	Circuit Breaker 7 retrip	189
RT08	Circuit Breaker 8 retrip	190
RT09	Circuit Breaker 9 retrip	191
RT10	Circuit Breaker 10 retrip	192
RT11	Circuit Breaker 11 retrip	193
RT12	Circuit Breaker 12 retrip	194
RT13	Circuit Breaker 13 retrip	195
RT14	Circuit Breaker 14 retrip	196
RT15	Circuit Breaker 15 retrip	197
RT16	Circuit Breaker 16 retrip	198
RT17	Circuit Breaker 17 retrip	199

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 61 of 79)

Name	Bit Description	Row
RT18	Circuit Breaker 18 retrip	200
RT19	Circuit Breaker 19 retrip	201
RT20	Circuit Breaker 20 retrip	202
RT21	Circuit Breaker 21 retrip	203
RZSWOAL	Reset zone switching operation alarm	152
SALARM	Non-diagnostic alarm pulse	376
SBFTR	Any circuit breaker failure trip	239
SBFTR01	Circuit Breaker 01 breaker failure trip	236
SBFTR02	Circuit Breaker 02 breaker failure trip	236
SBFTR03	Circuit Breaker 03 breaker failure trip	236
SBFTR04	Circuit Breaker 04 breaker failure trip	236
SBFTR05	Circuit Breaker 05 breaker failure trip	236
SBFTR06	Circuit Breaker 06 breaker failure trip	236
SBFTR07	Circuit Breaker 07 breaker failure trip	236
SBFTR08	Circuit Breaker 08 breaker failure trip	236
SBFTR09	Circuit Breaker 09 breaker failure trip	237
SBFTR10	Circuit Breaker 10 breaker failure trip	237
SBFTR11	Circuit Breaker 11 breaker failure trip	237
SBFTR12	Circuit Breaker 12 breaker failure trip	237
SBFTR13	Circuit Breaker 13 breaker failure trip	237
SBFTR14	Circuit Breaker 14 breaker failure trip	237
SBFTR15	Circuit Breaker 15 breaker failure trip	237
SBFTR16	Circuit Breaker 16 breaker failure trip	237
SBFTR17	Circuit Breaker 17 breaker failure trip	238
SBFTR18	Circuit Breaker 18 breaker failure trip	238
SBFTR19	Circuit Breaker 19 breaker failure trip	238
SBFTR20	Circuit Breaker 20 breaker failure trip	238
SBFTR21	Circuit Breaker 21 breaker failure trip	238
SC850BM	SELOGIC control for IEC 61850 blocked mode	476
SC850LS	SELOGIC control for control authority at station level	480
SC850SM	SELOGIC control for IEC 61850 simulation mode	476
SC850TM	SELOGIC control for IEC 61850 test mode	476
SER_BNP	Bad jitter on serial port and the IRIG-B signal is lost afterwards	473
SER_OK	IRIG-B signal from serial port 1 is available and has sufficient quality	472
SER_RST	Disqualify serial IRIG-B time source	472
SER_SET	Qualify serial IRIG-B time source	472
SER_TIM	A valid IRIG-B time source is detected on serial port	473
SERSYNC	Synchronized to a high-quality serial IRIG source	474
SETCHG	Pulsed when settings change	376
SG1	Settings Group 1 active	255
SG2	Settings Group 2 active	255

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 62 of 79)

Name	Bit Description	Row
SG3	Settings Group 3 active	255
SG4	Settings Group 4 active	255
SG5	Settings Group 5 active	255
SG6	Settings Group 6 active	255
SPEN	Signal Profiling enabled	467
TBNC	The active relay time source is BNC IRIG	378
TESTDB	Communications card database test bit	406
TESTDB2	DNP test bit	406
TESTFM	Fast meter test bit	406
TESTPUL	Pulse test bit	406
TGLOBAL	Relay calendar clock and ADC sampling synchronized to a high-priority Global time source	379
TIRIG	Assert while time is based on IRIG for both mark and value	378
TLED_1	Front-panel target LED 1	1
TLED_10	Front-panel target LED 10	2
TLED_11	Front-panel target LED 11	2
TLED_12	Front-panel target LED 12	2
TLED_13	Front-panel target LED 13	2
TLED_14	Front-panel target LED 14	2
TLED_15	Front-panel target LED 15	2
TLED_16	Front-panel target LED 16	2
TLED_17	Front-panel target LED 17	3
TLED_18	Front-panel target LED 18	3
TLED_19	Front-panel target LED 19	3
TLED_2	Front-panel target LED 2	1
TLED_20	Front-panel target LED 20	3
TLED_21	Front-panel target LED 21	3
TLED_22	Front-panel target LED 22	3
TLED_23	Front-panel target LED 23	3
TLED_24	Front-panel target LED 24	3
TLED_3	Front-panel target LED 3	1
TLED_4	Front-panel target LED 4	1
TLED_5	Front-panel target LED 5	1
TLED_6	Front-panel target LED 6	1
TLED_7	Front-panel target LED 7	1
TLED_8	Front-panel target LED 8	1
TLED_9	Front-panel target LED 9	2
TLOCAL	Relay calendar clock and ADC sampling synchronized to a high-priority local time source	379
TMB1A	Channel A transmit MIRRORED BIT 1	401
TMB1B	Channel B transmit MIRRORED BIT 1	403
TMB2A	Channel A transmit MIRRORED BIT 2	401
TMB2B	Channel B transmit MIRRORED BIT 2	403

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 63 of 79)

Name	Bit Description	Row
TMB3A	Channel A transmit MIRRORED BIT 3	401
TMB3B	Channel B transmit MIRRORED BIT 3	403
TMB4A	Channel A transmit MIRRORED BIT 4	401
TMB4B	Channel B transmit MIRRORED BIT 4	403
TMB5A	Channel A transmit MIRRORED BIT 5	401
TMB5B	Channel B transmit MIRRORED BIT 5	403
TMB6A	Channel A transmit MIRRORED BIT 6	401
TMB6B	Channel B transmit MIRRORED BIT 6	403
TMB7A	Channel A transmit MIRRORED BIT 7	401
TMB7B	Channel B transmit MIRRORED BIT 7	403
TMB8A	Channel A transmit MIRRORED BIT 8	401
TMB8B	Channel B transmit MIRRORED BIT 8	403
TOS01	Terminal 01 out of service	180
TOS02	Terminal 02 out of service	180
TOS03	Terminal 03 out of service	180
TOS04	Terminal 04 out of service	180
TOS05	Terminal 05 out of service	180
TOS06	Terminal 06 out of service	180
TOS07	Terminal 07 out of service	180
TOS08	Terminal 08 out of service	180
TOS09	Terminal 09 out of service	181
TOS10	Terminal 10 out of service	181
TOS11	Terminal 11 out of service	181
TOS12	Terminal 12 out of service	181
TOS13	Terminal 13 out of service	181
TOS14	Terminal 14 out of service	181
TOS15	Terminal 15 out of service	181
TOS16	Terminal 16 out of service	181
TOS17	Terminal 17 out of service	182
TOS18	Terminal 18 out of service	182
TOS19	Terminal 19 out of service	182
TOS20	Terminal 20 out of service	182
TOS21	Terminal 21 out of service	182
TPLLEXT	Update PLL using external signal	379
TPTP	The active relay time source is PTP	378
TQUAL1	Time quality, binary, add 1 when asserted	470
TQUAL2	Time quality, binary, add 2 when asserted	470
TQUAL4	Time quality, binary, add 4 when asserted	470
TQUAL8	Time quality, binary, add 8 when asserted	470
TRGTR	Reset all active target Relay Words	466
TRIP	Any terminal trip output	245

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 64 of 79)

Name	Bit Description	Row
TRIP01	Terminal 01 trip output	242
TRIP02	Terminal 02 trip output	242
TRIP03	Terminal 03 trip output	242
TRIP04	Terminal 04 trip output	242
TRIP05	Terminal 05 trip output	242
TRIP06	Terminal 06 trip output	242
TRIP07	Terminal 07 trip output	242
TRIP08	Terminal 08 trip output	242
TRIP09	Terminal 09 trip output	243
TRIP10	Terminal 10 trip output	243
TRIP11	Terminal 11 trip output	243
TRIP12	Terminal 12 trip output	243
TRIP13	Terminal 13 trip output	243
TRIP14	Terminal 14 trip output	243
TRIP15	Terminal 15 trip output	243
TRIP16	Terminal 16 trip output	243
TRIP17	Terminal 17 trip output	244
TRIP18	Terminal 18 trip output	244
TRIP19	Terminal 19 trip output	244
TRIP20	Terminal 20 trip output	244
TRIP21	Terminal 21 trip output	244
TRIPLED	Trip LED	0
TSER	The active relay time source is serial IRIG	378
TSNTPB	Asserts if time was synchronized with backup NTP server before SNTP time-out period expired	379
TSNTPP	Asserts if time was synchronized with primary NTP server before SNTP time-out period expired	379
TSOK	Assert if current time-source accuracy is sufficient for synchronized phasor measurements	378
TSSW	High-priority time source switching	379
TSYNC	Assert when ADC sampling is synchronized to a valid high-priority time source	379
TSYNCA	Assert while the time mark from time source or fixed internal source is not synchronized	378
TUPDH	Assert if update source is high-priority time source	378
TUTC1	IRIG-B offset hours from UTC time, binary, add 1 if asserted	469
TUTC2	IRIG-B offset hours from UTC time, binary, add 2 if asserted	469
TUTC4	IRIG-B offset hours from UTC time, binary, add 4 if asserted	469
TUTC8	IRIG-B offset hours from UTC time, binary, add 8 if asserted	469
TUTCH	IRIG-B offset half-hour from UTC time, binary, add 0.5 if asserted	469
TUTCS	IRIG-B offset hours sign from UTC time, subtract the UTC offset if TUTCS is asserted, add otherwise	469
ULTR01	Terminal 01 unlatch trip	246
ULTR02	Terminal 02 unlatch trip	246
ULTR03	Terminal 03 unlatch trip	246
ULTR04	Terminal 04 unlatch trip	246
ULTR05	Terminal 05 unlatch trip	246

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 65 of 79)

Name	Bit Description	Row
ULTR06	Terminal 06 unlatch trip	246
ULTR07	Terminal 07 unlatch trip	246
ULTR08	Terminal 08 unlatch trip	246
ULTR09	Terminal 09 unlatch trip	247
ULTR10	Terminal 10 unlatch trip	247
ULTR11	Terminal 11 unlatch trip	247
ULTR12	Terminal 12 unlatch trip	247
ULTR13	Terminal 13 unlatch trip	247
ULTR14	Terminal 14 unlatch trip	247
ULTR15	Terminal 15 unlatch trip	247
ULTR16	Terminal 16 unlatch trip	247
ULTR17	Terminal 17 unlatch trip	248
ULTR18	Terminal 18 unlatch trip	248
ULTR19	Terminal 19 unlatch trip	248
ULTR20	Terminal 20 unlatch trip	248
ULTR21	Terminal 21 unlatch trip	248
UPD_BLK	Block updating internal clock period and master time	472
UPD_EN	Enable updating internal clock with selected external time source	378
VB001	Virtual Bit 001	439
VB002	Virtual Bit 002	439
VB003	Virtual Bit 003	439
VB004	Virtual Bit 004	439
VB005	Virtual Bit 005	439
VB006	Virtual Bit 006	439
VB007	Virtual Bit 007	439
VB008	Virtual Bit 008	439
VB009	Virtual Bit 009	438
VB010	Virtual Bit 010	438
VB011	Virtual Bit 011	438
VB012	Virtual Bit 012	438
VB013	Virtual Bit 013	438
VB014	Virtual Bit 014	438
VB015	Virtual Bit 015	438
VB016	Virtual Bit 016	438
VB017	Virtual Bit 017	437
VB018	Virtual Bit 018	437
VB019	Virtual Bit 019	437
VB020	Virtual Bit 020	437
VB021	Virtual Bit 021	437
VB022	Virtual Bit 022	437
VB023	Virtual Bit 023	437

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 66 of 79)

Name	Bit Description	Row
VB024	Virtual Bit 024	437
VB025	Virtual Bit 025	436
VB026	Virtual Bit 026	436
VB027	Virtual Bit 027	436
VB028	Virtual Bit 028	436
VB029	Virtual Bit 029	436
VB030	Virtual Bit 030	436
VB031	Virtual Bit 031	436
VB032	Virtual Bit 032	436
VB033	Virtual Bit 033	435
VB034	Virtual Bit 034	435
VB035	Virtual Bit 035	435
VB036	Virtual Bit 036	435
VB037	Virtual Bit 037	435
VB038	Virtual Bit 038	435
VB039	Virtual Bit 039	435
VB040	Virtual Bit 040	435
VB041	Virtual Bit 041	434
VB042	Virtual Bit 042	434
VB043	Virtual Bit 043	434
VB044	Virtual Bit 044	434
VB045	Virtual Bit 045	434
VB046	Virtual Bit 046	434
VB047	Virtual Bit 047	434
VB048	Virtual Bit 048	434
VB049	Virtual Bit 049	433
VB050	Virtual Bit 050	433
VB051	Virtual Bit 051	433
VB052	Virtual Bit 052	433
VB053	Virtual Bit 053	433
VB054	Virtual Bit 054	433
VB055	Virtual Bit 055	433
VB056	Virtual Bit 056	433
VB057	Virtual Bit 057	432
VB058	Virtual Bit 058	432
VB059	Virtual Bit 059	432
VB060	Virtual Bit 060	432
VB061	Virtual Bit 061	432
VB062	Virtual Bit 062	432
VB063	Virtual Bit 063	432
VB064	Virtual Bit 064	432

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 67 of 79)

Name	Bit Description	Row
VB065	Virtual Bit 065	431
VB066	Virtual Bit 066	431
VB067	Virtual Bit 067	431
VB068	Virtual Bit 068	431
VB069	Virtual Bit 069	431
VB070	Virtual Bit 070	431
VB071	Virtual Bit 071	431
VB072	Virtual Bit 072	431
VB073	Virtual Bit 073	430
VB074	Virtual Bit 074	430
VB075	Virtual Bit 075	430
VB076	Virtual Bit 076	430
VB077	Virtual Bit 077	430
VB078	Virtual Bit 078	430
VB079	Virtual Bit 079	430
VB080	Virtual Bit 080	430
VB081	Virtual Bit 081	429
VB082	Virtual Bit 082	429
VB083	Virtual Bit 083	429
VB084	Virtual Bit 084	429
VB085	Virtual Bit 085	429
VB086	Virtual Bit 086	429
VB087	Virtual Bit 087	429
VB088	Virtual Bit 088	429
VB089	Virtual Bit 089	428
VB090	Virtual Bit 090	428
VB091	Virtual Bit 091	428
VB092	Virtual Bit 092	428
VB093	Virtual Bit 093	428
VB094	Virtual Bit 094	428
VB095	Virtual Bit 095	428
VB096	Virtual Bit 096	428
VB097	Virtual Bit 097	427
VB098	Virtual Bit 098	427
VB099	Virtual Bit 099	427
VB100	Virtual Bit 100	427
VB101	Virtual Bit 101	427
VB102	Virtual Bit 102	427
VB103	Virtual Bit 103	427
VB104	Virtual Bit 104	427
VB105	Virtual Bit 105	426

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 68 of 79)

Name	Bit Description	Row
VB106	Virtual Bit 106	426
VB107	Virtual Bit 107	426
VB108	Virtual Bit 108	426
VB109	Virtual Bit 109	426
VB110	Virtual Bit 110	426
VB111	Virtual Bit 111	426
VB112	Virtual Bit 112	426
VB113	Virtual Bit 113	425
VB114	Virtual Bit 114	425
VB115	Virtual Bit 115	425
VB116	Virtual Bit 116	425
VB117	Virtual Bit 117	425
VB118	Virtual Bit 118	425
VB119	Virtual Bit 119	425
VB120	Virtual Bit 120	425
VB121	Virtual Bit 121	424
VB122	Virtual Bit 122	424
VB123	Virtual Bit 123	424
VB124	Virtual Bit 124	424
VB125	Virtual Bit 125	424
VB126	Virtual Bit 126	424
VB127	Virtual Bit 127	424
VB128	Virtual Bit 128	424
VB129	Virtual Bit 129	423
VB130	Virtual Bit 130	423
VB131	Virtual Bit 131	423
VB132	Virtual Bit 132	423
VB133	Virtual Bit 133	423
VB134	Virtual Bit 134	423
VB135	Virtual Bit 135	423
VB136	Virtual Bit 136	423
VB137	Virtual Bit 137	422
VB138	Virtual Bit 138	422
VB139	Virtual Bit 139	422
VB140	Virtual Bit 140	422
VB141	Virtual Bit 141	422
VB142	Virtual Bit 142	422
VB143	Virtual Bit 143	422
VB144	Virtual Bit 144	422
VB145	Virtual Bit 145	421
VB146	Virtual Bit 146	421

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 69 of 79)

Name	Bit Description	Row
VB147	Virtual Bit 147	421
VB148	Virtual Bit 148	421
VB149	Virtual Bit 149	421
VB150	Virtual Bit 150	421
VB151	Virtual Bit 151	421
VB152	Virtual Bit 152	421
VB153	Virtual Bit 153	420
VB154	Virtual Bit 154	420
VB155	Virtual Bit 155	420
VB156	Virtual Bit 156	420
VB157	Virtual Bit 157	420
VB158	Virtual Bit 158	420
VB159	Virtual Bit 159	420
VB160	Virtual Bit 160	420
VB161	Virtual Bit 161	419
VB162	Virtual Bit 162	419
VB163	Virtual Bit 163	419
VB164	Virtual Bit 164	419
VB165	Virtual Bit 165	419
VB166	Virtual Bit 166	419
VB167	Virtual Bit 167	419
VB168	Virtual Bit 168	419
VB169	Virtual Bit 169	418
VB170	Virtual Bit 170	418
VB171	Virtual Bit 171	418
VB172	Virtual Bit 172	418
VB173	Virtual Bit 173	418
VB174	Virtual Bit 174	418
VB175	Virtual Bit 175	418
VB176	Virtual Bit 176	418
VB177	Virtual Bit 177	417
VB178	Virtual Bit 178	417
VB179	Virtual Bit 179	417
VB180	Virtual Bit 180	417
VB181	Virtual Bit 181	417
VB182	Virtual Bit 182	417
VB183	Virtual Bit 183	417
VB184	Virtual Bit 184	417
VB185	Virtual Bit 185	416
VB186	Virtual Bit 186	416
VB187	Virtual Bit 187	416

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 70 of 79)

Name	Bit Description	Row
VB188	Virtual Bit 188	416
VB189	Virtual Bit 189	416
VB190	Virtual Bit 190	416
VB191	Virtual Bit 191	416
VB192	Virtual Bit 192	416
VB193	Virtual Bit 193	415
VB194	Virtual Bit 194	415
VB195	Virtual Bit 195	415
VB196	Virtual Bit 196	415
VB197	Virtual Bit 197	415
VB198	Virtual Bit 198	415
VB199	Virtual Bit 199	415
VB200	Virtual Bit 200	415
VB201	Virtual Bit 201	414
VB202	Virtual Bit 202	414
VB203	Virtual Bit 203	414
VB204	Virtual Bit 204	414
VB205	Virtual Bit 205	414
VB206	Virtual Bit 206	414
VB207	Virtual Bit 207	414
VB208	Virtual Bit 208	414
VB209	Virtual Bit 209	413
VB210	Virtual Bit 210	413
VB211	Virtual Bit 211	413
VB212	Virtual Bit 212	413
VB213	Virtual Bit 213	413
VB214	Virtual Bit 214	413
VB215	Virtual Bit 215	413
VB216	Virtual Bit 216	413
VB217	Virtual Bit 217	412
VB218	Virtual Bit 218	412
VB219	Virtual Bit 219	412
VB220	Virtual Bit 220	412
VB221	Virtual Bit 221	412
VB222	Virtual Bit 222	412
VB223	Virtual Bit 223	412
VB224	Virtual Bit 224	412
VB225	Virtual Bit 225	411
VB226	Virtual Bit 226	411
VB227	Virtual Bit 227	411
VB228	Virtual Bit 228	411

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 71 of 79)

Name	Bit Description	Row
VB229	Virtual Bit 229	411
VB230	Virtual Bit 230	411
VB231	Virtual Bit 231	411
VB232	Virtual Bit 232	411
VB233	Virtual Bit 233	410
VB234	Virtual Bit 234	410
VB235	Virtual Bit 235	410
VB236	Virtual Bit 236	410
VB237	Virtual Bit 237	410
VB238	Virtual Bit 238	410
VB239	Virtual Bit 239	410
VB240	Virtual Bit 240	410
VB241	Virtual Bit 241	409
VB242	Virtual Bit 242	409
VB243	Virtual Bit 243	409
VB244	Virtual Bit 244	409
VB245	Virtual Bit 245	409
VB246	Virtual Bit 246	409
VB247	Virtual Bit 247	409
VB248	Virtual Bit 248	409
VB249	Virtual Bit 249	408
VB250	Virtual Bit 250	408
VB251	Virtual Bit 251	408
VB252	Virtual Bit 252	408
VB253	Virtual Bit 253	408
VB254	Virtual Bit 254	408
VB255	Virtual Bit 255	408
VB256	Virtual Bit 256	408
XBF01	Circuit Breaker 1 external breaker failure input (SELOGIC control equation)	183
XBF02	Circuit Breaker 2 external breaker failure input (SELOGIC control equation)	184
XBF03	Circuit Breaker 3 external breaker failure input (SELOGIC control equation)	185
XBF04	Circuit Breaker 4 external breaker failure input (SELOGIC control equation)	186
XBF05	Circuit Breaker 5 external breaker failure input (SELOGIC control equation)	187
XBF06	Circuit Breaker 6 external breaker failure input (SELOGIC control equation)	188
XBF07	Circuit Breaker 7 external breaker failure input (SELOGIC control equation)	189
XBF08	Circuit Breaker 8 external breaker failure input (SELOGIC control equation)	190
XBF09	Circuit Breaker 9 external breaker failure input (SELOGIC control equation)	191
XBF10	Circuit Breaker 10 external breaker failure input (SELOGIC control equation)	192
XBF11	Circuit Breaker 11 external breaker failure input (SELOGIC control equation)	193
XBF12	Circuit Breaker 12 external breaker failure input (SELOGIC control equation)	194
XBF13	Circuit Breaker 13 external breaker failure input (SELOGIC control equation)	195

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 72 of 79)

Name	Bit Description	Row
XBF14	Circuit Breaker 14 external breaker failure input (SELOGIC control equation)	196
XBF15	Circuit Breaker 15 external breaker failure input (SELOGIC control equation)	197
XBF16	Circuit Breaker 16 external breaker failure input (SELOGIC control equation)	198
XBF17	Circuit Breaker 17 external breaker failure input (SELOGIC control equation)	199
XBF18	Circuit Breaker 18 external breaker failure input (SELOGIC control equation)	200
XBF19	Circuit Breaker 19 external breaker failure input (SELOGIC control equation)	201
XBF20	Circuit Breaker 20 external breaker failure input (SELOGIC control equation)	202
XBF21	Circuit Breaker 21 external breaker failure input (SELOGIC control equation)	203
YEAR1	IRIG-B year information, binary-coded-decimal, add 1 if asserted	468
YEAR10	IRIG-B year information, binary-coded-decimal, add 10 if asserted	468
YEAR2	IRIG-B year information, binary-coded-decimal, add 2 if asserted	468
YEAR20	IRIG-B year information, binary-coded-decimal, add 20 if asserted	468
YEAR4	IRIG-B year information, binary-coded-decimal, add 4 if asserted	468
YEAR40	IRIG-B year information, binary-coded-decimal, add 40 if asserted	468
YEAR8	IRIG-B year information, binary-coded-decimal, add 8 if asserted	468
YEAR80	IRIG-B year information, binary-coded-decimal, add 80 if asserted	468
Z1BZ1	Bus-Zone 1 is part of Protective Zone 1	144
Z1BZ2	Bus-Zone 2 is part of Protective Zone 1	144
Z1BZ3	Bus-Zone 3 is part of Protective Zone 1	144
Z1BZ4	Bus-Zone 4 is part of Protective Zone 1	144
Z1BZ5	Bus-Zone 5 is part of Protective Zone 1	144
Z1BZ6	Bus-Zone 6 is part of Protective Zone 1	144
Z1S	Zone 1 supervision asserted	153
Z2BZ2	Bus-Zone 2 is part of Protective Zone 2	145
Z2BZ3	Bus-Zone 3 is part of Protective Zone 2	145
Z2BZ4	Bus-Zone 4 is part of Protective Zone 2	145
Z2BZ5	Bus-Zone 5 is part of Protective Zone 2	145
Z2BZ6	Bus-Zone 6 is part of Protective Zone 2	145
Z2S	Zone 2 supervision asserted	153
Z3BZ3	Bus-Zone 3 is part of Protective Zone 3	146
Z3BZ4	Bus-Zone 4 is part of Protective Zone 3	146
Z3BZ5	Bus-Zone 5 is part of Protective Zone 3	146
Z3BZ6	Bus-Zone 6 is part of Protective Zone 3	146
Z3S	Zone 3 supervision asserted	153
Z4BZ4	Bus-Zone 4 is part of Protective Zone 4	147
Z4BZ5	Bus-Zone 5 is part of Protective Zone 4	147
Z4BZ6	Bus-Zone 6 is part of Protective Zone 4	147
Z4S	Zone 4 supervision asserted	153
Z5BZ5	Bus-Zone 5 is part of Protective Zone 5	148
Z5BZ6	Bus-Zone 6 is part of Protective Zone 5	148
Z5S	Zone 5 supervision asserted	153

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 73 of 79)

Name	Bit Description	Row
Z6BZ6	Bus-Zone 6 is part of Protective Zone 6	149
Z6S	Zone 6 supervision asserted	153
ZN1I01	Terminal 01 connected to Zone 1	80
ZN1I01T	Terminal 01 connected to Zone 1 and will be tripped	104
ZN1I02	Terminal 02 connected to Zone 1	80
ZN1I02T	Terminal 02 connected to Zone 1 and will be tripped	104
ZN1I03	Terminal 03 connected to Zone 1	80
ZN1I03T	Terminal 03 connected to Zone 1 and will be tripped	104
ZN1I04	Terminal 04 connected to Zone 1	80
ZN1I04T	Terminal 04 connected to Zone 1 and will be tripped	104
ZN1I05	Terminal 05 connected to Zone 1	80
ZN1I05T	Terminal 05 connected to Zone 1 and will be tripped	104
ZN1I06	Terminal 06 connected to Zone 1	80
ZN1I06T	Terminal 06 connected to Zone 1 and will be tripped	104
ZN1I07	Terminal 07 connected to Zone 1	80
ZN1I07T	Terminal 07 connected to Zone 1 and will be tripped	104
ZN1I08	Terminal 08 connected to Zone 1	80
ZN1I08T	Terminal 08 connected to Zone 1 and will be tripped	104
ZN1I09	Terminal 09 connected to Zone 1	81
ZN1I09T	Terminal 09 connected to Zone 1 and will be tripped	105
ZN1I10	Terminal 10 connected to Zone 1	81
ZN1I10T	Terminal 10 connected to Zone 1 and will be tripped	105
ZN1I11	Terminal 11 connected to Zone 1	81
ZN1I11T	Terminal 11 connected to Zone 1 and will be tripped	105
ZN1I12	Terminal 12 connected to Zone 1	81
ZN1I12T	Terminal 12 connected to Zone 1 and will be tripped	105
ZN1I13	Terminal 13 connected to Zone 1	81
ZN1I13T	Terminal 13 connected to Zone 1 and will be tripped	105
ZN1I14	Terminal 14 connected to Zone 1	81
ZN1I14T	Terminal 14 connected to Zone 1 and will be tripped	105
ZN1I15	Terminal 15 connected to Zone 1	81
ZN1I15T	Terminal 15 connected to Zone 1 and will be tripped	105
ZN1I16	Terminal 16 connected to Zone 1	81
ZN1I16T	Terminal 16 connected to Zone 1 and will be tripped	105
ZN1I17	Terminal 17 connected to Zone 1	82
ZN1I17T	Terminal 17 connected to Zone 1 and will be tripped	106
ZN1I18	Terminal 18 connected to Zone 1	82
ZN1I18T	Terminal 18 connected to Zone 1 and will be tripped	106
ZN1I19	Terminal 19 connected to Zone 1	82
ZN1I19T	Terminal 19 connected to Zone 1 and will be tripped	106
ZN1I20	Terminal 20 connected to Zone 1	82

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 74 of 79)

Name	Bit Description	Row
ZN1I20T	Terminal 20 connected to Zone 1 and will be tripped	106
ZN1I21	Terminal 21 connected to Zone 1	82
ZN1I21T	Terminal 21 connected to Zone 1 and will be tripped	106
ZN2I01	Terminal 01 connected to Zone 2	84
ZN2I01T	Terminal 01 connected to Zone 2 and will be tripped	108
ZN2I02	Terminal 02 connected to Zone 2	84
ZN2I02T	Terminal 02 connected to Zone 2 and will be tripped	108
ZN2I03	Terminal 03 connected to Zone 2	84
ZN2I03T	Terminal 03 connected to Zone 2 and will be tripped	108
ZN2I04	Terminal 04 connected to Zone 2	84
ZN2I04T	Terminal 04 connected to Zone 2 and will be tripped	108
ZN2I05	Terminal 05 connected to Zone 2	84
ZN2I05T	Terminal 05 connected to Zone 2 and will be tripped	108
ZN2I06	Terminal 06 connected to Zone 2	84
ZN2I06T	Terminal 06 connected to Zone 2 and will be tripped	108
ZN2I07	Terminal 07 connected to Zone 2	84
ZN2I07T	Terminal 07 connected to Zone 2 and will be tripped	108
ZN2I08	Terminal 08 connected to Zone 2	84
ZN2I08T	Terminal 08 connected to Zone 2 and will be tripped	108
ZN2I09	Terminal 09 connected to Zone 2	85
ZN2I09T	Terminal 09 connected to Zone 2 and will be tripped	109
ZN2I10	Terminal 10 connected to Zone 2	85
ZN2I10T	Terminal 10 connected to Zone 2 and will be tripped	109
ZN2I11	Terminal 11 connected to Zone 2	85
ZN2I11T	Terminal 11 connected to Zone 2 and will be tripped	109
ZN2I12	Terminal 12 connected to Zone 2	85
ZN2I12T	Terminal 12 connected to Zone 2 and will be tripped	109
ZN2I13	Terminal 13 connected to Zone 2	85
ZN2I13T	Terminal 13 connected to Zone 2 and will be tripped	109
ZN2I14	Terminal 14 connected to Zone 2	85
ZN2I14T	Terminal 14 connected to Zone 2 and will be tripped	109
ZN2I15	Terminal 15 connected to Zone 2	85
ZN2I15T	Terminal 15 connected to Zone 2 and will be tripped	109
ZN2I16	Terminal 16 connected to Zone 2	85
ZN2I16T	Terminal 16 connected to Zone 2 and will be tripped	109
ZN2I17	Terminal 17 connected to Zone 2	86
ZN2I17T	Terminal 17 connected to Zone 2 and will be tripped	110
ZN2I18	Terminal 18 connected to Zone 2	86
ZN2I18T	Terminal 18 connected to Zone 2 and will be tripped	110
ZN2I19	Terminal 19 connected to Zone 2	86
ZN2I19T	Terminal 19 connected to Zone 2 and will be tripped	110

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 75 of 79)

Name	Bit Description	Row
ZN2I20	Terminal 20 connected to Zone 2	86
ZN2I20T	Terminal 20 connected to Zone 2 and will be tripped	110
ZN2I21	Terminal 21 connected to Zone 2	86
ZN2I21T	Terminal 21 connected to Zone 2 and will be tripped	110
ZN3I01	Terminal 01 connected to Zone 3	88
ZN3I01T	Terminal 01 connected to Zone 3 and will be tripped	112
ZN3I02	Terminal 02 connected to Zone 3	88
ZN3I02T	Terminal 02 connected to Zone 3 and will be tripped	112
ZN3I03	Terminal 03 connected to Zone 3	88
ZN3I03T	Terminal 03 connected to Zone 3 and will be tripped	112
ZN3I04	Terminal 04 connected to Zone 3	88
ZN3I04T	Terminal 04 connected to Zone 3 and will be tripped	112
ZN3I05	Terminal 05 connected to Zone 3	88
ZN3I05T	Terminal 05 connected to Zone 3 and will be tripped	112
ZN3I06	Terminal 06 connected to Zone 3	88
ZN3I06T	Terminal 06 connected to Zone 3 and will be tripped	112
ZN3I07	Terminal 07 connected to Zone 3	88
ZN3I07T	Terminal 07 connected to Zone 3 and will be tripped	112
ZN3I08	Terminal 08 connected to Zone 3	88
ZN3I08T	Terminal 08 connected to Zone 3 and will be tripped	112
ZN3I09	Terminal 09 connected to Zone 3	89
ZN3I09T	Terminal 09 connected to Zone 3 and will be tripped	113
ZN3I10	Terminal 10 connected to Zone 3	89
ZN3I10T	Terminal 10 connected to Zone 3 and will be tripped	113
ZN3I11	Terminal 11 connected to Zone 3	89
ZN3I11T	Terminal 11 connected to Zone 3 and will be tripped	113
ZN3I12	Terminal 12 connected to Zone 3	89
ZN3I12T	Terminal 12 connected to Zone 3 and will be tripped	113
ZN3I13	Terminal 13 connected to Zone 3	89
ZN3I13T	Terminal 13 connected to Zone 3 and will be tripped	113
ZN3I14	Terminal 14 connected to Zone 3	89
ZN3I14T	Terminal 14 connected to Zone 3 and will be tripped	113
ZN3I15	Terminal 15 connected to Zone 3	89
ZN3I15T	Terminal 15 connected to Zone 3 and will be tripped	113
ZN3I16	Terminal 16 connected to Zone 3	89
ZN3I16T	Terminal 16 connected to Zone 3 and will be tripped	113
ZN3I17	Terminal 17 connected to Zone 3	90
ZN3I17T	Terminal 17 connected to Zone 3 and will be tripped	114
ZN3I18	Terminal 18 connected to Zone 3	90
ZN3I18T	Terminal 18 connected to Zone 3 and will be tripped	114
ZN3I19	Terminal 19 connected to Zone 3	90

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 76 of 79)

Name	Bit Description	Row
ZN3I19T	Terminal 19 connected to Zone 3 and will be tripped	114
ZN3I20	Terminal 20 connected to Zone 3	90
ZN3I20T	Terminal 20 connected to Zone 3 and will be tripped	114
ZN3I21	Terminal 21 connected to Zone 3	90
ZN3I21T	Terminal 21 connected to Zone 3 and will be tripped	114
ZN4I01	Terminal 01 connected to Zone 4	92
ZN4I01T	Terminal 01 connected to Zone 4 and will be tripped	116
ZN4I02	Terminal 02 connected to Zone 4	92
ZN4I02T	Terminal 02 connected to Zone 4 and will be tripped	116
ZN4I03	Terminal 03 connected to Zone 4	92
ZN4I03T	Terminal 03 connected to Zone 4 and will be tripped	116
ZN4I04	Terminal 04 connected to Zone 4	92
ZN4I04T	Terminal 04 connected to Zone 4 and will be tripped	116
ZN4I05	Terminal 05 connected to Zone 4	92
ZN4I05T	Terminal 05 connected to Zone 4 and will be tripped	116
ZN4I06	Terminal 06 connected to Zone 4	92
ZN4I06T	Terminal 06 connected to Zone 4 and will be tripped	116
ZN4I07	Terminal 07 connected to Zone 4	92
ZN4I07T	Terminal 07 connected to Zone 4 and will be tripped	116
ZN4I08	Terminal 08 connected to Zone 4	92
ZN4I08T	Terminal 08 connected to Zone 4 and will be tripped	116
ZN4I09	Terminal 09 connected to Zone 4	93
ZN4I09T	Terminal 09 connected to Zone 4 and will be tripped	117
ZN4I10	Terminal 10 connected to Zone 4	93
ZN4I10T	Terminal 10 connected to Zone 4 and will be tripped	117
ZN4I11	Terminal 11 connected to Zone 4	93
ZN4I11T	Terminal 11 connected to Zone 4 and will be tripped	117
ZN4I12	Terminal 12 connected to Zone 4	93
ZN4I12T	Terminal 12 connected to Zone 4 and will be tripped	117
ZN4I13	Terminal 13 connected to Zone 4	93
ZN4I13T	Terminal 13 connected to Zone 4 and will be tripped	117
ZN4I14	Terminal 14 connected to Zone 4	93
ZN4I14T	Terminal 14 connected to Zone 4 and will be tripped	117
ZN4I15	Terminal 15 connected to Zone 4	93
ZN4I15T	Terminal 15 connected to Zone 4 and will be tripped	117
ZN4I16	Terminal 16 connected to Zone 4	93
ZN4I16T	Terminal 16 connected to Zone 4 and will be tripped	117
ZN4I17	Terminal 17 connected to Zone 4	94
ZN4I17T	Terminal 17 connected to Zone 4 and will be tripped	118
ZN4I18	Terminal 18 connected to Zone 4	94
ZN4I18T	Terminal 18 connected to Zone 4 and will be tripped	118

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 77 of 79)

Name	Bit Description	Row
ZN4I19	Terminal 19 connected to Zone 4	94
ZN4I19T	Terminal 19 connected to Zone 4 and will be tripped	118
ZN4I20	Terminal 20 connected to Zone 4	94
ZN4I20T	Terminal 20 connected to Zone 4 and will be tripped	118
ZN4I21	Terminal 21 connected to Zone 4	94
ZN4I21T	Terminal 21 connected to Zone 4 and will be tripped	118
ZN5I01	Terminal 01 connected to Zone 5	96
ZN5I01T	Terminal 01 connected to Zone 5 and will be tripped	120
ZN5I02	Terminal 02 connected to Zone 5	96
ZN5I02T	Terminal 02 connected to Zone 5 and will be tripped	120
ZN5I03	Terminal 03 connected to Zone 5	96
ZN5I03T	Terminal 03 connected to Zone 5 and will be tripped	120
ZN5I04	Terminal 04 connected to Zone 5	96
ZN5I04T	Terminal 04 connected to Zone 5 and will be tripped	120
ZN5I05	Terminal 05 connected to Zone 5	96
ZN5I05T	Terminal 05 connected to Zone 5 and will be tripped	120
ZN5I06	Terminal 06 connected to Zone 5	96
ZN5I06T	Terminal 06 connected to Zone 5 and will be tripped	120
ZN5I07	Terminal 07 connected to Zone 5	96
ZN5I07T	Terminal 07 connected to Zone 5 and will be tripped	120
ZN5I08	Terminal 08 connected to Zone 5	96
ZN5I08T	Terminal 08 connected to Zone 5 and will be tripped	120
ZN5I09	Terminal 09 connected to Zone 5	97
ZN5I09T	Terminal 09 connected to Zone 5 and will be tripped	121
ZN5I10	Terminal 10 connected to Zone 5	97
ZN5I10T	Terminal 10 connected to Zone 5 and will be tripped	121
ZN5I11	Terminal 11 connected to Zone 5	97
ZN5I11T	Terminal 11 connected to Zone 5 and will be tripped	121
ZN5I12	Terminal 12 connected to Zone 5	97
ZN5I12T	Terminal 12 connected to Zone 5 and will be tripped	121
ZN5I13	Terminal 13 connected to Zone 5	97
ZN5I13T	Terminal 13 connected to Zone 5 and will be tripped	121
ZN5I14	Terminal 14 connected to Zone 5	97
ZN5I14T	Terminal 14 connected to Zone 5 and will be tripped	121
ZN5I15	Terminal 15 connected to Zone 5	97
ZN5I15T	Terminal 15 connected to Zone 5 and will be tripped	121
ZN5I16	Terminal 16 connected to Zone 5	97
ZN5I16T	Terminal 16 connected to Zone 5 and will be tripped	121
ZN5I17	Terminal 17 connected to Zone 5	98
ZN5I17T	Terminal 17 connected to Zone 5 and will be tripped	122
ZN5I18	Terminal 18 connected to Zone 5	98

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 78 of 79)

Name	Bit Description	Row
ZN5I18T	Terminal 18 connected to Zone 5 and will be tripped	122
ZN5I19	Terminal 19 connected to Zone 5	98
ZN5I19T	Terminal 19 connected to Zone 5 and will be tripped	122
ZN5I20	Terminal 20 connected to Zone 5	98
ZN5I20T	Terminal 20 connected to Zone 5 and will be tripped	122
ZN5I21	Terminal 21 connected to Zone 5	98
ZN5I21T	Terminal 21 connected to Zone 5 and will be tripped	122
ZN6I01	Terminal 01 connected to Zone 6	100
ZN6I01T	Terminal 01 connected to Zone 6 and will be tripped	124
ZN6I02	Terminal 02 connected to Zone 6	100
ZN6I02T	Terminal 02 connected to Zone 6 and will be tripped	124
ZN6I03	Terminal 03 connected to Zone 6	100
ZN6I03T	Terminal 03 connected to Zone 6 and will be tripped	124
ZN6I04	Terminal 04 connected to Zone 6	100
ZN6I04T	Terminal 04 connected to Zone 6 and will be tripped	124
ZN6I05	Terminal 05 connected to Zone 6	100
ZN6I05T	Terminal 05 connected to Zone 6 and will be tripped	124
ZN6I06	Terminal 06 connected to Zone 6	100
ZN6I06T	Terminal 06 connected to Zone 6 and will be tripped	124
ZN6I07	Terminal 07 connected to Zone 6	100
ZN6I07T	Terminal 07 connected to Zone 6 and will be tripped	124
ZN6I08	Terminal 08 connected to Zone 6	100
ZN6I08T	Terminal 08 connected to Zone 6 and will be tripped	124
ZN6I09	Terminal 09 connected to Zone 6	101
ZN6I09T	Terminal 09 connected to Zone 6 and will be tripped	125
ZN6I10	Terminal 10 connected to Zone 6	101
ZN6I10T	Terminal 10 connected to Zone 6 and will be tripped	125
ZN6I11	Terminal 11 connected to Zone 6	101
ZN6I11T	Terminal 11 connected to Zone 6 and will be tripped	125
ZN6I12	Terminal 12 connected to Zone 6	101
ZN6I12T	Terminal 12 connected to Zone 6 and will be tripped	125
ZN6I13	Terminal 13 connected to Zone 6	101
ZN6I13T	Terminal 13 connected to Zone 6 and will be tripped	125
ZN6I14	Terminal 14 connected to Zone 6	101
ZN6I14T	Terminal 14 connected to Zone 6 and will be tripped	125
ZN6I15	Terminal 15 connected to Zone 6	101
ZN6I15T	Terminal 15 connected to Zone 6 and will be tripped	125
ZN6I16	Terminal 16 connected to Zone 6	101
ZN6I16T	Terminal 16 connected to Zone 6 and will be tripped	125
ZN6I17	Terminal 17 connected to Zone 6	102
ZN6I17T	Terminal 17 connected to Zone 6 and will be tripped	126

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 79 of 79)

Name	Bit Description	Row
ZN6I18	Terminal 18 connected to Zone 6	102
ZN6I18T	Terminal 18 connected to Zone 6 and will be tripped	126
ZN6I19	Terminal 19 connected to Zone 6	102
ZN6I19T	Terminal 19 connected to Zone 6 and will be tripped	126
ZN6I20	Terminal 20 connected to Zone 6	102
ZN6I20T	Terminal 20 connected to Zone 6 and will be tripped	126
ZN6I21	Terminal 21 connected to Zone 6	102
ZN6I21T	Terminal 21 connected to Zone 6 and will be tripped	126
ZONE1	Differential Zone 1 is active	150
ZONE2	Differential Zone 2 is active	150
ZONE3	Differential Zone 3 is active	150
ZONE4	Differential Zone 4 is active	150
ZONE5	Differential Zone 5 is active	150
ZONE6	Differential Zone 6 is active	150
ZSWO	Zone switching operation	152
ZSWOAL	Zone switching operation alarm	152
ZSWOIP	Zone switching operation in progress	152
ZSWOP	Change to either bus-zone-to-bus-zone or terminal-to-bus-zone conditions in any zone	151
ZSWOP1	Change to either bus-zone-to-bus-zone or terminal-to-bus-zone conditions in Zone 1	151
ZSWOP2	Change to either bus-zone-to-bus-zone or terminal-to-bus-zone conditions in Zone 2	151
ZSWOP3	Change to either bus-zone-to-bus-zone or terminal-to-bus-zone conditions in Zone 3	151
ZSWOP4	Change to either bus-zone-to-bus-zone or terminal-to-bus-zone conditions in Zone 4	151
ZSWOP5	Change to either bus-zone-to-bus-zone or terminal-to-bus-zone conditions in Zone 5	151
ZSWOP6	Change to either bus-zone-to-bus-zone or terminal-to-bus-zone conditions in Zone 6	151

Row List

Table 11.2 Row List of Relay Word Bits (Sheet 1 of 100)

Row	Name	Bit Description
Enable and Target LEDs		
0	EN	Relay enabled
0	TRIPLED	Trip LED
0	*	Reserved
0	*	Reserved
0	*	Reserved
0	*	Reserved
0	*	Reserved
0	*	Reserved

Table 11.2 Row List of Relay Word Bits (Sheet 2 of 100)

Row	Name	Bit Description
Target LEDs		
1	TLED_1	Front-panel target LED 1
1	TLED_2	Front-panel target LED 2
1	TLED_3	Front-panel target LED 3
1	TLED_4	Front-panel target LED 4
1	TLED_5	Front-panel target LED 5
1	TLED_6	Front-panel target LED 6
1	TLED_7	Front-panel target LED 7
1	TLED_8	Front-panel target LED 8
2	TLED_9	Front-panel target LED 9
2	TLED_10	Front-panel target LED 10
2	TLED_11	Front-panel target LED 11
2	TLED_12	Front-panel target LED 12
2	TLED_13	Front-panel target LED 13
2	TLED_14	Front-panel target LED 14
2	TLED_15	Front-panel target LED 15
2	TLED_16	Front-panel target LED 16
3	TLED_17	Front-panel target LED 17
3	TLED_18	Front-panel target LED 18
3	TLED_19	Front-panel target LED 19
3	TLED_20	Front-panel target LED 20
3	TLED_21	Front-panel target LED 21
3	TLED_22	Front-panel target LED 22
3	TLED_23	Front-panel target LED 23
3	TLED_24	Front-panel target LED 24
Open-Phase Detectors		
4	OPH08	Terminal 08 open phase detected
4	OPH07	Terminal 07 open phase detected
4	OPH06	Terminal 06 open phase detected
4	OPH05	Terminal 05 open phase detected
4	OPH04	Terminal 04 open phase detected
4	OPH03	Terminal 03 open phase detected
4	OPH02	Terminal 02 open phase detected
4	OPH01	Terminal 01 open phase detected
5	OPH16	Terminal 16 open phase detected
5	OPH15	Terminal 15 open phase detected
5	OPH14	Terminal 14 open phase detected
5	OPH13	Terminal 13 open phase detected
5	OPH12	Terminal 12 open phase detected
5	OPH11	Terminal 11 open phase detected
5	OPH10	Terminal 10 open phase detected

Table 11.2 Row List of Relay Word Bits (Sheet 3 of 100)

Row	Name	Bit Description
5	OPH09	Terminal 09 open phase detected
6	*	Reserved
6	*	Reserved
6	*	Reserved
6	OPH21	Terminal 21 open phase detected
6	OPH20	Terminal 20 open phase detected
6	OPH19	Terminal 19 open phase detected
6	OPH18	Terminal 18 open phase detected
6	OPH17	Terminal 17 open phase detected
52 Status		
7	52AL03	Circuit Breaker 03 alarm
7	52A03	Circuit Breaker 03 status
7	52CL02	Circuit Breaker 02 closed
7	52AL02	Circuit Breaker 02 alarm
7	52A02	Circuit Breaker 02 status
7	52CL01	Circuit Breaker 01 closed
7	52AL01	Circuit Breaker 01 alarm
7	52A01	Circuit Breaker 01 status
8	52A06	Circuit Breaker 06 status
8	52CL05	Circuit Breaker 05 closed
8	52AL05	Circuit Breaker 05 alarm
8	52A05	Circuit Breaker 05 status
8	52CL04	Circuit Breaker 04 closed
8	52AL04	Circuit Breaker 04 alarm
8	52A04	Circuit Breaker 04 status
8	52CL03	Circuit Breaker 03 closed
9	52CL08	Circuit Breaker 08 closed
9	52AL08	Circuit Breaker 08 alarm
9	52A08	Circuit Breaker 08 status
9	52CL07	Circuit Breaker 07 closed
9	52AL07	Circuit Breaker 07 alarm
9	52A07	Circuit Breaker 07 status
9	52CL06	Circuit Breaker 06 closed
9	52AL06	Circuit Breaker 06 alarm
10	52AL11	Circuit Breaker 11 alarm
10	52A11	Circuit Breaker 11 status
10	52CL10	Circuit Breaker 10 closed
10	52AL10	Circuit Breaker 10 alarm
10	52A10	Circuit Breaker 10 status
10	52CL09	Circuit Breaker 09 closed
10	52AL09	Circuit Breaker 09 alarm

Table 11.2 Row List of Relay Word Bits (Sheet 4 of 100)

Row	Name	Bit Description
10	52A09	Circuit Breaker 09 status
11	52A14	Circuit Breaker 14 status
11	52CL13	Circuit Breaker 13 closed
11	52AL13	Circuit Breaker 13 alarm
11	52A13	Circuit Breaker 13 status
11	52CL12	Circuit Breaker 12 closed
11	52AL12	Circuit Breaker 12 alarm
11	52A12	Circuit Breaker 12 status
11	52CL11	Circuit Breaker 11 closed
12	52CL16	Circuit Breaker 16 closed
12	52AL16	Circuit Breaker 16 alarm
12	52A16	Circuit Breaker 16 status
12	52CL15	Circuit Breaker 15 closed
12	52AL15	Circuit Breaker 15 alarm
12	52A15	Circuit Breaker 15 status
12	52CL14	Circuit Breaker 14 closed
12	52AL14	Circuit Breaker 14 alarm
13	52AL19	Circuit Breaker 19 alarm
13	52A19	Circuit Breaker 19 status
13	52CL18	Circuit Breaker 18 closed
13	52AL18	Circuit Breaker 18 alarm
13	52A18	Circuit Breaker 18 status
13	52CL17	Circuit Breaker 17 closed
13	52AL17	Circuit Breaker 17 alarm
13	52A17	Circuit Breaker 17 status
14	52AL	Any circuit breaker alarm
14	52CL21	Circuit Breaker 21 closed
14	52AL21	Circuit Breaker 21 alarm
14	52A21	Circuit Breaker 21 status
14	52CL20	Circuit Breaker 20 closed
14	52AL20	Circuit Breaker 20 alarm
14	52A20	Circuit Breaker 20 status
14	52CL19	Circuit Breaker 19 closed
15	*	Reserved
15	*	Reserved
15	*	Reserved
15	*	Reserved
15	*	Reserved
15	*	Reserved
15	*	Reserved
15	*	Reserved

Table 11.2 Row List of Relay Word Bits (Sheet 5 of 100)

Row	Name	Bit Description
16	*	Reserved
16	*	Reserved
16	*	Reserved
16	*	Reserved
16	*	Reserved
16	*	Reserved
16	*	Reserved
16	*	Reserved
89 Disconnect Status		
17	89CL02	Disconnect 02 closed
17	89B02	Disconnect 02 B auxiliary contact closed
17	89A02	Disconnect 02 A auxiliary contact closed
17	89AL01	Disconnect 01 auxiliary contact discrepancy alarm
17	89OIP01	Disconnect 01 operation in progress
17	89CL01	Disconnect 01 closed
17	89B01	Disconnect 01 B auxiliary contact closed
17	89A01	Disconnect 01 A auxiliary contact closed
18	89A04	Disconnect 04 A auxiliary contact closed
18	89AL03	Disconnect 03 auxiliary contact discrepancy alarm
18	89OIP03	Disconnect 03 operation in progress
18	89CL03	Disconnect 03 closed
18	89B03	Disconnect 03 B auxiliary contact closed
18	89A03	Disconnect 03 A auxiliary contact closed
18	89AL02	Disconnect 02 auxiliary contact discrepancy alarm
18	89OIP02	Disconnect 02 operation in progress
19	89OIP05	Disconnect 05 operation in progress
19	89CL05	Disconnect 05 closed
19	89B05	Disconnect 05 B auxiliary contact closed
19	89A05	Disconnect 05 A auxiliary contact closed
19	89AL04	Disconnect 04 auxiliary contact discrepancy alarm
19	89OIP04	Disconnect 04 operation in progress
19	89CL04	Disconnect 04 closed
19	89B04	Disconnect 04 B auxiliary contact closed
20	89B07	Disconnect 07 B auxiliary contact closed
20	89A07	Disconnect 07 A auxiliary contact closed
20	89AL06	Disconnect 06 auxiliary contact discrepancy alarm
20	89OIP06	Disconnect 06 operation in progress
20	89CL06	Disconnect 06 closed
20	89B06	Disconnect 06 B auxiliary contact closed
20	89A06	Disconnect 06 A auxiliary contact closed
20	89AL05	Disconnect 05 auxiliary contact discrepancy alarm

Table 11.2 Row List of Relay Word Bits (Sheet 6 of 100)

Row	Name	Bit Description
21	89AL08	Disconnect 08 auxiliary contact discrepancy alarm
21	89OIP08	Disconnect 08 operation in progress
21	89CL08	Disconnect 08 closed
21	89B08	Disconnect 08 B auxiliary contact closed
21	89A08	Disconnect 08 A auxiliary contact closed
21	89AL07	Disconnect 07 auxiliary contact discrepancy alarm
21	89OIP07	Disconnect 07 operation in progress
21	89CL07	Disconnect 07 closed
22	89CL10	Disconnect 10 closed
22	89B10	Disconnect 10 B auxiliary contact closed
22	89A10	Disconnect 10 A auxiliary contact closed
22	89AL09	Disconnect 09 auxiliary contact discrepancy alarm
22	89OIP09	Disconnect 09 operation in progress
22	89CL09	Disconnect 09 closed
22	89B09	Disconnect 09 B auxiliary contact closed
22	89A09	Disconnect 09 A auxiliary contact closed
23	89A12	Disconnect 12 A auxiliary contact closed
23	89AL11	Disconnect 11 auxiliary contact discrepancy alarm
23	89OIP11	Disconnect 11 operation in progress
23	89CL11	Disconnect 11 closed
23	89B11	Disconnect 11 B auxiliary contact closed
23	89A11	Disconnect 11 A auxiliary contact closed
23	89AL10	Disconnect 10 auxiliary contact discrepancy alarm
23	89OIP10	Disconnect 10 operation in progress
24	89OIP13	Disconnect 13 operation in progress
24	89CL13	Disconnect 13 closed
24	89B13	Disconnect 13 B auxiliary contact closed
24	89A13	Disconnect 13 A auxiliary contact closed
24	89AL12	Disconnect 12 auxiliary contact discrepancy alarm
24	89OIP12	Disconnect 12 operation in progress
24	89CL12	Disconnect 12 closed
24	89B12	Disconnect 12 B auxiliary contact closed
25	89B15	Disconnect 15 B auxiliary contact closed
25	89A15	Disconnect 15 A auxiliary contact closed
25	89AL14	Disconnect 14 auxiliary contact discrepancy alarm
25	89OIP14	Disconnect 14 operation in progress
25	89CL14	Disconnect 14 closed
25	89B14	Disconnect 14 B auxiliary contact closed
25	89A14	Disconnect 14 A auxiliary contact closed
25	89AL13	Disconnect 13 auxiliary contact discrepancy alarm
26	89AL16	Disconnect 16 auxiliary contact discrepancy alarm

Table 11.2 Row List of Relay Word Bits (Sheet 7 of 100)

Row	Name	Bit Description
26	89OIP16	Disconnect 16 operation in progress
26	89CL16	Disconnect 16 closed
26	89B16	Disconnect 16 B auxiliary contact closed
26	89A16	Disconnect 16 A auxiliary contact closed
26	89AL15	Disconnect 15 auxiliary contact discrepancy alarm
26	89OIP15	Disconnect 15 operation in progress
26	89CL15	Disconnect 15 closed
27	89CL18	Disconnect 18 closed
27	89B18	Disconnect 18 B auxiliary contact closed
27	89A18	Disconnect 18 A auxiliary contact closed
27	89AL17	Disconnect 17 auxiliary contact discrepancy alarm
27	89OIP17	Disconnect 17 operation in progress
27	89CL17	Disconnect 17 closed
27	89B17	Disconnect 17 B auxiliary contact closed
27	89A17	Disconnect 17 A auxiliary contact closed
28	89A20	Disconnect 20 A auxiliary contact closed
28	89AL19	Disconnect 19 auxiliary contact discrepancy alarm
28	89OIP19	Disconnect 19 operation in progress
28	89CL19	Disconnect 19 closed
28	89B19	Disconnect 19 B auxiliary contact closed
28	89A19	Disconnect 19 A auxiliary contact closed
28	89AL18	Disconnect 18 auxiliary contact discrepancy alarm
28	89OIP18	Disconnect 18 operation in progress
29	89OIP21	Disconnect 21 operation in progress
29	89CL21	Disconnect 21 closed
29	89B21	Disconnect 21 B auxiliary contact closed
29	89A21	Disconnect 21 A auxiliary contact closed
29	89AL20	Disconnect 20 auxiliary contact discrepancy alarm
29	89OIP20	Disconnect 20 operation in progress
29	89CL20	Disconnect 20 closed
29	89B20	Disconnect 20 B auxiliary contact closed
30	89B23	Disconnect 23 B auxiliary contact closed
30	89A23	Disconnect 23 A auxiliary contact closed
30	89AL22	Disconnect 22 auxiliary contact discrepancy alarm
30	89OIP22	Disconnect 22 operation in progress
30	89CL22	Disconnect 22 closed
30	89B22	Disconnect 22 B auxiliary contact closed
30	89A22	Disconnect 22 A auxiliary contact closed
30	89AL21	Disconnect 21 auxiliary contact discrepancy alarm
31	89AL24	Disconnect 24 auxiliary contact discrepancy alarm
31	89OIP24	Disconnect 24 operation in progress

Table 11.2 Row List of Relay Word Bits (Sheet 8 of 100)

Row	Name	Bit Description
31	89CL24	Disconnect 24 closed
31	89B24	Disconnect 24 B auxiliary contact closed
31	89A24	Disconnect 24 A auxiliary contact closed
31	89AL23	Disconnect 23 auxiliary contact discrepancy alarm
31	89OIP23	Disconnect 23 operation in progress
31	89CL23	Disconnect 23 closed
32	89CL26	Disconnect 26 closed
32	89B26	Disconnect 26 B auxiliary contact closed
32	89A26	Disconnect 26 A auxiliary contact closed
32	89AL25	Disconnect 25 auxiliary contact discrepancy alarm
32	89OIP25	Disconnect 25 operation in progress
32	89CL25	Disconnect 25 closed
32	89B25	Disconnect 25 B auxiliary contact closed
32	89A25	Disconnect 25 A auxiliary contact closed
33	89A28	Disconnect 28 A auxiliary contact closed
33	89AL27	Disconnect 27 auxiliary contact discrepancy alarm
33	89OIP27	Disconnect 27 operation in progress
33	89CL27	Disconnect 27 closed
33	89B27	Disconnect 27 B auxiliary contact closed
33	89A27	Disconnect 27 A auxiliary contact closed
33	89AL26	Disconnect 26 auxiliary contact discrepancy alarm
33	89OIP26	Disconnect 26 operation in progress
34	89OIP29	Disconnect 29 operation in progress
34	89CL29	Disconnect 29 closed
34	89B29	Disconnect 29 B auxiliary contact closed
34	89A29	Disconnect 29 A auxiliary contact closed
34	89AL28	Disconnect 28 auxiliary contact discrepancy alarm
34	89OIP28	Disconnect 28 operation in progress
34	89CL28	Disconnect 28 closed
34	89B28	Disconnect 28 B auxiliary contact closed
35	89B31	Disconnect 31 B auxiliary contact closed
35	89A31	Disconnect 31 A auxiliary contact closed
35	89AL30	Disconnect 30 auxiliary contact discrepancy alarm
35	89OIP30	Disconnect 30 operation in progress
35	89CL30	Disconnect 30 closed
35	89B30	Disconnect 30 B auxiliary contact closed
35	89A30	Disconnect 30 A auxiliary contact closed
35	89AL29	Disconnect 29 auxiliary contact discrepancy alarm
36	89AL32	Disconnect 32 auxiliary contact discrepancy alarm
36	89OIP32	Disconnect 32 operation in progress
36	89CL32	Disconnect 32 closed

Table 11.2 Row List of Relay Word Bits (Sheet 9 of 100)

Row	Name	Bit Description
36	89B32	Disconnect 32 B auxiliary contact closed
36	89A32	Disconnect 32 A auxiliary contact closed
36	89AL31	Disconnect 31 auxiliary contact discrepancy alarm
36	89OIP31	Disconnect 31 operation in progress
36	89CL31	Disconnect 31 closed
37	89CL34	Disconnect 34 closed
37	89B34	Disconnect 34 B auxiliary contact closed
37	89A34	Disconnect 34 A auxiliary contact closed
37	89AL33	Disconnect 33 auxiliary contact discrepancy alarm
37	89OIP33	Disconnect 33 operation in progress
37	89CL33	Disconnect 33 closed
37	89B33	Disconnect 33 B auxiliary contact closed
37	89A33	Disconnect 33 A auxiliary contact closed
38	89A36	Disconnect 36 A auxiliary contact closed
38	89AL35	Disconnect 35 auxiliary contact discrepancy alarm
38	89OIP35	Disconnect 35 operation in progress
38	89CL35	Disconnect 35 closed
38	89B35	Disconnect 35 B auxiliary contact closed
38	89A35	Disconnect 35 A auxiliary contact closed
38	89AL34	Disconnect 34 auxiliary contact discrepancy alarm
38	89OIP34	Disconnect 34 operation in progress
39	89OIP37	Disconnect 37 operation in progress
39	89CL37	Disconnect 37 closed
39	89B37	Disconnect 37 B auxiliary contact closed
39	89A37	Disconnect 37 A auxiliary contact closed
39	89AL36	Disconnect 36 auxiliary contact discrepancy alarm
39	89OIP36	Disconnect 36 operation in progress
39	89CL36	Disconnect 36 closed
39	89B36	Disconnect 36 B auxiliary contact closed
40	89B39	Disconnect 39 B auxiliary contact closed
40	89A39	Disconnect 39 A auxiliary contact closed
40	89AL38	Disconnect 38 auxiliary contact discrepancy alarm
40	89OIP38	Disconnect 38 operation in progress
40	89CL38	Disconnect 38 closed
40	89B38	Disconnect 38 B auxiliary contact closed
40	89A38	Disconnect 38 A auxiliary contact closed
40	89AL37	Disconnect 37 auxiliary contact discrepancy alarm
41	89AL40	Disconnect 40 auxiliary contact discrepancy alarm
41	89OIP40	Disconnect 40 operation in progress
41	89CL40	Disconnect 40 closed
41	89B40	Disconnect 40 B auxiliary contact closed

Table 11.2 Row List of Relay Word Bits (Sheet 10 of 100)

Row	Name	Bit Description
41	89A40	Disconnect 40 A auxiliary contact closed
41	89AL39	Disconnect 39 auxiliary contact discrepancy alarm
41	89OIP39	Disconnect 39 operation in progress
41	89CL39	Disconnect 39 closed
42	89CL42	Disconnect 42 closed
42	89B42	Disconnect 42 B auxiliary contact closed
42	89A42	Disconnect 42 A auxiliary contact closed
42	89AL41	Disconnect 41 auxiliary contact discrepancy alarm
42	89OIP41	Disconnect 41 operation in progress
42	89CL41	Disconnect 41 closed
42	89B41	Disconnect 41 B auxiliary contact closed
42	89A41	Disconnect 41 A auxiliary contact closed
43	89A44	Disconnect 44 A auxiliary contact closed
43	89AL43	Disconnect 43 auxiliary contact discrepancy alarm
43	89OIP43	Disconnect 43 operation in progress
43	89CL43	Disconnect 43 closed
43	89B43	Disconnect 43 B auxiliary contact closed
43	89A43	Disconnect 43 A auxiliary contact closed
43	89AL42	Disconnect 42 auxiliary contact discrepancy alarm
43	89OIP42	Disconnect 42 operation in progress
44	89OIP45	Disconnect 45 operation in progress
44	89CL45	Disconnect 45 closed
44	89B45	Disconnect 45 B auxiliary contact closed
44	89A45	Disconnect 45 A auxiliary contact closed
44	89AL44	Disconnect 44 auxiliary contact discrepancy alarm
44	89OIP44	Disconnect 44 operation in progress
44	89CL44	Disconnect 44 closed
44	89B44	Disconnect 44 B auxiliary contact closed
45	89B47	Disconnect 47 B auxiliary contact closed
45	89A47	Disconnect 47 A auxiliary contact closed
45	89AL46	Disconnect 46 auxiliary contact discrepancy alarm
45	89OIP46	Disconnect 46 operation in progress
45	89CL46	Disconnect 46 closed
45	89B46	Disconnect 46 B auxiliary contact closed
45	89A46	Disconnect 46 A auxiliary contact closed
45	89AL45	Disconnect 45 auxiliary contact discrepancy alarm
46	89AL48	Disconnect 48 auxiliary contact discrepancy alarm
46	89OIP48	Disconnect 48 operation in progress
46	89CL48	Disconnect 48 closed
46	89B48	Disconnect 48 B auxiliary contact closed
46	89A48	Disconnect 48 A auxiliary contact closed

Table 11.2 Row List of Relay Word Bits (Sheet 11 of 100)

Row	Name	Bit Description
46	89AL47	Disconnect 47 auxiliary contact discrepancy alarm
46	89OIP47	Disconnect 47 operation in progress
46	89CL47	Disconnect 47 closed
47	89CL50	Disconnect 50 closed
47	89B50	Disconnect 50 B auxiliary contact closed
47	89A50	Disconnect 50 A auxiliary contact closed
47	89AL49	Disconnect 49 auxiliary contact discrepancy alarm
47	89OIP49	Disconnect 49 operation in progress
47	89CL49	Disconnect 49 closed
47	89B49	Disconnect 49 B auxiliary contact closed
47	89A49	Disconnect 49 A auxiliary contact closed
48	89A52	Disconnect 52 A auxiliary contact closed
48	89AL51	Disconnect 51 auxiliary contact discrepancy alarm
48	89OIP51	Disconnect 51 operation in progress
48	89CL51	Disconnect 51 closed
48	89B51	Disconnect 51 B auxiliary contact closed
48	89A51	Disconnect 51 A auxiliary contact closed
48	89AL50	Disconnect 50 auxiliary contact discrepancy alarm
48	89OIP50	Disconnect 50 operation in progress
49	89OIP53	Disconnect 53 operation in progress
49	89CL53	Disconnect 53 closed
49	89B53	Disconnect 53 B auxiliary contact closed
49	89A53	Disconnect 53 A auxiliary contact closed
49	89AL52	Disconnect 52 auxiliary contact discrepancy alarm
49	89OIP52	Disconnect 52 operation in progress
49	89CL52	Disconnect 52 closed
49	89B52	Disconnect 52 B auxiliary contact closed
50	89B55	Disconnect 55 B auxiliary contact closed
50	89A55	Disconnect 55 A auxiliary contact closed
50	89AL54	Disconnect 54 auxiliary contact discrepancy alarm
50	89OIP54	Disconnect 54 operation in progress
50	89CL54	Disconnect 54 closed
50	89B54	Disconnect 54 B auxiliary contact closed
50	89A54	Disconnect 54 A auxiliary contact closed
50	89AL53	Disconnect 53 auxiliary contact discrepancy alarm
51	89AL56	Disconnect 56 auxiliary contact discrepancy alarm
51	89OIP56	Disconnect 56 operation in progress
51	89CL56	Disconnect 56 closed
51	89B56	Disconnect 56 B auxiliary contact closed
51	89A56	Disconnect 56 A auxiliary contact closed
51	89AL55	Disconnect 55 auxiliary contact discrepancy alarm

Table 11.2 Row List of Relay Word Bits (Sheet 12 of 100)

Row	Name	Bit Description
51	89OIP55	Disconnect 55 operation in progress
51	89CL55	Disconnect 55 closed
52	89CL58	Disconnect 58 closed
52	89B58	Disconnect 58 B auxiliary contact closed
52	89A58	Disconnect 58 A auxiliary contact closed
52	89AL57	Disconnect 57 auxiliary contact discrepancy alarm
52	89OIP57	Disconnect 57 operation in progress
52	89CL57	Disconnect 57 closed
52	89B57	Disconnect 57 B auxiliary contact closed
52	89A57	Disconnect 57 A auxiliary contact closed
53	89A60	Disconnect 60 A auxiliary contact closed
53	89AL59	Disconnect 59 auxiliary contact discrepancy alarm
53	89OIP59	Disconnect 59 operation in progress
53	89CL59	Disconnect 59 closed
53	89B59	Disconnect 59 B auxiliary contact closed
53	89A59	Disconnect 59 A auxiliary contact closed
53	89AL58	Disconnect 58 auxiliary contact discrepancy alarm
53	89OIP58	Disconnect 58 operation in progress
54	*	Reserved
54	*	Reserved
54	*	Reserved
54	*	Reserved
54	89AL60	Disconnect 60 auxiliary contact discrepancy alarm
54	89OIP60	Disconnect 60 operation in progress
54	89CL60	Disconnect 60 closed
54	89B60	Disconnect 60 B auxiliary contact closed
55	*	Reserved
55	*	Reserved
55	*	Reserved
55	*	Reserved
55	*	Reserved
55	*	Reserved
55	89OIP	Any Disconnect operation in progress
55	89AL	Any Disconnect auxiliary contact discrepancy alarm
Terminal-to-Bus-Zone Connection		
56	I08BZ1V	Terminal I08 connected to BZ1
56	I07BZ1V	Terminal I07 connected to BZ1
56	I06BZ1V	Terminal I06 connected to BZ1
56	I05BZ1V	Terminal I05 connected to BZ1
56	I04BZ1V	Terminal I04 connected to BZ1
56	I03BZ1V	Terminal I03 connected to BZ1

Table 11.2 Row List of Relay Word Bits (Sheet 13 of 100)

Row	Name	Bit Description
56	I02BZ1V	Terminal I02 connected to BZ1
56	I01BZ1V	Terminal I01 connected to BZ1
57	I16BZ1V	Terminal I16 connected to BZ1
57	I15BZ1V	Terminal I15 connected to BZ1
57	I14BZ1V	Terminal I14 connected to BZ1
57	I13BZ1V	Terminal I13 connected to BZ1
57	I12BZ1V	Terminal I12 connected to BZ1
57	I11BZ1V	Terminal I11 connected to BZ1
57	I10BZ1V	Terminal I10 connected to BZ1
57	I09BZ1V	Terminal I09 connected to BZ1
58	*	Reserved
58	*	Reserved
58	*	Reserved
58	I21BZ1V	Terminal I21 connected to BZ1
58	I20BZ1V	Terminal I20 connected to BZ1
58	I19BZ1V	Terminal I19 connected to BZ1
58	I18BZ1V	Terminal I18 connected to BZ1
58	I17BZ1V	Terminal I17 connected to BZ1
59	*	Reserved
59	*	Reserved
59	*	Reserved
59	*	Reserved
59	*	Reserved
59	*	Reserved
59	*	Reserved
59	*	Reserved
60	I08BZ2V	Terminal I08 connected to BZ2
60	I07BZ2V	Terminal I07 connected to BZ2
60	I06BZ2V	Terminal I06 connected to BZ2
60	I05BZ2V	Terminal I05 connected to BZ2
60	I04BZ2V	Terminal I04 connected to BZ2
60	I03BZ2V	Terminal I03 connected to BZ2
60	I02BZ2V	Terminal I02 connected to BZ2
60	I01BZ2V	Terminal I01 connected to BZ2
61	I16BZ2V	Terminal I16 connected to BZ2
61	I15BZ2V	Terminal I15 connected to BZ2
61	I14BZ2V	Terminal I14 connected to BZ2
61	I13BZ2V	Terminal I13 connected to BZ2
61	I12BZ2V	Terminal I12 connected to BZ2
61	I11BZ2V	Terminal I11 connected to BZ2
61	I10BZ2V	Terminal I10 connected to BZ2

Table 11.2 Row List of Relay Word Bits (Sheet 14 of 100)

Row	Name	Bit Description
61	I09BZ2V	Terminal I09 connected to BZ2
62	*	Reserved
62	*	Reserved
62	*	Reserved
62	I21BZ2V	Terminal I21 connected to BZ2
62	I20BZ2V	Terminal I20 connected to BZ2
62	I19BZ2V	Terminal I19 connected to BZ2
62	I18BZ2V	Terminal I18 connected to BZ2
62	I17BZ2V	Terminal I17 connected to BZ2
63	*	Reserved
63	*	Reserved
63	*	Reserved
63	*	Reserved
63	*	Reserved
63	*	Reserved
63	*	Reserved
63	*	Reserved
64	I08BZ3V	Terminal I08 connected to BZ3
64	I07BZ3V	Terminal I07 connected to BZ3
64	I06BZ3V	Terminal I06 connected to BZ3
64	I05BZ3V	Terminal I05 connected to BZ3
64	I04BZ3V	Terminal I04 connected to BZ3
64	I03BZ3V	Terminal I03 connected to BZ3
64	I02BZ3V	Terminal I02 connected to BZ3
64	I01BZ3V	Terminal I01 connected to BZ3
65	I16BZ3V	Terminal I16 connected to BZ3
65	I15BZ3V	Terminal I15 connected to BZ3
65	I14BZ3V	Terminal I14 connected to BZ3
65	I13BZ3V	Terminal I13 connected to BZ3
65	I12BZ3V	Terminal I12 connected to BZ3
65	I11BZ3V	Terminal I11 connected to BZ3
65	I10BZ3V	Terminal I10 connected to BZ3
65	I09BZ3V	Terminal I09 connected to BZ3
66	*	Reserved
66	*	Reserved
66	*	Reserved
66	I21BZ3V	Terminal I21 connected to BZ3
66	I20BZ3V	Terminal I20 connected to BZ3
66	I19BZ3V	Terminal I19 connected to BZ3
66	I18BZ3V	Terminal I18 connected to BZ3
66	I17BZ3V	Terminal I17 connected to BZ3

Table 11.2 Row List of Relay Word Bits (Sheet 15 of 100)

Row	Name	Bit Description
67	*	Reserved
67	*	Reserved
67	*	Reserved
67	*	Reserved
67	*	Reserved
67	*	Reserved
67	*	Reserved
67	*	Reserved
68	I08BZ4V	Terminal I08 connected to BZ4
68	I07BZ4V	Terminal I07 connected to BZ4
68	I06BZ4V	Terminal I06 connected to BZ4
68	I05BZ4V	Terminal I05 connected to BZ4
68	I04BZ4V	Terminal I04 connected to BZ4
68	I03BZ4V	Terminal I03 connected to BZ4
68	I02BZ4V	Terminal I02 connected to BZ4
68	I01BZ4V	Terminal I01 connected to BZ4
69	I16BZ4V	Terminal I16 connected to BZ4
69	I15BZ4V	Terminal I15 connected to BZ4
69	I14BZ4V	Terminal I14 connected to BZ4
69	I13BZ4V	Terminal I13 connected to BZ4
69	I12BZ4V	Terminal I12 connected to BZ4
69	I11BZ4V	Terminal I11 connected to BZ4
69	I10BZ4V	Terminal I10 connected to BZ4
69	I09BZ4V	Terminal I09 connected to BZ4
70	*	Reserved
70	*	Reserved
70	*	Reserved
70	I21BZ4V	Terminal I21 connected to BZ4
70	I20BZ4V	Terminal I20 connected to BZ4
70	I19BZ4V	Terminal I19 connected to BZ4
70	I18BZ4V	Terminal I18 connected to BZ4
70	I17BZ4V	Terminal I17 connected to BZ4
71	*	Reserved
71	*	Reserved
71	*	Reserved
71	*	Reserved
71	*	Reserved
71	*	Reserved
71	*	Reserved
71	*	Reserved
72	I08BZ5V	Terminal I08 connected to BZ5

Table 11.2 Row List of Relay Word Bits (Sheet 16 of 100)

Row	Name	Bit Description
72	I07BZ5V	Terminal I07 connected to BZ5
72	I06BZ5V	Terminal I06 connected to BZ5
72	I05BZ5V	Terminal I05 connected to BZ5
72	I04BZ5V	Terminal I04 connected to BZ5
72	I03BZ5V	Terminal I03 connected to BZ5
72	I02BZ5V	Terminal I02 connected to BZ5
72	I01BZ5V	Terminal I01 connected to BZ5
73	I16BZ5V	Terminal I16 connected to BZ5
73	I15BZ5V	Terminal I15 connected to BZ5
73	I14BZ5V	Terminal I14 connected to BZ5
73	I13BZ5V	Terminal I13 connected to BZ5
73	I12BZ5V	Terminal I12 connected to BZ5
73	I11BZ5V	Terminal I11 connected to BZ5
73	I10BZ5V	Terminal I10 connected to BZ5
73	I09BZ5V	Terminal I09 connected to BZ5
74	*	Reserved
74	*	Reserved
74	*	Reserved
74	I21BZ5V	Terminal I21 connected to BZ5
74	I20BZ5V	Terminal I20 connected to BZ5
74	I19BZ5V	Terminal I19 connected to BZ5
74	I18BZ5V	Terminal I18 connected to BZ5
74	I17BZ5V	Terminal I17 connected to BZ5
75	*	Reserved
75	*	Reserved
75	*	Reserved
75	*	Reserved
75	*	Reserved
75	*	Reserved
75	*	Reserved
75	*	Reserved
76	I08BZ6V	Terminal I08 connected to BZ6
76	I07BZ6V	Terminal I07 connected to BZ6
76	I06BZ6V	Terminal I06 connected to BZ6
76	I05BZ6V	Terminal I05 connected to BZ6
76	I04BZ6V	Terminal I04 connected to BZ6
76	I03BZ6V	Terminal I03 connected to BZ6
76	I02BZ6V	Terminal I02 connected to BZ6
76	I01BZ6V	Terminal I01 connected to BZ6
77	I16BZ6V	Terminal I16 connected to BZ6
77	I15BZ6V	Terminal I15 connected to BZ6

Table 11.2 Row List of Relay Word Bits (Sheet 17 of 100)

Row	Name	Bit Description
77	I14BZ6V	Terminal I14 connected to BZ6
77	I13BZ6V	Terminal I13 connected to BZ6
77	I12BZ6V	Terminal I12 connected to BZ6
77	I11BZ6V	Terminal I11 connected to BZ6
77	I10BZ6V	Terminal I10 connected to BZ6
77	I09BZ6V	Terminal I09 connected to BZ6
78	*	Reserved
78	*	Reserved
78	*	Reserved
78	I21BZ6V	Terminal I21 connected to BZ6
78	I20BZ6V	Terminal I20 connected to BZ6
78	I19BZ6V	Terminal I19 connected to BZ6
78	I18BZ6V	Terminal I18 connected to BZ6
78	I17BZ6V	Terminal I17 connected to BZ6
79	*	Reserved
79	*	Reserved
79	*	Reserved
79	*	Reserved
79	*	Reserved
79	*	Reserved
79	*	Reserved
79	*	Reserved
80	ZN1I08	Terminal 08 connected to Zone 1
80	ZN1I07	Terminal 07 connected to Zone 1
80	ZN1I06	Terminal 06 connected to Zone 1
80	ZN1I05	Terminal 05 connected to Zone 1
80	ZN1I04	Terminal 04 connected to Zone 1
80	ZN1I03	Terminal 03 connected to Zone 1
80	ZN1I02	Terminal 02 connected to Zone 1
80	ZN1I01	Terminal 01 connected to Zone 1
81	ZN1I16	Terminal 16 connected to Zone 1
81	ZN1I15	Terminal 15 connected to Zone 1
81	ZN1I14	Terminal 14 connected to Zone 1
81	ZN1I13	Terminal 13 connected to Zone 1
81	ZN1I12	Terminal 12 connected to Zone 1
81	ZN1I11	Terminal 11 connected to Zone 1
81	ZN1I10	Terminal 10 connected to Zone 1
81	ZN1I09	Terminal 09 connected to Zone 1
82	*	Reserved
82	*	Reserved
82	*	Reserved

Table 11.2 Row List of Relay Word Bits (Sheet 18 of 100)

Row	Name	Bit Description
82	ZN1I21	Terminal 21 connected to Zone 1
82	ZN1I20	Terminal 20 connected to Zone 1
82	ZN1I19	Terminal 19 connected to Zone 1
82	ZN1I18	Terminal 18 connected to Zone 1
82	ZN1I17	Terminal 17 connected to Zone 1
83	*	Reserved
83	*	Reserved
83	*	Reserved
83	*	Reserved
83	*	Reserved
83	*	Reserved
83	*	Reserved
83	*	Reserved
84	ZN2I08	Terminal 08 connected to Zone 2
84	ZN2I07	Terminal 07 connected to Zone 2
84	ZN2I06	Terminal 06 connected to Zone 2
84	ZN2I05	Terminal 05 connected to Zone 2
84	ZN2I04	Terminal 04 connected to Zone 2
84	ZN2I03	Terminal 03 connected to Zone 2
84	ZN2I02	Terminal 02 connected to Zone 2
84	ZN2I01	Terminal 01 connected to Zone 2
85	ZN2I16	Terminal 16 connected to Zone 2
85	ZN2I15	Terminal 15 connected to Zone 2
85	ZN2I14	Terminal 14 connected to Zone 2
85	ZN2I13	Terminal 13 connected to Zone 2
85	ZN2I12	Terminal 12 connected to Zone 2
85	ZN2I11	Terminal 11 connected to Zone 2
85	ZN2I10	Terminal 10 connected to Zone 2
85	ZN2I09	Terminal 09 connected to Zone 2
86	*	Reserved
86	*	Reserved
86	*	Reserved
86	ZN2I21	Terminal 21 connected to Zone 2
86	ZN2I20	Terminal 20 connected to Zone 2
86	ZN2I19	Terminal 19 connected to Zone 2
86	ZN2I18	Terminal 18 connected to Zone 2
86	ZN2I17	Terminal 17 connected to Zone 2
87	*	Reserved
87	*	Reserved
87	*	Reserved
87	*	Reserved

Table 11.2 Row List of Relay Word Bits (Sheet 19 of 100)

Row	Name	Bit Description
87	*	Reserved
87	*	Reserved
87	*	Reserved
87	*	Reserved
88	ZN3I08	Terminal 08 connected to Zone 3
88	ZN3I07	Terminal 07 connected to Zone 3
88	ZN3I06	Terminal 06 connected to Zone 3
88	ZN3I05	Terminal 05 connected to Zone 3
88	ZN3I04	Terminal 04 connected to Zone 3
88	ZN3I03	Terminal 03 connected to Zone 3
88	ZN3I02	Terminal 02 connected to Zone 3
88	ZN3I01	Terminal 01 connected to Zone 3
89	ZN3I16	Terminal 16 connected to Zone 3
89	ZN3I15	Terminal 15 connected to Zone 3
89	ZN3I14	Terminal 14 connected to Zone 3
89	ZN3I13	Terminal 13 connected to Zone 3
89	ZN3I12	Terminal 12 connected to Zone 3
89	ZN3I11	Terminal 11 connected to Zone 3
89	ZN3I10	Terminal 10 connected to Zone 3
89	ZN3I09	Terminal 09 connected to Zone 3
90	*	Reserved
90	*	Reserved
90	*	Reserved
90	ZN3I21	Terminal 21 connected to Zone 3
90	ZN3I20	Terminal 20 connected to Zone 3
90	ZN3I19	Terminal 19 connected to Zone 3
90	ZN3I18	Terminal 18 connected to Zone 3
90	ZN3I17	Terminal 17 connected to Zone 3
91	*	Reserved
91	*	Reserved
91	*	Reserved
91	*	Reserved
91	*	Reserved
91	*	Reserved
91	*	Reserved
91	*	Reserved
92	ZN4I08	Terminal 08 connected to Zone 4
92	ZN4I07	Terminal 07 connected to Zone 4
92	ZN4I06	Terminal 06 connected to Zone 4
92	ZN4I05	Terminal 05 connected to Zone 4
92	ZN4I04	Terminal 04 connected to Zone 4

Table 11.2 Row List of Relay Word Bits (Sheet 20 of 100)

Row	Name	Bit Description
92	ZN4I03	Terminal 03 connected to Zone 4
92	ZN4I02	Terminal 02 connected to Zone 4
92	ZN4I01	Terminal 01 connected to Zone 4
93	ZN4I16	Terminal 16 connected to Zone 4
93	ZN4I15	Terminal 15 connected to Zone 4
93	ZN4I14	Terminal 14 connected to Zone 4
93	ZN4I13	Terminal 13 connected to Zone 4
93	ZN4I12	Terminal 12 connected to Zone 4
93	ZN4I11	Terminal 11 connected to Zone 4
93	ZN4I10	Terminal 10 connected to Zone 4
93	ZN4I09	Terminal 09 connected to Zone 4
94	*	Reserved
94	*	Reserved
94	*	Reserved
94	ZN4I21	Terminal 21 connected to Zone 4
94	ZN4I20	Terminal 20 connected to Zone 4
94	ZN4I19	Terminal 19 connected to Zone 4
94	ZN4I18	Terminal 18 connected to Zone 4
94	ZN4I17	Terminal 17 connected to Zone 4
95	*	Reserved
95	*	Reserved
95	*	Reserved
95	*	Reserved
95	*	Reserved
95	*	Reserved
95	*	Reserved
95	*	Reserved
96	ZN5I08	Terminal 08 connected to Zone 5
96	ZN5I07	Terminal 07 connected to Zone 5
96	ZN5I06	Terminal 06 connected to Zone 5
96	ZN5I05	Terminal 05 connected to Zone 5
96	ZN5I04	Terminal 04 connected to Zone 5
96	ZN5I03	Terminal 03 connected to Zone 5
96	ZN5I02	Terminal 02 connected to Zone 5
96	ZN5I01	Terminal 01 connected to Zone 5
97	ZN5I16	Terminal 16 connected to Zone 5
97	ZN5I15	Terminal 15 connected to Zone 5
97	ZN5I14	Terminal 14 connected to Zone 5
97	ZN5I13	Terminal 13 connected to Zone 5
97	ZN5I12	Terminal 12 connected to Zone 5
97	ZN5I11	Terminal 11 connected to Zone 5

Table 11.2 Row List of Relay Word Bits (Sheet 21 of 100)

Row	Name	Bit Description
97	ZN5I10	Terminal 10 connected to Zone 5
97	ZN5I09	Terminal 09 connected to Zone 5
98	*	Reserved
98	*	Reserved
98	*	Reserved
98	ZN5I21	Terminal 21 connected to Zone 5
98	ZN5I20	Terminal 20 connected to Zone 5
98	ZN5I19	Terminal 19 connected to Zone 5
98	ZN5I18	Terminal 18 connected to Zone 5
98	ZN5I17	Terminal 17 connected to Zone 5
99	*	Reserved
99	*	Reserved
99	*	Reserved
99	*	Reserved
99	*	Reserved
99	*	Reserved
99	*	Reserved
99	*	Reserved
100	ZN6I08	Terminal 08 connected to Zone 6
100	ZN6I07	Terminal 07 connected to Zone 6
100	ZN6I06	Terminal 06 connected to Zone 6
100	ZN6I05	Terminal 05 connected to Zone 6
100	ZN6I04	Terminal 04 connected to Zone 6
100	ZN6I03	Terminal 03 connected to Zone 6
100	ZN6I02	Terminal 02 connected to Zone 6
100	ZN6I01	Terminal 01 connected to Zone 6
101	ZN6I16	Terminal 16 connected to Zone 6
101	ZN6I15	Terminal 15 connected to Zone 6
101	ZN6I14	Terminal 14 connected to Zone 6
101	ZN6I13	Terminal 13 connected to Zone 6
101	ZN6I12	Terminal 12 connected to Zone 6
101	ZN6I11	Terminal 11 connected to Zone 6
101	ZN6I10	Terminal 10 connected to Zone 6
101	ZN6I09	Terminal 09 connected to Zone 6
102	*	Reserved
102	*	Reserved
102	*	Reserved
102	ZN6I21	Terminal 21 connected to Zone 6
102	ZN6I20	Terminal 20 connected to Zone 6
102	ZN6I19	Terminal 19 connected to Zone 6
102	ZN6I18	Terminal 18 connected to Zone 6

Table 11.2 Row List of Relay Word Bits (Sheet 22 of 100)

Row	Name	Bit Description
102	ZN6I17	Terminal 17 connected to Zone 6
103	*	Reserved
103	*	Reserved
103	*	Reserved
103	*	Reserved
103	*	Reserved
103	*	Reserved
103	*	Reserved
103	*	Reserved
104	ZN1I08T	Terminal 08 connected to Zone 1 and will be tripped
104	ZN1I07T	Terminal 07 connected to Zone 1 and will be tripped
104	ZN1I06T	Terminal 06 connected to Zone 1 and will be tripped
104	ZN1I05T	Terminal 05 connected to Zone 1 and will be tripped
104	ZN1I04T	Terminal 04 connected to Zone 1 and will be tripped
104	ZN1I03T	Terminal 03 connected to Zone 1 and will be tripped
104	ZN1I02T	Terminal 02 connected to Zone 1 and will be tripped
104	ZN1I01T	Terminal 01 connected to Zone 1 and will be tripped
105	ZN1I16T	Terminal 16 connected to Zone 1 and will be tripped
105	ZN1I15T	Terminal 15 connected to Zone 1 and will be tripped
105	ZN1I14T	Terminal 14 connected to Zone 1 and will be tripped
105	ZN1I13T	Terminal 13 connected to Zone 1 and will be tripped
105	ZN1I12T	Terminal 12 connected to Zone 1 and will be tripped
105	ZN1I11T	Terminal 11 connected to Zone 1 and will be tripped
105	ZN1I10T	Terminal 10 connected to Zone 1 and will be tripped
105	ZN1I09T	Terminal 09 connected to Zone 1 and will be tripped
106	*	Reserved
106	*	Reserved
106	*	Reserved
106	ZN1I21T	Terminal 21 connected to Zone 1 and will be tripped
106	ZN1I20T	Terminal 20 connected to Zone 1 and will be tripped
106	ZN1I19T	Terminal 19 connected to Zone 1 and will be tripped
106	ZN1I18T	Terminal 18 connected to Zone 1 and will be tripped
106	ZN1I17T	Terminal 17 connected to Zone 1 and will be tripped
107	*	Reserved
107	*	Reserved
107	*	Reserved
107	*	Reserved
107	*	Reserved
107	*	Reserved
107	*	Reserved
107	*	Reserved

Table 11.2 Row List of Relay Word Bits (Sheet 23 of 100)

Row	Name	Bit Description
108	ZN2I08T	Terminal 08 connected to Zone 2 and will be tripped
108	ZN2I07T	Terminal 07 connected to Zone 2 and will be tripped
108	ZN2I06T	Terminal 06 connected to Zone 2 and will be tripped
108	ZN2I05T	Terminal 05 connected to Zone 2 and will be tripped
108	ZN2I04T	Terminal 04 connected to Zone 2 and will be tripped
108	ZN2I03T	Terminal 03 connected to Zone 2 and will be tripped
108	ZN2I02T	Terminal 02 connected to Zone 2 and will be tripped
108	ZN2I01T	Terminal 01 connected to Zone 2 and will be tripped
109	ZN2I16T	Terminal 16 connected to Zone 2 and will be tripped
109	ZN2I15T	Terminal 15 connected to Zone 2 and will be tripped
109	ZN2I14T	Terminal 14 connected to Zone 2 and will be tripped
109	ZN2I13T	Terminal 13 connected to Zone 2 and will be tripped
109	ZN2I12T	Terminal 12 connected to Zone 2 and will be tripped
109	ZN2I11T	Terminal 11 connected to Zone 2 and will be tripped
109	ZN2I10T	Terminal 10 connected to Zone 2 and will be tripped
109	ZN2I09T	Terminal 09 connected to Zone 2 and will be tripped
110	*	Reserved
110	*	Reserved
110	*	Reserved
110	ZN2I21T	Terminal 21 connected to Zone 2 and will be tripped
110	ZN2I20T	Terminal 20 connected to Zone 2 and will be tripped
110	ZN2I19T	Terminal 19 connected to Zone 2 and will be tripped
110	ZN2I18T	Terminal 18 connected to Zone 2 and will be tripped
110	ZN2I17T	Terminal 17 connected to Zone 2 and will be tripped
111	*	Reserved
111	*	Reserved
111	*	Reserved
111	*	Reserved
111	*	Reserved
111	*	Reserved
111	*	Reserved
111	*	Reserved
112	ZN3I08T	Terminal 08 connected to Zone 3 and will be tripped
112	ZN3I07T	Terminal 07 connected to Zone 3 and will be tripped
112	ZN3I06T	Terminal 06 connected to Zone 3 and will be tripped
112	ZN3I05T	Terminal 05 connected to Zone 3 and will be tripped
112	ZN3I04T	Terminal 04 connected to Zone 3 and will be tripped
112	ZN3I03T	Terminal 03 connected to Zone 3 and will be tripped
112	ZN3I02T	Terminal 02 connected to Zone 3 and will be tripped
112	ZN3I01T	Terminal 01 connected to Zone 3 and will be tripped
113	ZN3I16T	Terminal 16 connected to Zone 3 and will be tripped

Table 11.2 Row List of Relay Word Bits (Sheet 24 of 100)

Row	Name	Bit Description
113	ZN3I15T	Terminal 15 connected to Zone 3 and will be tripped
113	ZN3I14T	Terminal 14 connected to Zone 3 and will be tripped
113	ZN3I13T	Terminal 13 connected to Zone 3 and will be tripped
113	ZN3I12T	Terminal 12 connected to Zone 3 and will be tripped
113	ZN3I11T	Terminal 11 connected to Zone 3 and will be tripped
113	ZN3I10T	Terminal 10 connected to Zone 3 and will be tripped
113	ZN3I09T	Terminal 09 connected to Zone 3 and will be tripped
114	*	Reserved
114	*	Reserved
114	*	Reserved
114	ZN3I21T	Terminal 21 connected to Zone 3 and will be tripped
114	ZN3I20T	Terminal 20 connected to Zone 3 and will be tripped
114	ZN3I19T	Terminal 19 connected to Zone 3 and will be tripped
114	ZN3I18T	Terminal 18 connected to Zone 3 and will be tripped
114	ZN3I17T	Terminal 17 connected to Zone 3 and will be tripped
115	*	Reserved
115	*	Reserved
115	*	Reserved
115	*	Reserved
115	*	Reserved
115	*	Reserved
115	*	Reserved
115	*	Reserved
116	ZN4I08T	Terminal 08 connected to Zone 4 and will be tripped
116	ZN4I07T	Terminal 07 connected to Zone 4 and will be tripped
116	ZN4I06T	Terminal 06 connected to Zone 4 and will be tripped
116	ZN4I05T	Terminal 05 connected to Zone 4 and will be tripped
116	ZN4I04T	Terminal 04 connected to Zone 4 and will be tripped
116	ZN4I03T	Terminal 03 connected to Zone 4 and will be tripped
116	ZN4I02T	Terminal 02 connected to Zone 4 and will be tripped
116	ZN4I01T	Terminal 01 connected to Zone 4 and will be tripped
117	ZN4I16T	Terminal 16 connected to Zone 4 and will be tripped
117	ZN4I15T	Terminal 15 connected to Zone 4 and will be tripped
117	ZN4I14T	Terminal 14 connected to Zone 4 and will be tripped
117	ZN4I13T	Terminal 13 connected to Zone 4 and will be tripped
117	ZN4I12T	Terminal 12 connected to Zone 4 and will be tripped
117	ZN4I11T	Terminal 11 connected to Zone 4 and will be tripped
117	ZN4I10T	Terminal 10 connected to Zone 4 and will be tripped
117	ZN4I09T	Terminal 09 connected to Zone 4 and will be tripped
118	*	Reserved
118	*	Reserved

Table 11.2 Row List of Relay Word Bits (Sheet 25 of 100)

Row	Name	Bit Description
118	*	Reserved
118	ZN4I21T	Terminal 21 connected to Zone 4 and will be tripped
118	ZN4I20T	Terminal 20 connected to Zone 4 and will be tripped
118	ZN4I19T	Terminal 19 connected to Zone 4 and will be tripped
118	ZN4I18T	Terminal 18 connected to Zone 4 and will be tripped
118	ZN4I17T	Terminal 17 connected to Zone 4 and will be tripped
119	*	Reserved
119	*	Reserved
119	*	Reserved
119	*	Reserved
119	*	Reserved
119	*	Reserved
119	*	Reserved
119	*	Reserved
120	ZN5I08T	Terminal 08 connected to Zone 5 and will be tripped
120	ZN5I07T	Terminal 07 connected to Zone 5 and will be tripped
120	ZN5I06T	Terminal 06 connected to Zone 5 and will be tripped
120	ZN5I05T	Terminal 05 connected to Zone 5 and will be tripped
120	ZN5I04T	Terminal 04 connected to Zone 5 and will be tripped
120	ZN5I03T	Terminal 03 connected to Zone 5 and will be tripped
120	ZN5I02T	Terminal 02 connected to Zone 5 and will be tripped
120	ZN5I01T	Terminal 01 connected to Zone 5 and will be tripped
121	ZN5I16T	Terminal 16 connected to Zone 5 and will be tripped
121	ZN5I15T	Terminal 15 connected to Zone 5 and will be tripped
121	ZN5I14T	Terminal 14 connected to Zone 5 and will be tripped
121	ZN5I13T	Terminal 13 connected to Zone 5 and will be tripped
121	ZN5I12T	Terminal 12 connected to Zone 5 and will be tripped
121	ZN5I11T	Terminal 11 connected to Zone 5 and will be tripped
121	ZN5I10T	Terminal 10 connected to Zone 5 and will be tripped
121	ZN5I09T	Terminal 09 connected to Zone 5 and will be tripped
122	*	Reserved
122	*	Reserved
122	*	Reserved
122	ZN5I21T	Terminal 21 connected to Zone 5 and will be tripped
122	ZN5I20T	Terminal 20 connected to Zone 5 and will be tripped
122	ZN5I19T	Terminal 19 connected to Zone 5 and will be tripped
122	ZN5I18T	Terminal 18 connected to Zone 5 and will be tripped
122	ZN5I17T	Terminal 17 connected to Zone 5 and will be tripped
123	*	Reserved
123	*	Reserved
123	*	Reserved

Table 11.2 Row List of Relay Word Bits (Sheet 26 of 100)

Row	Name	Bit Description
123	*	Reserved
123	*	Reserved
123	*	Reserved
123	*	Reserved
123	*	Reserved
124	ZN6I08T	Terminal 08 connected to Zone 6 and will be tripped
124	ZN6I07T	Terminal 07 connected to Zone 6 and will be tripped
124	ZN6I06T	Terminal 06 connected to Zone 6 and will be tripped
124	ZN6I05T	Terminal 05 connected to Zone 6 and will be tripped
124	ZN6I04T	Terminal 04 connected to Zone 6 and will be tripped
124	ZN6I03T	Terminal 03 connected to Zone 6 and will be tripped
124	ZN6I02T	Terminal 02 connected to Zone 6 and will be tripped
124	ZN6I01T	Terminal 01 connected to Zone 6 and will be tripped
125	ZN6I16T	Terminal 16 connected to Zone 6 and will be tripped
125	ZN6I15T	Terminal 15 connected to Zone 6 and will be tripped
125	ZN6I14T	Terminal 14 connected to Zone 6 and will be tripped
125	ZN6I13T	Terminal 13 connected to Zone 6 and will be tripped
125	ZN6I12T	Terminal 12 connected to Zone 6 and will be tripped
125	ZN6I11T	Terminal 11 connected to Zone 6 and will be tripped
125	ZN6I10T	Terminal 10 connected to Zone 6 and will be tripped
125	ZN6I09T	Terminal 09 connected to Zone 6 and will be tripped
126	*	Reserved
126	*	Reserved
126	*	Reserved
126	ZN6I21T	Terminal 21 connected to Zone 6 and will be tripped
126	ZN6I20T	Terminal 20 connected to Zone 6 and will be tripped
126	ZN6I19T	Terminal 19 connected to Zone 6 and will be tripped
126	ZN6I18T	Terminal 18 connected to Zone 6 and will be tripped
126	ZN6I17T	Terminal 17 connected to Zone 6 and will be tripped
127	*	Reserved
127	*	Reserved
127	*	Reserved
127	*	Reserved
127	*	Reserved
127	*	Reserved
127	*	Reserved
127	*	Reserved
Bus-Zone-to-Bus-Zone Connection		
128	*	Reserved
128	*	Reserved
128	BZ1BZ6V	A connection exists between BZ1 and BZ6

Table 11.2 Row List of Relay Word Bits (Sheet 27 of 100)

Row	Name	Bit Description
128	BZ1BZ5V	A connection exists between BZ1 and BZ5
128	BZ1BZ4V	A connection exists between BZ1 and BZ4
128	BZ1BZ3V	A connection exists between BZ1 and BZ3
128	BZ1BZ2V	A connection exists between BZ1 and BZ2
128	*	Reserved
129	*	Reserved
129	*	Reserved
129	BZ2BZ6V	A connection exists between BZ2 and BZ6
129	BZ2BZ5V	A connection exists between BZ2 and BZ5
129	BZ2BZ4V	A connection exists between BZ2 and BZ4
129	BZ2BZ3V	A connection exists between BZ2 and BZ3
129	*	Reserved
129	*	Reserved
130	*	Reserved
130	*	Reserved
130	BZ3BZ6V	A connection exists between BZ3 and BZ6
130	BZ3BZ5V	A connection exists between BZ3 and BZ5
130	BZ3BZ4V	A connection exists between BZ3 and BZ4
130	*	Reserved
130	*	Reserved
130	*	Reserved
131	*	Reserved
131	*	Reserved
131	BZ4BZ6V	A connection exists between BZ4 and BZ6
131	BZ4BZ5V	A connection exists between BZ4 and BZ5
131	*	Reserved
131	*	Reserved
131	*	Reserved
131	*	Reserved
132	*	Reserved
132	*	Reserved
132	BZ5BZ6V	A connection exists between BZ5 and BZ6
132	*	Reserved
132	*	Reserved
132	*	Reserved
132	*	Reserved
132	*	Reserved
133	*	Reserved
133	*	Reserved
133	*	Reserved
133	*	Reserved

Table 11.2 Row List of Relay Word Bits (Sheet 28 of 100)

Row	Name	Bit Description
133	*	Reserved
133	*	Reserved
133	*	Reserved
133	*	Reserved
134	*	Reserved
134	*	Reserved
134	*	Reserved
134	*	Reserved
134	*	Reserved
134	*	Reserved
134	*	Reserved
134	*	Reserved
135	*	Reserved
135	*	Reserved
135	*	Reserved
135	*	Reserved
135	*	Reserved
135	*	Reserved
135	*	Reserved
135	*	Reserved
136	*	Reserved
136	*	Reserved
136	BZ1BZ6R	A connection exists between BZ1 and BZ6 and a coupler is removed
136	BZ1BZ5R	A connection exists between BZ1 and BZ5 and a coupler is removed
136	BZ1BZ4R	A connection exists between BZ1 and BZ4 and a coupler is removed
136	BZ1BZ3R	A connection exists between BZ1 and BZ3 and a coupler is removed
136	BZ1BZ2R	A connection exists between BZ1 and BZ2 and a coupler is removed
136	*	Reserved
137	*	Reserved
137	*	Reserved
137	BZ2BZ6R	A connection exists between BZ2 and BZ6 and a coupler is removed
137	BZ2BZ5R	A connection exists between BZ2 and BZ5 and a coupler is removed
137	BZ2BZ4R	A connection exists between BZ2and BZ4 and a coupler is removed
137	BZ2BZ3R	A connection exists between BZ2 and BZ3 and a coupler is removed
137	*	Reserved
137	*	Reserved
138	*	Reserved
138	*	Reserved
138	BZ3BZ6R	A connection exists between BZ3 and BZ6 and a coupler is removed
138	BZ3BZ5R	A connection exists between BZ3 and BZ5 and a coupler is removed
138	BZ3BZ4R	A connection exists between BZ3 and BZ4 and a coupler is removed

Table 11.2 Row List of Relay Word Bits (Sheet 29 of 100)

Row	Name	Bit Description
138	*	Reserved
138	*	Reserved
138	*	Reserved
139	*	Reserved
139	*	Reserved
139	BZ4BZ6R	A connection exists between BZ4 and BZ6 and a coupler is removed
139	BZ4BZ5R	A connection exists between BZ4 and BZ5 and a coupler is removed
139	*	Reserved
139	*	Reserved
139	*	Reserved
139	*	Reserved
140	*	Reserved
140	*	Reserved
140	BZ5BZ6R	A connection exists between BZ5 and BZ6 and a coupler is removed
140	*	Reserved
140	*	Reserved
140	*	Reserved
140	*	Reserved
140	*	Reserved
141	*	Reserved
141	*	Reserved
141	*	Reserved
141	*	Reserved
141	*	Reserved
141	*	Reserved
141	*	Reserved
141	*	Reserved
142	*	Reserved
142	*	Reserved
142	*	Reserved
142	*	Reserved
142	*	Reserved
142	*	Reserved
142	*	Reserved
142	*	Reserved
143	*	Reserved
143	*	Reserved
143	*	Reserved
143	*	Reserved
143	*	Reserved
143	*	Reserved

Table 11.2 Row List of Relay Word Bits (Sheet 30 of 100)

Row	Name	Bit Description
143	*	Reserved
143	*	Reserved
144	*	Reserved
144	*	Reserved
144	Z1BZ6	Bus-Zone 6 is part of Protective Zone 1
144	Z1BZ5	Bus-Zone 5 is part of Protective Zone 1
144	Z1BZ4	Bus-Zone 4 is part of Protective Zone 1
144	Z1BZ3	Bus-Zone 3 is part of Protective Zone 1
144	Z1BZ2	Bus-Zone 2 is part of Protective Zone 1
144	Z1BZ1	Bus-Zone 1 is part of Protective Zone 1
145	*	Reserved
145	*	Reserved
145	Z2BZ6	Bus-Zone 6 is part of Protective Zone 2
145	Z2BZ5	Bus-Zone 5 is part of Protective Zone 2
145	Z2BZ4	Bus-Zone 4 is part of Protective Zone 2
145	Z2BZ3	Bus-Zone 3 is part of Protective Zone 2
145	Z2BZ2	Bus-Zone 2 is part of Protective Zone 2
145	*	Reserved
146	*	Reserved
146	*	Reserved
146	Z3BZ6	Bus-Zone 6 is part of Protective Zone 3
146	Z3BZ5	Bus-Zone 5 is part of Protective Zone 3
146	Z3BZ4	Bus-Zone 4 is part of Protective Zone 3
146	Z3BZ3	Bus-Zone 3 is part of Protective Zone 3
146	*	Reserved
146	*	Reserved
147	*	Reserved
147	*	Reserved
147	Z4BZ6	Bus-Zone 6 is part of Protective Zone 4
147	Z4BZ5	Bus-Zone 5 is part of Protective Zone 4
147	Z4BZ4	Bus-Zone 4 is part of Protective Zone 4
147	*	Reserved
147	*	Reserved
147	*	Reserved
148	*	Reserved
148	*	Reserved
148	Z5BZ6	Bus-Zone 6 is part of Protective Zone 5
148	Z5BZ5	Bus-Zone 5 is part of Protective Zone 5
148	*	Reserved
148	*	Reserved
148	*	Reserved

Table 11.2 Row List of Relay Word Bits (Sheet 31 of 100)

Row	Name	Bit Description
148	*	Reserved
149	*	Reserved
149	*	Reserved
149	Z6BZ6	Bus-Zone 6 is part of Protective Zone 6
149	*	Reserved
149	*	Reserved
149	*	Reserved
149	*	Reserved
149	*	Reserved
Zone Selection		
150	*	Reserved
150	*	Reserved
150	ZONE6	Differential Zone 6 is active
150	ZONE5	Differential Zone 5 is active
150	ZONE4	Differential Zone 4 is active
150	ZONE3	Differential Zone 3 is active
150	ZONE2	Differential Zone 2 is active
150	ZONE1	Differential Zone 1 is active
151	*	Reserved
151	ZSWOP	Change to either bus-zone-to-bus-zone or terminal-to-bus-zone conditions in any zone
151	ZSWOP6	Change to either bus-zone-to-bus-zone or terminal-to-bus-zone conditions in Zone 6
151	ZSWOP5	Change to either bus-zone-to-bus-zone or terminal-to-bus-zone conditions in Zone 5
151	ZSWOP4	Change to either bus-zone-to-bus-zone or terminal-to-bus-zone conditions in Zone 4
151	ZSWOP3	Change to either bus-zone-to-bus-zone or terminal-to-bus-zone conditions in Zone 3
151	ZSWOP2	Change to either bus-zone-to-bus-zone or terminal-to-bus-zone conditions in Zone 2
151	ZSWOP1	Change to either bus-zone-to-bus-zone or terminal-to-bus-zone conditions in Zone 1
152	*	Reserved
152	*	Reserved
152	*	Reserved
152	*	Reserved
152	ZSWOAL	Zone switching operation alarm
152	ZSWOIP	Zone switching operation in progress
152	ZSWO	Zone switching operation
152	RZSWOAL	Reset zone switching operation alarm
Zone Supervision		
153	*	Reserved
153	*	Reserved
153	Z6S	Zone 6 supervision asserted
153	Z5S	Zone 5 supervision asserted
153	Z4S	Zone 4 supervision asserted
153	Z3S	Zone 3 supervision asserted

Table 11.2 Row List of Relay Word Bits (Sheet 32 of 100)

Row	Name	Bit Description
153	Z2S	Zone 2 supervision asserted
153	Z1S	Zone 1 supervision asserted
Open CT Detector		
154	*	Reserved
154	*	Reserved
154	ROCTZ6	Zone 6 open CT logic reset
154	ROCTZ5	Zone 5 open CT logic reset
154	ROCTZ4	Zone 4 open CT logic reset
154	ROCTZ3	Zone 3 open CT logic reset
154	ROCTZ2	Zone 2 open CT logic reset
154	ROCTZ1	Zone 1 open CT logic reset
155	*	Reserved
155	*	Reserved
155	OCTZ6	Zone 6 open CT detection
155	OCTZ5	Zone 5 open CT detection
155	OCTZ4	Zone 4 open CT detection
155	OCTZ3	Zone 3 open CT detection
155	OCTZ2	Zone 2 open CT detection
155	OCTZ1	Zone 1 open CT detection
156	*	Reserved
156	*	Reserved
156	RSTOCT6	Zone 6 open CT detection reset
156	RSTOCT5	Zone 5 open CT detection reset
156	RSTOCT4	Zone 4 open CT detection reset
156	RSTOCT3	Zone 3 open CT detection reset
156	RSTOCT2	Zone 2 open CT detection reset
156	RSTOCT1	Zone 1 open CT detection reset
Sensitive Element (87S)		
157	*	Reserved
157	*	Reserved
157	87S6	Zone 6 sensitive differential element picked up
157	87S5	Zone 5 sensitive differential element picked up
157	87S4	Zone 4 sensitive differential element picked up
157	87S3	Zone 3 sensitive differential element picked up
157	87S2	Zone 2 sensitive differential element picked up
157	87S1	Zone 1 sensitive differential element picked up
158	*	Reserved
158	87ST	Any sensitive differential element timer timed out
158	87ST6	Zone 6 sensitive differential element timed out
158	87ST5	Zone 5 sensitive differential element timed out
158	87ST4	Zone 4 sensitive differential element timed out

Table 11.2 Row List of Relay Word Bits (Sheet 33 of 100)

Row	Name	Bit Description
158	87ST3	Zone 3 sensitive differential element timed out
158	87ST2	Zone 2 sensitive differential element timed out
158	87ST1	Zone 1 sensitive differential element timed out
Differential Elements		
159	87R1	Zone 1 restraint differential element picked up
159	P87R1	Zone 1 instantaneous differential element picked up
159	87O1	Zone 1 restraint differential operating current above O87P
159	FAULT1	Zone 1 fault detector picked up
159	CON1	Zone 1 in high-security mode
159	EXT1	Zone 1 external fault declaration
159	DOP1	Zone 1 incremental operating current picked up
159	DRT1	Zone 1 incremental restraint current picked up
160	*	Reserved
160	*	Reserved
160	*	Reserved
160	*	Reserved
160	FDIF1	Zone 1 filtered restrained differential element picked up
160	RDIF1	Zone 1 unfiltered restrained differential element picked up
160	IFAULT1	Zone 1 fault detection
160	GFAULT1	Zone 1 fast fault detection
161	87R2	Zone 2 restraint differential element picked up
161	P87R2	Zone 2 instantaneous differential element picked up
161	87O2	Zone 2 restraint differential operating current above O87P
161	FAULT2	Zone 2 fault detector picked up
161	CON2	Zone 2 in high-security mode
161	EXT2	Zone 2 external fault declaration
161	DOP2	Zone 2 incremental operating current picked up
161	DRT2	Zone 2 incremental restraint current picked up
162	*	Reserved
162	*	Reserved
162	*	Reserved
162	*	Reserved
162	FDIF2	Zone 2 filtered restrained differential element picked up
162	RDIF2	Zone 2 unfiltered restrained differential element picked up
162	IFAULT2	Zone 2 fault detection
162	GFAULT2	Zone 2 fast fault detection
163	87R3	Zone 3 restraint differential element picked up
163	P87R3	Zone 3 instantaneous differential element picked up
163	87O3	Zone 3 restraint differential operating current above O87P
163	FAULT3	Zone 3 fault detector picked up
163	CON3	Zone 3 in high-security mode

Table 11.2 Row List of Relay Word Bits (Sheet 34 of 100)

Row	Name	Bit Description
163	EXT3	Zone 3 external fault declaration
163	DOP3	Zone 3 incremental operating current picked up
163	DRT3	Zone 3 incremental restraint current picked up
164	*	Reserved
164	*	Reserved
164	*	Reserved
164	*	Reserved
164	FDIF3	Zone 3 filtered restrained differential element picked up
164	RDIF3	Zone 3 unfiltered restrained differential element picked up
164	IFAULT3	Zone 3 fault detection
164	GFAULT3	Zone 3 fast fault detection
165	87R4	Zone 4 restraint differential element picked up
165	P87R4	Zone 4 instantaneous differential element picked up
165	87O4	Zone 4 restraint differential operating current above O87P
165	FAULT4	Zone 4 fault detector picked up
165	CON4	Zone 4 in high-security mode
165	EXT4	Zone 4 external fault declaration
165	DOP4	Zone 4 incremental operating current picked up
165	DRT4	Zone 4 incremental restraint current picked up
166	*	Reserved
166	*	Reserved
166	*	Reserved
166	*	Reserved
166	FDIF4	Zone 4 filtered restrained differential element picked up
166	RDIF4	Zone 4 unfiltered restrained differential element picked up
166	IFAULT4	Zone 4 fault detection
166	GFAULT4	Zone 4 fast fault detection
167	87R5	Zone 5 restraint differential element picked up
167	P87R5	Zone 5 instantaneous differential element picked up
167	87O5	Zone 5 restraint differential operating current above O87P
167	FAULT5	Zone 5 fault detector picked up
167	CON5	Zone 5 in high-security mode
167	EXT5	Zone 5 external fault declaration
167	DOP5	Zone 5 incremental operating current picked up
167	DRT5	Zone 5 incremental restraint current picked up
168	*	Reserved
168	*	Reserved
168	*	Reserved
168	*	Reserved
168	FDIF5	Zone 5 filtered restrained differential element picked up
168	RDIF5	Zone 5 unfiltered restrained differential element picked up

Table 11.2 Row List of Relay Word Bits (Sheet 35 of 100)

Row	Name	Bit Description
168	IFAULT5	Zone 5 fault detection
168	GFAULT5	Zone 5 fast fault detection
169	87R6	Zone 6 restraint differential element picked up
169	P87R6	Zone 6 instantaneous differential element picked up
169	87O6	Zone 6 restraint differential operating current above O87P
169	FAULT6	Zone 6 fault detector picked up
169	CON6	Zone 6 in high-security mode
169	EXT6	Zone 6 external fault declaration
169	DOP6	Zone 6 incremental operating current picked up
169	DRT6	Zone 6 incremental restraint current picked up
170	*	Reserved
170	*	Reserved
170	*	Reserved
170	*	Reserved
170	FDIF6	Zone 6 filtered restrained differential element picked up
170	RDIF6	Zone 6 unfiltered restrained differential element picked up
170	IFAULT6	Zone 6 fault detection
170	GFAULT6	Zone 6 fast fault detection
171	*	Reserved
171	*	Reserved
171	*	Reserved
171	*	Reserved
171	*	Reserved
171	*	Reserved
171	*	Reserved
171	FAULT	Busbar fault in any zone
Directional Element (Diff Zone)		
172	*	Reserved
172	*	Reserved
172	DE6F	Zone 6 forward directional element picked up
172	DE5F	Zone 5 forward directional element picked up
172	DE4F	Zone 4 forward directional element picked up
172	DE3F	Zone 3 forward directional element picked up
172	DE2F	Zone 2 forward directional element picked up
172	DE1F	Zone 1 forward directional element picked up
173	50DS08	Terminal 08 directional element current threshold exceeded
173	50DS07	Terminal 07 directional element current threshold exceeded
173	50DS06	Terminal 06 directional element current threshold exceeded
173	50DS05	Terminal 05 directional element current threshold exceeded
173	50DS04	Terminal 04 directional element current threshold exceeded
173	50DS03	Terminal 03 directional element current threshold exceeded

Table 11.2 Row List of Relay Word Bits (Sheet 36 of 100)

Row	Name	Bit Description
173	50DS02	Terminal 02 directional element current threshold exceeded
173	50DS01	Terminal 01 directional element current threshold exceeded
174	50DS16	Terminal 16 directional element current threshold exceeded
174	50DS15	Terminal 15 directional element current threshold exceeded
174	50DS14	Terminal 14 directional element current threshold exceeded
174	50DS13	Terminal 13 directional element current threshold exceeded
174	50DS12	Terminal 12 directional element current threshold exceeded
174	50DS11	Terminal 11 directional element current threshold exceeded
174	50DS10	Terminal 10 directional element current threshold exceeded
174	50DS09	Terminal 09 directional element current threshold exceeded
175	*	Reserved
175	*	Reserved
175	*	Reserved
175	50DS21	Terminal 21 directional element current threshold exceeded
175	50DS20	Terminal 20 directional element current threshold exceeded
175	50DS19	Terminal 19 directional element current threshold exceeded
175	50DS18	Terminal 18 directional element current threshold exceeded
175	50DS17	Terminal 17 directional element current threshold exceeded
Coupler Security Logic		
176	*	Reserved
176	CSL1	Coupler 1 security logic picked up
176	ACTRPT1	Coupler 1 accelerated trip timed out
176	ACTRP1	Coupler 1 accelerated trip SELOGIC control equation
176	CBCLST1	Coupler 1 close command timed out
176	CBCLS1	Coupler 1 close command SELOGIC control equation
176	CB52T1	Coupler 1 status timed out
176	CB52A1	Coupler 1 status SELOGIC control equation
177	*	Reserved
177	CSL2	Coupler 2 security logic picked up
177	ACTRPT2	Coupler 2 accelerated trip timed out
177	ACTRP2	Coupler 2 accelerated trip SELOGIC control equation
177	CBCLST2	Coupler 2 close command timed out
177	CBCLS2	Coupler 2 close command SELOGIC control equation
177	CB52T2	Coupler 2 status timed out
177	CB52A2	Coupler 2 status SELOGIC control equation
178	*	Reserved
178	CSL3	Coupler 3 security logic picked up
178	ACTRPT3	Coupler 3 accelerated trip timed out
178	ACTRP3	Coupler 3 accelerated trip SELOGIC control equation
178	CBCLST3	Coupler 3 close command timed out
178	CBCLS3	Coupler 3 close command SELOGIC control equation

Table 11.2 Row List of Relay Word Bits (Sheet 37 of 100)

Row	Name	Bit Description
178	CB52T3	Coupler 3 status timed out
178	CB52A3	Coupler 3 status SELOGIC control equation
179	*	Reserved
179	CSL4	Coupler 4 security logic picked up
179	ACTRPT4	Coupler 4 accelerated trip timed out
179	ACTRP4	Coupler 4 accelerated trip SELOGIC control equation
179	CBCLST4	Coupler 4 close command timed out
179	CBCLS4	Coupler 4 close command SELOGIC control equation
179	CB52T4	Coupler 4 status timed out
179	CB52A4	Coupler 4 status SELOGIC control equation
Terminal Out of Service		
180	TOS08	Terminal 08 out of service
180	TOS07	Terminal 07 out of service
180	TOS06	Terminal 06 out of service
180	TOS05	Terminal 05 out of service
180	TOS04	Terminal 04 out of service
180	TOS03	Terminal 03 out of service
180	TOS02	Terminal 02 out of service
180	TOS01	Terminal 01 out of service
181	TOS16	Terminal 16 out of service
181	TOS15	Terminal 15 out of service
181	TOS14	Terminal 14 out of service
181	TOS13	Terminal 13 out of service
181	TOS12	Terminal 12 out of service
181	TOS11	Terminal 11 out of service
181	TOS10	Terminal 10 out of service
181	TOS09	Terminal 09 out of service
182	*	Reserved
182	*	Reserved
182	*	Reserved
182	TOS21	Terminal 21 out of service
182	TOS20	Terminal 20 out of service
182	TOS19	Terminal 19 out of service
182	TOS18	Terminal 18 out of service
182	TOS17	Terminal 17 out of service
Breaker Failure		
183	FBF01	Circuit Breaker 1 failure
183	XBF01	Circuit Breaker 1 external breaker failure input (SELOGIC control equation)
183	RT01	Circuit Breaker 1 retrip
183	ABFIT01	Circuit Breaker 1 alternate circuit breaker failure initiate
183	ATBFI01	Circuit Breaker 1 alternate breaker failure initiate SELOGIC control equation

Table 11.2 Row List of Relay Word Bits (Sheet 38 of 100)

Row	Name	Bit Description
183	BFIT01	Circuit Breaker 1 breaker failure timed out
183	BFI01	Circuit Breaker 1 breaker failure initiate SELOGIC control equation
183	50F01	Circuit Breaker 1 breaker failure current threshold exceeded
184	FBF02	Circuit Breaker 2 failure
184	XBF02	Circuit Breaker 2 external breaker failure input (SELOGIC control equation)
184	RT02	Circuit Breaker 2 retrip
184	ABFIT02	Circuit Breaker 2 alternate circuit breaker failure initiate
184	ATBFI02	Circuit Breaker 2 alternate breaker failure initiate SELOGIC control equation
184	BFIT02	Circuit Breaker 2 breaker failure timed out
184	BFI02	Circuit Breaker 2 breaker failure initiate SELOGIC control equation
184	50F02	Circuit Breaker 2 breaker failure current threshold exceeded
185	FBF03	Circuit Breaker 3 failure
185	XBF03	Circuit Breaker 3 external breaker failure input (SELOGIC control equation)
185	RT03	Circuit Breaker 3 retrip
185	ABFIT03	Circuit Breaker 3 alternate circuit breaker failure initiate
185	ATBFI03	Circuit Breaker 3 alternate breaker failure initiate SELOGIC control equation
185	BFIT03	Circuit Breaker 3 breaker failure timed out
185	BFI03	Circuit Breaker 3 breaker failure initiate SELOGIC control equation
185	50F03	Circuit Breaker 3 breaker failure current threshold exceeded
186	FBF04	Circuit Breaker 4 failure
186	XBF04	Circuit Breaker 4 external breaker failure input (SELOGIC control equation)
186	RT04	Circuit Breaker 4 retrip
186	ABFIT04	Circuit Breaker 4 alternate circuit breaker failure initiate
186	ATBFI04	Circuit Breaker 4 alternate breaker failure initiate SELOGIC control equation
186	BFIT04	Circuit Breaker 4 breaker failure timed out
186	BFI04	Circuit Breaker 4 breaker failure initiate SELOGIC control equation
186	50F04	Circuit Breaker 4 breaker failure current threshold exceeded
187	FBF05	Circuit Breaker 5 failure
187	XBF05	Circuit Breaker 5 external breaker failure input (SELOGIC control equation)
187	RT05	Circuit Breaker 5 retrip
187	ABFIT05	Circuit Breaker 5 alternate circuit breaker failure initiate
187	ATBFI05	Circuit Breaker 5 alternate breaker failure initiate SELOGIC control equation
187	BFIT05	Circuit Breaker 5 breaker failure timed out
187	BFI05	Circuit Breaker 5 breaker failure initiate SELOGIC control equation
187	50F05	Circuit Breaker 5 breaker failure current threshold exceeded
188	FBF06	Circuit Breaker 6 failure
188	XBF06	Circuit Breaker 6 external breaker failure input (SELOGIC control equation)
188	RT06	Circuit Breaker 6 retrip
188	ABFIT06	Circuit Breaker 6 alternate circuit breaker failure initiate
188	ATBFI06	Circuit Breaker 6 alternate breaker failure initiate SELOGIC control equation
188	BFIT06	Circuit Breaker 6 breaker failure timed out

Table 11.2 Row List of Relay Word Bits (Sheet 39 of 100)

Row	Name	Bit Description
188	BFI06	Circuit Breaker 6 breaker failure initiate SELOGIC control equation
188	50F06	Circuit Breaker 6 breaker failure current threshold exceeded
189	FBF07	Circuit Breaker 7 failure
189	XBF07	Circuit Breaker 7 external breaker failure input (SELOGIC control equation)
189	RT07	Circuit Breaker 7 retrip
189	ABFIT07	Circuit Breaker 7 alternate circuit breaker failure initiate
189	ATBFI07	Circuit Breaker 7 alternate breaker failure initiate SELOGIC control equation
189	BFIT07	Circuit Breaker 7 breaker failure timed out
189	BFI07	Circuit Breaker 7 breaker failure initiate SELOGIC control equation
189	50F07	Circuit Breaker 7 breaker failure current threshold exceeded
190	FBF08	Circuit Breaker 8 failure
190	XBF08	Circuit Breaker 8 external breaker failure input (SELOGIC control equation)
190	RT08	Circuit Breaker 8 retrip
190	ABFIT08	Circuit Breaker 8 alternate circuit breaker failure initiate
190	ATBFI08	Circuit Breaker 8 alternate breaker failure initiate SELOGIC control equation
190	BFIT08	Circuit Breaker 8 breaker failure timed out
190	BFI08	Circuit Breaker 8 breaker failure initiate SELOGIC control equation
190	50F08	Circuit Breaker 8 breaker failure current threshold exceeded
191	FBF09	Circuit Breaker 9 failure
191	XBF09	Circuit Breaker 9 external breaker failure input (SELOGIC control equation)
191	RT09	Circuit Breaker 9 retrip
191	ABFIT09	Circuit Breaker 9 alternate circuit breaker failure initiate
191	ATBFI09	Circuit Breaker 9 alternate breaker failure initiate SELOGIC control equation
191	BFIT09	Circuit Breaker 9 breaker failure timed out
191	BFI09	Circuit Breaker 9 breaker failure initiate SELOGIC control equation
191	50F09	Circuit Breaker 9 breaker failure current threshold exceeded
192	FBF10	Circuit Breaker 10 failure
192	XBF10	Circuit Breaker 10 external breaker failure input (SELOGIC control equation)
192	RT10	Circuit Breaker 10 retrip
192	ABFIT10	Circuit Breaker 10 alternate circuit breaker failure initiate
192	ATBFI10	Circuit Breaker 10 alternate breaker failure initiate SELOGIC control equation
192	BFIT10	Circuit Breaker 10 breaker failure timed out
192	BFI10	Circuit Breaker 10 breaker failure initiate SELOGIC control equation
192	50F10	Circuit Breaker 10 breaker failure current threshold exceeded
193	FBF11	Circuit Breaker 11 failure
193	XBF11	Circuit Breaker 11 external breaker failure input (SELOGIC control equation)
193	RT11	Circuit Breaker 11 retrip
193	ABFIT11	Circuit Breaker 11 alternate circuit breaker failure initiate
193	ATBFI11	Circuit Breaker 11 alternate breaker failure initiate SELOGIC control equation
193	BFIT11	Circuit Breaker 11 breaker failure timed out
193	BFI11	Circuit Breaker 11 breaker failure initiate SELOGIC control equation

Table 11.2 Row List of Relay Word Bits (Sheet 40 of 100)

Row	Name	Bit Description
193	50F11	Circuit Breaker 11 breaker failure current threshold exceeded
194	FBF12	Circuit Breaker 12 failure
194	XBF12	Circuit Breaker 12 external breaker failure input (SELOGIC control equation)
194	RT12	Circuit Breaker 12 retrip
194	ABFIT12	Circuit Breaker 12 alternate circuit breaker failure initiate
194	ATBFI12	Circuit Breaker 12 alternate breaker failure initiate SELOGIC control equation
194	BFIT12	Circuit Breaker 12 breaker failure timed out
194	BFI12	Circuit Breaker 12 breaker failure initiate SELOGIC control equation
194	50F12	Circuit Breaker 12 breaker failure current threshold exceeded
195	FBF13	Circuit Breaker 13 failure
195	XBF13	Circuit Breaker 13 external breaker failure input (SELOGIC control equation)
195	RT13	Circuit Breaker 13 retrip
195	ABFIT13	Circuit Breaker 13 alternate circuit breaker failure initiate
195	ATBFI13	Circuit Breaker 13 alternate breaker failure initiate SELOGIC control equation
195	BFIT13	Circuit Breaker 13 breaker failure timed out
195	BFI13	Circuit Breaker 13 breaker failure initiate SELOGIC control equation
195	50F13	Circuit Breaker 13 breaker failure current threshold exceeded
196	FBF14	Circuit Breaker 14 failure
196	XBF14	Circuit Breaker 14 external breaker failure input (SELOGIC control equation)
196	RT14	Circuit Breaker 14 retrip
196	ABFIT14	Circuit Breaker 14 alternate circuit breaker failure initiate
196	ATBFI14	Circuit Breaker 14 alternate breaker failure initiate SELOGIC control equation
196	BFIT14	Circuit Breaker 14 breaker failure timed out
196	BFI14	Circuit Breaker 14 breaker failure initiate SELOGIC control equation
196	50F14	Circuit Breaker 14 breaker failure current threshold exceeded
197	FBF15	Circuit Breaker 15 failure
197	XBF15	Circuit Breaker 15 external breaker failure input (SELOGIC control equation)
197	RT15	Circuit Breaker 15 retrip
197	ABFIT15	Circuit Breaker 15 alternate circuit breaker failure initiate
197	ATBFI15	Circuit Breaker 15 alternate breaker failure initiate SELOGIC control equation
197	BFIT15	Circuit Breaker 15 breaker failure timed out
197	BFI15	Circuit Breaker 15 breaker failure initiate SELOGIC control equation
197	50F15	Circuit Breaker 15 breaker failure current threshold exceeded
198	FBF16	Circuit Breaker 16 failure
198	XBF16	Circuit Breaker 16 external breaker failure input (SELOGIC control equation)
198	RT16	Circuit Breaker 16 retrip
198	ABFIT16	Circuit Breaker 16 alternate circuit breaker failure initiate
198	ATBFI16	Circuit Breaker 16 alternate breaker failure initiate SELOGIC control equation
198	BFIT16	Circuit Breaker 16 breaker failure timed out
198	BFI16	Circuit Breaker 16 breaker failure initiate SELOGIC control equation
198	50F16	Circuit Breaker 16 breaker failure current threshold exceeded

Table 11.2 Row List of Relay Word Bits (Sheet 41 of 100)

Row	Name	Bit Description
199	FBF17	Circuit Breaker 17 failure
199	XBF17	Circuit Breaker 17 external breaker failure input (SELOGIC control equation)
199	RT17	Circuit Breaker 17 retrip
199	ABFIT17	Circuit Breaker 17 alternate circuit breaker failure initiate
199	ATBFI17	Circuit Breaker 17 alternate breaker failure initiate SELOGIC control equation
199	BFIT17	Circuit Breaker 17 breaker failure timed out
199	BFI17	Circuit Breaker 17 breaker failure initiate SELOGIC control equation
199	50F17	Circuit Breaker 17 breaker failure current threshold exceeded
200	FBF18	Circuit Breaker 18 failure
200	XBF18	Circuit Breaker 18 external breaker failure input (SELOGIC control equation)
200	RT18	Circuit Breaker 18 retrip
200	ABFIT18	Circuit Breaker 18 alternate circuit breaker failure initiate
200	ATBFI18	Circuit Breaker 18 alternate breaker failure initiate SELOGIC control equation
200	BFIT18	Circuit Breaker 18 breaker failure timed out
200	BFI18	Circuit Breaker 18 breaker failure initiate SELOGIC control equation
200	50F18	Circuit Breaker 18 breaker failure current threshold exceeded
201	FBF19	Circuit Breaker 19 failure
201	XBF19	Circuit Breaker 19 external breaker failure input (SELOGIC control equation)
201	RT19	Circuit Breaker 19 retrip
201	ABFIT19	Circuit Breaker 19 alternate circuit breaker failure initiate
201	ATBFI19	Circuit Breaker 19 alternate breaker failure initiate SELOGIC control equation
201	BFIT19	Circuit Breaker 19 breaker failure timed out
201	BFI19	Circuit Breaker 19 breaker failure initiate SELOGIC control equation
201	50F19	Circuit Breaker 19 breaker failure current threshold exceeded
202	FBF20	Circuit Breaker 20 failure
202	XBF20	Circuit Breaker 20 external breaker failure input (SELOGIC control equation)
202	RT20	Circuit Breaker 20 retrip
202	ABFIT20	Circuit Breaker 20 alternate circuit breaker failure initiate
202	ATBFI20	Circuit Breaker 20 alternate breaker failure initiate SELOGIC control equation
202	BFIT20	Circuit Breaker 20 breaker failure timed out
202	BFI20	Circuit Breaker 20 breaker failure initiate SELOGIC control equation
202	50F20	Circuit Breaker 20 breaker failure current threshold exceeded
203	FBF21	Circuit Breaker 21 failure
203	XBF21	Circuit Breaker 21 external breaker failure input (SELOGIC control equation)
203	RT21	Circuit Breaker 21 retrip
203	ABFIT21	Circuit Breaker 21 alternate circuit breaker failure initiate
203	ATBFI21	Circuit Breaker 21 alternate breaker failure initiate SELOGIC control equation
203	BFIT21	Circuit Breaker 21 breaker failure timed out
203	BFI21	Circuit Breaker 21 breaker failure initiate SELOGIC control equation
203	50F21	Circuit Breaker 21 breaker failure current threshold exceeded
204	*	Reserved

Table 11.2 Row List of Relay Word Bits (Sheet 42 of 100)

Row	Name	Bit Description
204	*	Reserved
204	*	Reserved
204	*	Reserved
204	*	Reserved
204	*	Reserved
204	*	Reserved
204	*	Reserved
205	*	Reserved
205	*	Reserved
205	*	Reserved
205	*	Reserved
205	*	Reserved
205	*	Reserved
205	*	Reserved
205	*	Reserved
206	*	Reserved
206	*	Reserved
206	*	Reserved
206	*	Reserved
206	*	Reserved
206	*	Reserved
206	*	Reserved
206	*	Reserved
Overcurrent Elements		
207	50P04T	Terminal 04 definite-time overcurrent element timed out
207	50P04	Terminal 04 instantaneous overcurrent element
207	50P03T	Terminal 03 definite-time overcurrent element timed out
207	50P03	Terminal 03 instantaneous overcurrent element
207	50P02T	Terminal 02 definite-time overcurrent element timed out
207	50P02	Terminal 02 instantaneous overcurrent element
207	50P01T	Terminal 01 definite-time overcurrent element timed out
207	50P01	Terminal 01 instantaneous overcurrent element
208	50P08T	Terminal 08 definite-time overcurrent element timed out
208	50P08	Terminal 08 instantaneous overcurrent element
208	50P07T	Terminal 07 definite-time overcurrent element timed out
208	50P07	Terminal 07 instantaneous overcurrent element
208	50P06T	Terminal 06 definite-time overcurrent element timed out
208	50P06	Terminal 06 instantaneous overcurrent element
208	50P05T	Terminal 05 definite-time overcurrent element timed out
208	50P05	Terminal 05 instantaneous overcurrent element
209	50P12T	Terminal 12 definite-time overcurrent element timed out

Table 11.2 Row List of Relay Word Bits (Sheet 43 of 100)

Row	Name	Bit Description
209	50P12	Terminal 12 instantaneous overcurrent element
209	50P11T	Terminal 11 definite-time overcurrent element timed out
209	50P11	Terminal 11 instantaneous overcurrent element
209	50P10T	Terminal 10 definite-time overcurrent element timed out
209	50P10	Terminal 10 instantaneous overcurrent element
209	50P09T	Terminal 09 definite-time overcurrent element timed out
209	50P09	Terminal 09 instantaneous overcurrent element
210	50P16T	Terminal 16 definite-time overcurrent element timed out
210	50P16	Terminal 16 instantaneous overcurrent element
210	50P15T	Terminal 15 definite-time overcurrent element timed out
210	50P15	Terminal 15 instantaneous overcurrent element
210	50P14T	Terminal 14 definite-time overcurrent element timed out
210	50P14	Terminal 14 instantaneous overcurrent element
210	50P13T	Terminal 13 definite-time overcurrent element timed out
210	50P13	Terminal 13 instantaneous overcurrent element
211	50P20T	Terminal 20 definite-time overcurrent element timed out
211	50P20	Terminal 20 instantaneous overcurrent element
211	50P19T	Terminal 19 definite-time overcurrent element timed out
211	50P19	Terminal 19 instantaneous overcurrent element
211	50P18T	Terminal 18 definite-time overcurrent element timed out
211	50P18	Terminal 18 instantaneous overcurrent element
211	50P17T	Terminal 17 definite-time overcurrent element timed out
211	50P17	Terminal 17 instantaneous overcurrent element
212	*	Reserved
212	*	Reserved
212	*	Reserved
212	*	Reserved
212	*	Reserved
212	*	Reserved
212	50P21T	Terminal 21 definite-time overcurrent element timed out
212	50P21	Terminal 21 instantaneous overcurrent element
Inverse-Time Overcurrent Elements		
213	51S04	Inverse-time Element 04 picked up
213	51T04	Inverse-time Element 04 timed out
213	51S03	Inverse-time Element 03 picked up
213	51T03	Inverse-time Element 03 timed out
213	51S02	Inverse-time Element 02 picked up
213	51T02	Inverse-time Element 02 timed out
213	51S01	Inverse-time Element 01 picked up
213	51T01	Inverse-time Element 01 timed out
214	51S08	Inverse-time Element 08 picked up

Table 11.2 Row List of Relay Word Bits (Sheet 44 of 100)

Row	Name	Bit Description
214	51T08	Inverse-time Element 08 timed out
214	51S07	Inverse-time Element 07 picked up
214	51T07	Inverse-time Element 07 timed out
214	51S06	Inverse-time Element 06 picked up
214	51T06	Inverse-time Element 06 timed out
214	51S05	Inverse-time Element 05 picked up
214	51T05	Inverse-time Element 05 timed out
215	51S12	Inverse-time Element 12 picked up
215	51T12	Inverse-time Element 12 timed out
215	51S11	Inverse-time Element 11 picked up
215	51T11	Inverse-time Element 11 timed out
215	51S10	Inverse-time Element 10 picked up
215	51T10	Inverse-time Element 10 timed out
215	51S09	Inverse-time Element 09 picked up
215	51T09	Inverse-time Element 09 timed out
216	51S16	Inverse-time Element 16 picked up
216	51T16	Inverse-time Element 16 timed out
216	51S15	Inverse-time Element 15 picked up
216	51T15	Inverse-time Element 15 timed out
216	51S14	Inverse-time Element 14 picked up
216	51T14	Inverse-time Element 14 timed out
216	51S13	Inverse-time Element 13 picked up
216	51T13	Inverse-time Element 13 timed out
217	51S20	Inverse-time Element 20 picked up
217	51T20	Inverse-time Element 20 timed out
217	51S19	Inverse-time Element 19 picked up
217	51T19	Inverse-time Element 19 timed out
217	51S18	Inverse-time Element 18 picked up
217	51T18	Inverse-time Element 18 timed out
217	51S17	Inverse-time Element 17 picked up
217	51T17	Inverse-time Element 17 timed out
218	*	Reserved
218	*	Reserved
218	*	Reserved
218	*	Reserved
218	*	Reserved
218	*	Reserved
218	51S21	Inverse-time Element 21 picked up
218	51T21	Inverse-time Element 21 timed out
219	51MM04	Inverse-time Element 04 pickup setting outside of specified limits
219	51TM04	Inverse-time Element 04 time-dial setting outside of specified limits

Table 11.2 Row List of Relay Word Bits (Sheet 45 of 100)

Row	Name	Bit Description
219	51MM03	Inverse-time Element 03 pickup setting outside of specified limits
219	51TM03	Inverse-time Element 03 time-dial setting outside of specified limits
219	51MM02	Inverse-time Element 02 pickup setting outside of specified limits
219	51TM02	Inverse-time Element 02 time-dial setting outside of specified limits
219	51MM01	Inverse-time Element 01 pickup setting outside of specified limits
219	51TM01	Inverse-time Element 01 time-dial setting outside of specified limits
220	51MM08	Inverse-time Element 08 pickup setting outside of specified limits
220	51TM08	Inverse-time Element 08 time-dial setting outside of specified limits
220	51MM07	Inverse-time Element 07 pickup setting outside of specified limits
220	51TM07	Inverse-time Element 07 time-dial setting outside of specified limits
220	51MM06	Inverse-time Element 06 pickup setting outside of specified limits
220	51TM06	Inverse-time Element 06 time-dial setting outside of specified limits
220	51MM05	Inverse-time Element 05 pickup setting outside of specified limits
220	51TM05	Inverse-time Element 05 time-dial setting outside of specified limits
Under- and Overvoltage Elements		
221	271P1	Undervoltage Element 1, Level 1 asserted
221	271P1T	Undervoltage Element 1, Level 1 timed out
221	271P2	Undervoltage Element 1, Level 2 asserted
221	27TC1	Undervoltage Element 1, torque control
221	272P1	Undervoltage Element 2, Level 1 asserted
221	272P1T	Undervoltage Element 2, Level 1 timed out
221	272P2	Undervoltage Element 2, Level 2 asserted
221	27TC2	Undervoltage Element 2, torque control
222	273P1	Undervoltage Element 3, Level 1 asserted
222	273P1T	Undervoltage Element 3, Level 1 timed out
222	273P2	Undervoltage Element 3, Level 2 asserted
222	27TC3	Undervoltage Element 3, torque control
222	274P1	Undervoltage Element 4, Level 1 asserted
222	274P1T	Undervoltage Element 4, Level 1 timed out
222	274P2	Undervoltage Element 4, Level 2 asserted
222	27TC4	Undervoltage Element 4, torque control
223	275P1	Undervoltage Element 5, Level 1 asserted
223	275P1T	Undervoltage Element 5, Level 1 timed out
223	275P2	Undervoltage Element 5, Level 2 asserted
223	27TC5	Undervoltage Element 5, torque control
223	276P1	Undervoltage Element 6, Level 1 asserted
223	276P1T	Undervoltage Element 6, Level 1 timed out
223	276P2	Undervoltage Element 6, Level 2 asserted
223	27TC6	Undervoltage Element 6, torque control
224	591P1	Overvoltage Element 1, Level 1 asserted
224	591P1T	Overvoltage Element 1, Level 1 timed out

Table 11.2 Row List of Relay Word Bits (Sheet 46 of 100)

Row	Name	Bit Description
224	591P2	Overvoltage Element 1, Level 2 asserted
224	59TC1	Overvoltage Element 1, torque control
224	592P1	Overvoltage Element 2, Level 1 asserted
224	592P1T	Overvoltage Element 2, Level 1 timed out
224	592P2	Overvoltage Element 2, Level 2 asserted
224	59TC2	Overvoltage Element 2, torque control
225	593P1	Overvoltage Element 3, Level 1 asserted
225	593P1T	Overvoltage Element 3, Level 1 timed out
225	593P2	Overvoltage Element 3, Level 2 asserted
225	59TC3	Overvoltage Element 3, torque control
225	594P1	Overvoltage Element 4, Level 1 asserted
225	594P1T	Overvoltage Element 4, Level 1 timed out
225	594P2	Overvoltage Element 4, Level 2 asserted
225	59TC4	Overvoltage Element 4, torque control
226	595P1	Overvoltage Element 5, Level 1 asserted
226	595P1T	Overvoltage Element 5, Level 1 timed out
226	595P2	Overvoltage Element 5, Level 2 asserted
226	59TC5	Overvoltage Element 5, torque control
226	596P1	Overvoltage Element 6, Level 1 asserted
226	596P1T	Overvoltage Element 6, Level 1 timed out
226	596P2	Overvoltage Element 6, Level 2 asserted
226	59TC6	Overvoltage Element 6, torque control
Battery Monitor		
227	DC1F	DC monitor fail alarm
227	DC1W	DC monitor warning alarm
227	DC1G	DC monitor ground fault alarm
227	DC1R	DC monitor alarm for ac ripple
227	*	Reserved
227	*	Reserved
227	*	Reserved
227	*	Reserved
Bus-Zone Trip		
228	87BTR08	Terminal 08 bus-zone differential trip asserted
228	87BTR07	Terminal 07 bus-zone differential trip asserted
228	87BTR06	Terminal 06 bus-zone differential trip asserted
228	87BTR05	Terminal 05 bus-zone differential trip asserted
228	87BTR04	Terminal 04 bus-zone differential trip asserted
228	87BTR03	Terminal 03 bus-zone differential trip asserted
228	87BTR02	Terminal 02 bus-zone differential trip asserted
228	87BTR01	Terminal 01 bus-zone differential trip asserted
229	87BTR16	Terminal 16 bus-zone differential trip asserted

Table 11.2 Row List of Relay Word Bits (Sheet 47 of 100)

Row	Name	Bit Description
229	87BTR15	Terminal 15 bus-zone differential trip asserted
229	87BTR14	Terminal 14 bus-zone differential trip asserted
229	87BTR13	Terminal 13 bus-zone differential trip asserted
229	87BTR12	Terminal 12 bus-zone differential trip asserted
229	87BTR11	Terminal 11 bus-zone differential trip asserted
229	87BTR10	Terminal 10 bus-zone differential trip asserted
229	87BTR09	Terminal 09 bus-zone differential trip asserted
230	*	Reserved
230	*	Reserved
230	*	Any terminal bus-zone differential trip asserted
230	87BTR21	Terminal 21 bus-zone differential trip asserted
230	87BTR20	Terminal 20 bus-zone differential trip asserted
230	87BTR19	Terminal 19 bus-zone differential trip asserted
230	87BTR18	Terminal 18 bus-zone differential trip asserted
230	87BTR17	Terminal 17 bus-zone differential trip asserted
231	*	Reserved
231	*	Reserved
231	*	Reserved
231	*	Reserved
231	*	Reserved
231	*	Reserved
231	*	Reserved
231	87BTR	Any terminal bus-zone differential trip asserted
Inverse-Time Overcurrent Elements		
232	51MM12	Inverse-time Element 12 pickup setting outside of specified limits
232	51TM12	Inverse-time Element 12 time-dial setting outside of specified limits
232	51MM11	Inverse-time Element 11 pickup setting outside of specified limits
232	51TM11	Inverse-time Element 11 time-dial setting outside of specified limits
232	51MM10	Inverse-time Element 10 pickup setting outside of specified limits
232	51TM10	Inverse-time Element 10 time-dial setting outside of specified limits
232	51MM09	Inverse-time Element 09 pickup setting outside of specified limits
232	51TM09	Inverse-time Element 09 time-dial setting outside of specified limits
233	51MM16	Inverse-time Element 16 pickup setting outside of specified limits
233	51TM16	Inverse-time Element 16 time-dial setting outside of specified limits
233	51MM15	Inverse-time Element 15 pickup setting outside of specified limits
233	51TM15	Inverse-time Element 15 time-dial setting outside of specified limits
233	51MM14	Inverse-time Element 14 pickup setting outside of specified limits
233	51TM14	Inverse-time Element 14 time-dial setting outside of specified limits
233	51MM13	Inverse-time Element 13 pickup setting outside of specified limits
233	51TM13	Inverse-time Element 13 time-dial setting outside of specified limits
234	51MM20	Inverse-time Element 20 pickup setting outside of specified limits

Table 11.2 Row List of Relay Word Bits (Sheet 48 of 100)

Row	Name	Bit Description
234	51TM20	Inverse-time Element 20 time-dial setting outside of specified limits
234	51MM19	Inverse-time Element 19 pickup setting outside of specified limits
234	51TM19	Inverse-time Element 19 time-dial setting outside of specified limits
234	51MM18	Inverse-time Element 18 pickup setting outside of specified limits
234	51TM18	Inverse-time Element 18 time-dial setting outside of specified limits
234	51MM17	Inverse-time Element 17 pickup setting outside of specified limits
234	51TM17	Inverse-time Element 17 time-dial setting outside of specified limits
Bus-Zone Trip		
235	*	Reserved
235	*	Reserved
235	87Z6	Zone 6 differential element trip
235	87Z5	Zone 5 differential element trip
235	87Z4	Zone 4 differential element trip
235	87Z3	Zone 3 differential element trip
235	87Z2	Zone 2 differential element trip
235	87Z1	Zone 1 differential element trip
Breaker Failure Trip		
236	SBFTR08	Circuit Breaker 08 breaker failure trip
236	SBFTR07	Circuit Breaker 07 breaker failure trip
236	SBFTR06	Circuit Breaker 06 breaker failure trip
236	SBFTR05	Circuit Breaker 05 breaker failure trip
236	SBFTR04	Circuit Breaker 04 breaker failure trip
236	SBFTR03	Circuit Breaker 03 breaker failure trip
236	SBFTR02	Circuit Breaker 02 breaker failure trip
236	SBFTR01	Circuit Breaker 01 breaker failure trip
237	SBFTR16	Circuit Breaker 16 breaker failure trip
237	SBFTR15	Circuit Breaker 15 breaker failure trip
237	SBFTR14	Circuit Breaker 14 breaker failure trip
237	SBFTR13	Circuit Breaker 13 breaker failure trip
237	SBFTR12	Circuit Breaker 12 breaker failure trip
237	SBFTR11	Circuit Breaker 11 breaker failure trip
237	SBFTR10	Circuit Breaker 10 breaker failure trip
237	SBFTR09	Circuit Breaker 09 breaker failure trip
238	*	Reserved
238	*	Reserved
238	*	Reserved
238	SBFTR21	Circuit Breaker 21 breaker failure trip
238	SBFTR20	Circuit Breaker 20 breaker failure trip
238	SBFTR19	Circuit Breaker 19 breaker failure trip
238	SBFTR18	Circuit Breaker 18 breaker failure trip
238	SBFTR17	Circuit Breaker 17 breaker failure trip

Table 11.2 Row List of Relay Word Bits (Sheet 49 of 100)

Row	Name	Bit Description
239	*	Reserved
239	*	Reserved
239	*	Reserved
239	*	Reserved
239	*	Reserved
239	*	Reserved
239	*	Reserved
239	SBFTR	Any circuit breaker failure trip
240	*	Reserved
240	*	Reserved
240	BFZ6	Zone 6 breaker failure
240	BFZ5	Zone 5 breaker failure
240	BFZ4	Zone 4 breaker failure
240	BFZ3	Zone 3 breaker failure
240	BFZ2	Zone 2 breaker failure
240	BFZ1	Zone 1 breaker failure
Miscellaneous Logic Elements		
241	ER	Event report trigger equation (SELOGIC control equation)
241	EVELOCK	Event summary lock period
241	*	Reserved
241	*	Reserved
241	*	Reserved
241	*	Reserved
241	*	Reserved
241	*	Reserved
Trip and Unlatch		
242	TRIP08	Terminal 08 trip output
242	TRIP07	Terminal 07 trip output
242	TRIP06	Terminal 06 trip output
242	TRIP05	Terminal 05 trip output
242	TRIP04	Terminal 04 trip output
242	TRIP03	Terminal 03 trip output
242	TRIP02	Terminal 02 trip output
242	TRIP01	Terminal 01 trip output
243	TRIP16	Terminal 16 trip output
243	TRIP15	Terminal 15 trip output
243	TRIP14	Terminal 14 trip output
243	TRIP13	Terminal 13 trip output
243	TRIP12	Terminal 12 trip output
243	TRIP11	Terminal 11 trip output
243	TRIP10	Terminal 10 trip output

Table 11.2 Row List of Relay Word Bits (Sheet 50 of 100)

Row	Name	Bit Description
243	TRIP09	Terminal 09 trip output
244	*	Reserved
244	*	Reserved
244	*	Reserved
244	TRIP21	Terminal 21 trip output
244	TRIP20	Terminal 20 trip output
244	TRIP19	Terminal 19 trip output
244	TRIP18	Terminal 18 trip output
244	TRIP17	Terminal 17 trip output
245	*	Reserved
245	*	Reserved
245	*	Reserved
245	*	Reserved
245	*	Reserved
245	*	Reserved
245	*	Reserved
245	TRIP	Any terminal trip output
246	ULTR08	Terminal 08 unlatch trip
246	ULTR07	Terminal 07 unlatch trip
246	ULTR06	Terminal 06 unlatch trip
246	ULTR05	Terminal 05 unlatch trip
246	ULTR04	Terminal 04 unlatch trip
246	ULTR03	Terminal 03 unlatch trip
246	ULTR02	Terminal 02 unlatch trip
246	ULTR01	Terminal 01 unlatch trip
247	ULTR16	Terminal 16 unlatch trip
247	ULTR15	Terminal 15 unlatch trip
247	ULTR14	Terminal 14 unlatch trip
247	ULTR13	Terminal 13 unlatch trip
247	ULTR12	Terminal 12 unlatch trip
247	ULTR11	Terminal 11 unlatch trip
247	ULTR10	Terminal 10 unlatch trip
247	ULTR09	Terminal 09 unlatch trip
248	*	Reserved
248	*	Reserved
248	*	Reserved
248	ULTR21	Terminal 21 unlatch trip
248	ULTR20	Terminal 20 unlatch trip
248	ULTR19	Terminal 19 unlatch trip
248	ULTR18	Terminal 18 unlatch trip
248	ULTR17	Terminal 17 unlatch trip

Table 11.2 Row List of Relay Word Bits (Sheet 51 of 100)

Row	Name	Bit Description
Breaker Open Controls		
249	OC08	Circuit Breaker 08 open command
249	OC07	Circuit Breaker 07 open command
249	OC06	Circuit Breaker 06 open command
249	OC05	Circuit Breaker 05 open command
249	OC04	Circuit Breaker 04 open command
249	OC03	Circuit Breaker 03 open command
249	OC02	Circuit Breaker 02 open command
249	OC01	Circuit Breaker 01 open command
250	OC16	Circuit Breaker 16 open command
250	OC15	Circuit Breaker 15 open command
250	OC14	Circuit Breaker 14 open command
250	OC13	Circuit Breaker 13 open command
250	OC12	Circuit Breaker 12 open command
250	OC11	Circuit Breaker 11 open command
250	OC10	Circuit Breaker 10 open command
250	OC09	Circuit Breaker 09 open command
251	*	Reserved
251	*	Reserved
251	*	Reserved
251	OC21	Circuit Breaker 21 open command
251	OC20	Circuit Breaker 20 open command
251	OC19	Circuit Breaker 19 open command
251	OC18	Circuit Breaker 18 open command
251	OC17	Circuit Breaker 17 open command
Inverse-Time Overcurrent Elements		
252	*	Reserved
252	*	Reserved
252	*	Reserved
252	*	Reserved
252	*	Reserved
252	*	Reserved
252	51MM21	Inverse-time Element 21 pickup setting outside of specified limits
252	51TM21	Inverse-time Element 21 time-dial setting outside of specified limits
253	51R16	Inverse-time Element 16 reset
253	51R15	Inverse-time Element 15 reset
253	51R14	Inverse-time Element 14 reset
253	51R13	Inverse-time Element 13 reset
253	51R12	Inverse-time Element 12 reset
253	51R11	Inverse-time Element 11 reset
253	51R10	Inverse-time Element 10 reset

Table 11.2 Row List of Relay Word Bits (Sheet 52 of 100)

Row	Name	Bit Description
253	51R09	Inverse-time Element 09 reset
254	51R08	Inverse-time Element 08 reset
254	51R07	Inverse-time Element 07 reset
254	51R06	Inverse-time Element 06 reset
254	51R05	Inverse-time Element 05 reset
254	51R04	Inverse-time Element 04 reset
254	51R03	Inverse-time Element 03 reset
254	51R02	Inverse-time Element 02 reset
254	51R01	Inverse-time Element 01 reset
Setting Group Bits		
255	SG6	Settings Group 6 active
255	SG5	Settings Group 5 active
255	SG4	Settings Group 4 active
255	SG3	Settings Group 3 active
255	SG2	Settings Group 2 active
255	SG1	Settings Group 1 active
255	CHSG	Asserted during settings group change
255	*	Reserved
Local Bits		
256	LB08	Local Bit 08
256	LB07	Local Bit 07
256	LB06	Local Bit 06
256	LB05	Local Bit 05
256	LB04	Local Bit 04
256	LB03	Local Bit 03
256	LB02	Local Bit 02
256	LB01	Local Bit 01
257	LB16	Local Bit 16
257	LB15	Local Bit 15
257	LB14	Local Bit 14
257	LB13	Local Bit 13
257	LB12	Local Bit 12
257	LB11	Local Bit 11
257	LB10	Local Bit 10
257	LB09	Local Bit 09
258	LB24	Local Bit 24
258	LB23	Local Bit 23
258	LB22	Local Bit 22
258	LB21	Local Bit 21
258	LB20	Local Bit 20
258	LB19	Local Bit 19

Table 11.2 Row List of Relay Word Bits (Sheet 53 of 100)

Row	Name	Bit Description
258	LB18	Local Bit 18
258	LB17	Local Bit 17
259	LB32	Local Bit 32
259	LB31	Local Bit 31
259	LB30	Local Bit 30
259	LB29	Local Bit 29
259	LB28	Local Bit 28
259	LB27	Local Bit 27
259	LB26	Local Bit 26
259	LB25	Local Bit 25
Remote Bits		
260	RB89	Remote Bit 89
260	RB90	Remote Bit 90
260	RB91	Remote Bit 91
260	RB92	Remote Bit 92
260	RB93	Remote Bit 93
260	RB94	Remote Bit 94
260	RB95	Remote Bit 95
260	RB96	Remote Bit 96
261	RB81	Remote Bit 81
261	RB82	Remote Bit 82
261	RB83	Remote Bit 83
261	RB84	Remote Bit 84
261	RB85	Remote Bit 85
261	RB86	Remote Bit 86
261	RB87	Remote Bit 87
261	RB88	Remote Bit 88
262	RB73	Remote Bit 73
262	RB74	Remote Bit 74
262	RB75	Remote Bit 75
262	RB76	Remote Bit 76
262	RB77	Remote Bit 77
262	RB78	Remote Bit 78
262	RB79	Remote Bit 79
262	RB80	Remote Bit 80
263	RB65	Remote Bit 65
263	RB66	Remote Bit 66
263	RB67	Remote Bit 67
263	RB68	Remote Bit 68
263	RB69	Remote Bit 69
263	RB70	Remote Bit 70

Table 11.2 Row List of Relay Word Bits (Sheet 54 of 100)

Row	Name	Bit Description
263	RB71	Remote Bit 71
263	RB72	Remote Bit 72
264	RB57	Remote Bit 57
264	RB58	Remote Bit 58
264	RB59	Remote Bit 59
264	RB60	Remote Bit 60
264	RB61	Remote Bit 61
264	RB62	Remote Bit 62
264	RB63	Remote Bit 63
264	RB64	Remote Bit 64
265	RB49	Remote Bit 49
265	RB50	Remote Bit 50
265	RB51	Remote Bit 51
265	RB52	Remote Bit 52
265	RB53	Remote Bit 53
265	RB54	Remote Bit 54
265	RB55	Remote Bit 55
265	RB56	Remote Bit 56
266	RB41	Remote Bit 41
266	RB42	Remote Bit 42
266	RB43	Remote Bit 43
266	RB44	Remote Bit 44
266	RB45	Remote Bit 45
266	RB46	Remote Bit 46
266	RB47	Remote Bit 47
266	RB48	Remote Bit 48
267	RB33	Remote Bit 33
267	RB34	Remote Bit 34
267	RB35	Remote Bit 35
267	RB36	Remote Bit 36
267	RB37	Remote Bit 37
267	RB38	Remote Bit 38
267	RB39	Remote Bit 39
267	RB40	Remote Bit 40
268	RB25	Remote Bit 25
268	RB26	Remote Bit 26
268	RB27	Remote Bit 27
268	RB28	Remote Bit 28
268	RB29	Remote Bit 29
268	RB30	Remote Bit 30
268	RB31	Remote Bit 31

Table 11.2 Row List of Relay Word Bits (Sheet 55 of 100)

Row	Name	Bit Description
268	RB32	Remote Bit 32
269	RB17	Remote Bit 17
269	RB18	Remote Bit 18
269	RB19	Remote Bit 19
269	RB20	Remote Bit 20
269	RB21	Remote Bit 21
269	RB22	Remote Bit 22
269	RB23	Remote Bit 23
269	RB24	Remote Bit 24
270	RB09	Remote Bit 09
270	RB10	Remote Bit 10
270	RB11	Remote Bit 11
270	RB12	Remote Bit 12
270	RB13	Remote Bit 13
270	RB14	Remote Bit 14
270	RB15	Remote Bit 15
270	RB16	Remote Bit 16
271	RB01	Remote Bit 01
271	RB02	Remote Bit 02
271	RB03	Remote Bit 03
271	RB04	Remote Bit 04
271	RB05	Remote Bit 05
271	RB06	Remote Bit 06
271	RB07	Remote Bit 07
271	RB08	Remote Bit 08
Contact Inputs		
272	*	Reserved
272	IN107	Main board Input 07
272	IN106	Main board Input 06
272	IN105	Main board Input 05
272	IN104	Main board Input 04
272	IN103	Main board Input 03
272	IN102	Main board Input 02
272	IN101	Main board Input 01
273	*	Reserved
273	*	Reserved
273	*	Reserved
273	*	Reserved
273	*	Reserved
273	*	Reserved
273	*	Reserved

Table 11.2 Row List of Relay Word Bits (Sheet 56 of 100)

Row	Name	Bit Description
273	*	Reserved
274	*	Reserved
274	*	Reserved
274	*	Reserved
274	*	Reserved
274	*	Reserved
274	*	Reserved
274	*	Reserved
274	*	Reserved
275	*	Reserved
275	*	Reserved
275	*	Reserved
275	*	Reserved
275	*	Reserved
275	*	Reserved
275	*	Reserved
275	*	Reserved
276	IN208	Optional I/O Board 1 Input 08
276	IN207	Optional I/O Board 1 Input 07
276	IN206	Optional I/O Board 1 Input 06
276	IN205	Optional I/O Board 1 Input 05
276	IN204	Optional I/O Board 1 Input 04
276	IN203	Optional I/O Board 1 Input 03
276	IN202	Optional I/O Board 1 Input 02
276	IN201	Optional I/O Board 1 Input 01
277	IN216	Optional I/O Board 1 Input 16
277	IN215	Optional I/O Board 1 Input 15
277	IN214	Optional I/O Board 1 Input 14
277	IN213	Optional I/O Board 1 Input 13
277	IN212	Optional I/O Board 1 Input 12
277	IN211	Optional I/O Board 1 Input 11
277	IN210	Optional I/O Board 1 Input 10
277	IN209	Optional I/O Board 1 Input 09
278	IN224	Optional I/O Board 1 Input 24
278	IN223	Optional I/O Board 1 Input 23
278	IN222	Optional I/O Board 1 Input 22
278	IN221	Optional I/O Board 1 Input 21
278	IN220	Optional I/O Board 1 Input 20
278	IN219	Optional I/O Board 1 Input 19
278	IN218	Optional I/O Board 1 Input 18
278	IN217	Optional I/O Board 1 Input 17

Table 11.2 Row List of Relay Word Bits (Sheet 57 of 100)

Row	Name	Bit Description
279	*	Reserved
279	*	Reserved
279	*	Reserved
279	*	Reserved
279	*	Reserved
279	*	Reserved
279	*	Reserved
279	*	Reserved
280	IN308	Optional I/O Board 2 input 08
280	IN307	Optional I/O Board 2 input 07
280	IN306	Optional I/O Board 2 input 06
280	IN305	Optional I/O Board 2 input 05
280	IN304	Optional I/O Board 2 input 04
280	IN303	Optional I/O Board 2 input 03
280	IN302	Optional I/O Board 2 input 02
280	IN301	Optional I/O Board 2 input 01
281	IN316	Optional I/O Board 2 input 16
281	IN315	Optional I/O Board 2 input 15
281	IN314	Optional I/O Board 2 input 14
281	IN313	Optional I/O Board 2 input 13
281	IN312	Optional I/O Board 2 input 12
281	IN311	Optional I/O Board 2 input 11
281	IN310	Optional I/O Board 2 input 10
281	IN309	Optional I/O Board 2 input 09
282	IN324	Optional I/O Board 2 input 24
282	IN323	Optional I/O Board 2 input 23
282	IN322	Optional I/O Board 2 input 22
282	IN321	Optional I/O Board 2 input 21
282	IN320	Optional I/O Board 2 input 20
282	IN319	Optional I/O Board 2 input 19
282	IN318	Optional I/O Board 2 input 18
282	IN317	Optional I/O Board 2 input 17
283	*	Reserved
283	*	Reserved
283	*	Reserved
283	*	Reserved
283	*	Reserved
283	*	Reserved
283	*	Reserved
283	*	Reserved
284	IN408	Optional I/O Board 3 input 08

Table 11.2 Row List of Relay Word Bits (Sheet 58 of 100)

Row	Name	Bit Description
284	IN407	Optional I/O Board 3 input 07
284	IN406	Optional I/O Board 3 input 06
284	IN405	Optional I/O Board 3 input 05
284	IN404	Optional I/O Board 3 input 04
284	IN403	Optional I/O Board 3 input 03
284	IN402	Optional I/O Board 3 input 02
284	IN401	Optional I/O Board 3 input 01
285	IN416	Optional I/O Board 3 input 16
285	IN415	Optional I/O Board 3 input 15
285	IN414	Optional I/O Board 3 input 14
285	IN413	Optional I/O Board 3 input 13
285	IN412	Optional I/O Board 3 input 12
285	IN411	Optional I/O Board 3 input 11
285	IN410	Optional I/O Board 3 input 10
285	IN409	Optional I/O Board 3 input 09
286	IN424	Optional I/O Board 3 input 24
286	IN423	Optional I/O Board 3 input 23
286	IN422	Optional I/O Board 3 input 22
286	IN421	Optional I/O Board 3 input 21
286	IN420	Optional I/O Board 3 input 20
286	IN419	Optional I/O Board 3 input 19
286	IN418	Optional I/O Board 3 input 18
286	IN417	Optional I/O Board 3 input 17
287	*	Reserved
287	*	Reserved
287	*	Reserved
287	*	Reserved
287	*	Reserved
287	*	Reserved
287	*	Reserved
287	*	Reserved
288	IN508	Optional I/O Board 4 input 08
288	IN507	Optional I/O Board 4 input 07
288	IN506	Optional I/O Board 4 input 06
288	IN505	Optional I/O Board 4 input 05
288	IN504	Optional I/O Board 4 input 04
288	IN503	Optional I/O Board 4 input 03
288	IN502	Optional I/O Board 4 input 02
288	IN501	Optional I/O Board 4 input 01
289	IN516	Optional I/O Board 4 input 16
289	IN515	Optional I/O Board 4 input 15

Table 11.2 Row List of Relay Word Bits (Sheet 59 of 100)

Row	Name	Bit Description
289	IN514	Optional I/O Board 4 input 14
289	IN513	Optional I/O Board 4 input 13
289	IN512	Optional I/O Board 4 input 12
289	IN511	Optional I/O Board 4 input 11
289	IN510	Optional I/O Board 4 input 10
289	IN509	Optional I/O Board 4 input 09
290	IN524	Optional I/O Board 4 input 24
290	IN523	Optional I/O Board 4 input 23
290	IN522	Optional I/O Board 4 input 22
290	IN521	Optional I/O Board 4 input 21
290	IN520	Optional I/O Board 4 input 20
290	IN519	Optional I/O Board 4 input 19
290	IN518	Optional I/O Board 4 input 18
290	IN517	Optional I/O Board 4 input 17
291	*	Reserved
291	*	Reserved
291	*	Reserved
291	*	Reserved
291	*	Reserved
291	*	Reserved
291	*	Reserved
291	*	Reserved
Protection SELOGIC Variables		
292	PSV08	Protection SELOGIC control equation Variable 08
292	PSV07	Protection SELOGIC control equation Variable 07
292	PSV06	Protection SELOGIC control equation Variable 06
292	PSV05	Protection SELOGIC control equation Variable 05
292	PSV04	Protection SELOGIC control equation Variable 04
292	PSV03	Protection SELOGIC control equation Variable 03
292	PSV02	Protection SELOGIC control equation Variable 02
292	PSV01	Protection SELOGIC control equation Variable 01
293	PSV16	Protection SELOGIC control equation Variable 16
293	PSV15	Protection SELOGIC control equation Variable 15
293	PSV14	Protection SELOGIC control equation Variable 14
293	PSV13	Protection SELOGIC control equation Variable 13
293	PSV12	Protection SELOGIC control equation Variable 12
293	PSV11	Protection SELOGIC control equation Variable 11
293	PSV10	Protection SELOGIC control equation Variable 10
293	PSV09	Protection SELOGIC control equation Variable 09
294	PSV24	Protection SELOGIC control equation Variable 24
294	PSV23	Protection SELOGIC control equation Variable 23

Table 11.2 Row List of Relay Word Bits (Sheet 60 of 100)

Row	Name	Bit Description
294	PSV22	Protection SELOGIC control equation Variable 22
294	PSV21	Protection SELOGIC control equation Variable 21
294	PSV20	Protection SELOGIC control equation Variable 20
294	PSV19	Protection SELOGIC control equation Variable 19
294	PSV18	Protection SELOGIC control equation Variable 18
294	PSV17	Protection SELOGIC control equation Variable 17
295	PSV32	Protection SELOGIC control equation Variable 32
295	PSV31	Protection SELOGIC control equation Variable 31
295	PSV30	Protection SELOGIC control equation Variable 30
295	PSV29	Protection SELOGIC control equation Variable 29
295	PSV28	Protection SELOGIC control equation Variable 28
295	PSV27	Protection SELOGIC control equation Variable 27
295	PSV26	Protection SELOGIC control equation Variable 26
295	PSV25	Protection SELOGIC control equation Variable 25
296	PSV40	Protection SELOGIC control equation Variable 40
296	PSV39	Protection SELOGIC control equation Variable 39
296	PSV38	Protection SELOGIC control equation Variable 38
296	PSV37	Protection SELOGIC control equation Variable 37
296	PSV36	Protection SELOGIC control equation Variable 36
296	PSV35	Protection SELOGIC control equation Variable 35
296	PSV34	Protection SELOGIC control equation Variable 34
296	PSV33	Protection SELOGIC control equation Variable 33
297	PSV48	Protection SELOGIC control equation Variable 48
297	PSV47	Protection SELOGIC control equation Variable 47
297	PSV46	Protection SELOGIC control equation Variable 46
297	PSV45	Protection SELOGIC control equation Variable 45
297	PSV44	Protection SELOGIC control equation Variable 44
297	PSV43	Protection SELOGIC control equation Variable 43
297	PSV42	Protection SELOGIC control equation Variable 42
297	PSV41	Protection SELOGIC control equation Variable 41
298	PSV56	Protection SELOGIC control equation Variable 56
298	PSV55	Protection SELOGIC control equation Variable 55
298	PSV54	Protection SELOGIC control equation Variable 54
298	PSV53	Protection SELOGIC control equation Variable 53
298	PSV52	Protection SELOGIC control equation Variable 52
298	PSV51	Protection SELOGIC control equation Variable 51
298	PSV50	Protection SELOGIC control equation Variable 50
298	PSV49	Protection SELOGIC control equation Variable 49
299	PSV64	Protection SELOGIC control equation Variable 64
299	PSV63	Protection SELOGIC control equation Variable 63
299	PSV62	Protection SELOGIC control equation Variable 62

Table 11.2 Row List of Relay Word Bits (Sheet 61 of 100)

Row	Name	Bit Description
299	PSV61	Protection SELOGIC control equation Variable 61
299	PSV60	Protection SELOGIC control equation Variable 60
299	PSV59	Protection SELOGIC control equation Variable 59
299	PSV58	Protection SELOGIC control equation Variable 58
299	PSV57	Protection SELOGIC control equation Variable 57
Protection SELOGIC Latches		
300	PLT08	Protection Latch 08
300	PLT07	Protection Latch 07
300	PLT06	Protection Latch 06
300	PLT05	Protection Latch 05
300	PLT04	Protection Latch 04
300	PLT03	Protection Latch 03
300	PLT02	Protection Latch 02
300	PLT01	Protection Latch 01
301	PLT16	Protection Latch 16
301	PLT15	Protection Latch 15
301	PLT14	Protection Latch 14
301	PLT13	Protection Latch 13
301	PLT12	Protection Latch 12
301	PLT11	Protection Latch 11
301	PLT10	Protection Latch 10
301	PLT09	Protection Latch 09
302	PLT24	Protection Latch 24
302	PLT23	Protection Latch 23
302	PLT22	Protection Latch 22
302	PLT21	Protection Latch 21
302	PLT20	Protection Latch 20
302	PLT19	Protection Latch 19
302	PLT18	Protection Latch 18
302	PLT17	Protection Latch 17
303	PLT32	Protection Latch 32
303	PLT31	Protection Latch 31
303	PLT30	Protection Latch 30
303	PLT29	Protection Latch 29
303	PLT28	Protection Latch 28
303	PLT27	Protection Latch 27
303	PLT26	Protection Latch 26
303	PLT25	Protection Latch 25
Protection SELOGIC Conditioning Timers		
304	PCT08Q	Protection conditioning timer Output 08
304	PCT07Q	Protection conditioning timer Output 07

Table 11.2 Row List of Relay Word Bits (Sheet 62 of 100)

Row	Name	Bit Description
304	PCT06Q	Protection conditioning timer Output 06
304	PCT05Q	Protection conditioning timer Output 05
304	PCT04Q	Protection conditioning timer Output 04
304	PCT03Q	Protection conditioning timer Output 03
304	PCT02Q	Protection conditioning timer Output 02
304	PCT01Q	Protection conditioning timer Output 01
305	PCT16Q	Protection conditioning timer Output 16
305	PCT15Q	Protection conditioning timer Output 15
305	PCT14Q	Protection conditioning timer Output 14
305	PCT13Q	Protection conditioning timer Output 13
305	PCT12Q	Protection conditioning timer Output 12
305	PCT11Q	Protection conditioning timer Output 11
305	PCT10Q	Protection conditioning timer Output 10
305	PCT09Q	Protection conditioning timer Output 09
Protection SELogic Sequencing Timers		
306	PST08Q	Protection sequencing timer Output 08
306	PST07Q	Protection sequencing timer Output 07
306	PST06Q	Protection sequencing timer Output 06
306	PST05Q	Protection sequencing timer Output 05
306	PST04Q	Protection sequencing timer Output 04
306	PST03Q	Protection sequencing timer Output 03
306	PST02Q	Protection sequencing timer Output 02
306	PST01Q	Protection sequencing timer Output 01
307	PST16Q	Protection sequencing timer Output 16
307	PST15Q	Protection sequencing timer Output 15
307	PST14Q	Protection sequencing timer Output 14
307	PST13Q	Protection sequencing timer Output 13
307	PST12Q	Protection sequencing timer Output 12
307	PST11Q	Protection sequencing timer Output 11
307	PST10Q	Protection sequencing timer Output 10
307	PST09Q	Protection sequencing timer Output 09
308	PST24Q	Protection sequencing timer Output 24
308	PST23Q	Protection sequencing timer Output 23
308	PST22Q	Protection sequencing timer Output 22
308	PST21Q	Protection sequencing timer Output 21
308	PST20Q	Protection sequencing timer Output 20
308	PST19Q	Protection sequencing timer Output 19
308	PST18Q	Protection sequencing timer Output 18
308	PST17Q	Protection sequencing timer Output 17
309	PST32Q	Protection sequencing timer Output 32
309	PST31Q	Protection sequencing timer Output 31

Table 11.2 Row List of Relay Word Bits (Sheet 63 of 100)

Row	Name	Bit Description
309	PST30Q	Protection sequencing timer Output 30
309	PST29Q	Protection sequencing timer Output 29
309	PST28Q	Protection sequencing timer Output 28
309	PST27Q	Protection sequencing timer Output 27
309	PST26Q	Protection sequencing timer Output 26
309	PST25Q	Protection sequencing timer Output 25
310	PST08R	Protection sequencing timer Reset 08
310	PST07R	Protection sequencing timer Reset 07
310	PST06R	Protection sequencing timer Reset 06
310	PST05R	Protection sequencing timer Reset 05
310	PST04R	Protection sequencing timer Reset 04
310	PST03R	Protection sequencing timer Reset 03
310	PST02R	Protection sequencing timer Reset 02
310	PST01R	Protection sequencing timer Reset 01
311	PST16R	Protection sequencing timer Reset 16
311	PST15R	Protection sequencing timer Reset 15
311	PST14R	Protection sequencing timer Reset 14
311	PST13R	Protection sequencing timer Reset 13
311	PST12R	Protection sequencing timer Reset 12
311	PST11R	Protection sequencing timer Reset 11
311	PST10R	Protection sequencing timer Reset 10
311	PST09R	Protection sequencing timer Reset 09
312	PST24R	Protection sequencing timer Reset 24
312	PST23R	Protection sequencing timer Reset 23
312	PST22R	Protection sequencing timer Reset 22
312	PST21R	Protection sequencing timer Reset 21
312	PST20R	Protection sequencing timer Reset 20
312	PST19R	Protection sequencing timer Reset 19
312	PST18R	Protection sequencing timer Reset 18
312	PST17R	Protection sequencing timer Reset 17
313	PST32R	Protection sequencing timer Reset 32
313	PST31R	Protection sequencing timer Reset 31
313	PST30R	Protection sequencing timer Reset 30
313	PST29R	Protection sequencing timer Reset 29
313	PST28R	Protection sequencing timer Reset 28
313	PST27R	Protection sequencing timer Reset 27
313	PST26R	Protection sequencing timer Reset 26
313	PST25R	Protection sequencing timer Reset 25
Protection SELogic Counters		
314	PCN08Q	Protection counter Output 08
314	PCN07Q	Protection counter Output 07

Table 11.2 Row List of Relay Word Bits (Sheet 64 of 100)

Row	Name	Bit Description
314	PCN06Q	Protection counter Output 06
314	PCN05Q	Protection counter Output 05
314	PCN04Q	Protection counter Output 04
314	PCN03Q	Protection counter Output 03
314	PCN02Q	Protection counter Output 02
314	PCN01Q	Protection counter Output 01
315	PCN16Q	Protection counter Output 16
315	PCN15Q	Protection counter Output 15
315	PCN14Q	Protection counter Output 14
315	PCN13Q	Protection counter Output 13
315	PCN12Q	Protection counter Output 12
315	PCN11Q	Protection counter Output 11
315	PCN10Q	Protection counter Output 10
315	PCN09Q	Protection counter Output 09
316	PCN24Q	Protection counter Output 24
316	PCN23Q	Protection counter Output 23
316	PCN22Q	Protection counter Output 22
316	PCN21Q	Protection counter Output 21
316	PCN20Q	Protection counter Output 20
316	PCN19Q	Protection counter Output 19
316	PCN18Q	Protection counter Output 18
316	PCN17Q	Protection counter Output 17
317	PCN32Q	Protection counter Output 32
317	PCN31Q	Protection counter Output 31
317	PCN30Q	Protection counter Output 30
317	PCN29Q	Protection counter Output 29
317	PCN28Q	Protection counter Output 28
317	PCN27Q	Protection counter Output 27
317	PCN26Q	Protection counter Output 26
317	PCN25Q	Protection counter Output 25
318	PCN08R	Protection counter reset 08
318	PCN07R	Protection counter reset 07
318	PCN06R	Protection counter reset 06
318	PCN05R	Protection counter reset 05
318	PCN04R	Protection counter reset 04
318	PCN03R	Protection counter reset 03
318	PCN02R	Protection counter reset 02
318	PCN01R	Protection counter reset 01
319	PCN16R	Protection counter reset 16
319	PCN15R	Protection counter reset 15
319	PCN14R	Protection counter reset 14

Table 11.2 Row List of Relay Word Bits (Sheet 65 of 100)

Row	Name	Bit Description
319	PCN13R	Protection counter reset 13
319	PCN12R	Protection counter reset 12
319	PCN11R	Protection counter reset 11
319	PCN10R	Protection counter reset 10
319	PCN09R	Protection counter reset 09
320	PCN24R	Protection counter reset 24
320	PCN23R	Protection counter reset 23
320	PCN22R	Protection counter reset 22
320	PCN21R	Protection counter reset 21
320	PCN20R	Protection counter reset 20
320	PCN19R	Protection counter reset 19
320	PCN18R	Protection counter reset 18
320	PCN17R	Protection counter reset 17
321	PCN32R	Protection counter reset 32
321	PCN31R	Protection counter reset 31
321	PCN30R	Protection counter reset 30
321	PCN29R	Protection counter reset 29
321	PCN28R	Protection counter reset 28
321	PCN27R	Protection counter reset 27
321	PCN26R	Protection counter reset 26
321	PCN25R	Protection counter reset 25
Automation SELOGIC Variables		
322	ASV008	Automation SELOGIC control equation Variable 8
322	ASV007	Automation SELOGIC control equation Variable 7
322	ASV006	Automation SELOGIC control equation Variable 6
322	ASV005	Automation SELOGIC control equation Variable 5
322	ASV004	Automation SELOGIC control equation Variable 4
322	ASV003	Automation SELOGIC control equation Variable 3
322	ASV002	Automation SELOGIC control equation Variable 2
322	ASV001	Automation SELOGIC control equation Variable 1
323	ASV016	Automation SELOGIC control equation Variable 16
323	ASV015	Automation SELOGIC control equation Variable 15
323	ASV014	Automation SELOGIC control equation Variable 14
323	ASV013	Automation SELOGIC control equation Variable 13
323	ASV012	Automation SELOGIC control equation Variable 12
323	ASV011	Automation SELOGIC control equation Variable 11
323	ASV010	Automation SELOGIC control equation Variable 10
323	ASV009	Automation SELOGIC control equation Variable 09
324	ASV024	Automation SELOGIC control equation Variable 24
324	ASV023	Automation SELOGIC control equation Variable 23
324	ASV022	Automation SELOGIC control equation Variable 22

Table 11.2 Row List of Relay Word Bits (Sheet 66 of 100)

Row	Name	Bit Description
324	ASV021	Automation SELOGIC control equation Variable 21
324	ASV020	Automation SELOGIC control equation Variable 20
324	ASV019	Automation SELOGIC control equation Variable 19
324	ASV018	Automation SELOGIC control equation Variable 18
324	ASV017	Automation SELOGIC control equation Variable 17
325	ASV032	Automation SELOGIC control equation Variable 32
325	ASV031	Automation SELOGIC control equation Variable 31
325	ASV030	Automation SELOGIC control equation Variable 30
325	ASV029	Automation SELOGIC control equation Variable 29
325	ASV028	Automation SELOGIC control equation Variable 28
325	ASV027	Automation SELOGIC control equation Variable 27
325	ASV026	Automation SELOGIC control equation Variable 26
325	ASV025	Automation SELOGIC control equation Variable 25
326	ASV040	Automation SELOGIC control equation Variable 40
326	ASV039	Automation SELOGIC control equation Variable 39
326	ASV038	Automation SELOGIC control equation Variable 38
326	ASV037	Automation SELOGIC control equation Variable 37
326	ASV036	Automation SELOGIC control equation Variable 36
326	ASV035	Automation SELOGIC control equation Variable 35
326	ASV034	Automation SELOGIC control equation Variable 34
326	ASV033	Automation SELOGIC control equation Variable 33
327	ASV048	Automation SELOGIC control equation Variable 48
327	ASV047	Automation SELOGIC control equation Variable 47
327	ASV046	Automation SELOGIC control equation Variable 46
327	ASV045	Automation SELOGIC control equation Variable 45
327	ASV044	Automation SELOGIC control equation Variable 44
327	ASV043	Automation SELOGIC control equation Variable 43
327	ASV042	Automation SELOGIC control equation Variable 42
327	ASV041	Automation SELOGIC control equation Variable 41
328	ASV056	Automation SELOGIC control equation Variable 56
328	ASV055	Automation SELOGIC control equation Variable 55
328	ASV054	Automation SELOGIC control equation Variable 54
328	ASV053	Automation SELOGIC control equation Variable 53
328	ASV052	Automation SELOGIC control equation Variable 52
328	ASV051	Automation SELOGIC control equation Variable 51
328	ASV050	Automation SELOGIC control equation Variable 50
328	ASV049	Automation SELOGIC control equation Variable 49
329	ASV064	Automation SELOGIC control equation Variable 64
329	ASV063	Automation SELOGIC control equation Variable 63
329	ASV062	Automation SELOGIC control equation Variable 62
329	ASV061	Automation SELOGIC control equation Variable 61

Table 11.2 Row List of Relay Word Bits (Sheet 67 of 100)

Row	Name	Bit Description
329	ASV060	Automation SELOGIC control equation Variable 60
329	ASV059	Automation SELOGIC control equation Variable 59
329	ASV058	Automation SELOGIC control equation Variable 58
329	ASV057	Automation SELOGIC control equation Variable 57
330	ASV072	Automation SELOGIC control equation Variable 72
330	ASV071	Automation SELOGIC control equation Variable 71
330	ASV070	Automation SELOGIC control equation Variable 70
330	ASV069	Automation SELOGIC control equation Variable 69
330	ASV068	Automation SELOGIC control equation Variable 68
330	ASV067	Automation SELOGIC control equation Variable 67
330	ASV066	Automation SELOGIC control equation Variable 66
330	ASV065	Automation SELOGIC control equation Variable 65
331	ASV080	Automation SELOGIC control equation Variable 80
331	ASV079	Automation SELOGIC control equation Variable 79
331	ASV078	Automation SELOGIC control equation Variable 78
331	ASV077	Automation SELOGIC control equation Variable 77
331	ASV076	Automation SELOGIC control equation Variable 76
331	ASV075	Automation SELOGIC control equation Variable 75
331	ASV074	Automation SELOGIC control equation Variable 74
331	ASV073	Automation SELOGIC control equation Variable 73
332	ASV088	Automation SELOGIC control equation Variable 88
332	ASV087	Automation SELOGIC control equation Variable 87
332	ASV086	Automation SELOGIC control equation Variable 86
332	ASV085	Automation SELOGIC control equation Variable 85
332	ASV084	Automation SELOGIC control equation Variable 84
332	ASV083	Automation SELOGIC control equation Variable 83
332	ASV082	Automation SELOGIC control equation Variable 82
332	ASV081	Automation SELOGIC control equation Variable 81
333	ASV096	Automation SELOGIC control equation Variable 96
333	ASV095	Automation SELOGIC control equation Variable 95
333	ASV094	Automation SELOGIC control equation Variable 94
333	ASV093	Automation SELOGIC control equation Variable 93
333	ASV092	Automation SELOGIC control equation Variable 92
333	ASV091	Automation SELOGIC control equation Variable 91
333	ASV090	Automation SELOGIC control equation Variable 90
333	ASV089	Automation SELOGIC control equation Variable 89
334	ASV104	Automation SELOGIC control equation Variable 104
334	ASV103	Automation SELOGIC control equation Variable 103
334	ASV102	Automation SELOGIC control equation Variable 102
334	ASV101	Automation SELOGIC control equation Variable 101
334	ASV100	Automation SELOGIC control equation Variable 100

Table 11.2 Row List of Relay Word Bits (Sheet 68 of 100)

Row	Name	Bit Description
334	ASV099	Automation SELOGIC control equation Variable 099
334	ASV098	Automation SELOGIC control equation Variable 098
334	ASV097	Automation SELOGIC control equation Variable 097
335	ASV112	Automation SELOGIC control equation Variable 112
335	ASV111	Automation SELOGIC control equation Variable 111
335	ASV110	Automation SELOGIC control equation Variable 110
335	ASV109	Automation SELOGIC control equation Variable 109
335	ASV108	Automation SELOGIC control equation Variable 108
335	ASV107	Automation SELOGIC control equation Variable 107
335	ASV106	Automation SELOGIC control equation Variable 106
335	ASV105	Automation SELOGIC control equation Variable 105
336	ASV120	Automation SELOGIC control equation Variable 120
336	ASV119	Automation SELOGIC control equation Variable 119
336	ASV118	Automation SELOGIC control equation Variable 118
336	ASV117	Automation SELOGIC control equation Variable 117
336	ASV116	Automation SELOGIC control equation Variable 116
336	ASV115	Automation SELOGIC control equation Variable 115
336	ASV114	Automation SELOGIC control equation Variable 114
336	ASV113	Automation SELOGIC control equation Variable 113
337	ASV128	Automation SELOGIC control equation Variable 128
337	ASV127	Automation SELOGIC control equation Variable 127
337	ASV126	Automation SELOGIC control equation Variable 126
337	ASV125	Automation SELOGIC control equation Variable 125
337	ASV124	Automation SELOGIC control equation Variable 124
337	ASV123	Automation SELOGIC control equation Variable 123
337	ASV122	Automation SELOGIC control equation Variable 122
337	ASV121	Automation SELOGIC control equation Variable 121
338	ASV136	Automation SELOGIC control equation Variable 136
338	ASV135	Automation SELOGIC control equation Variable 135
338	ASV134	Automation SELOGIC control equation Variable 134
338	ASV133	Automation SELOGIC control equation Variable 133
338	ASV132	Automation SELOGIC control equation Variable 132
338	ASV131	Automation SELOGIC control equation Variable 131
338	ASV130	Automation SELOGIC control equation Variable 130
338	ASV129	Automation SELOGIC control equation Variable 129
339	ASV144	Automation SELOGIC control equation Variable 144
339	ASV143	Automation SELOGIC control equation Variable 143
339	ASV142	Automation SELOGIC control equation Variable 142
339	ASV141	Automation SELOGIC control equation Variable 141
339	ASV140	Automation SELOGIC control equation Variable 140
339	ASV139	Automation SELOGIC control equation Variable 139

Table 11.2 Row List of Relay Word Bits (Sheet 69 of 100)

Row	Name	Bit Description
339	ASV138	Automation SELOGIC control equation Variable 138
339	ASV137	Automation SELOGIC control equation Variable 137
340	ASV152	Automation SELOGIC control equation Variable 152
340	ASV151	Automation SELOGIC control equation Variable 151
340	ASV150	Automation SELOGIC control equation Variable 150
340	ASV149	Automation SELOGIC control equation Variable 149
340	ASV148	Automation SELOGIC control equation Variable 148
340	ASV147	Automation SELOGIC control equation Variable 147
340	ASV146	Automation SELOGIC control equation Variable 146
340	ASV145	Automation SELOGIC control equation Variable 145
341	ASV160	Automation SELOGIC control equation Variable 160
341	ASV159	Automation SELOGIC control equation Variable 159
341	ASV158	Automation SELOGIC control equation Variable 158
341	ASV157	Automation SELOGIC control equation Variable 157
341	ASV156	Automation SELOGIC control equation Variable 156
341	ASV155	Automation SELOGIC control equation Variable 155
341	ASV154	Automation SELOGIC control equation Variable 154
341	ASV153	Automation SELOGIC control equation Variable 153
342	ASV168	Automation SELOGIC control equation Variable 168
342	ASV167	Automation SELOGIC control equation Variable 167
342	ASV166	Automation SELOGIC control equation Variable 166
342	ASV165	Automation SELOGIC control equation Variable 165
342	ASV164	Automation SELOGIC control equation Variable 164
342	ASV163	Automation SELOGIC control equation Variable 163
342	ASV162	Automation SELOGIC control equation Variable 162
342	ASV161	Automation SELOGIC control equation Variable 161
343	ASV176	Automation SELOGIC control equation Variable 176
343	ASV175	Automation SELOGIC control equation Variable 175
343	ASV174	Automation SELOGIC control equation Variable 174
343	ASV173	Automation SELOGIC control equation Variable 173
343	ASV172	Automation SELOGIC control equation Variable 172
343	ASV171	Automation SELOGIC control equation Variable 171
343	ASV170	Automation SELOGIC control equation Variable 170
343	ASV169	Automation SELOGIC control equation Variable 169
344	ASV184	Automation SELOGIC control equation Variable 184
344	ASV183	Automation SELOGIC control equation Variable 183
344	ASV182	Automation SELOGIC control equation Variable 182
344	ASV181	Automation SELOGIC control equation Variable 181
344	ASV180	Automation SELOGIC control equation Variable 180
344	ASV179	Automation SELOGIC control equation Variable 179
344	ASV178	Automation SELOGIC control equation Variable 178

Table 11.2 Row List of Relay Word Bits (Sheet 70 of 100)

Row	Name	Bit Description
344	ASV177	Automation SELOGIC control equation Variable 177
345	ASV192	Automation SELOGIC control equation Variable 192
345	ASV191	Automation SELOGIC control equation Variable 191
345	ASV190	Automation SELOGIC control equation Variable 190
345	ASV189	Automation SELOGIC control equation Variable 189
345	ASV188	Automation SELOGIC control equation Variable 188
345	ASV187	Automation SELOGIC control equation Variable 187
345	ASV186	Automation SELOGIC control equation Variable 186
345	ASV185	Automation SELOGIC control equation Variable 185
346	ASV200	Automation SELOGIC control equation Variable 200
346	ASV199	Automation SELOGIC control equation Variable 199
346	ASV198	Automation SELOGIC control equation Variable 198
346	ASV197	Automation SELOGIC control equation Variable 197
346	ASV196	Automation SELOGIC control equation Variable 196
346	ASV195	Automation SELOGIC control equation Variable 195
346	ASV194	Automation SELOGIC control equation Variable 194
346	ASV193	Automation SELOGIC control equation Variable 193
347	ASV208	Automation SELOGIC control equation Variable 208
347	ASV207	Automation SELOGIC control equation Variable 207
347	ASV206	Automation SELOGIC control equation Variable 206
347	ASV205	Automation SELOGIC control equation Variable 205
347	ASV204	Automation SELOGIC control equation Variable 204
347	ASV203	Automation SELOGIC control equation Variable 203
347	ASV202	Automation SELOGIC control equation Variable 202
347	ASV201	Automation SELOGIC control equation Variable 201
348	ASV216	Automation SELOGIC control equation Variable 216
348	ASV215	Automation SELOGIC control equation Variable 215
348	ASV214	Automation SELOGIC control equation Variable 214
348	ASV213	Automation SELOGIC control equation Variable 213
348	ASV212	Automation SELOGIC control equation Variable 212
348	ASV211	Automation SELOGIC control equation Variable 211
348	ASV210	Automation SELOGIC control equation Variable 210
348	ASV209	Automation SELOGIC control equation Variable 209
349	ASV224	Automation SELOGIC control equation Variable 224
349	ASV223	Automation SELOGIC control equation Variable 223
349	ASV222	Automation SELOGIC control equation Variable 222
349	ASV221	Automation SELOGIC control equation Variable 221
349	ASV220	Automation SELOGIC control equation Variable 220
349	ASV219	Automation SELOGIC control equation Variable 219
349	ASV218	Automation SELOGIC control equation Variable 218
349	ASV217	Automation SELOGIC control equation Variable 217

Table 11.2 Row List of Relay Word Bits (Sheet 71 of 100)

Row	Name	Bit Description
350	ASV232	Automation SELOGIC control equation Variable 232
350	ASV231	Automation SELOGIC control equation Variable 231
350	ASV230	Automation SELOGIC control equation Variable 230
350	ASV229	Automation SELOGIC control equation Variable 229
350	ASV228	Automation SELOGIC control equation Variable 228
350	ASV227	Automation SELOGIC control equation Variable 227
350	ASV226	Automation SELOGIC control equation Variable 226
350	ASV225	Automation SELOGIC control equation Variable 225
351	ASV240	Automation SELOGIC control equation Variable 240
351	ASV239	Automation SELOGIC control equation Variable 239
351	ASV238	Automation SELOGIC control equation Variable 238
351	ASV237	Automation SELOGIC control equation Variable 237
351	ASV236	Automation SELOGIC control equation Variable 236
351	ASV235	Automation SELOGIC control equation Variable 235
351	ASV234	Automation SELOGIC control equation Variable 234
351	ASV233	Automation SELOGIC control equation Variable 233
352	ASV248	Automation SELOGIC control equation Variable 248
352	ASV247	Automation SELOGIC control equation Variable 247
352	ASV246	Automation SELOGIC control equation Variable 246
352	ASV245	Automation SELOGIC control equation Variable 245
352	ASV244	Automation SELOGIC control equation Variable 244
352	ASV243	Automation SELOGIC control equation Variable 243
352	ASV242	Automation SELOGIC control equation Variable 242
352	ASV241	Automation SELOGIC control equation Variable 241
353	ASV256	Automation SELOGIC control equation Variable 256
353	ASV255	Automation SELOGIC control equation Variable 255
353	ASV254	Automation SELOGIC control equation Variable 254
353	ASV253	Automation SELOGIC control equation Variable 253
353	ASV252	Automation SELOGIC control equation Variable 252
353	ASV251	Automation SELOGIC control equation Variable 251
353	ASV250	Automation SELOGIC control equation Variable 250
353	ASV249	Automation SELOGIC control equation Variable 249
Automation SELOGIC Latches		
354	ALT08	Automation Latch 8
354	ALT07	Automation Latch 7
354	ALT06	Automation Latch 6
354	ALT05	Automation Latch 5
354	ALT04	Automation Latch 4
354	ALT03	Automation Latch 3
354	ALT02	Automation Latch 2
354	ALT01	Automation Latch 1

Table 11.2 Row List of Relay Word Bits (Sheet 72 of 100)

Row	Name	Bit Description
355	ALT16	Automation Latch 16
355	ALT15	Automation Latch 15
355	ALT14	Automation Latch 14
355	ALT13	Automation Latch 13
355	ALT12	Automation Latch 12
355	ALT11	Automation Latch 11
355	ALT10	Automation Latch 10
355	ALT09	Automation Latch 9
356	ALT24	Automation Latch 24
356	ALT23	Automation Latch 23
356	ALT22	Automation Latch 22
356	ALT21	Automation Latch 21
356	ALT20	Automation Latch 20
356	ALT19	Automation Latch 19
356	ALT18	Automation Latch 18
356	ALT17	Automation Latch 17
357	ALT32	Automation Latch 32
357	ALT31	Automation Latch 31
357	ALT30	Automation Latch 30
357	ALT29	Automation Latch 29
357	ALT28	Automation Latch 28
357	ALT27	Automation Latch 27
357	ALT26	Automation Latch 26
357	ALT25	Automation Latch 25
Automation SELOGIC Sequencing Timers		
358	AST08Q	Automation sequencing timer Output 8
358	AST07Q	Automation sequencing timer Output 7
358	AST06Q	Automation sequencing timer Output 6
358	AST05Q	Automation sequencing timer Output 5
358	AST04Q	Automation sequencing timer Output 4
358	AST03Q	Automation sequencing timer Output 3
358	AST02Q	Automation sequencing timer Output 2
358	AST01Q	Automation sequencing timer Output 1
359	AST16Q	Automation sequencing timer Output 16
359	AST15Q	Automation sequencing timer Output 15
359	AST14Q	Automation sequencing timer Output 14
359	AST13Q	Automation sequencing timer Output 13
359	AST12Q	Automation sequencing timer Output 12
359	AST11Q	Automation sequencing timer Output 11
359	AST10Q	Automation sequencing timer Output 10
359	AST09Q	Automation sequencing timer Output 9

Table 11.2 Row List of Relay Word Bits (Sheet 73 of 100)

Row	Name	Bit Description
360	AST24Q	Automation sequencing timer Output 24
360	AST23Q	Automation sequencing timer Output 23
360	AST22Q	Automation sequencing timer Output 22
360	AST21Q	Automation sequencing timer Output 21
360	AST20Q	Automation sequencing timer Output 20
360	AST19Q	Automation sequencing timer Output 19
360	AST18Q	Automation sequencing timer Output 18
360	AST17Q	Automation sequencing timer Output 17
361	AST32Q	Automation sequencing timer Output 32
361	AST31Q	Automation sequencing timer Output 31
361	AST30Q	Automation sequencing timer Output 30
361	AST29Q	Automation sequencing timer Output 29
361	AST28Q	Automation sequencing timer Output 28
361	AST27Q	Automation sequencing timer Output 27
361	AST26Q	Automation sequencing timer Output 26
361	AST25Q	Automation sequencing timer Output 25
362	AST08R	Automation sequencing timer Reset 8
362	AST07R	Automation sequencing timer Reset 7
362	AST06R	Automation sequencing timer Reset 6
362	AST05R	Automation sequencing timer Reset 5
362	AST04R	Automation sequencing timer Reset 4
362	AST03R	Automation sequencing timer Reset 3
362	AST02R	Automation sequencing timer Reset 2
362	AST01R	Automation sequencing timer Reset 1
363	AST16R	Automation sequencing timer Reset 16
363	AST15R	Automation sequencing timer Reset 15
363	AST14R	Automation sequencing timer Reset 14
363	AST13R	Automation sequencing timer Reset 13
363	AST12R	Automation sequencing timer Reset 12
363	AST11R	Automation sequencing timer Reset 11
363	AST10R	Automation sequencing timer Reset 10
363	AST09R	Automation sequencing timer Reset 9
364	AST24R	Automation sequencing timer Reset 24
364	AST23R	Automation sequencing timer Reset 23
364	AST22R	Automation sequencing timer Reset 22
364	AST21R	Automation sequencing timer Reset 21
364	AST20R	Automation sequencing timer Reset 20
364	AST19R	Automation sequencing timer Reset 19
364	AST18R	Automation sequencing timer Reset 18
364	AST17R	Automation sequencing timer Reset 17
365	AST32R	Automation sequencing timer Reset 32

Table 11.2 Row List of Relay Word Bits (Sheet 74 of 100)

Row	Name	Bit Description
365	AST31R	Automation sequencing timer Reset 31
365	AST30R	Automation sequencing timer Reset 30
365	AST29R	Automation sequencing timer Reset 29
365	AST28R	Automation sequencing timer Reset 28
365	AST27R	Automation sequencing timer Reset 27
365	AST26R	Automation sequencing timer Reset 26
365	AST25R	Automation sequencing timer Reset 25
Automation SELogic Counters		
366	ACN08Q	Automation counter Output 8
366	ACN07Q	Automation counter Output 7
366	ACN06Q	Automation counter Output 6
366	ACN05Q	Automation counter Output 5
366	ACN04Q	Automation counter Output 4
366	ACN03Q	Automation counter Output 3
366	ACN02Q	Automation counter Output 2
366	ACN01Q	Automation counter Output 1
367	ACN16Q	Automation counter Output 16
367	ACN15Q	Automation counter Output 15
367	ACN14Q	Automation counter Output 14
367	ACN13Q	Automation counter Output 13
367	ACN12Q	Automation counter Output 12
367	ACN11Q	Automation counter Output 11
367	ACN10Q	Automation counter Output 10
367	ACN09Q	Automation counter Output 9
368	ACN24Q	Automation counter Output 24
368	ACN23Q	Automation counter Output 23
368	ACN22Q	Automation counter Output 22
368	ACN21Q	Automation counter Output 21
368	ACN20Q	Automation counter Output 20
368	ACN19Q	Automation counter Output 19
368	ACN18Q	Automation counter Output 18
368	ACN17Q	Automation counter Output 17
369	ACN32Q	Automation counter Output 32
369	ACN31Q	Automation counter Output 31
369	ACN30Q	Automation counter Output 30
369	ACN29Q	Automation counter Output 29
369	ACN28Q	Automation counter Output 28
369	ACN27Q	Automation counter Output 27
369	ACN26Q	Automation counter Output 26
369	ACN25Q	Automation counter Output 25
370	ACN08R	Automation counter Reset 8

Table 11.2 Row List of Relay Word Bits (Sheet 75 of 100)

Row	Name	Bit Description
370	ACN07R	Automation counter Reset 7
370	ACN06R	Automation counter Reset 6
370	ACN05R	Automation counter Reset 5
370	ACN04R	Automation counter Reset 4
370	ACN03R	Automation counter Reset 3
370	ACN02R	Automation counter Reset 2
370	ACN01R	Automation counter Reset 1
371	ACN16R	Automation counter Reset 16
371	ACN15R	Automation counter Reset 15
371	ACN14R	Automation counter Reset 14
371	ACN13R	Automation counter Reset 13
371	ACN12R	Automation counter Reset 12
371	ACN11R	Automation counter Reset 11
371	ACN10R	Automation counter Reset 10
371	ACN09R	Automation counter Reset 9
372	ACN24R	Automation counter Reset 24
372	ACN23R	Automation counter Reset 23
372	ACN22R	Automation counter Reset 22
372	ACN21R	Automation counter Reset 21
372	ACN20R	Automation counter Reset 20
372	ACN19R	Automation counter Reset 19
372	ACN18R	Automation counter Reset 18
372	ACN17R	Automation counter Reset 17
373	ACN32R	Automation counter Reset 32
373	ACN31R	Automation counter Reset 31
373	ACN30R	Automation counter Reset 30
373	ACN29R	Automation counter Reset 29
373	ACN28R	Automation counter Reset 28
373	ACN27R	Automation counter Reset 27
373	ACN26R	Automation counter Reset 26
373	ACN25R	Automation counter Reset 25
SELOGIC Error and Status Reporting		
374	PUNRLBL	Protection SELOGIC control equation unresolved label
374	PFRTEX	Protection SELOGIC control equation first execution
374	MATHERR	SELOGIC control equation math error
374	*	Reserved
374	*	Reserved
374	*	Reserved
374	*	Reserved
374	*	Reserved
375	AUNRLBL	Automation SELOGIC control equation unresolved label

Table 11.2 Row List of Relay Word Bits (Sheet 76 of 100)

Row	Name	Bit Description
375	AFRTEXP	Automation SELOGIC control equation first execution protection
375	AFRTEXA	Automation SELOGIC control equation first execution automation
375	*	Reserved
375	*	Reserved
375	*	Reserved
375	*	Reserved
375	*	Reserved
Alarms		
376	SALARM	Non-diagnostic alarm pulse
376	HALARM	Relay diagnostic failure or warning
376	BADPASS	Pulsed when user enters three successive bad passwords
376	HALARML	Latching relay failure alarm
376	HALARMP	Relay warning alarm pulse
376	HALARMA	Relay warning periodic alarm
376	SETCHG	Pulsed when settings change
376	GRPSW	Pulsed when settings group changes
377	ACCESS	A user is connected at Access Level B or higher
377	ACCESSP	Pulsed when higher level access achieved
377	EACC	Enable Level 1 access (SELOGIC control equation)
377	E2AC	Enable Levels 1–2 access (SELOGIC control equation)
377	*	
377	*	
377	*	
377	*	
377	PASSDIS	Asserts to indicate password disable jumper is installed
377	BRKENAB	Asserts to indicate breaker control enable jumper is installed
Time and Date Management		
378	TBNC	The active relay time source is BNC IRIG
378	TPTP	The active relay time source is PTP
378	TIRIG	Assert while time is based on IRIG for both mark and value
378	TUPDH	Assert if update source is high-priority time source
378	TSYNCA	Assert while the time mark from time source or fixed internal source is not synchronized
378	TSOK	Assert if current time-source accuracy is sufficient for synchronized phasor measurements
378	TSER	The active relay time source is serial IRIG
378	UPD_EN	Enable updating internal clock with selected external time source
379	TSYNC	Assert when ADC sampling is synchronized to a valid high-priority time source
379	BLKLPTS	Block low priority source from updating relay time
379	TLOCAL	Relay calendar clock and ADC sampling synchronized to a high-priority local time source
379	TPLLEXT	Update PLL using external signal
379	TSSW	High priority time source switching
379	TGLOBAL	Relay calendar clock and ADC sampling synchronized to a high-priority Global time source

Table 11.2 Row List of Relay Word Bits (Sheet 77 of 100)

Row	Name	Bit Description
379	TSNTPP	Asserts if time was synchronized with primary NTP server before SNTP time-out period expired
379	TSNTPB	Asserts if time was synchronized with backup NTP server before SNTP time-out period expired
380	*	Reserved
380	*	Reserved
380	*	Reserved
380	*	Reserved
380	*	Reserved
380	*	Reserved
380	*	Reserved
380	*	Reserved
Inverse-Time Overcurrent Elements		
381	*	Reserved
381	*	Reserved
381	*	Reserved
381	51R21	Inverse-time Element 21 reset
381	51R20	Inverse-time Element 20 reset
381	51R19	Inverse-time Element 19 reset
381	51R18	Inverse-time Element 18 reset
381	51R17	Inverse-time Element 17 reset
Pushbuttons		
382	PB1	Pushbutton 1
382	PB2	Pushbutton 2
382	PB3	Pushbutton 3
382	PB4	Pushbutton 4
382	PB5	Pushbutton 5
382	PB6	Pushbutton 6
382	PB7	Pushbutton 7
382	PB8	Pushbutton 8
383	PB9	Pushbutton 9
383	PB10	Pushbutton 10
383	PB11	Pushbutton 11
383	PB12	Pushbutton 12
383	*	Reserved
383	*	Reserved
383	*	Reserved
383	*	Reserved
Contact Outputs		
384	OUT108	Main board Output 8
384	OUT107	Main board Output 7
384	OUT106	Main board Output 6
384	OUT105	Main board Output 5

Table 11.2 Row List of Relay Word Bits (Sheet 78 of 100)

Row	Name	Bit Description
384	OUT104	Main board Output 4
384	OUT103	Main board Output 3
384	OUT102	Main board Output 2
384	OUT101	Main board Output 1
385	*	Reserved
385	*	Reserved
385	*	Reserved
385	*	Reserved
385	*	Reserved
385	*	Reserved
385	*	Reserved
385	*	Reserved
386	*	Reserved
386	*	Reserved
386	*	Reserved
386	*	Reserved
386	*	Reserved
386	*	Reserved
386	*	Reserved
386	*	Reserved
387	*	Reserved
387	*	Reserved
387	*	Reserved
387	*	Reserved
387	*	Reserved
387	*	Reserved
387	*	Reserved
387	*	Reserved
388	OUT208	Optional I/O Board 1 Output 8
388	OUT207	Optional I/O Board 1 Output 7
388	OUT206	Optional I/O Board 1 Output 6
388	OUT205	Optional I/O Board 1 Output 5
388	OUT204	Optional I/O Board 1 Output 4
388	OUT203	Optional I/O Board 1 Output 3
388	OUT202	Optional I/O Board 1 Output 2
388	OUT201	Optional I/O Board 1 Output 1
389	OUT216	Optional I/O Board 1 Output 16
389	OUT215	Optional I/O Board 1 Output 15
389	OUT214	Optional I/O Board 1 Output 14
389	OUT213	Optional I/O Board 1 Output 13
389	OUT212	Optional I/O Board 1 Output 12

Table 11.2 Row List of Relay Word Bits (Sheet 79 of 100)

Row	Name	Bit Description
389	OUT211	Optional I/O Board 1 Output 11
389	OUT210	Optional I/O Board 1 Output 10
389	OUT209	Optional I/O Board 1 Output 9
390	OUT308	Optional I/O Board 2 Output 8
390	OUT307	Optional I/O Board 2 Output 7
390	OUT306	Optional I/O Board 2 Output 6
390	OUT305	Optional I/O Board 2 Output 5
390	OUT304	Optional I/O Board 2 Output 4
390	OUT303	Optional I/O Board 2 Output 3
390	OUT302	Optional I/O Board 2 Output 2
390	OUT301	Optional I/O Board 2 Output 1
391	OUT316	Optional I/O Board 2 Output 16
391	OUT315	Optional I/O Board 2 Output 15
391	OUT314	Optional I/O Board 2 Output 14
391	OUT313	Optional I/O Board 2 Output 13
391	OUT312	Optional I/O Board 2 Output 12
391	OUT311	Optional I/O Board 2 Output 11
391	OUT310	Optional I/O Board 2 Output 10
391	OUT309	Optional I/O Board 2 Output 9
392	OUT408	Optional I/O Board 3 Output 8
392	OUT407	Optional I/O Board 3 Output 7
392	OUT406	Optional I/O Board 3 Output 6
392	OUT405	Optional I/O Board 3 Output 5
392	OUT404	Optional I/O Board 3 Output 4
392	OUT403	Optional I/O Board 3 Output 3
392	OUT402	Optional I/O Board 3 Output 2
392	OUT401	Optional I/O Board 3 Output 1
393	OUT416	Optional I/O Board 3 Output 16
393	OUT415	Optional I/O Board 3 Output 15
393	OUT414	Optional I/O Board 3 Output 14
393	OUT413	Optional I/O Board 3 Output 13
393	OUT412	Optional I/O Board 3 Output 12
393	OUT411	Optional I/O Board 3 Output 11
393	OUT410	Optional I/O Board 3 Output 10
393	OUT409	Optional I/O Board 3 Output 9
394	OUT508	Optional I/O Board 4 Output 8
394	OUT507	Optional I/O Board 4 Output 7
394	OUT506	Optional I/O Board 4 Output 6
394	OUT505	Optional I/O Board 4 Output 5
394	OUT504	Optional I/O Board 4 Output 4
394	OUT503	Optional I/O Board 4 Output 3

Table 11.2 Row List of Relay Word Bits (Sheet 80 of 100)

Row	Name	Bit Description
394	OUT502	Optional I/O Board 4 Output 2
394	OUT501	Optional I/O Board 4 Output 1
395	OUT516	Optional I/O Board 4 Output 16
395	OUT515	Optional I/O Board 4 Output 15
395	OUT514	Optional I/O Board 4 Output 14
395	OUT513	Optional I/O Board 4 Output 13
395	OUT512	Optional I/O Board 4 Output 12
395	OUT511	Optional I/O Board 4 Output 11
395	OUT510	Optional I/O Board 4 Output 10
395	OUT509	Optional I/O Board 4 Output 9
Pushbuttons Pulse Inputs		
396	PB1_PUL	Pushbutton 1 pulse input
396	PB2_PUL	Pushbutton 2 pulse input
396	PB3_PUL	Pushbutton 3 pulse input
396	PB4_PUL	Pushbutton 4 pulse input
396	PB5_PUL	Pushbutton 5 pulse input
396	PB6_PUL	Pushbutton 6 pulse input
396	PB7_PUL	Pushbutton 7 pulse input
396	PB8_PUL	Pushbutton 8 pulse input
397	PB9_PUL	Pushbutton 9 pulse input
397	PB10PUL	Pushbutton 10 pulse input
397	PB11PUL	Pushbutton 11 pulse input
397	PB12PUL	Pushbutton 12 pulse input
397	*	Reserved
397	*	Reserved
397	*	Reserved
397	*	Reserved
Pushbutton LED Bits		
398	PB1_LED	Pushbutton 1 LED
398	PB2_LED	Pushbutton 2 LED
398	PB3_LED	Pushbutton 3 LED
398	PB4_LED	Pushbutton 4 LED
398	PB5_LED	Pushbutton 5 LED
398	PB6_LED	Pushbutton 6 LED
398	PB7_LED	Pushbutton 7 LED
398	PB8_LED	Pushbutton 8 LED
399	PB9_LED	Pushbutton 9 LED
399	PB10LED	Pushbutton 10 LED
399	PB11LED	Pushbutton 11 LED
399	PB12LED	Pushbutton 12 LED
399	*	Reserved

Table 11.2 Row List of Relay Word Bits (Sheet 81 of 100)

Row	Name	Bit Description
399	*	Reserved
399	*	Reserved
399	*	Reserved
MIRRORED BITS		
400	RMB8A	Channel A receive MIRRORED BIT 8
400	RMB7A	Channel A receive MIRRORED BIT 7
400	RMB6A	Channel A receive MIRRORED BIT 6
400	RMB5A	Channel A receive MIRRORED BIT 5
400	RMB4A	Channel A receive MIRRORED BIT 4
400	RMB3A	Channel A receive MIRRORED BIT 3
400	RMB2A	Channel A receive MIRRORED BIT 2
400	RMB1A	Channel A receive MIRRORED BIT 1
401	TMB8A	Channel A transmit MIRRORED BIT 8
401	TMB7A	Channel A transmit MIRRORED BIT 7
401	TMB6A	Channel A transmit MIRRORED BIT 6
401	TMB5A	Channel A transmit MIRRORED BIT 5
401	TMB4A	Channel A transmit MIRRORED BIT 4
401	TMB3A	Channel A transmit MIRRORED BIT 3
401	TMB2A	Channel A transmit MIRRORED BIT 2
401	TMB1A	Channel A transmit MIRRORED BIT 1
402	RMB8B	Channel B receive MIRRORED BIT 8
402	RMB7B	Channel B receive MIRRORED BIT 7
402	RMB6B	Channel B receive MIRRORED BIT 6
402	RMB5B	Channel B receive MIRRORED BIT 5
402	RMB4B	Channel B receive MIRRORED BIT 4
402	RMB3B	Channel B receive MIRRORED BIT 3
402	RMB2B	Channel B receive MIRRORED BIT 2
402	RMB1B	Channel B receive MIRRORED BIT 1
403	TMB8B	Channel B transmit MIRRORED BIT 8
403	TMB7B	Channel B transmit MIRRORED BIT 7
403	TMB6B	Channel B transmit MIRRORED BIT 6
403	TMB5B	Channel B transmit MIRRORED BIT 5
403	TMB4B	Channel B transmit MIRRORED BIT 4
403	TMB3B	Channel B transmit MIRRORED BIT 3
403	TMB2B	Channel B transmit MIRRORED BIT 2
403	TMB1B	Channel B transmit MIRRORED BIT 1
404	ROKA	Channel A MIRRORED BITS normal status (non-loopback)
404	RBADA	Channel A MIRRORED BITS outage too long
404	CBADA	Channel A MIRRORED BITS unavailability
404	LBOKA	Channel A MIRRORED BITS normal status (loopback)
404	ANOKA	Channel A MIRRORED BITS analog transfer OK

Table 11.2 Row List of Relay Word Bits (Sheet 82 of 100)

Row	Name	Bit Description
404	DOKA	Channel A MIRRORED BITS communications normal status
404	*	Reserved
404	*	Reserved
405	ROKB	Channel B MIRRORED BITS normal status (non-loopback mode)
405	RBADB	Channel B MIRRORED BITS outage too long
405	CBADB	Channel B MIRRORED BITS unavailability
405	LBOKB	Channel B MIRRORED BITS normal status (loopback mode)
405	ANOKB	Channel B MIRRORED BITS analog transfer OK
405	DOKB	Channel B MIRRORED BITS communications normal status
405	*	Reserved
405	*	Reserved
Test Bits		
406	TESTDB2	DNP test bit
406	TESTDB	Communications card database test bit
406	TESTFM	Fast meter test bit
406	TESTPUL	Pulse test bit
406	LPHDSIM	IEC 61850 Logical Node for physical device simulation
406	*	Reserved
406	*	Reserved
406	*	Reserved
Advanced Check Zone Bits		
407	CZ24R	Include Bus Coupler 4 in Check Zone 2
407	CZ23R	Include Bus Coupler 3 in Check Zone 2
407	CZ22R	Include Bus Coupler 2 in Check Zone 2
407	CZ21R	Include Bus Coupler 1 in Check Zone 2
407	CZ14R	Include Bus Coupler 4 in Check Zone 1
407	CZ13R	Include Bus Coupler 3 in Check Zone 1
407	CZ12R	Include Bus Coupler 2 in Check Zone 1
407	CZ11R	Include Bus Coupler 1 in Check Zone 1
Virtual Bits		
408	VB249	Virtual Bit 249
408	VB250	Virtual Bit 250
408	VB251	Virtual Bit 251
408	VB252	Virtual Bit 252
408	VB253	Virtual Bit 253
408	VB254	Virtual Bit 254
408	VB255	Virtual Bit 255
408	VB256	Virtual Bit 256
409	VB241	Virtual Bit 241
409	VB242	Virtual Bit 242
409	VB243	Virtual Bit 243

Table 11.2 Row List of Relay Word Bits (Sheet 83 of 100)

Row	Name	Bit Description
409	VB244	Virtual Bit 244
409	VB245	Virtual Bit 245
409	VB246	Virtual Bit 246
409	VB247	Virtual Bit 247
409	VB248	Virtual Bit 248
410	VB233	Virtual Bit 233
410	VB234	Virtual Bit 234
410	VB235	Virtual Bit 235
410	VB236	Virtual Bit 236
410	VB237	Virtual Bit 237
410	VB238	Virtual Bit 238
410	VB239	Virtual Bit 239
410	VB240	Virtual Bit 240
411	VB225	Virtual Bit 225
411	VB226	Virtual Bit 226
411	VB227	Virtual Bit 227
411	VB228	Virtual Bit 228
411	VB229	Virtual Bit 229
411	VB230	Virtual Bit 230
411	VB231	Virtual Bit 231
411	VB232	Virtual Bit 232
412	VB217	Virtual Bit 217
412	VB218	Virtual Bit 218
412	VB219	Virtual Bit 219
412	VB220	Virtual Bit 220
412	VB221	Virtual Bit 221
412	VB222	Virtual Bit 222
412	VB223	Virtual Bit 223
412	VB224	Virtual Bit 224
413	VB209	Virtual Bit 209
413	VB210	Virtual Bit 210
413	VB211	Virtual Bit 211
413	VB212	Virtual Bit 212
413	VB213	Virtual Bit 213
413	VB214	Virtual Bit 214
413	VB215	Virtual Bit 215
413	VB216	Virtual Bit 216
414	VB201	Virtual Bit 201
414	VB202	Virtual Bit 202
414	VB203	Virtual Bit 203
414	VB204	Virtual Bit 204

Table 11.2 Row List of Relay Word Bits (Sheet 84 of 100)

Row	Name	Bit Description
414	VB205	Virtual Bit 205
414	VB206	Virtual Bit 206
414	VB207	Virtual Bit 207
414	VB208	Virtual Bit 208
415	VB193	Virtual Bit 193
415	VB194	Virtual Bit 194
415	VB195	Virtual Bit 195
415	VB196	Virtual Bit 196
415	VB197	Virtual Bit 197
415	VB198	Virtual Bit 198
415	VB199	Virtual Bit 199
415	VB200	Virtual Bit 200
416	VB185	Virtual Bit 185
416	VB186	Virtual Bit 186
416	VB187	Virtual Bit 187
416	VB188	Virtual Bit 188
416	VB189	Virtual Bit 189
416	VB190	Virtual Bit 190
416	VB191	Virtual Bit 191
416	VB192	Virtual Bit 192
417	VB177	Virtual Bit 177
417	VB178	Virtual Bit 178
417	VB179	Virtual Bit 179
417	VB180	Virtual Bit 180
417	VB181	Virtual Bit 181
417	VB182	Virtual Bit 182
417	VB183	Virtual Bit 183
417	VB184	Virtual Bit 184
418	VB169	Virtual Bit 169
418	VB170	Virtual Bit 170
418	VB171	Virtual Bit 171
418	VB172	Virtual Bit 172
418	VB173	Virtual Bit 173
418	VB174	Virtual Bit 174
418	VB175	Virtual Bit 175
418	VB176	Virtual Bit 176
419	VB161	Virtual Bit 161
419	VB162	Virtual Bit 162
419	VB163	Virtual Bit 163
419	VB164	Virtual Bit 164
419	VB165	Virtual Bit 165

Table 11.2 Row List of Relay Word Bits (Sheet 85 of 100)

Row	Name	Bit Description
419	VB166	Virtual Bit 166
419	VB167	Virtual Bit 167
419	VB168	Virtual Bit 168
420	VB153	Virtual Bit 153
420	VB154	Virtual Bit 154
420	VB155	Virtual Bit 155
420	VB156	Virtual Bit 156
420	VB157	Virtual Bit 157
420	VB158	Virtual Bit 158
420	VB159	Virtual Bit 159
420	VB160	Virtual Bit 160
421	VB145	Virtual Bit 145
421	VB146	Virtual Bit 146
421	VB147	Virtual Bit 147
421	VB148	Virtual Bit 148
421	VB149	Virtual Bit 149
421	VB150	Virtual Bit 150
421	VB151	Virtual Bit 151
421	VB152	Virtual Bit 152
422	VB137	Virtual Bit 137
422	VB138	Virtual Bit 138
422	VB139	Virtual Bit 139
422	VB140	Virtual Bit 140
422	VB141	Virtual Bit 141
422	VB142	Virtual Bit 142
422	VB143	Virtual Bit 143
422	VB144	Virtual Bit 144
423	VB129	Virtual Bit 129
423	VB130	Virtual Bit 130
423	VB131	Virtual Bit 131
423	VB132	Virtual Bit 132
423	VB133	Virtual Bit 133
423	VB134	Virtual Bit 134
423	VB135	Virtual Bit 135
423	VB136	Virtual Bit 136
424	VB121	Virtual Bit 121
424	VB122	Virtual Bit 122
424	VB123	Virtual Bit 123
424	VB124	Virtual Bit 124
424	VB125	Virtual Bit 125
424	VB126	Virtual Bit 126

Table 11.2 Row List of Relay Word Bits (Sheet 86 of 100)

Row	Name	Bit Description
424	VB127	Virtual Bit 127
424	VB128	Virtual Bit 128
425	VB113	Virtual Bit 113
425	VB114	Virtual Bit 114
425	VB115	Virtual Bit 115
425	VB116	Virtual Bit 116
425	VB117	Virtual Bit 117
425	VB118	Virtual Bit 118
425	VB119	Virtual Bit 119
425	VB120	Virtual Bit 120
426	VB105	Virtual Bit 105
426	VB106	Virtual Bit 106
426	VB107	Virtual Bit 107
426	VB108	Virtual Bit 108
426	VB109	Virtual Bit 109
426	VB110	Virtual Bit 110
426	VB111	Virtual Bit 111
426	VB112	Virtual Bit 112
427	VB097	Virtual Bit 097
427	VB098	Virtual Bit 098
427	VB099	Virtual Bit 099
427	VB100	Virtual Bit 100
427	VB101	Virtual Bit 101
427	VB102	Virtual Bit 102
427	VB103	Virtual Bit 103
427	VB104	Virtual Bit 104
428	VB089	Virtual Bit 089
428	VB090	Virtual Bit 090
428	VB091	Virtual Bit 091
428	VB092	Virtual Bit 092
428	VB093	Virtual Bit 093
428	VB094	Virtual Bit 094
428	VB095	Virtual Bit 095
428	VB096	Virtual Bit 096
429	VB081	Virtual Bit 081
429	VB082	Virtual Bit 082
429	VB083	Virtual Bit 083
429	VB084	Virtual Bit 084
429	VB085	Virtual Bit 085
429	VB086	Virtual Bit 086
429	VB087	Virtual Bit 087

Table 11.2 Row List of Relay Word Bits (Sheet 87 of 100)

Row	Name	Bit Description
429	VB088	Virtual Bit 088
430	VB073	Virtual Bit 073
430	VB074	Virtual Bit 074
430	VB075	Virtual Bit 075
430	VB076	Virtual Bit 076
430	VB077	Virtual Bit 077
430	VB078	Virtual Bit 078
430	VB079	Virtual Bit 079
430	VB080	Virtual Bit 080
431	VB065	Virtual Bit 065
431	VB066	Virtual Bit 066
431	VB067	Virtual Bit 067
431	VB068	Virtual Bit 068
431	VB069	Virtual Bit 069
431	VB070	Virtual Bit 070
431	VB071	Virtual Bit 071
431	VB072	Virtual Bit 072
432	VB057	Virtual Bit 057
432	VB058	Virtual Bit 058
432	VB059	Virtual Bit 059
432	VB060	Virtual Bit 060
432	VB061	Virtual Bit 061
432	VB062	Virtual Bit 062
432	VB063	Virtual Bit 063
432	VB064	Virtual Bit 064
433	VB049	Virtual Bit 049
433	VB050	Virtual Bit 050
433	VB051	Virtual Bit 051
433	VB052	Virtual Bit 052
433	VB053	Virtual Bit 053
433	VB054	Virtual Bit 054
433	VB055	Virtual Bit 055
433	VB056	Virtual Bit 056
434	VB041	Virtual Bit 041
434	VB042	Virtual Bit 042
434	VB043	Virtual Bit 043
434	VB044	Virtual Bit 044
434	VB045	Virtual Bit 045
434	VB046	Virtual Bit 046
434	VB047	Virtual Bit 047
434	VB048	Virtual Bit 048

Table 11.2 Row List of Relay Word Bits (Sheet 88 of 100)

Row	Name	Bit Description
435	VB033	Virtual Bit 033
435	VB034	Virtual Bit 034
435	VB035	Virtual Bit 035
435	VB036	Virtual Bit 036
435	VB037	Virtual Bit 037
435	VB038	Virtual Bit 038
435	VB039	Virtual Bit 039
435	VB040	Virtual Bit 040
436	VB025	Virtual Bit 025
436	VB026	Virtual Bit 026
436	VB027	Virtual Bit 027
436	VB028	Virtual Bit 028
436	VB029	Virtual Bit 029
436	VB030	Virtual Bit 030
436	VB031	Virtual Bit 031
436	VB032	Virtual Bit 032
437	VB017	Virtual Bit 017
437	VB018	Virtual Bit 018
437	VB019	Virtual Bit 019
437	VB020	Virtual Bit 020
437	VB021	Virtual Bit 021
437	VB022	Virtual Bit 022
437	VB023	Virtual Bit 023
437	VB024	Virtual Bit 024
438	VB009	Virtual Bit 009
438	VB010	Virtual Bit 010
438	VB011	Virtual Bit 011
438	VB012	Virtual Bit 012
438	VB013	Virtual Bit 013
438	VB014	Virtual Bit 014
438	VB015	Virtual Bit 015
438	VB016	Virtual Bit 016
439	VB001	Virtual Bit 001
439	VB002	Virtual Bit 002
439	VB003	Virtual Bit 003
439	VB004	Virtual Bit 004
439	VB005	Virtual Bit 005
439	VB006	Virtual Bit 006
439	VB007	Virtual Bit 007
439	VB008	Virtual Bit 008

Table 11.2 Row List of Relay Word Bits (Sheet 89 of 100)

Row	Name	Bit Description
Data Reset Bits		
440	RST_BAT	Reset battery monitoring
440	RSTTRGT	Target reset (SELOGIC control equation)
440	RSTDNPE	Reset DNP fault summary data
440	RST_HAL	Reset HALARMA
440	*	Reserved
440	*	Reserved
440	*	Reserved
440	*	Reserved
Ethernet Switch		
441	LINK5A	Link status of Port 5A connection
441	LINK5B	Link status of Port 5B connection
441	LINK5C	Link status of Port 5C connection
441	LINK5D	Link status of Port 5D connection
441	LNKFAIL	Link status of the active port
441	*	Reserved
441	*	Reserved
441	*	Reserved
442	P5ASEL	Port 5A active/inactive
442	P5BSEL	Port 5B active/inactive
442	P5CSEL	Port 5C active/inactive
442	P5DSEL	Port 5D active/inactive
442	*	Reserved
442	*	Reserved
442	*	Reserved
442	*	Reserved
Advanced Check Zone Bits		
443	*	Reserved
443	*	Reserved
443	*	Reserved
443	*	Reserved
443	CZ34R	Include Bus Coupler 4 in Check Zone 3
443	CZ33R	Include Bus Coupler 3 in Check Zone 3
443	CZ32R	Include Bus Coupler 2 in Check Zone 3
443	CZ31R	Include Bus Coupler 1 in Check Zone 3
Fast SER Enable Bits		
444	FSERP1	Fast SER enabled for Serial Port 1
444	FSERP2	Fast SER enabled for Serial Port 2
444	FSERP3	Fast SER enabled for Serial Port 3
444	FSERPF	Fast SER enabled for Serial Port F
444	FSERP5	Fast SER enabled for Serial Port 5

Table 11.2 Row List of Relay Word Bits (Sheet 90 of 100)

Row	Name	Bit Description
444	*	Reserved
444	*	Reserved
444	*	Reserved
Check Zone Activation		
445	*	Reserved
445	*	Reserved
445	*	Reserved
445	*	Reserved
445	*	Reserved
445	CZONE3	Check Zone 3 is active
445	CZONE2	Check Zone 2 is active
445	CZONE1	Check Zone 1 is active
Check Zone Supervision		
446	*	Reserved
446	*	Reserved
446	*	Reserved
446	*	Reserved
446	*	Reserved
446	CZ3S	Check Zone 3 supervision asserted
446	CZ2S	Check Zone 2 supervision asserted
446	CZ1S	Check Zone 1 supervision asserted
Check Zone Trip		
447	*	Reserved
447	*	Reserved
447	*	Reserved
447	*	Reserved
447	*	Reserved
447	87CZ3	Check Zone 3 differential element trip
447	87CZ2	Check Zone 2 differential element trip
447	87CZ1	Check Zone 1 differential element trip
Check Zone Elements		
448	*	Reserved
448	*	Reserved
448	*	Reserved
448	*	Reserved
448	*	Reserved
448	87SCZ3	Check Zone 3 sensitive differential element picked up
448	87SCZ2	Check Zone 2 sensitive differential element picked up
448	87SCZ1	Check Zone 1 sensitive differential element picked up
449	*	Reserved
449	*	Reserved

Table 11.2 Row List of Relay Word Bits (Sheet 91 of 100)

Row	Name	Bit Description
449	*	Reserved
449	*	Reserved
449	*	Reserved
449	87STCZ3	Check Zone 3 sensitive differential element timed out
449	87STCZ2	Check Zone 2 sensitive differential element timed out
449	87STCZ1	Check Zone 1 sensitive differential element timed out
450	87RCZ1	Check Zone 1 restraint differential element picked up
450	P87RCZ1	Check Zone 1 instantaneous differential element picked up
450	87OCZ1	Check Zone 1 restraint differential operating current above CZO87P
450	FLTCZ1	Check Zone 1 fault detector picked up
450	CONCZ1	Check Zone 1 in high-security mode
450	EXTCZ1	Check Zone 1 external fault declaration
450	DOPCZ1	Check Zone 1 incremental operating current picked up
450	DRTCZ1	Check Zone 1 incremental restraint current picked up
451	*	Reserved
451	*	Reserved
451	*	Reserved
451	*	Reserved
451	FDIFCZ1	Check Zone 1 filtered restrained differential element picked up
451	RDIFCZ1	Check Zone 1 unfiltered restrained differential element picked up
451	IFLTCZ1	Check Zone 1 fault detection
451	GFLTCZ1	Check Zone 1 fast fault detection
452	87RCZ2	Check Zone 2 restraint differential element picked up
452	P87RCZ2	Check Zone 2 instantaneous differential element picked up
452	87OCZ2	Check Zone 2 restraint differential operating current above CZO87P
452	FLTCZ2	Check Zone 2 fault detector picked up
452	CONCZ2	Check Zone 2 in high-security mode
452	EXTCZ2	Check Zone 2 external fault declaration
452	DOPCZ2	Check Zone 2 incremental operating current picked up
452	DRTCZ2	Check Zone 2 incremental restraint current picked up
453	*	Reserved
453	*	Reserved
453	*	Reserved
453	*	Reserved
453	FDIFCZ2	Check Zone 2 filtered restrained differential element picked up
453	RDIFCZ2	Check Zone 2 unfiltered restrained differential element picked up
453	IFLTCZ2	Check Zone 2 fault detection
453	GFLTCZ2	Check Zone 2 fast fault detection
454	87RCZ3	Check Zone 3 restraint differential element picked up
454	P87RCZ3	Check Zone 3 instantaneous differential element picked up
454	87OCZ3	Check Zone 3 restraint differential operating current above CZO87P

Table 11.2 Row List of Relay Word Bits (Sheet 92 of 100)

Row	Name	Bit Description
454	FLTCZ3	Check Zone 3 fault detector picked up
454	CONCZ3	Check Zone 3 in high-security mode
454	EXTCZ3	Check Zone 3 external fault declaration
454	DOPCZ3	Check Zone 3 incremental operating current picked up
454	DRTCZ3	Check Zone 3 incremental restraint current picked up
455	*	Reserved
455	*	Reserved
455	*	Reserved
455	*	Reserved
455	FDIFCZ3	Check Zone 3 filtered restrained differential element picked up
455	RDIFCZ3	Check Zone 3 unfiltered restrained differential element picked up
455	IFLTCZ3	Check Zone 3 fault detection
455	GFLTCZ3	Check Zone 3 fast fault detection
456	*	Reserved
456	*	Reserved
456	*	Reserved
456	*	Reserved
456	*	Reserved
456	DECZ3F	Check Zone 3 forward directional element picked up
456	DECZ2F	Check Zone 2 forward directional element picked up
456	DECZ1F	Check Zone 1 forward directional element picked up
Local Bit Supervision		
457	LB_SP08	Local Bit 08 supervision (SELOGIC control equation)
457	LB_SP07	Local Bit 07 supervision (SELOGIC control equation)
457	LB_SP06	Local Bit 06 supervision (SELOGIC control equation)
457	LB_SP05	Local Bit 05 supervision (SELOGIC control equation)
457	LB_SP04	Local Bit 04 supervision (SELOGIC control equation)
457	LB_SP03	Local Bit 03 supervision (SELOGIC control equation)
457	LB_SP02	Local Bit 02 supervision (SELOGIC control equation)
457	LB_SP01	Local Bit 01 supervision (SELOGIC control equation)
458	LB_SP16	Local Bit 16 supervision (SELOGIC control equation)
458	LB_SP15	Local Bit 15 supervision (SELOGIC control equation)
458	LB_SP14	Local Bit 14 supervision (SELOGIC control equation)
458	LB_SP13	Local Bit 13 supervision (SELOGIC control equation)
458	LB_SP12	Local Bit 12 supervision (SELOGIC control equation)
458	LB_SP11	Local Bit 11 supervision (SELOGIC control equation)
458	LB_SP10	Local Bit 10 supervision (SELOGIC control equation)
458	LB_SP09	Local Bit 09 supervision (SELOGIC control equation)
459	LB_SP24	Local Bit 24 supervision (SELOGIC control equation)
459	LB_SP23	Local Bit 23 supervision (SELOGIC control equation)
459	LB_SP22	Local Bit 22 supervision (SELOGIC control equation)

Table 11.2 Row List of Relay Word Bits (Sheet 93 of 100)

Row	Name	Bit Description
459	LB_SP21	Local Bit 21 supervision (SELOGIC control equation)
459	LB_SP20	Local Bit 20 supervision (SELOGIC control equation)
459	LB_SP19	Local Bit 19 supervision (SELOGIC control equation)
459	LB_SP18	Local Bit 18 supervision (SELOGIC control equation)
459	LB_SP17	Local Bit 17 supervision (SELOGIC control equation)
460	LB_SP32	Local Bit 32 supervision (SELOGIC control equation)
460	LB_SP31	Local Bit 31 supervision (SELOGIC control equation)
460	LB_SP30	Local Bit 30 supervision (SELOGIC control equation)
460	LB_SP29	Local Bit 29 supervision (SELOGIC control equation)
460	LB_SP28	Local Bit 28 supervision (SELOGIC control equation)
460	LB_SP27	Local Bit 27 supervision (SELOGIC control equation)
460	LB_SP26	Local Bit 26 supervision (SELOGIC control equation)
460	LB_SP25	Local Bit 25 supervision (SELOGIC control equation)
Local Bit Status		
461	LB_DP08	Local Bit 08 status display (SELOGIC control equation)
461	LB_DP07	Local Bit 07 status display (SELOGIC control equation)
461	LB_DP06	Local Bit 06 status display (SELOGIC control equation)
461	LB_DP05	Local Bit 05 status display (SELOGIC control equation)
461	LB_DP04	Local Bit 04 status display (SELOGIC control equation)
461	LB_DP03	Local Bit 03 status display (SELOGIC control equation)
461	LB_DP02	Local Bit 02 status display (SELOGIC control equation)
461	LB_DP01	Local Bit 01 status display (SELOGIC control equation)
462	LB_DP16	Local Bit 16 status display (SELOGIC control equation)
462	LB_DP15	Local Bit 15 status display (SELOGIC control equation)
462	LB_DP14	Local Bit 14 status display (SELOGIC control equation)
462	LB_DP13	Local Bit 13 status display (SELOGIC control equation)
462	LB_DP12	Local Bit 12 status display (SELOGIC control equation)
462	LB_DP11	Local Bit 11 status display (SELOGIC control equation)
462	LB_DP10	Local Bit 10 status display (SELOGIC control equation)
462	LB_DP09	Local Bit 09 status display (SELOGIC control equation)
463	LB_DP24	Local Bit 24 status display (SELOGIC control equation)
463	LB_DP23	Local Bit 23 status display (SELOGIC control equation)
463	LB_DP22	Local Bit 22 status display (SELOGIC control equation)
463	LB_DP21	Local Bit 21 status display (SELOGIC control equation)
463	LB_DP20	Local Bit 20 status display (SELOGIC control equation)
463	LB_DP19	Local Bit 19 status display (SELOGIC control equation)
463	LB_DP18	Local Bit 18 status display (SELOGIC control equation)
463	LB_DP17	Local Bit 17 status display (SELOGIC control equation)
464	LB_DP32	Local Bit 32 status display (SELOGIC control equation)
464	LB_DP31	Local Bit 31 status display (SELOGIC control equation)
464	LB_DP30	Local Bit 30 status display (SELOGIC control equation)

Table 11.2 Row List of Relay Word Bits (Sheet 94 of 100)

Row	Name	Bit Description
464	LB_DP29	Local Bit 29 status display (SELOGIC control equation)
464	LB_DP28	Local Bit 28 status display (SELOGIC control equation)
464	LB_DP27	Local Bit 27 status display (SELOGIC control equation)
464	LB_DP26	Local Bit 26 status display (SELOGIC control equation)
464	LB_DP25	Local Bit 25 status display (SELOGIC control equation)
465	*	Reserved
465	*	Reserved
465	*	Reserved
465	*	Reserved
465	*	Reserved
465	*	Reserved
465	*	Reserved
465	*	Reserved
Target Logic Bits		
466	TRGTR	Reset all active target Relay Words
466	*	Reserved
466	*	Reserved
466	*	Reserved
466	*	Reserved
466	*	Reserved
466	*	Reserved
466	*	Reserved
Signal Profiling		
467	SPEN	Signal profiling enabled
467	*	Reserved
467	*	Reserved
467	*	Reserved
467	*	Reserved
467	*	Reserved
467	*	Reserved
467	*	Reserved
IRIG-B Control Bits		
468	YEAR80	IRIG-B year information, binary-coded-decimal, add 80 if asserted
468	YEAR40	IRIG-B year information, binary-coded-decimal, add 40 if asserted
468	YEAR20	IRIG-B year information, binary-coded-decimal, add 20 if asserted
468	YEAR10	IRIG-B year information, binary-coded-decimal, add 10 if asserted
468	YEAR8	IRIG-B year information, binary-coded-decimal, add 8 if asserted
468	YEAR4	IRIG-B year information, binary-coded-decimal, add 4 if asserted
468	YEAR2	IRIG-B year information, binary-coded-decimal, add 2 if asserted
468	YEAR1	IRIG-B year information, binary-coded-decimal, add 1 if asserted
469	*	Reserved

Table 11.2 Row List of Relay Word Bits (Sheet 95 of 100)

Row	Name	Bit Description
469	*	Reserved
469	TUTCH	IRIG-B offset half-hour from UTC time, binary, add 0.5 if asserted
469	TUTC8	IRIG-B offset hours from UTC time, binary, add 8 if asserted
469	TUTC4	IRIG-B offset hours from UTC time, binary, add 4 if asserted
469	TUTC2	IRIG-B offset hours from UTC time, binary, add 2 if asserted
469	TUTC1	IRIG-B offset hours from UTC time, binary, add 1 if asserted
469	TUTCS	IRIG-B offset hours sign from UTC time, subtract the UTC offset if TUTCS is asserted, add otherwise
470	DST	Daylight-saving time
470	DSTP	IRIG-B daylight-saving time pending
470	LPSEC	Direction of the upcoming leap second. During the time that LPSECP is asserted, if LPSEC is asserted, the upcoming leap second is deleted; otherwise, the leap second is added.
470	LPSECP	Leap second pending
470	TQUAL8	Time quality, binary, add 8 when asserted
470	TQUAL4	Time quality, binary, add 4 when asserted
470	TQUAL2	Time quality, binary, add 2 when asserted
470	TQUAL1	Time quality, binary, add 1 when asserted
471	DUMMY	0
471	*	Reserved
471	*	Reserved
471	*	Reserved
471	*	Reserved
471	*	Reserved
471	*	Reserved
471	*	Reserved
Time and Date Management		
472	SER_SET	Qualify serial IRIG-B time source
472	SER_RST	Disqualify serial IRIG-B time source
472	BNC_SET	Qualify BNC IRIG-B time source
472	BNC_RST	Disqualify BNC IRIG-B time source
472	BNC_OK	IRIG-B signal from BNC port is available and has sufficient quality
472	SER_OK	IRIG-B signal from Serial Port 1 is available and has sufficient quality
472	UPD_BLK	Block updating internal clock period and master time
472	BNC_BNP	Bad jitter on BNC port and the IRIG-B signal is lost afterwards
473	SER_BNP	Bad jitter on serial port and the IRIG-B signal is lost afterwards
473	BNC_TIM	A valid IRIG-B time source is detected on BNC port
473	SER_TIM	A valid IRIG-B time source is detected on serial port
473	PTP_TIM	A valid PTP time source is detected
473	PTP_SET	Qualify PTP time source
473	PTP_RST	Disqualify PTP time source
473	PTP_OK	PTP is available and has sufficient quality
473	P5ABSW	Port 5A or 5B has just become active

Table 11.2 Row List of Relay Word Bits (Sheet 96 of 100)

Row	Name	Bit Description
474	PTPSYNC	Synchronized to a high-quality PTP source
474	PTP_BNP	Bad jitter on PTP signals and the PTP signal is lost afterwards
474	SERSYNC	Synchronized to a high-quality serial IRIG source
474	BNCSYNC	Synchronized to a high-quality BNC IRIG source
474	*	Reserved
474	*	Reserved
474	*	Reserved
474	*	Reserved
Axion Status		
475	IO500OK	Communications are good with virtual interface board 500
475	IO400OK	Communications are good with virtual interface board 400
475	IO300OK	Communications are good with virtual interface board 300
475	*	Reserved
475	*	Reserved
475	*	Reserved
475	*	Reserved
475	*	Reserved
IEC 61850 Mode Control Bits		
476	SC850TM	SELOGIC control for IEC 61850 test mode
476	SC850BM	SELOGIC control for IEC 61850 blocked mode
476	SC850SM	SELOGIC control for IEC 61850 simulation mode
476	*	Reserved
476	*	Reserved
476	*	Reserved
476	*	Reserved
476	*	Reserved
IED Local Remote Bits		
480	LOC	Control authority at local (bay) level
480	SC850LS	SELOGIC control for control authority at station level
480	MLTLEV	Multi-level control authority
480	LOCSTA	Control authority at station level
480	*	Reserved
480	*	Reserved
480	*	Reserved
480	*	Reserved
Automation SELOGIC Conditioning Timers		
484	ACT08Q	Automation conditioning timer Output 08
484	ACT07Q	Automation conditioning timer Output 07
484	ACT06Q	Automation conditioning timer Output 06
484	ACT05Q	Automation conditioning timer Output 05
484	ACT04Q	Automation conditioning timer Output 04

Table 11.2 Row List of Relay Word Bits (Sheet 97 of 100)

Row	Name	Bit Description
484	ACT03Q	Automation conditioning timer Output 03
484	ACT02Q	Automation conditioning timer Output 02
484	ACT01Q	Automation conditioning timer Output 01
485	ACT16Q	Automation conditioning timer Output 16
485	ACT15Q	Automation conditioning timer Output 15
485	ACT14Q	Automation conditioning timer Output 14
485	ACT13Q	Automation conditioning timer Output 13
485	ACT12Q	Automation conditioning timer Output 12
485	ACT11Q	Automation conditioning timer Output 11
485	ACT10Q	Automation conditioning timer Output 10
485	ACT09Q	Automation conditioning timer Output 09
486	ACT24Q	Automation conditioning timer Output 24
486	ACT23Q	Automation conditioning timer Output 23
486	ACT22Q	Automation conditioning timer Output 22
486	ACT21Q	Automation conditioning timer Output 21
486	ACT20Q	Automation conditioning timer Output 20
486	ACT19Q	Automation conditioning timer Output 19
486	ACT18Q	Automation conditioning timer Output 18
486	ACT17Q	Automation conditioning timer Output 17
487	ACT32Q	Automation conditioning timer Output 32
487	ACT31Q	Automation conditioning timer Output 31
487	ACT30Q	Automation conditioning timer Output 30
487	ACT29Q	Automation conditioning timer Output 29
487	ACT28Q	Automation conditioning timer Output 28
487	ACT27Q	Automation conditioning timer Output 27
487	ACT26Q	Automation conditioning timer Output 26
487	ACT25Q	Automation conditioning timer Output 25
Local Bits 2		
488	LB40	Local Bit 40
488	LB39	Local Bit 39
488	LB38	Local Bit 38
488	LB37	Local Bit 37
488	LB36	Local Bit 36
488	LB35	Local Bit 35
488	LB34	Local Bit 34
488	LB33	Local Bit 33
489	LB48	Local Bit 48
489	LB47	Local Bit 47
489	LB46	Local Bit 46
489	LB45	Local Bit 45
489	LB44	Local Bit 44

Table 11.2 Row List of Relay Word Bits (Sheet 98 of 100)

Row	Name	Bit Description
489	LB43	Local Bit 43
489	LB42	Local Bit 42
489	LB41	Local Bit 41
490	LB56	Local Bit 56
490	LB55	Local Bit 55
490	LB54	Local Bit 54
490	LB53	Local Bit 53
490	LB52	Local Bit 52
490	LB51	Local Bit 51
490	LB50	Local Bit 50
490	LB49	Local Bit 49
491	LB64	Local Bit 64
491	LB63	Local Bit 63
491	LB62	Local Bit 62
491	LB61	Local Bit 61
491	LB60	Local Bit 60
491	LB59	Local Bit 59
491	LB58	Local Bit 58
491	LB57	Local Bit 57
Local Bit Supervision 2		
492	LB_SP40	Local Bit 40 supervision (SELOGIC control equation)
492	LB_SP39	Local Bit 39 supervision (SELOGIC control equation)
492	LB_SP38	Local Bit 38 supervision (SELOGIC control equation)
492	LB_SP37	Local Bit 37 supervision (SELOGIC control equation)
492	LB_SP36	Local Bit 36 supervision (SELOGIC control equation)
492	LB_SP35	Local Bit 35 supervision (SELOGIC control equation)
492	LB_SP34	Local Bit 34 supervision (SELOGIC control equation)
492	LB_SP33	Local Bit 33 supervision (SELOGIC control equation)
493	LB_SP48	Local Bit 48 supervision (SELOGIC control equation)
493	LB_SP46	Local Bit 46 supervision (SELOGIC control equation)
493	LB_SP45	Local Bit 45 supervision (SELOGIC control equation)
493	LB_SP44	Local Bit 44 supervision (SELOGIC control equation)
493	LB_SP43	Local Bit 43 supervision (SELOGIC control equation)
493	LB_SP42	Local Bit 42 supervision (SELOGIC control equation)
493	LB_SP41	Local Bit 41 supervision (SELOGIC control equation)
494	LB_SP56	Local Bit 56 supervision (SELOGIC control equation)
494	LB_SP55	Local Bit 55 supervision (SELOGIC control equation)
494	LB_SP54	Local Bit 54 supervision (SELOGIC control equation)
494	LB_SP53	Local Bit 53 supervision (SELOGIC control equation)
494	LB_SP52	Local Bit 52 supervision (SELOGIC control equation)
494	LB_SP51	Local Bit 51 supervision (SELOGIC control equation)

Table 11.2 Row List of Relay Word Bits (Sheet 99 of 100)

Row	Name	Bit Description
494	LB_SP50	Local Bit 50 supervision (SELOGIC control equation)
494	LB_SP49	Local Bit 49 supervision (SELOGIC control equation)
495	LB_SP64	Local Bit 64 supervision (SELOGIC control equation)
495	LB_SP63	Local Bit 63 supervision (SELOGIC control equation)
495	LB_SP62	Local Bit 62 supervision (SELOGIC control equation)
495	LB_SP61	Local Bit 61 supervision (SELOGIC control equation)
495	LB_SP60	Local Bit 60 supervision (SELOGIC control equation)
495	LB_SP59	Local Bit 59 supervision (SELOGIC control equation)
495	LB_SP58	Local Bit 58 supervision (SELOGIC control equation)
495	LB_SP57	Local Bit 57 supervision (SELOGIC control equation)
Local Bit Status 2		
496	LB_DP40	Local Bit 40 status display (SELOGIC control equation)
496	LB_DP39	Local Bit 39 status display (SELOGIC control equation)
496	LB_DP38	Local Bit 38 status display (SELOGIC control equation)
496	LB_DP37	Local Bit 37 status display (SELOGIC control equation)
496	LB_DP36	Local Bit 36 status display (SELOGIC control equation)
496	LB_DP35	Local Bit 35 status display (SELOGIC control equation)
496	LB_DP34	Local Bit 34 status display (SELOGIC control equation)
496	LB_DP33	Local Bit 33 status display (SELOGIC control equation)
497	LB_DP48	Local Bit 48 status display (SELOGIC control equation)
497	LB_DP47	Local Bit 47 status display (SELOGIC control equation)
497	LB_DP46	Local Bit 46 status display (SELOGIC control equation)
497	LB_DP45	Local Bit 45 status display (SELOGIC control equation)
497	LB_DP44	Local Bit 44 status display (SELOGIC control equation)
497	LB_DP43	Local Bit 43 status display (SELOGIC control equation)
497	LB_DP42	Local Bit 42 status display (SELOGIC control equation)
497	LB_DP41	Local Bit 41 status display (SELOGIC control equation)
498	LB_DP57	Local Bit 57 status display (SELOGIC control equation)
498	LB_DP56	Local Bit 56 status display (SELOGIC control equation)
498	LB_DP55	Local Bit 55 status display (SELOGIC control equation)
498	LB_DP54	Local Bit 54 status display (SELOGIC control equation)
498	LB_DP53	Local Bit 53 status display (SELOGIC control equation)
498	LB_DP52	Local Bit 52 status display (SELOGIC control equation)
498	LB_DP51	Local Bit 51 status display (SELOGIC control equation)
498	LB_DP50	Local Bit 50 status display (SELOGIC control equation)
498	LB_DP49	Local Bit 49 status display (SELOGIC control equation)
499	LB_DP64	Local Bit 64 status display (SELOGIC control equation)
499	LB_DP63	Local Bit 63 status display (SELOGIC control equation)
499	LB_DP62	Local Bit 62 status display (SELOGIC control equation)
499	LB_DP61	Local Bit 61 status display (SELOGIC control equation)
499	LB_DP60	Local Bit 60 status display (SELOGIC control equation)

Table 11.2 Row List of Relay Word Bits (Sheet 100 of 100)

Row	Name	Bit Description
499	LB_DP59	Local Bit 59 status display (SELOGIC control equation)
499	LB_DP58	Local Bit 58 status display (SELOGIC control equation)

SECTION 12

Analog Quantities

This section contains tables of the analog quantities available within the SEL-487B relay.

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 3)

Label	Description	Units
3V0FII	Filtered instantaneous zero sequence voltage (imaginary)	Volts [V] (secondary)
3V0FIM	Filtered instantaneous zero sequence voltage (magnitude)	Volts [V] (secondary)
3V0FIR	Filtered instantaneous zero sequence voltage (real)	Volts [V] (secondary)
3V2FII	Filtered instantaneous negative sequence voltage (imaginary)	Volts [V] (secondary)
3V2FIM	Filtered instantaneous negative sequence voltage (magnitude)	Volts [V] (secondary)
3V2FIR	Filtered instantaneous negative sequence voltage (real)	Volts [V] (secondary)
51P01–51P21	51 element 01–21 pickup value	Amperes [A] (secondary)
51TD01–51TD21	51 element 01–21 time-dial setting	–
ACN01CV–ACN32CV	Automation SELOGIC counter current value	
ACN01PV–ACN32PV	Automation SELOGIC counter preset value	
ACT01DO–ACT32DO	Automation SELOGIC conditioning timer dropout time	seconds
ACT01PU–ACT32PU	Automation SELOGIC conditioning timer pickup time	seconds
ACTGRP	Active group setting	
AMV001–AMV256	Automation SELOGIC math variable	
AST01ET–AST32ET	Automation SELOGIC math sequencing timer elapsed time	seconds
AST01PT–AST32PT	Automation SELOGIC sequencing timer preset time	seconds
BNCDSJI	BNC port 100PPS 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 100PPS pulses	µs
CUR_SRC	Current high-priority time source	
DC1	Station Battery 1 dc voltage	Volts [V]
DC1MAX	Maximum dc 1 voltage	Volts [V]
DC1MIN	Minimum dc 1 voltage	Volts [V]
DC1NE	Average negative-to-ground dc 1 voltage	Volts [V]
DC1PO	Average positive-to-ground dc 1 voltage	Volts [V]
DC1RI	AC ripple of dc 1 voltage	Volts [V]
DDOM	UTC Date, day of the month (1–31)	day

Table 12.1 Analog Quantities Sorted Alphabetically (Sheet 2 of 3)

Label	Description	Units
DDOW	UTC Date, day of the week (1-SU,.., 7-SA)	
DDOY	UTC Date, day of the year (1–366)	day
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
DMON	UTC date, month (1–12)	month
DYEAR	UTC date, year (2000–2200)	year
I01FA–I21FA	1-cycle average phase current (angle)	Degrees [°]
I01FIA–I21FIA	Filtered instantaneous phase current (angle)	Degrees [°]
I01FII–I21FII	Filtered instantaneous phase current (imaginary)	Amperes [A] (secondary)
I01FIM–I21FIM	Filtered instantaneous phase current (magnitude)	Amperes [A] (secondary)
I01FIR–I21FIR	Filtered instantaneous phase current (real)	Amperes [A] (secondary)
I01FM–I21FM	1-cycle average phase current (magnitude)	Amperes [A] (primary)
I850MOD	IEC 61850 mode/behavior status	N/A
IOPCZ1–IOPCZ3	Check Zone 1–3 operating current	per unit [pu]
IOPCZ1F–IOPCZ3F	1-cycle average Check Zone 1–3 operating current	per unit [pu]
IOP1–IOP6	Zone 1–6 operating current	per unit [pu]
IOP1F–IOP6F	1-cycle average Zone 1–6 operating current	per unit [pu]
IRTCZ1–IRTCZ3	Check Zone 1–3 Restraint current	per unit [pu]
IRTCZ1F–IRTCZ3F	1-cycle average Check Zone 1–3 restraint current	per unit [pu]
IRT1–IRT6	Zone 1–6 restraint current	per unit [pu]
IRT1F–IRT6F	1-cycle average Zone 1–6 restraint current	per unit [pu]
MB1A–MB7A	A Channel received MIRRORED BITS analog values	
MB1B–MB7B	B Channel received MIRRORED BITS analog values	
NEW_SRC	Selected high-priority time source	
PCN01CV–PCN32CV	Protection SELOGIC counter current value	
PCN01PV–PCN32PV	Protection SELOGIC counter preset value	
PCT01DO–PCT16DO	Protection SELOGIC conditioning timer dropout time	cycles
PCT01PU–PCT16PU	Protection SELOGIC conditioning timer pickup time	cycles
PMV01–PMV64	Protection SELOGIC math variable	
PST01ET–PST32ET	Protection SELOGIC sequencing timer elapsed time	cycles
PST01PT–PST32PT	Protection SELOGIC sequencing timer preset time	cycles
PTPDSJI	PTP 100PPS data stream jitter in µs	µs
PTPMCC	PTP master clock class enumerated value	N/A
PTPOFST	Raw 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	

Table 12.1 Analog Quantities Sorted Alphabetically (Sheet 3 of 3)

Label	Description	Units
PTPTBTW	Time between PTP 100PPS pulses in µs	µs
RA001–RA256	Remote analogs	
RAO01–RAO64	Remote analog output	–
RLYTEMP	Relay temperature (temperature of the box)	°C (degrees Celsius)
SERDSJI	Serial port 100PPS 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 100PPS pulses	µs
SQUAL	Synchronization accuracy of the selected high-priority time source	µs
THR	UTC time, hour (0–23)	hour
TLHR	Local time, hour (0–23)	hour
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)	seconds
TMIN	UTC time, minute (0–59)	minutes
TMSEC	UTC time, milliseconds (0–999)	ms
TNSEC	UTC time, nanoseconds (0–999999)	ns
TODMS	UTC time of day in milliseconds (0–86400000)	ms
TQUAL	Worst-case clock time error of the selected high-priority time source	seconds
TSEC	UTC time, seconds (0–59)	seconds
TUTC	Offset from local time to UTC time	hours
V1FII	Filtered instantaneous positive-sequence voltage (imaginary)	Volts [V] (secondary)
V1FIM	Filtered instantaneous positive-sequence voltage (magnitude)	Volts [V] (secondary)
V1FIR	Filtered instantaneous positive-sequence voltage (real)	Volts [V] (secondary)
V01FA–V03FA	1-cycle average phase voltage (angle)	Degrees [°]
V01FIA–V03FIA	Filtered instantaneous phase voltage (angle)	Degrees [°]
V01FII–F03FII	Filtered instantaneous phase voltage (imaginary)	Volts [V] (secondary)
V01FIM–V03FIM	Filtered instantaneous phase voltage (magnitude)	Volts [V] (secondary)
V01FIR–F03FIR	Filtered instantaneous phase voltage (real)	Volts [V] (secondary)
V01FM–V03FM	1-cycle average phase voltage (magnitude)	Kilovolts [kV] (primary)

Table 12.2 Analog Quantities Sorted by Function (Sheet 1 of 4)

Label	Description	Units
Current		
I*nn*FIM[a]	Phase-filtered instantaneous current magnitude	A (sec)
I*nn*FIA[a]	Phase-filtered instantaneous current angle	degrees
I*nn*FIR[a]	Phase-filtered instantaneous current (real)	A (sec)
I*nn*FII[a]	Phase-filtered instantaneous current (imaginary)	A (sec)
I*nn*FM[a]	Phase one-cycle average current magnitude	A (pri)

Table 12.2 Analog Quantities Sorted by Function (Sheet 2 of 4)

Label	Description	Units
I*nn*FA[a]	Phase one-cycle average current angle	degrees
IOP*k*[b]	Zone *k* operating current	pu
IOPCZ*p*[c]	Check Zone *p* operating current	pu
IRT*k*[b]	Zone *k* restraint current	pu
IRTCZ*p*[c]	Check Zone *p* restraint current	pu
IOP*k*F[b]	Zone *k* one-cycle average operating current	pu
IOPCZ*p*F[c]	Check Zone *p* one-cycle average operating current	pu
IRT*k*F[b]	Zone *k* one-cycle average restraint current	pu
IRTCZ*p*F[c]	Check Zone *p* one-cycle average restraint current	pu
Voltage		
V*mm*FIM[d]	Phase-filtered instantaneous voltage magnitude	V (sec)
V*mm*FIA[d]	Phase-filtered instantaneous voltage angle	degrees
V*mm*FIR[d]	Phase-filtered instantaneous voltage (real)	V (sec)
V*mm*FII[d]	Phase-filtered instantaneous voltage (imaginary)	V (sec)
V*mm*FM[d]	Phase one-cycle average voltage magnitude	kV (pri)
V*mm*FA[d]	Phase one-cycle average voltage angle	degrees
V1FIM	Positive-sequence filtered instantaneous voltage magnitude, V1	V (sec)
V1FIR	Positive-sequence filtered instantaneous voltage (real)	V (sec)
V1FII	Positive-sequence filtered instantaneous voltage (imaginary)	V (sec)
3V2FIM	Negative-sequence filtered instantaneous voltage magnitude, 3V2	V (sec)
3V2FIR	Negative-sequence filtered instantaneous voltage (real)	V (sec)
3V2FII	Negative-sequence filtered instantaneous voltage (imaginary)	V (sec)
3V0FIM	Zero-sequence filtered instantaneous voltage magnitude, 3V0	V (sec)
3V0FIR	Zero-sequence filtered instantaneous voltage (real)	V (sec)
3V0FII	Zero-sequence filtered instantaneous voltage (imaginary)	V (sec)
DC1	Filtered dc monitor voltage	V
DC1PO	Average positive-to-ground dc voltage	V
DC1NE	Average negative-to-ground dc voltage	V
DC1RI	AC ripple of dc voltage (peak-to-peak)	V
DC1MIN	Minimum dc voltage	V
DC1MAX	Maximum dc voltage	V
Database Structure		
RA001–RA256	Remote analogs from Ethernet card	N/A
Output Settings		
RAO001–RAO064	Remote analog output	N/A
Date and Time		
TODMS	UTC time of day in milliseconds (0–86399999)	ms
THR	UTC time, hour (0–23)	hours
TMIN	UTC time, minute (0–59)	minutes
TSEC	UTC time, seconds (0–59)	seconds
TMSEC	UTC time, milliseconds (0–999)	ms

Table 12.2 Analog Quantities Sorted by Function (Sheet 3 of 4)

Label	Description	Units
TNSEC	UTC time, nanoseconds (0–999999)	ns
DDOW	UTC date, day of the week (Encoded value: 1 = Sun, 2 = Mon, 3 = Tue, 4 = Wed, 5 = Thu, 6 = Fri, 7 = Sat)	n/a
DDOM	UTC date, day of the month (1–31)	day
DDOY	UTC date, day of the year (1–366)	day
DMON	UTC date, month (1–12)	month
DYEAR	UTC date, year (2000–2200)	year
TLODMS	Local time of Day in Milliseconds (0–86400000)	ms
TLHR	Local time, hour (0–23)	hr
TLMIN	Local time, minute (0–59)	min
TLSEC	Local time, seconds (0–59)	s
TLMSEC	Local time, milliseconds (0–999)	ms
TLNSEC	Local time, nanoseconds (0–999999)	ns
DLDOW	Local date, day of the week (1-SU,.., 7-SA)	n/a
DLDOM	Local date, day of the month (1–31)	day
DLDOY	Local date, day of the year (1–366)	day
DLMON	Local date, month (1–12)	month
DLYEAR	Local date, year (2000–2200)	year
High-Priority Time Analogs		
TUTC	Offset from local time to UTC time	hr
TQUAL	Worst-case clock time error of the selected high-priority time source	s
NEW_SRC	Selected high-priority time source	n/a
CUR_SRC	Current high-priority time source	n/a
SQUAL	Synchronization accuracy of the selected high-priority time source	µs
BNCDSJI	BNC port 100PPS data stream jitter	µs
BNCOTJS	Slow converging BNC port ON TIME marker jitter, fine accuracy	µs
BNCOTJF	Fast converging BNC port ON TIME marker jitter, coarse accuracy	µs
BNCTBTW	Time between BNC 100PPS pulses	µs
SERDSJI	Serial port 100PPS data stream jitter	µs
SEROTJS	Slow converging serial port ON TIME marker jitter, fine accuracy	µs
SEROTJF	Fast converging serial port ON TIME marker jitter, coarse accuracy	µs
SERTBTW	Time between serial 100PPS pulses	µs
MIRRORED BITS Communications		
MB1A–MB7A	MIRRORED BITS communications Channel A received analog values	n/a
MB1B–MB7B	MIRRORED BITS communications Channel B received analog values	n/a
SELOGIC and Automation Elements		
PMV01–PMV64	Protection SELOGIC control equation math variable	n/a
PCT01PU–PCT16PU	Protection conditioning timer pickup time	cycles
PCT01DO–PCT16DO	Protection conditioning timer dropout time	cycles
PST01ET–PST32ET	Protection sequencing timer elapsed time	cycles
PST01PT–PST32PT	Protection sequencing timer preset time	cycles

Table 12.2 Analog Quantities Sorted by Function (Sheet 4 of 4)

Label	Description	Units
PCN01CV–PCN32CV	Protection counter current value	n/a
PCN01PV–PCN32PV	Protection counter preset value	n/a
AMV001–AMV256	Automation SELOGIC control equation math variable	n/a
ACT01PU–ACT32PU	Automation conditioning timer pickup time	seconds
ACT01DO–ACT32DO	Automation conditioning timer dropout time	seconds
AST01ET–AST32ET	Automation sequencing timer elapsed time	seconds
AST01PT–AST32PT	Automation sequencing timer preset time	seconds
ACN01CV–ACN32CV	Automation counter current value	n/a
ACN01PV–ACN32PV	Automation counter preset value	n/a
Setting Group		
ACTGRP	Active group setting	n/a
51 Elements		
51P*mm*[d]	51 element *mm* pickup value	A (sec)
51TD*mm*[d]	51 element *mm* time-dial setting	n/a
Auxiliary Channels		
RLYTEMP	Relay temperature (temperature of the box)	°C (degrees Celsius)
IEEE 1588 PTP Status		
PTPDSJI	PTPDSJI PTP 100PPS data stream jitter in µs	µs
PTPMCC	PTP master clock class enumerated value	N/A
PTPOTJS	PTPOTJS Slow converging PTP ON TIME marker jitter in µs, fine accuracy	µs
PTPOTJF	PTPOTJF Fast converging PTP ON TIME marker jitter in µs, coarse accuracy	µs
PTPOFST	PTPOFST Raw clock offset between PTP master and relay time	ns
PTPPORT	Active PTP port number	N/A
PTPTBTW	PTPTBTW Time between PTP 100PPS pulses in µs	µs
PTPSTEN	PTPSTEN PTP Port State enumerated value	
IEC 61850 Mode/Behavior Status		
I850MOD	IEC 61850 mode/behavior status	N/A

[a] nn = 01–21.
[b] k = 1–6.
[c] p = 1–3.
[d] mm = 01–03.

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.

NOTE: The SEL-487B-1 relay (firmware versions R3xx) is incompatible with the SEL-487B-0 and SEL-487B-2 relays (firmware versions R1xx and R4xx). Do not attempt to load firmware on incompatible hardware.

A standard release is identified by a change in the R-number of the device FID number.

Existing firmware:

FID=SEL-487B-**R302**-V0-Z001001-Dxxxxxxxx

Standard release firmware:

FID=SEL-487B-**R303**-V0-Z001001-Dxxxxxxxx

A point release is identified by a change in the V-number of the device FID number.

Existing firmware:

FID=SEL-487B-R307-**V0**-Z001001-Dxxxxxxxx

Point release firmware:

FID=SEL-487B-R307-**V1**-Z001001-Dxxxxxxxx

The settings software driver for an associated firmware is identified by the Z-number of the device FID number.

FID=SEL-487B-R307-V0-**Z001**001-Dxxxxxxxx

The date code is after the D. For example, the following is firmware version number R302, date code November 7, 2011.

FID=SEL-487B-R302-V0-Z007005-**D20111107**

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, revision 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 12)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-487B-1-R319-V0-Z018007-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. ➤ Resolved an issue where the relay could incorrectly indicate the time synchronization status when the relay is transitioning between two Grandmaster clock sources and the active clock source is no longer available. This does not apply when both clocks are globally time-synchronized. ➤ Resolved an issue in the previous firmware version, where PTP messages were not processed on one of the ports when NETMODE = PRP and PTPPRO = C37.238. ➤ 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.	20250214

Table A.1 Firmware Revision History (Sheet 2 of 12)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ 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.	
SEL-487B-1-R318-V1-Z018007-D20240509	Includes all the functions of SEL-487B-1-R318-V0-Z018007-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-487B-1-R318-V0-Z018007-D20231207	➤ 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. ➤ 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. ➤ 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. ➤ 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. ➤ Modified the synchronization status values reported in IEC 61850 LTMS.TmSyn.stVal to accurately reflect the definitions in IEC 61850-9-2. ➤ Modified the firmware to improve the IEC 61850 time accuracy value LTMS.TmAcc.stVal. ➤ 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 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.	20231207
SEL-487B-1-R317-V1-Z017007-D20230830	Includes all the functions of SEL-487B-1-R317-V0-Z017007-D20220523 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. ➤ [Cybersecurity] Resolved a rare issue where continuous event report polling requests from a communication processor can cause the relay to disable.	20230830

Table A.1 Firmware Revision History (Sheet 3 of 12)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ 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.	
SEL-487B-1-R317-V0-Z017007-D20220523	➤ [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 new communications Ethernet card. ➤ 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 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. ➤ 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.	20220523
SEL-487B-1-R316-V3-Z016007-D20230830	Includes all the functions of SEL-487B-1-R316-V2-Z016007-D20220630 with the following additions: ➤ [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. ➤ [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. ➤ [Cybersecurity] Resolved a rare issue where continuous event report polling requests from a communication processor can cause the relay to disable. ➤ 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.	20230830
SEL-487B-1-R316-V2-Z016007-D20220630	Includes all the functions of SEL-487B-1-R316-V1-Z016007-D20211203 with the following addition: ➤ Added support for new Ethernet communications card.	20220630

Table A.1 Firmware Revision History (Sheet 4 of 12)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-487B-1-R316-V1-Z016007-D20211203	Includes all the functions of SEL-487B-1-R316-V0-Z016007-D20210514 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-487B-1-R316-V0-Z016007-D20210514	➤ Added settings EACC, E2AC, and EPAC to support port access control using SELOGIC control equations. ➤ Added conditioning timers to Automation SELOGIC. ➤ Improved processing consistency of breaker 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. ➤ 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. ➤ Enhanced the internal fault detection logic associated with the differential element. ➤ Increased the number of available display points to 192. ➤ Increased the number of available local 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.	20210514
SEL-487B-1-R315-V4-Z015006-D20230830	Includes all the functions of SEL-487B-1-R315-V3-Z015006-D20220630 with the following additions: ➤ [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. ➤ [Cybersecurity] Improved web server security against session hijacking. ➤ [Cybersecurity] Improved web server security against intentionally large files causing denial of service.	20230830

Table A.1 Firmware Revision History (Sheet 5 of 12)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ [Cybersecurity] Improved web server security against cross-site scripting and misuse of session tokens. ➤ [Cybersecurity] Resolved a rare issue where continuous event report polling requests from a communication processor can cause the relay to disable. ➤ 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.	
SEL-487B-1-R315-V3-Z015006-D20220630	Includes all the functions of SEL-487B-1-R315-V2-Z015006-D20210428 with the following addition: ➤ Added support for new Ethernet communications card.	20220630
SEL-487B-1-R315-V2-Z015006-D20210428	Includes all the functions of SEL-487B-1-R315-V1-Z015006-D20201009 with the following additions: ➤ 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.	20210428
SEL-487B-1-R315-V1-Z015006-D20201009	Includes all the functions of SEL-487B-1-R315-V0-Z015006-D20200229 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-487B-1-R315-V0-Z015006-D20200229 **NOTE:** This firmware release only supports .zds digitally signed firmware files. SELBOOT R300 or newer is required for this and all new firmware versions. See Appendix B: Firmware Upgrade Instructions in the SEL-400 Series Relays Instruction Manual for more information.	➤ Modified firmware to enable DNP and IEC 61850 breaker control only when the circuit breaker jumper is installed. ➤ Added the ability to remotely upgrade relay firmware over an Ethernet network. ➤ Improved relay response to three consecutive failed login attempts within a one-minute interval to pulse the BADPASS and SALARM Relay Word bits for all communication interfaces. ➤ Enhanced relay self-tests to detect current or voltage magnitudes that exceed the maximum analog-to-digital converter output and perform an automatic diagnostic restart. ➤ Enhanced FTP Network Security. ➤ Modified firmware to retain stored data after successful reads of SER.TXT, CSER.TXT, PRO.TXT, and CPRO.TXT over Ethernet connections. ➤ Modified firmware to support all printable ASCII characters in the password entry HMI screen. ➤ Modified firmware to interpret Group settings RTDI, OPDI, CZRTDI, and CZOPDI as peak values instead of rms. ➤ Modified firmware to increment the state number (stNum) in GOOSE messages for all changes in quality. ➤ Modified firmware to support default profile for Precision Time Protocol when NETMODE = PRP. ➤ Added support for new IEC 61850 control and settings common data classes. ➤ Enhanced wildcard parsing used in the YMODEM file-transfer operations. ➤ Improved reference angle selection for metering.	20200229

Table A.1 Firmware Revision History (Sheet 6 of 12)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-487B-1-R314-V4-Z014006-D20230830	Includes all the functions of SEL-487B-1-R314-V3-Z014006-D20220630 with the following additions: ➤ [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. ➤ [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. ➤ [Cybersecurity] Resolved a rare issue where continuous event report polling requests from a communication processor can cause the relay to disable. ➤ 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.	20230830
SEL-487B-1-R314-V3-Z014006-D20220630	Includes all the functions of SEL-487B-1-R314-V2-Z014006-D20201009 with the following addition: ➤ Added support for new Ethernet communications card.	20220630
SEL-487B-1-R314-V2-Z014006-D20201009	Includes all the functions of SEL-487B-1-R314-V1-Z014006-D20191210 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-487B-1-R314-V1-Z014006-D20191210	Includes all the functions of SEL-487B-1-R314-V0-Z014006-D20181115 with the following addition: ➤ Modified processing of pulsed Relay Word bits.	20191210
SEL-487B-1-R314-V0-Z014006-D20181115	➤ Added IEC 61850 standard operating modes, including TEST, TEST-BLOCKED, ON, ON-BLOCKED, and OFF. ➤ Modified Ethernet communications to automatically correct a loss of synchronization between the communications subsystem and the other relay subsystems. ➤ Modified the relay to prevent rare cases of a CID file reverting to the previous version of the file during a firmware upgrade. ➤ Improved the processing consistency of remote and local control bits with a one-processing interval pulse width. ➤ Improved error handling for the Ethernet interface. ➤ Modified the firmware to verify that Precision Time Protocol (PTP) is enabled (EPTP = Y) as an initial validity check for all PTP messages being received by the relay. ➤ Modified MMS file reads to allow mixed-case file names. ➤ Improved backward compatibility with certain MMS clients. ➤ Enhanced dc offset processing. ➤ Modified the firmware to prevent settings read/write issues when Port 5 is disabled and an IEC 61850 configuration file is loaded.	20181115

Table A.1 Firmware Revision History (Sheet 7 of 12)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Modified the firmware to address an issue in retransmitted TCP/IP frames with PRP trailer, which in previous firmware may have been discarded on reception. ➤ Added support for IEEE C37.111-2013 COMTRADE. ➤ Added the company name Global setting (CONAM). ➤ Added the open-phase detection setting (OPHDO) under advanced Global settings. ➤ Modified the VECTOR command (**VEC**) to show all Sequential Events Recorder (SER) entries.	
SEL-487B-1-R313-V3-Z013005-D20230830	Includes all the functions of SEL-487B-1-R313-V2-Z013005-D20220630 with the following additions: ➤ [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. ➤ [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. ➤ [Cybersecurity] Resolved a rare issue where continuous event report polling requests from a communication processor can cause the relay to disable. ➤ 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.	20230830
SEL-487B-1-R313-V2-Z013005-D20220630	Includes all the functions of SEL-487B-1-R313-V1-Z013005-D20201009 with the following addition: ➤ Added support for new Ethernet communications card.	20220630
SEL-487B-1-R313-V1-Z013005-D20201009	Includes all the functions of SEL-487B-1-R313-V0-Z013005-D20180105 with the following addition: ➤ 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-487B-1-R313-V0-Z013005-D20180105	➤ Updated firmware ID (FID) to support ACSELERATOR QuickSet SEL-5030 Software with features added in release R312-V0.	20180105
SEL-487B-1-R312-V3-Z012005-D20230830	Includes all the functions of SEL-487B-1-R312-V2-Z012005-D20220630 with the following additions: ➤ [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. ➤ [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.	20230830

Table A.1 Firmware Revision History (Sheet 8 of 12)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ [Cybersecurity] Resolved a rare issue where continuous event report polling requests from a communication processor can cause the relay to disable. ➤ 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.	
SEL-487B-1-R312-V2-Z012005-D20220630	Includes all the functions of SEL-487B-1-R312-V1-Z012005-D20201009 with the following addition: ➤ Added support for new Ethernet communications card.	20220630
SEL-487B-1-R312-V1-Z012005-D20201009	Includes all the functions of SEL-487B-1-R312-V1-Z012005-D20201009 with the following addition: ➤ 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-487B-1-R312-V0-Z012005-D20171008 **NOTE:** ACSELERATOR QuickSet SEL-5030 Software does not include some of the added features, analog quantities, or Relay Word bits for this release.	➤ Added a new analog quantity, PTPMCC, to indicate the clock class of the PTP master. ➤ Enhanced memory read diagnostics. ➤ DNP3 data are now reported with a LOCAL_FORCED flag when they have been overridden through use of the TEST DB2 command. ➤ Updated IEC 61850 protocol implementation to IEC 61850 Edition 2. ➤ Modified the relay response to an MMS identify request so that it will respond with the firmware ID (FID) string. ➤ Improved MMS file services performance with successive file transfers. ➤ Enhanced wild card parsing used in MMS file transfer operations. ➤ Modified the **ID** command to display a string that uniquely identifies the IEC 61850 firmware present in the relay. ➤ Modified firmware to replace non-printable characters with question marks in settings that are sent to the front panel of the HMI. ➤ Modified firmware to allow SNTPPIP to be set to 0.0.0.0 when ESNTP = BROADCAST. ➤ DNP3 data are now reported with an overridden flag when they have been overridden using the **TEST DB2** command. ➤ Modified firmware to allow all settings changes when the relay is disabled. ➤ The **ETH** command now shows both MAC addresses ➤ Modified firmware to indicate an enabled or disable transition of the IEC 61850 Buffer Report Control Block (BRCB) by sending an overflow flag on the next report sent after the transition. ➤ Modified firmware to avoid false GOOSE out of sequence errors while in PRP mode. ➤ Modified firmware to allow the relay to synchronize to an external time source more responsively. ➤ Modified firmware to display the history region correctly. ➤ IEC 61850 Product ICD File Datasets and Report Names changed to be consistent with other products. ➤ Increased the default MMS inactivity timeout from 2 to 15 minutes. ➤ Modified IEEE-1588 PTP power profile to be supported in Parallel Redundancy Protocol (PRP) mode.	20171008

Table A.1 Firmware Revision History (Sheet 9 of 12)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-487B-1-R311-V4-Z012005-D20230830	Includes all the functions of SEL-487B-1-R311-V3-Z012005-D20220630 with the following additions: ➤ [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. ➤ [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.	20230830
SEL-487B-1-R311-V3-Z012005-D20220630	Includes all the functions of SEL-487B-1-R311-V2-Z012005-D20171021 with the following addition: ➤ Added support for new Ethernet communications card.	20220630
SEL-487B-1-R311-V2-Z012005-D20171021	Includes all the functions of SEL-487B-1-R311-V1-Z012005-D20170809 with the following addition: ➤ Enhanced memory read diagnostics.	20171021
SEL-487B-1-R311-V1-Z012005-D20170809	Includes all the functions of SEL-487B-1-R311-V0-Z012005-D20170329 with the following addition: ➤ Resolved an issue where certain Ethernet traffic could cause diagnostic restarts.	20170809
SEL-487B-1-R311-V0-Z012005-D20170329	➤ Added an event report digital setting, ERDIG, which can be set to S (some) or A (all) to allow the option for all Relay Word bits to be added to COMTRADE event reports. ➤ Improved Simple Network Time Protocol (SNTP) accuracy to ± 1 ms in an ideal network. ➤ Added time-domain link (TiDL) technology. ➤ Modified firmware to prevent delays in periodic MMS reports. ➤ Modified firmware to allow the MMS inactivity time-out to be turned off.	20170329
SEL-487B-1-R310-V2-Z011005-D20171021	Includes all the functions of SEL-487B-1-R310-V1-Z011005-D20170820 with the following addition: ➤ Enhanced memory read diagnostics.	20171021
SEL-487B-1-R310-V1-Z011005-D20170820	Includes all the functions of SEL-487B-1-R310-V0-Z011005-D20160718 with the following addition: ➤ Resolved an issue where certain Ethernet traffic could cause diagnostic restarts.	20170820
SEL-487B-1-R310-V0-Z011005-D20160718	➤ Added support for IEEE 1588-2008 Precision Time Protocol (PTP) time synchronization. ➤ Added ordering option to select Ethernet Ports 5A/5B for PTP. ➤ Added EVEMOD*n* (where *n* = 1–6 for DNP LAN/WAN, or empty for DNP serial) setting to force the relay to start in single- or multiple-event mode. ➤ Enhanced front-panel operations to show settings warnings, in addition to settings errors already displayed, during settings changes. ➤ Modified DNP Object 0, Variation 242 to report the firmware V-number.	20160718

Table A.1 Firmware Revision History (Sheet 10 of 12)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Improved MIRRORED BITS performance under a high level of GOOSE traffic. ➤ Improved relay startup time. ➤ Modified Virtual Bits to reset upon a successful CID file download. ➤ Modified GOOSE subscription to update data after the messages transition from bad to good quality. ➤ Modified the handling of a leap year when the relay setting and clock disagree. ➤ Modified the **TEST DB2** functionality to override Relay Word bits that are in the Sequential Events Recorder (SER). ➤ Modified the **TEST DB2 OFF** command to disable the overridden remote analog output and digital values in IEC 61850 GOOSE messages.	
SEL-487B-1-R309-V3-Z010005-D20170820	Includes all the functions of SEL-487B-1-R309-V2-Z010005-D20160323 with the following addition: ➤ Resolved an issue where certain Ethernet traffic could cause diagnostic restarts.	20170820
SEL-487B-1-R309-V2-Z010005-D20160323	Includes all the functions of SEL-487B-1-R309-V1-Z010005-D20151102 with the following addition: ➤ Modified firmware to initialize all instances of Check Zone settings when multiple settings groups are sent to the relay or following a group switch operation.	20160323
SEL-487B-1-R309-V1-Z010005-D20151102	➤ Improved firmware upgrade process to correctly initialize Check Zone settings within Zone Configuration settings group and the Breaker and Disconnect Inputs SELOGIC equations within Global settings group.	20151102
SEL-487B-1-R309-V0-Z010005-D20150421	➤ Added local time and date analog quantities. ➤ Added Isolated IP mode (NETMODE = ISOLATEIP) that permits IEC 61850 GOOSE messages on two ports, but restricts IP traffic to just one port. ➤ Added the option to change settings groups with IEC 61850. ➤ Changed Group and Global settings so they are now available via the front-panel HMI. ➤ Added pulsed remote bits in Automation SELOGIC. ➤ Added support for the stSeld attribute in IEC 61850 SBO controls. ➤ Added the LPHD.Sim logical node so the relay will accept GOOSE messages with the test flag asserted. ➤ Updated the profile and compressed profile commands (**PRO** and **CPRO**, respectively) to display the available analog signal profiling records regardless of the state of the signal profile enable (SPEN) setting. ➤ Enhanced the embedded HTTP server user interface to be consistent with other SEL relays. ➤ Enhanced the report time records to save the active UTC offset (UTCOFF) value with each report. Now, when the relay collects a report, it assigns the time stamp based on the UTC time and the UTCOFF value at the time the relay stores the report. ➤ Improved Port 5 functionality to disable auto-messages when the auto-messages setting is equal to no (AUTO=N). ➤ Changed the IEC 61850 Configured IED Description (CID) file to support non-Relay Word bit binary elements included in a GOOSE message. ➤ Modified the relay to support MMS file transfer service even if the relay contains an invalid CID file.	20150421

Table A.1 Firmware Revision History (Sheet 11 of 12)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Modified the firmware to prevent IP traffic from becoming unresponsive when the Parallel Redundancy Protocol (PRP) is enabled. ➤ Changed the Station ID label in the COMTRADE configuration (.cfg) file to prevent non-alphanumeric characters per the COMTRADE IEEE C37.111-1999 standard. ➤ Reset the port timeout on transmitted Telnet messages. ➤ Enhanced performance to ensure that the relay does not become unresponsive when MIRRORED BITS is used on the front port. In previous firmware, the relay could become unresponsive on rare occasions if the front port is set to MIRRORED BITS protocol. ➤ Modified the embedded HTTP server web access to always require a valid relay Access Level 1 (ACC) password. ➤ Clarified the message generated by the relay in response to an invalid CID file. ➤ Closed an outgoing UDP port that was reported as open by a port scanner when IEC 61850 was enabled. ➤ Removed the alias names from the compressed event report (CEV) and compressed ASCII summary (CSU) headers to match the compressed ASCII (CAS) header labels. Added new labels ILAB*nn* (*nn* = 01–21) and VLAB*mm* (*mm* = 01–03) to reference to the alias names. ➤ Modified firmware to correctly process the last row of Relay Word bits in the four samples per cycle event reports. ➤ Improved relay performance during certain incorrect memory reads. ➤ Modified firmware to correctly process the last row of Relay Word bits in the four samples per cycle compressed event reports. ➤ Changed the result of a SELOGIC equation math error from NAN (not a number) to the previously stored valid result.	
SEL-487B-1-R308-V0-Z010005-D20150421	**Note:** This firmware did not production release.	—
SEL-487B-1-R307-V1-Z009005-D20170820	Includes all the functions of SEL-487B-1-R307-V0-Z009005-D20131014 with the following addition: ➤ Resolved an issue where certain Ethernet traffic could cause diagnostic restarts.	20170820
SEL-487B-1-R307-V0-Z009005-D20131014	➤ Improved the accuracy of GOOSE message data time stamps. ➤ Closed an outgoing UDP port that was reported as open by a port scanner when IEC 61850 was enabled. ➤ Added MMS file transfer. ➤ Included the DNP settings labels in DNP Maps 1–5. ➤ Added support for MMS authentication. ➤ Added Parallel Redundancy Protocol (PRP). ➤ Increased the number of binary outputs to 100 for DNP map. ➤ Increased the number of buffered and unbuffered reports to seven for MMS reporting. ➤ Increased the number of GOOSE message subscriptions to 128. ➤ Improved ability to select subscribed GOOSE message attributes for control of relay rejection or acceptance of incoming GOOSE messages. ➤ Implemented multiple updates to the DNP3 control point operations.	20131014

Table A.1 Firmware Revision History (Sheet 12 of 12)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-487B-1-R306-V0-Z007005-D20130606	➤ Corrected the calculation of SELOGIC Execution Capacity. ➤ Updated IRIG output to report local time instead of UTC time. ➤ Fixed an issue of rejected IP packets with VLAN ID tags.	20130606
SEL-487B-1-R305-V0-Z007005-D20121221	➤ Corrected an issue that causes Fast Message Meter data to be reported incorrectly. These data are made available in communications processors as METER2 data.	20121221
SEL-487B-1-R304-V0-Z007005-D20120828	Note: This firmware version was not production released. See R305, above, which also includes the enhancements in R304. ➤ Added Connectorized option.	20120828
SEL-487B-1-R303-V0-Z007005-D20120508	➤ Added DNP1-5 to **HELP SET** command. ➤ Added DNP to **HELP COPY** command. ➤ Improved relay diagnostic response. ➤ Fixed problem when maximum LER setting would be rejected upon subsequent **SET R** command to relay. ➤ Reduced DNP current cut off from 5.0% to 0.5% of nominal current. ➤ Enhanced performance to ensure the relay does not become unresponsive when connected to another relay through the serial port with automessaging enabled on both ports (AUTO=Y).	20120508
SEL-487B-1-R302-V0-Z007005-D20111107	➤ Initial version.	20111107

SELBOOT

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. If upgrading from R2xx SELBOOT to R3xx SELBOOT, load the .s19 file. Do not load a .zds file when using R2xx SELBOOT.

SELBOOT is a firmware package inside the relay that handles hardware initialization and provides the functions needed to support firmware upgrades. To determine the SELBOOT version, view the status report by using the serial port **STATUS** command or the front panel. The device will report the SELBOOT firmware identification (BFID) label as:

BFID=SLBT-4XX-Rxxx-Vx-Zxxxxxx-Dxxxxxxxx

Table A.2 lists the SELBOOT releases used with the SEL-487B and revision descriptions. The most recent SELBOOT revision is listed first.

Table A.2 SELBOOT Revision History

SELBOOT Firmware Identification (BFID)	Summary of Revisions
SLBT-4XX-R300-V0-Z001002-D20200229	➤ Modified SELBOOT to support digitally signed firmware.
SLBT-4XX-R209-V0-Z001002-D20150130	➤ Modified the firmware to prevent an issue that could cause the relay to become unresponsive.
SLBT-4XX-R208-V0-Z001002-D20120220	➤ Added support for a new main board variant.
SLBT-4XX-R207-V0-Z001002-D20110922	➤ First revision used with SEL-487B-1.

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-487B-1-R201-V0-Z307005-D20130828

The ICD revision number is after the R (e.g., 201) and the date code is after the D. 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 002. Previous ClassFileVersions do not provide an informative Z-number.

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., 307). 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	Summary of Revisions	Minimum Relay Firmware	ClassFile Version	Manual Date Code
ICD-487B-R405-V0-Z319010-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 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.	R319	010	20250214
ICD-487B-R404-V0-Z318009-D20231207 **NOTE:** ClassFileVersions 007 and 008 did not production release.	➤ Updated IEC 61850 Edition 2 Conformance. ➤ Updated ClassFileVersion to 009. ➤ Added support for MMS buffered and unbuffered report reservation.	R318	009	20231207
ICD-487B-R403-V0-Z316006-D20210204	➤ Added PRBGGIO logical nodes to support pulsing remote bits. ➤ Corrected the IEC 61850 Data Object number extensions according to the Ed 2 number usage.	R316	006	20210514

Table A.3 ICD File Revision History (Sheet 2 of 2)

configVersion	Summary of Revisions	Minimum Relay Firmware	ClassFile Version	Manual Date Code
	➤ 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 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.			
ICD-487B-R402-V0-Z315006-D20200229	➤ Added BFR*n*R8BRF protection logical nodes (where *n* = 1–21). ➤ Added ALMGGIO, ETHGGIO, and SGGGIO annunciator logical nodes. ➤ Added DCZBAT metering logical node. ➤ Moved IEC 61850 mode/behavior control from logical node LPHD to LLN0. ➤ Improved consistency in deadband units for the ICD file to use voltage in kV and power in MW. ➤ Added system logical nodes LGOS, LTIM, LTMS, and LCCH.	R315	006	20200229
ICD-487B-R401-V0-Z314006-D20181105	➤ Added the ability to control mode and behavior through an MMS write to the LPHD local node Mod.ctlVal attribute. ➤ Addressed nonfunctional settings link tab within ACSELERATOR Architect SEL-5032 Software by disabling "System setFileSupported" in the ICD file.	R314	006	20181115
ICD-487B-R400-V0-Z312006-D20170731	➤ IEC 61850 Edition 2 Conformance. ➤ Updated ClassFileVersion to 006. ➤ Increased the default MMS inactivity timeout value to 900 seconds. ➤ Updated data set and MMS report names.	R312	006	20171008
ICD-487B-R302-V0-Z311005-D20170318	➤ Added the ability to turn off the MMS inactivity timeout.	R311-V0	005	20170329
ICD-487B-R300-V0-Z308005-D20150325	➤ Added support for IEC 61850 group switch, Simulated Goose and stSeld.	R308	005	20150421
ICD-487B-R202-V0-Z307005-D20150324	➤ Conformance Enhancements.	R307	005	20150421
ICD-487B-R201-V0-Z307005-D20130828	➤ Added support for 128 incoming GOOSE subscriptions, MMS authentication, and user-configurable GOOSE filtering.	R307	005	20131014
ICD-487B-R103-V0-Z302004-D20130828	➤ Modified the dead band for voltages from 10000 to 10.	R302	004	20150421
ICD-487B-R102-V0-Z002001-D20110810	➤ SEL-487B-1 initial ICD file release.	R302	004	20111107

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 4)

Date Code	Summary of Revisions
20250214	General ➤ Removed references to product literature DVD and firmware CD. Section 1 ➤ Updated *Specifications*. Section 10 ➤ Updated *Table 10.8: SEL-487B DNP3 Reference Data Map*. Appendix A ➤ Updated for firmware version R319. ➤ Updated for ICD file version R405.
20240927	Section 1 ➤ Changed *Object Penetration* to *Ingress Protection* and updated contents in *Specifications*.
20240509	Appendix A ➤ [Cybersecurity] Updated for firmware version R318-V1.
20231207	Section 1 ➤ Updated *Figure 1.1: SEL-487B Relay Basic Functions in a Double-Bus Application*. ➤ Updated *Models and Options* and *Specifications*. Section 4 ➤ Updated *Figure 4.11: Factory-Default Operator Control Pushbuttons*. Section 5 ➤ Updated *Figure 5.23: U.S. Curves U1, U2, U3, and U4* and *Figure 5.28: Open-Phase Detection*. Section 12 ➤ Updated *Table 12.2: Analog Quantities Sorted by Function*. Appendix A ➤ Updated for firmware version R318. ➤ Updated note in *SELBOOT*. ➤ Updated for ICD file version R404. Appendix B ➤ Updated *Table B.5: Serial DNP Basic Binary Input Reference Mapping*.
20230830	Appendix A ➤ Updated for firmware versions R311-V4, R312-V3, R313-V3, R314-V4, R315-V4, R316-V3, R317-V1.
20220630	Appendix A ➤ Updated for firmware versions R311-V3, R312-V2, R313-V2, R314-V3, R315-V3, and R316-V2.
20220523	Section 1 ➤ Updated *Figure 1.1: SEL-487B Relay Basic Functions in a Double-Bus Application*. ➤ Updated *Models and Options, Applications,* and *Specifications*. Section 2 ➤ Updated *Relay Sizes, Time-Domain Link,* and *Secondary Circuits*. ➤ Added *Hybrid (High-Current Interrupting) Control Outputs*. ➤ Updated *High-Speed, High-Current Interrupting Control Outputs, TiDL (EtherCAT) Connections,* and *Commissioning*.

Table A.4 Instruction Manual Revision History (Sheet 2 of 4)

Date Code	Summary of Revisions
	Section 5 ➤ Clarified notes regarding TiDL (EtherCAT) operating times. ➤ Updated *Polarity, Terminal Configurations,* and *Bus Coupler (Tie Breaker) Configurations*. **Section 6** ➤ Updated *Bus-Zone Configurations*. **Section 7** ➤ Added *COMTRADE Relay Word Bit Behavior*. **Section 8** ➤ Updated *Table 8.5: Station DC Monitor* and *Table 8.44: Inverse-Time Overcurrent Elements*. **Section 11** ➤ Updated *Table 11.2: Row List of Relay Word Bits*. **Appendix A** ➤ Updated for firmware version R317-V0. **Command Summary** ➤ Updated descriptions for *CFG CTNOM i* and *CFG NFREQ f*.
20211203	**Appendix A** ➤ Updated for firmware version R316-V1. ➤ Updated Summary of Revisions for ICD file version R403 in *Table A.3: ICD File Revision History*.
20210708	**Section 1** ➤ Updated *Specifications*.
20210514	**Section 1** ➤ Updated *Table 1.2: SEL-487B Relay Characteristics*. ➤ Updated *Specifications*. **Section 2** ➤ Updated *High-Speed, High-Current Interrupting Control Outputs*. **Section 5** ➤ Updated *Internal Fault Detection Logic, Selectable Time-Overcurrent Elements (51), Coupler Security Logic* and *Circuit Breaker Status Logic*. **Section 6** ➤ Updated *End-Zone Protection*, *Breaker Status Logic*, *End-Zone Protection* in *Application 2: Single Bus and Tie Breaker (Single Relay)*. ➤ Updated *Zone Configuration Group Settings* in *Application 4: Single Bus and Transfer Bus With Bus Coupler*. ➤ Updated *Zone Configuration Group Settings* and *Protection Group Settings* in *Application 7: Double and Transfer Bus (Outboard CTs)*. **Section 8** ➤ Added *Table 8.17: Access Controls*. **Section 10** ➤ Updated *Table 10.4: SEL-487B Database Structure—TARGET Region*, *Table 10.12: Logical Device: PRO (Protection)*, and *Table 10.13: Logical Device: MET (Metering)*. ➤ Added *Table 10.14: FLTYPE—Fault Type* and *Table 10.15: FLTCAUS—Fault Cause*. **Section 11** ➤ Updated *Table 11.1: Alphabetic 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 R316-V0. ➤ Updated for ICD version R403.

Table A.4 Instruction Manual Revision History (Sheet 3 of 4)

Date Code	Summary of Revisions
20210428	Appendix A ➤ Updated for firmware versions R315-V2.
20201204	Preface ➤ Updated *SEL-400 Series Relays Instruction Manual* and *Safety Marks*.
20201009	Appendix A ➤ Updated for firmware versions R312-V1, R313-V1, R314-V2, and R315-V1.
20200617	Section 2 ➤ Updated *Jumpers* for new BREAKER jumper description. Appendix A ➤ Updated for firmware version R315-V0.
20200229	Section 1 ➤ Updated *Specifications*. Section 10 ➤ Updated *Table 10.12: Logical Device: PRO (Protection)*, *Table 10.13: Logical Device: MET (Metering)*, and *Table 10.14: Logical Device: CON (Remote Control)*. Section 11 ➤ Updated *Table 11.1: Alphabetic List of Relay Word Bits* and *Table 11.2: Row List of Relay Word Bits* for SC850TM and SC850BM. Section 12 ➤ Updated *Table 12.1: Analog Quantities Sorted Alphabetically* and *Table 12.2: Analog Quantities Sorted by Function* for I850MOD. Appendix A ➤ Updated for firmware version R315. ➤ Updated for ICD file version R402.
20191210	Appendix A ➤ Updated for firmware version R314-V1.
20181210	Appendix A ➤ Updated for firmware version R314-V0.
20181115	Section 8 ➤ Added *Table 8.18: Open-Phase Logic*. Appendix A ➤ Updated for firmware version R314-V0. ➤ Updated for ICD file version R401.
20180105	Appendix A ➤ Updated for firmware version R313.
20171021	Appendix A ➤ Updated for firmware versions R310-V2 and R311-V2.
20171008	Section 10 ➤ Updated *Table 10.12 Logical Device: PRO (Protection)* and *Table 10.13 Logical Device: MET (Metering)*. Section 12 ➤ Updated *Table 12.1: Analog Quantities Sorted Alphabetically* and *Table 12.2: Analog Quantities Sorted by Function* for PRPMCC and PTPPORT. Appendix A ➤ Updated for firmware version R312. ➤ Updated for ICD file version R400.
20170820	Appendix A ➤ Updated for firmware versions R307-V1, R309-V3, and R310-V1.

Table A.4 Instruction Manual Revision History (Sheet 4 of 4)

Date Code	Summary of Revisions
20170809	Appendix A ➤ Updated for firmware version R311-V1.
20170428	Cover ➤ Updated copyright information. Section 1 ➤ Updated *Specifications*. Section 2 ➤ Updated *Figure 2.25: SEL-2243 Power Coupler*.
20170329	Section 1 ➤ Updated *Specifications*. Section 2 ➤ Removed *Figure 2.14: IRIG-B Terminating Resistors* and the *IRIG-B Jumper* section. ➤ Added *TiDL Connections*. Section 5 ➤ Updated *Selectable Time-Overcurrent Element (51)*. Section 6 ➤ Updated *Figure 6.15: Polarity Marks Above the Odd-Numbered CT Terminals at the Rear of the Relay*. Section 7 ➤ Updated *Table 7.12: Event Report Nonvolatile Storage Capability When ERDIG=S*. ➤ Added *Table 7.13: Event Report Nonvolatile Storage Capability When ERDIG=A*. Section 9 ➤ Added **CFG CTNOM** and **CFG NFREQ** to *Table 9.1: SEL-487E List of Commands*. Section 10 ➤ Updated *Table 10.15: Logical Device*. Section 11 ➤ Updated *Table 11.1: Alphabetic List of Relay Word Bits.* ➤ Updated *Table 11.2: Row List of Relay Word Bits*. Section 12 ➤ Updated *Table 12.2: Analog Quantities Sorted by Function*. Appendix A ➤ Updated for firmware version R311-V0. ➤ Updated for ICD file version R302. Command Summary ➤ Added **COM PTP**, **CFG CTNOM**, and **CFG NFREQ**.
20160718	➤ Initial version.

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APPENDIX B

Converting Settings From SEL-487B-0 to SEL-487B-1

Because of hardware changes and feature enhancements between the SEL-487B-0 and the SEL-487B-1 relays, the handling of a number of settings has changed. In particular, the replacement of the SEL-2702 Ethernet Processor with integrated Ethernet has significantly changed the handling of Ethernet-related settings. This appendix describes the key differences to aid users who need to convert their settings from an SEL-487B-0 to an SEL-487B-1.

Relay Word Bit Changes

Relay Word bits are used in SELOGIC control equations and many other settings. Some of these bits have different names or do not exist in the latest relay version. *Table B.1* lists these differences.

The SEL-487B-1 contains six pairs of under- and overvoltage elements. The input voltage for each pair is selectable using the 27O*n* and 59O*n* settings, where *n* = 1–6. Likewise, the input current for the time-overcurrent elements is selectable in the SEL-487B-1 using the 51O*qq* settings, where *qq* = 1–21.

Selections for these settings are listed in *Table B.1* to help match the 27, 59, and 51 Relay Word bits in the SEL-487B-1 to those in the SEL-487B-0.

Table B.1 Relay Word Bit Differences (Sheet 1 of 2)

SEL-487B-0 Relay Word Bit	Corresponding SEL-487B-1 Relay Word Bit	Comments
27P11	271P1	Assumes 27O1 = V01FIM
27P12	271P2	Assumes 27O1 = V01FIM
27P21	272P1	Assumes 27O2 = V02FIM
27P22	272P2	Assumes 27O2 = V02FIM
27P31	273P1	Assumes 27O3 = V03FIM
27P32	273P2	Assumes 27O3 = V03FIM
59P11	591P1	Assumes 59O1 = V01FIM
59P12	591P2	Assumes 59O1 = V01FIM
59P21	592P1	Assumes 59O2 = V02FIM
59P22	592P2	Assumes 59O2 = V02FIM
59P31	593P1	Assumes 59O3 = V03FIM
59P32	593P2	Assumes 59O3 = V03FIM
59PQ1	594P1	Assumes 59O4 = 3V2FIM
59PQ2	594P2	Assumes 59O4 = 3V2FIM

Table B.1 Relay Word Bit Differences (Sheet 2 of 2)

SEL-487B-0 Relay Word Bit	Corresponding SEL-487B-1 Relay Word Bit	Comments
59PN1	595P1	Assumes 59O5 = 3V0FIM
59PN2	595P2	Assumes 59O5 = 3V0FIM
51P01–51P18	51S01–51S18	Assumes 51O*xx*[a] = I*xx*FIM[a]
51P01T–5118T	51T01–51T18	Assumes 51O*xx*[a] = I*xx*FIM[a]
51P01R–51P18R	51R01–51R18	Assumes 51O*xx*[a] = I*xx*FIM[a]
CCALARM	--	No longer needed because of SEL-2702 removal.
CCOK	--	No longer needed because of SEL-2702 removal.
TESTDNP	TESTDB2	
CCIN001–CCIN128	VB001–VB128	
CCOUT01–CCOUT32	--	Any Relay Word bit may now be used for outgoing GOOSE.
CCSTA01–CCSTA32	--	No longer needed because of SEL-2702 removal. The previous bits provided communications card status information. New bits LINK5C, LINK5D, LNK-FAIL, P5CSEL, and P5DSEL have no direct correspondence to the previous bits, but provide status information about Ethernet connectivity.

[a] xx = 01–18.

Group Settings

The SEL-487B-1 includes settings for selecting the voltage and current inputs for the 27, 59, and 51 elements. In *Table B.2*, these settings are chosen to match the fixed input quantities in the SEL-487B-0.

Table B.2 Group Settings Differences (Sheet 1 of 2)

SEL-487B-0 Setting	SEL-487B-1 Setting	Notes
--	27O1 = V01FIM	This setting selects the voltage input for the first undervoltage pair. This was fixed at V01FIM in the SEL-487B-0.
27P11P	27P1P1	
27P12P	27P1P2	
--	27O2 = V02FIM	This setting selects the voltage input for the second undervoltage pair. This was fixed at V02FIM in the SEL-487B-0.
27P21P	27P2P1	
27P22P	27P2P2	
--	27O3 = V03FIM	This setting selects the voltage input for the third undervoltage pair. This was fixed at V03FIM in the SEL-487B-0.
27P31P	27P3P1	
27P32P	27P3P2	
--	59O1 = V01FIM	This setting selects the voltage input for the first overvoltage pair. This was fixed at V01FIM in the SEL-487B-0.
59P11P	59P1P1	
59P12P	59P1P2	
--	59O2 = V02FIM	This setting selects the voltage input for the second overvoltage pair. This was fixed at V02FIM in the SEL-487B-0.
59P21P	59P2P1	

Table B.2 Group Settings Differences (Sheet 2 of 2)

SEL-487B-0 Setting	SEL-487B-1 Setting	Notes
59P22P	59P2P2	
--	59O3 = V03FIM	This setting selects the voltage input for the third overvoltage pair. This was fixed at V03FIM in the SEL-487B-0.
59P31P	59P3P1	
59P32P	59P3P2	
--	59O4 = 3V2FIM	This setting selects the voltage input for the fourth overvoltage pair. This was fixed at 3V2FIM in the SEL-487B-0.
59Q1P	59P4P1	
59Q2P	59P4P2	
--	59O5 = 3V0FIM	This setting selects the voltage input for the fifth overvoltage pair. This was fixed at 3V0FIM in the SEL-487B-0.
59N1P	59P5P1	
59N2P	59P5P2	
--	51O01 = I01FIM	
51O02 = I02FIM		
. . .		
51O18 = I18FIM		These are 18 of the 21 settings used to select the current inputs for the time-overcurrent elements in the SEL-487B-1. These were fixed to the respective current terminal in the SEL-487B-0 (i.e., 51P01P used the I01 terminal).
51P01P–51P18P	51P01–51P18	
51P01C–51P18C	51C01–51C18	
51P01TD–51P18TD	51TD01–51TD18	
51P01RS–51P18RS	51RS01–51RS18	
51P01TC–51P18TC	51TC01–51TC18	

Port Settings Changes

Serial Port Settings

Table B.3 highlights key differences in the serial port settings between the SEL-487B-0 and the SEL-487B-1.

Table B.3 Serial Port Settings Differences

SEL-487B-0 Settings	SEL-487B-1 Setting	Notes
--	DNPCL	This is a new setting. It needs to be set to Y to enable control operations on a DNP port. In the SEL-487B-0, control was always enabled.

Ethernet Port (Port 5) Settings

In the SEL-487B-0, Ethernet was supplied by the SEL-2702 Ethernet Processor. In the SEL-487B-1, Ethernet is native to the relay, with the interfaces provided by the E4 daughter card. This has a significant effect on the settings, as described in *Table B.4*.

Table B.4 Ethernet Port Settings Differences (Sheet 1 of 2)

SEL-487B-0 Settings	SEL-487B-1 Setting	Notes
IPADDR SUBNETM	IPADDR	This setting now operates using CIDR rules, which consolidates the old SUBNETM setting into the IPADDR setting.
FAILOVER	NETMODE	FAILOVER of N is equivalent to a NETMODE of FIXED. FAILOVER of Y is equivalent to a NETMODE of FAILOVER. NETMODE also has a SWITCHED option, which enables both ports.
NETPORT	NETPORT	The old setting had choices of A, B, and D, for ports A, B, and to disable. The SEL-487B-1 setting has choices of C and D for ports C and D.
NETASPD	NETCSPD	
NETBSPD	NETDSPD	
HOST*n*	--	This setting no longer exists.
IPADR*n*	--	This setting no longer exists.
T1RECV	ETELNET	
T1CBAN	TCBAN	
T1INIT	--	This setting no longer exists.
T1PNUM	TPORT	
T2CBAN	--	The T2CBAN, T2RECV, and T2PNUM settings have been eliminated. They existed for access to the SEL-2702 local interface, which no longer exists.
T2RECV	--	
T2PNUM	--	
ENDNP	EDNP	While ENDNP was a Y, N selection, the EDNP setting in the SEL-487B-1 provides a range, from 0 to 6, for the number of DNP sessions you can enable.
DNPPNUM	DNPPNUM	The range is slightly more restrictive in the SEL-487B-1 implementation. The lowest assignable port is 1025.
DNPMAP	--	This setting has been eliminated. Maps are now always custom.
RPADR01–RPADR06	REPADR1–REPADR6	
RPADR07–RPADR10	--	This setting no longer exists; the SEL-487B-1 supports 6 sessions instead of the prior 10.
DNIP01–DNPIP06	DNPIP1–DNPIP6	
DNPIP07–DNPIP10	--	This setting no longer exists; now supports six sessions instead of the prior 10.
DNPTR01–DNPTR06	DNPTR1–DNPTR6	
DNPTR07–DNPTR10	--	This setting no longer exists; now supports six sessions instead of the prior 10.
DNPUP01–DNPUP06	DNPUDP1–DNPUDP6	The range is slightly more restrictive in the SEL-487B-1 implementation. The lowest assignable port is 1025.
DNPUP07–DNPUP10	--	This setting no longer exists; now supports six sessions instead of the prior 10.
UNSL01–UNSL06	UNSOL1–UNSOL6	
UNSL07–UNSL10	--	This setting no longer exists; now supports six sessions instead of the prior 10.
PUNSL01–PUNSL06	PUNSOL1–PUNSOL6	
PUNSL07–PUNSL10	--	No longer exist; now support six sessions instead of the prior 10.
DNPMP01–DNPMP06	DNPMAP1–DNPMAP6	

Table B.4 Ethernet Port Settings Differences (Sheet 2 of 2)

SEL-487B-0 Settings	SEL-487B-1 Setting	Notes
DNPMP07–DNPMP10	--	No longer exist; now support six sessions instead of the prior 10.
DNPCL01–DNPCL06	DNPCL1–DNPCL6	
DNPCL07–DNPCL10	--	No longer exist; now support six sessions instead of the prior 10.
ECLASSA	CLASSA1–CLASSA6	Old setting allowed 0–3. SEL-487B-1 setting has OFF, 1–3. Old setting 0 is equivalent to new setting OFF.
ECLASSB	CLASSB1–CLASSB6	Old setting allowed 0–3. SEL-487B-1 setting has OFF, 1–3. Old setting 0 is equivalent to new setting OFF.
ECLASSC	CLASSC1–CLASSC6	Old setting allowed 0–3. SEL-487B-1 setting has OFF, 1–3. Old setting 0 is equivalent to new setting OFF.
DECPL	DECPLA1–DECPLA6	
	DECPLV1–DECPLV6	
	DECPLM1–DECPLM6	
ANADB	ANADBA1–ANADBA6	
	ANADBV1–ANADBV6	
	ANADBM1–ANADBM6	
16BIT	AIVAR1–AIVAR6	The old setting allowed the choice between 16-bit and 32-bit variations. The SEL-487B-1 settings allow the choice between any of the six valid analog input variations. The old setting of 16 is equivalent to 2, and 32 is equivalent to 1.
STIMEO	STIMEO1–STIMEO6	The SEL-487B-1 settings accept integers only.
DNPPAIR	--	This setting no longer exists. Selection of paired controls is now a function of configuring the map.
DNPINA	DNPINA1–DNPINA6	
NUMEVE	NUMEVE1–NUMEVE6	
ETIMEO	ETIMEO1–ETIMEO6	
URETRY	URETRY1–URETRY6	
UTIMEO	UTIMEO1–UTIMEO6	

DNP3 Mapping Changes

DNP3 Settings Classes

In the SEL-487B-0 implementations of DNP3, there was one map for serial DNP3 (SETTINGS\SET_D1.TXT) and five maps for Ethernet DNP3 (SETTINGS\CARD\SET_DNP*n*.TXT, where *n* = 1–5). Now in the SEL-487B-1, there are simply five maps (SETTINGS\SET_D*n*.TXT, where *n* = 1–5) that can be used for serial or Ethernet DNP3.

Serial DNP3 Map Value Changes

The SEL-487B-0 serial DNP3 map was based on numeric references for all data. The SEL-487B-1 DNP3 mapping uses labels. The following tables show the relationships between the old numeric references and the labels.

Binary Inputs (MAPSEL = B)

Table B.5 lists the valid numeric references used when MAPSEL = B in the SEL-487B-0 with the equivalent label in the SEL-487B-1. Note that the numeric reference ranges 0–799 and 800–1599 are equivalent, the only difference being whether SER quality time-tags are used. In the SEL-487B-1, SER quality time-tags are always used, if available. If a bit does not appear in the table, then there is no equivalent in the SEL-487B-1.

Table B.5 Serial DNP Basic Binary Input Reference Mapping (Sheet 1 of 17)

Numeric Reference	Label Reference
6, 806	TRIPLED
7, 807	EN
8, 808	TLED_8
9, 809	TLED_7
10, 810	TLED_6
11, 811	TLED_5
12, 812	TLED_4
13, 813	TLED_3
14, 814	TLED_2
15, 815	TLED_1
16, 816	TLED_16
17, 817	TLED_15
18, 818	TLED_14
19, 819	TLED_13
20, 820	TLED_12
21, 821	TLED_11
22, 822	TLED_10
23, 823	TLED_9
24, 824	52A01
25, 825	52AL01
26, 826	52CL01
27, 827	52A02
28, 828	52AL02
29, 829	52CL02
30, 830	52A03
31, 831	52AL03
32, 832	52CL03
33, 833	52A04
34, 834	52AL04
35, 835	52CL04
36, 836	52A05
37, 837	52AL05
38, 838	52CL05
39, 839	52A06

Table B.5 Serial DNP Basic Binary Input Reference Mapping (Sheet 2 of 17)

Numeric Reference	Label Reference
40, 840	ZONE1
41, 841	ZONE2
42, 842	ZONE3
43, 843	ZONE4
44, 844	ZONE5
45, 845	ZONE6
48, 848	RZSWOAL
49, 849	ZSWO
50, 850	ZSWOIP
51, 851	ZSWOAL
56, 856	87ST1
57, 857	87ST2
58, 858	87ST3
59, 859	87ST4
60, 860	87ST5
61, 861	87ST6
62, 862	87ST
64, 864	CB52A1
65, 865	CB52T1
66, 866	CBCLS1
67, 867	CBCLST1
68, 868	ACTRP1
69, 869	ACTRPT1
70, 870	CSL1
72, 872	CB52A2
73, 873	CB52T2
74, 874	CBCLS2
75, 875	CBCLST2
76, 876	ACTRP2
77, 877	ACTRPT2
78, 878	CSL2
80, 880	TOS01
81, 881	TOS02
82, 882	TOS03
83, 883	TOS04
84, 884	TOS05
85, 885	TOS06
86, 886	TOS07
87, 887	TOS08
88, 888	TOS09
89, 889	TOS10

Table B.5 Serial DNP Basic Binary Input Reference Mapping (Sheet 3 of 17)

Numeric Reference	Label Reference
90, 890	TOS11
91, 891	TOS12
92, 892	TOS13
93, 893	TOS14
94, 894	TOS15
95, 895	TOS16
96, 896	TOS17
97, 897	TOS18
105, 905	CHSG
106, 906	SG1
107, 907	SG2
108, 908	SG3
109, 909	SG4
110, 910	SG5
111, 911	SG6
112, 912	RB32
113, 913	RB31
114, 914	RB30
115, 915	RB29
116, 916	RB28
117, 917	RB27
118, 918	RB26
119, 919	RB25
120, 920	RB24
121, 921	RB23
122, 922	RB22
123, 923	RB21
124, 924	RB20
125, 925	RB19
126, 926	RB18
127, 927	RB17
128, 928	RB16
129, 929	RB15
130, 930	RB14
131, 931	RB13
132, 932	RB12
133, 933	RB11
134, 934	RB10
135, 935	RB09
136, 936	RB08
137, 937	RB07

Table B.5 Serial DNP Basic Binary Input Reference Mapping (Sheet 4 of 17)

Numeric Reference	Label Reference
138, 938	RB06
139, 939	RB05
140, 940	RB04
141, 941	RB03
142, 942	RB02
143, 943	RB01
144, 944	IN101
145, 945	IN102
146, 946	IN103
147, 947	IN104
148, 948	IN105
149, 949	1N106
150, 950	IN107
152, 952	IN201
153, 953	IN202
154, 954	IN203
155, 955	IN204
156, 956	IN205
157, 957	IN206
158, 958	IN207
159, 959	IN208
160, 960	IN209
161, 961	IN210
162, 962	IN211
163, 963	IN212
164, 964	IN213
165, 965	IN214
166, 966	IN215
167, 967	IN216
168, 968	IN217
169, 969	IN218
170, 970	IN219
171, 971	IN220
172, 972	IN221
173, 973	IN222
174, 974	IN223
175, 975	IN224
176, 976	IN301
177, 977	IN302
178, 978	IN303
179, 979	IN304

Table B.5 Serial DNP Basic Binary Input Reference Mapping (Sheet 5 of 17)

Numeric Reference	Label Reference
180, 980	IN305
181, 981	IN306
182, 982	IN307
183, 983	IN308
184, 984	IN309
185, 985	IN310
186, 986	IN311
187, 987	IN312
188, 988	IN313
189, 989	IN314
190, 990	IN315
191, 991	IN316
192, 992	IN317
193, 993	IN318
194, 994	IN319
195, 995	IN320
196, 996	IN321
197, 997	IN322
198, 998	IN323
199, 999	IN324
200, 1000	IN401
201, 1001	IN402
202, 1002	IN403
203, 1003	IN404
204, 1004	IN405
205, 1005	IN406
206, 1006	IN407
207, 1007	IN408
208, 1008	IN409
209, 1009	IN410
210, 1010	IN411
211, 1011	IN412
212, 1012	IN413
213, 1013	IN414
214, 1014	IN415
215, 1015	IN416
216, 1016	IN417
217, 1017	IN418
218, 1018	IN419
219, 1019	IN420
220, 1020	IN421

Table B.5 Serial DNP Basic Binary Input Reference Mapping (Sheet 6 of 17)

Numeric Reference	Label Reference
221, 1021	IN422
222, 1022	IN423
223, 1023	IN424
224, 1024	IN501
225, 1025	IN502
226, 1026	IN503
227, 1027	IN504
228, 1028	IN505
229, 1029	IN506
230, 1030	IN507
231, 1031	IN508
232, 1032	IN509
233, 1033	IN510
234, 1034	IN511
235, 1035	IN512
236, 1036	IN513
237, 1037	IN514
238, 1038	IN515
239, 1039	IN516
240, 1040	IN517
241, 1041	IN518
242, 1042	IN519
243, 1043	IN520
244, 1044	IN521
245, 1045	IN522
246, 1046	IN523
247, 1047	IN524
248, 1048	PSV01
249, 1049	PSV02
250, 1050	PSV03
251, 1051	PSV04
252, 1052	PSV05
253, 1053	PSV06
254, 1054	PSV07
255, 1055	PSV08
256, 1056	PSV09
257, 1057	PSV10
258, 1058	PSV11
259, 1059	PSV12
260, 1060	PSV13
261, 1061	PSV14

Table B.5 Serial DNP Basic Binary Input Reference Mapping (Sheet 7 of 17)

Numeric Reference	Label Reference
262, 1062	PSV15
263, 1063	PSV16
264, 1064	PSV17
265, 1065	PSV18
266, 1066	PSV19
267, 1067	PSV20
268, 1068	PSV21
269, 1069	PSV22
270, 1070	PSV23
271, 1071	PSV24
272, 1072	PSV25
273, 1073	PSV26
274, 1074	PSV27
275, 1075	PSV28
276, 1076	PSV29
277, 1077	PSV30
278, 1078	PSV31
279, 1079	PSV32
280, 1080	PSV33
281, 1081	PSV34
282, 1082	PSV35
283, 1083	PSV36
284, 1084	PSV37
285, 1085	PSV38
286, 1086	PSV39
287, 1087	PSV40
288, 1088	PSV41
289, 1089	PSV42
290, 1090	PSV43
291, 1091	PSV44
292, 1092	PSV45
293, 1093	PSV46
294, 1094	PSV47
295, 1095	PSV48
296, 1096	PSV49
297, 1097	PSV50
298, 1098	PSV51
299, 1099	PSV52
300, 1100	PSV53
301, 1101	PSV54
302, 1102	PSV55

Table B.5 Serial DNP Basic Binary Input Reference Mapping (Sheet 8 of 17)

Numeric Reference	Label Reference
303, 1103	PSV56
304, 1104	PSV57
305, 1105	PSV58
306, 1106	PSV59
307, 1107	PSV60
308, 1108	PSV61
309, 1109	PSV62
310, 1110	PSV63
311, 1111	PSV64
312, 1112	PLT01
313, 1113	PLT02
314, 1114	PLT03
315, 1115	PLT04
316, 1116	PLT05
317, 1117	PLT06
318, 1118	PLT07
319, 1119	PLT08
320, 1120	PLT09
321, 1121	PLT10
322, 1122	PLT11
323, 1123	PLT12
324, 1124	PLT13
325, 1125	PLT14
326, 1126	PLT15
327, 1127	PLT16
328, 1128	PCT01Q
329, 1129	PCT02Q
330, 1130	PCT03Q
331, 1131	PCT04Q
332, 1132	PCT05Q
333, 1133	PCT06Q
334, 1134	PCT07Q
335, 1135	PCT08Q
336, 1136	PCT09Q
337, 1137	PCT10Q
338, 1138	PCT11Q
339, 1139	PCT12Q
340, 1140	PCT13Q
341, 1141	PCT14Q
342, 1142	PCT15Q
343, 1143	PCT16Q

Table B.5 Serial DNP Basic Binary Input Reference Mapping (Sheet 9 of 17)

Numeric Reference	Label Reference
344, 1144	PST01Q
345, 1145	PST02Q
346, 1146	PST03Q
347, 1147	PST04Q
348, 1148	PST05Q
349, 1149	PST06Q
350, 1150	PST07Q
351, 1151	PST08Q
352, 1152	PST09Q
353, 1153	PST10Q
354, 1154	PST11Q
355, 1155	PST12Q
356, 1156	PST13Q
357, 1157	PST14Q
358, 1158	PST15Q
359, 1159	PST16Q
360, 1160	PCN01Q
361, 1161	PCN02Q
362, 1162	PCN03Q
363, 1163	PCN04Q
364, 1164	PCN05Q
365, 1165	PCN06Q
366, 1166	PCN07Q
367, 1167	PCN08Q
368, 1168	PCN09Q
369, 1169	PCN10Q
370, 1170	PCN11Q
371, 1171	PCN12Q
372, 1172	PCN13Q
373, 1173	PCN14Q
374, 1174	PCN15Q
375, 1175	PCN16Q
376, 1176	ASV001
377, 1177	ASV002
378, 1178	ASV003
379, 1179	ASV004
380, 1180	ASV005
381, 1181	ASV006
382, 1182	ASV007
383, 1183	ASV008
384, 1184	ASV009

Table B.5 Serial DNP Basic Binary Input Reference Mapping (Sheet 10 of 17)

Numeric Reference	Label Reference
385, 1185	ASV010
386, 1186	ASV011
387, 1187	ASV012
388, 1188	ASV013
389, 1189	ASV014
390, 1190	ASV015
391, 1191	ASV016
392, 1192	ASV017
393, 1193	ASV018
394, 1194	ASV019
395, 1195	ASV020
396, 1196	ASV021
397, 1197	ASV022
398, 1198	ASV023
399, 1199	ASV024
400, 1200	ASV025
401, 1201	ASV026
402, 1202	ASV027
403, 1203	ASV028
404, 1204	ASV029
405, 1205	ASV030
406, 1206	ASV031
407, 1207	ASV032
408, 1208	ASV033
409, 1209	ASV034
410, 1210	ASV035
411, 1211	ASV036
412, 1212	ASV037
413, 1213	ASV038
414, 1214	ASV039
415, 1215	ASV040
416, 1216	ASV041
417, 1217	ASV042
418, 1218	ASV043
419, 1219	ASV044
420, 1220	ASV045
421, 1221	ASV046
422, 1222	ASV047
423, 1223	ASV048
424, 1224	ASV049
425, 1225	ASV050

Table B.5 Serial DNP Basic Binary Input Reference Mapping (Sheet 11 of 17)

Numeric Reference	Label Reference
426, 1226	ASV051
427, 1227	ASV052
428, 1228	ASV053
429, 1229	ASV054
430, 1230	ASV055
431, 1231	ASV056
432, 1232	ASV057
433, 1233	ASV058
434, 1234	ASV059
435, 1235	ASV060
436, 1236	ASV061
437, 1237	ASV062
438, 1238	ASV063
439, 1239	ASV064
440, 1240	ALT01
441, 1241	ALT02
442, 1242	ALT03
443, 1243	ALT04
444, 1244	ALT05
445, 1245	ALT06
446, 1246	ALT07
447, 1247	ALT08
448, 1248	ALT09
449, 1249	ALT10
450, 1250	ALT11
451, 1251	ALT12
452, 1252	ALT13
453, 1253	ALT14
454, 1254	ALT15
455, 1255	ALT16
456, 1256	AST01Q
457, 1257	AST02Q
458, 1258	AST03Q
459, 1259	AST04Q
460, 1260	AST05Q
461, 1261	AST06Q
462, 1262	AST07Q
463, 1263	AST08Q
464, 1264	AST09Q
465, 1265	AST10Q
466, 1266	AST11Q

Table B.5 Serial DNP Basic Binary Input Reference Mapping (Sheet 12 of 17)

Numeric Reference	Label Reference
467, 1267	AST12Q
468, 1268	AST13Q
469, 1269	AST14Q
470, 1270	AST15Q
471, 1271	AST16Q
472, 1272	ACN01Q
473, 1273	ACN02Q
474, 1274	ACN03Q
475, 1275	ACN04Q
476, 1276	ACN05Q
477, 1277	ACN06Q
478, 1278	ACN07Q
479, 1279	ACN08Q
480, 1280	ACN09Q
481, 1281	ACN10Q
482, 1282	ACN11Q
483, 1283	ACN12Q
484, 1284	ACN13Q
485, 1285	ACN14Q
486, 1286	ACN15Q
487, 1287	ACN16Q
493, 1293	MATHERR
494, 1294	PFRTEX
495, 1295	PUNRLBL
501, 1301	AFRTEXA
502, 1302	AFRTEXP
503, 1303	AUNRLBL
508, 1308	CCALARM
509, 1309	BADPASS
510, 1310	HALARM
511, 1311	SALARM
516, 1316	TUPDH
517, 1317	TIRIG
520, 1320	OUT101
521, 1321	OUT102
522, 1322	OUT103
523, 1323	OUT104
524, 1324	OUT105
525, 1325	OUT106
526, 1326	OUT107
527, 1327	OUT108

Table B.5 Serial DNP Basic Binary Input Reference Mapping (Sheet 13 of 17)

Numeric Reference	Label Reference
528, 1328	OUT201
529, 1329	OUT202
530, 1330	OUT203
531, 1331	OUT204
532, 1332	OUT205
533, 1333	OUT206
534, 1334	OUT207
535, 1335	OUT208
536, 1336	OUT301
537, 1337	OUT302
538, 1338	OUT303
539, 1339	OUT304
540, 1340	OUT305
541, 1341	OUT306
542, 1342	OUT307
543, 1343	OUT308
544, 1344	OUT401
545, 1345	OUT402
546, 1346	OUT403
547, 1347	OUT404
548, 1348	OUT405
549, 1349	OUT406
550, 1350	OUT407
551, 1351	OUT408
552, 1352	OUT501
553, 1353	OUT502
554, 1354	OUT503
555, 1355	OUT504
556, 1356	OUT505
557, 1357	OUT506
558, 1358	OUT507
559, 1359	OUT508
560, 1360	PB8_LED
561, 1361	PB7_LED
562, 1362	PB6_LED
563, 1363	PB5_LED
564, 1364	PB4_LED
565, 1365	PB3_LED
566, 1366	PB2_LED
567, 1367	PB1_LED
568, 1368	RMB1A

Table B.5 Serial DNP Basic Binary Input Reference Mapping (Sheet 14 of 17)

Numeric Reference	Label Reference
569, 1369	RMB2A
570, 1370	RMB3A
571, 1371	RMB4A
572, 1372	RMB5A
573, 1373	RMB6A
574, 1374	RMB7A
575, 1375	RMB8A
576, 1376	TMB1A
577, 1377	TMB2A
578, 1378	TMB3A
579, 1379	TMB4A
580, 1380	TMB5A
581, 1381	TMB6A
582, 1382	TMB7A
583, 1383	TMB8A
584, 1384	RMB1B
585, 1385	RMB2B
586, 1386	RMB3B
587, 1387	RMB4B
588, 1388	RMB5B
589, 1389	RMB6B
590, 1390	RMB7B
591, 1391	RMB8B
592, 1392	TMB1B
593, 1393	TMB2B
594, 1394	TMB3B
595, 1395	TMB4B
596, 1396	TMB5B
597, 1397	TMB6B
598, 1398	TMB7B
599, 1399	TMB8B
602, 1402	DOKA
603, 1403	ANOKA
604, 1404	LBOKA
605, 1405	CBADA
606, 1406	RBADA
607, 1407	ROKA
610, 1410	DOKB
611, 1411	ANOKB
612, 1412	LBOKB
613, 1413	CBADB

Table B.5 Serial DNP Basic Binary Input Reference Mapping (Sheet 15 of 17)

Numeric Reference	Label Reference
614, 1414	RBADB
615, 1415	ROKB
620, 1420	TESTPUL
621, 1421	TESTFM
622, 1422	TESTDB
623, 1423	TESTDB2
624, 1424	VB32
625, 1425	VB31
626, 1426	VB30
627, 1427	VB29
628, 1428	VB28
629, 1429	VB27
630, 1430	VB26
631, 1431	VB25
632, 1432	VB24
633, 1433	VB23
634, 1434	VB22
635, 1435	VB21
636, 1436	VB20
637, 1437	VB19
638, 1438	VB18
639, 1439	VB17
640, 1440	VB16
641, 1441	VB15
642, 1442	VB14
643, 1443	VB13
644, 1444	VB12
645, 1445	VB11
646, 1446	VB10
647, 1447	VB09
648, 1448	VB08
649, 1449	VB07
650, 1450	VB06
651, 1451	VB05
652, 1452	VB04
653, 1453	VB03
654, 1454	VB02
655, 1455	VB01
724, 1524	FSERPF
725, 1525	FSERP3
726, 1526	FSERP2

Table B.5 Serial DNP Basic Binary Input Reference Mapping (Sheet 16 of 17)

Numeric Reference	Label Reference
727, 1527	FSERP1
728, 1528	CZONE1
736, 1536	87CZ1
744, 1544	87STCZ1
752, 1552	TLED_24
753, 1553	TLED_23
754, 1554	TLED_22
755, 1555	TLED_21
756, 1556	TLED_20
757, 1557	TLED_19
758, 1558	TLED_18
759, 1559	TLED_17
764, 1564	PB12LED
765, 1565	PB11LED
766, 1566	PB10LED
767, 1567	PB9_LED
1600	TLED_8
1601	TLED_7
1602	TLED_6
1603	TLED_5
1604	TLED_4
1605	TLED_3
1606	TLED_2
1607	TLED_1
1608	TLED_16
1609	TLED_15
1610	TLED_14
1611	TLED_13
1612	TLED_12
1613	TLED_11
1614	TLED_10
1615	TLED_9
1616	RLYDIS
1617	STFAIL
1618	STWARN
1619	UNRDEV
1620	STSET
1624	TLED_24
1625	TLED_23
1626	TLED_22
1627	TLED_21

Table B.5 Serial DNP Basic Binary Input Reference Mapping (Sheet 17 of 17)

Numeric Reference	Label Reference
1628	TLED_20
1629	TLED_19
1630	TLED_18
1631	TLED_17

Binary Inputs (MAPSEL = E)

Table B.6 lists the mapping for Binary Input points when MAPSEL = E on the SEL-487B-0.

Table B.6 Serial DNP Extended Map Binary Input Point Mapping

Numeric Reference	Label Reference	Notes
0	RLYDIS	
1	STFAIL	
2	STWARN	
3	UNRDEV	
4	STSET	
16–265	See below	
272 and above	See below	

References 16–265 do not have a good equivalent, because they were dependent on the SER settings.

References 266–271 are reserved so they have no equivalent mapping.

References 272 and above simply map to the SEL-487B-0 Relay Word, starting at bit 0. To find the label equivalent for these points, subtract 272 from the reference to get the bit number and then find the bit within *Section 11: Relay Word Bits*. You can then use that bit label in the SEL-487B-1 DNP3 map, except as noted in *Table B.1*.

Binary Outputs

Table B.7 Serial DNP3 Binary Outputs Point Mapping (Sheet 1 of 3)

Numeric Reference	Label Reference	Notes
0	RB01	
1	RB02	
2	RB03	
3	RB04	
4	RB05	
5	RB06	
6	RB07	
7	RB08	
8	RB09	
9	RB10	
10	RB11	

Table B.7 Serial DNP3 Binary Outputs Point Mapping (Sheet 2 of 3)

Numeric Reference	Label Reference	Notes
11	RB12	
12	RB13	
13	RB14	
14	RB15	
15	RB16	
16	OC1	
18	OC2	
20	OC3	
22	OC4	
24	RB01:RB02	
25	RB03:RB04	
26	RB05:RB06	
27	RB07:RB08	
28	RB09:RB10	
29	RB11:RB12	
30	RB13:RB14	
31	RB15:RB16	
32	OC1:0	Open “pair” for Circuit Breaker 1
33	OC2:0	Open “pair” for Circuit Breaker 2
34	OC3:0	Open “pair” for Circuit Breaker 3
35	OC4:0	Open “pair” for Circuit Breaker 4
40	RSTTRGT	
41	NXTEVE	
44	RB17	
45	RB18	
46	RB19	
47	RB20	
48	RB21	
49	RB22	
50	RB23	
51	RB24	
52	RB25	
53	RB26	
54	RB27	
55	RB28	
56	RB29	
57	RB30	
58	RB31	
59	RB32	
60	RB17:RB18	
61	RB19:RB20	

Table B.7 Serial DNP3 Binary Outputs Point Mapping (Sheet 3 of 3)

Numeric Reference	Label Reference	Notes
62	RB21:RB22	
63	RB23:RB24	
64	RB25:RB26	
65	RB27:RB28	
66	RB29:RB30	
67	RB31:RB32	
68	OC5	
70	OC6	
72	OC7	
74	OC8	
76	OC9	
78	OC10	
80	OC11	
82	OC12	
84	OC13	
86	OC14	
88	OC15	
90	OC16	
92	OC17	
94	OC18	
108	OC5:0	Open “pair” for Circuit Breaker 5
109	OC6:0	Open “pair” for Circuit Breaker 6
110	OC7:0	Open “pair” for Circuit Breaker 7
111	OC8:0	Open “pair” for Circuit Breaker 8
112	OC9:0	Open “pair” for Circuit Breaker 9
113	OC10:0	Open “pair” for Circuit Breaker 10
114	OC11:0	Open “pair” for Circuit Breaker 11
115	OC12:0	Open “pair” for Circuit Breaker 12
116	OC13:0	Open “pair” for Circuit Breaker 13
117	OC14:0	Open “pair” for Circuit Breaker 14
118	OC15:0	Open “pair” for Circuit Breaker 15
119	OC16:0	Open “pair” for Circuit Breaker 16
120	OC17:0	Open “pair” for Circuit Breaker 17
121	OC18:0	Open “pair” for Circuit Breaker 18

Counters

Table B.8 Serial DNP3 Counters Point Mapping

Numeric Reference	Label Reference
0	ACTGRP

Analog Inputs

Table B.9 Serial DNP3 Analog Inputs Point Mapping (Sheet 1 of 3)

Numeric Reference	Label Reference	Notes
0	I01FM	
1	I01FA	
2	I02FM	
3	I02FA	
4	I03FM	
5	I03FA	
6	I04FM	
7	I04FA	
8	I05FM	
9	I05FA	
10	I06FM	
11	I06FA	
12	I07FM	
13	I07FA	
14	I08FM	
15	I08FA	
16	I09FM	
17	I09FA	
18	I10FM	
19	I10FA	
20	I11FM	
21	I11FA	
22	I12FM	
23	I12FA	
24	I13FM	
25	I13FA	
26	I14FM	
27	I14FA	
28	I15FM	
29	I15FA	
30	I16FM	
31	I16FA	
32	I17FM	
33	I17FA	
34	I18FM	
35	I18FA	
48	V01FA	
49	V01FM	
50	V02FA	

Table B.9 Serial DNP3 Analog Inputs Point Mapping (Sheet 2 of 3)

Numeric Reference	Label Reference	Notes
51	V02FM	
52	V03FA	
53	V03FM	
60	IOP1	
61	IOP2	
62	IOP3	
63	IOP4	
64	IOP5	
65	IOP6	
68	IRT1	
69	IRT2	
70	IRT3	
71	IRT4	
72	IRT5	
73	IRT6	
76	IOPCZ1	
79	IRTCZ1	
100	VDC1	
176	FTYPE	
177	FTAR1	
178	FTAR2	
181	FGRP	
184	FIMEUH	UTC Time high byte
185	FTIMEUM	UTC Time middle byte
186	FTIMEUL	UTC Time low byte
196	AMV001	
197	AMV002	
198	AMV003	
199	AMV004	
200	AMV005	
201	AMV006	
202	AMV007	
203	AMV008	
204	AMV009	
205	AMV010	
206	AMV011	
207	AMV012	
208	AMV013	
209	AMV014	
210	AMV015	
211	AMV016	

Table B.9 Serial DNP3 Analog Inputs Point Mapping (Sheet 3 of 3)

Numeric Reference	Label Reference	Notes
212	AMV017	
213	AMV018	
214	AMV019	
215	AMV020	
216	AMV021	
217	AMV022	
218	AMV023	
219	AMV024	
220	AMV025	
221	AMV026	
222	AMV027	
223	AMV028	
224	AMV029	
225	AMV030	
226	AMV031	
227	AMV032	

Analog Outputs

Table B.10 Serial DNP Analog Output Point Mapping

Numeric Reference	Label Reference
0	ACTGRP

Ethernet DNP3 Map Value Changes

The SEL-487B-0 Ethernet DNP3 map was based on database references. The SEL-487B-1 DNP3 mapping uses direct data labels. The following sections describe how to get from this database mapping to the new direct data labels.

Binary Inputs

In the SEL-487B-0 mapping, any bit in the database could be referenced for use by DNP3 LAN/WAN. Now, only Relay Word bits and a few other special bits can be used. The SEL-487B-0 reference format looked like 1:addr:bit. If addr is 3004h or greater, but not greater than 4000h, then the bits can be associated with the SEL-487B-0 Relay Word. Address 3004h corresponds to Relay Word 0, 3005h to row 1, etc. The bits are simply references in the range 0–7 and match the bits within the Relay Word row. Thus the Relay Word bits can be mapped to labels by using the comparing the SEL-487B-0 Relay Word to the SEL-487B-1 Relay Word.

Table B.11 provides reference addresses and corresponding bit labels for the SEL-487B-0 Relay Word. Consult *Table B.1* for any Relay Word changes.

Binary Outputs

In the SEL-487B-0, indices 0–127 were used to map the CCIN bits. These were general-purpose, high-speed bits, but they are no longer available in the SEL-487B-1. The equivalent in the SEL-487B-1 is the VB bits. The end user will need to remap these to remote bits.

Table B.11 describes the mapping for the Binary Outputs.

Table B.11 Ethernet DNP Binary Output Point Mapping (Sheet 1 of 8)

Numeric Reference (CPId)	Label Reference
0	VB001
1	VB002
2	VB003
3	VB004
4	VB005
5	VB006
6	VB007
7	VB008
8	VB009
9	VB010
10	VB011
11	VB012
12	VB013
13	VB014
14	VB015
15	VB016
16	VB017
17	VB018
18	VB019
19	VB020
20	VB021
21	VB022
22	VB023
23	VB024
24	VB025
25	VB026
26	VB027
27	VB028
28	VB029
29	VB030
30	VB031
31	VB032
32	VB033
33	VB034

Table B.11 Ethernet DNP Binary Output Point Mapping (Sheet 2 of 8)

Numeric Reference (CPId)	Label Reference
34	VB035
35	VB036
36	VB037
37	VB038
38	VB039
39	VB040
40	VB041
41	VB042
42	VB043
43	VB044
44	VB045
45	VB046
46	VB047
47	VB048
48	VB049
49	VB050
50	VB051
51	VB052
52	VB053
53	VB054
54	VB055
55	VB056
56	VB057
57	VB058
58	VB059
59	VB060
60	VB061
61	VB062
62	VB063
63	VB064
64	VB065
65	VB066
66	VB067
67	VB068
68	VB069
69	VB070
70	VB071
71	VB072
72	VB073
73	VB074
74	VB075

Table B.11 Ethernet DNP Binary Output Point Mapping (Sheet 3 of 8)

Numeric Reference (CPId)	Label Reference
75	VB076
76	VB077
77	VB078
78	VB079
79	VB080
80	VB081
81	VB082
82	VB083
83	VB084
84	VB085
85	VB086
86	VB087
87	VB088
88	VB089
89	VB090
90	VB091
91	VB092
92	VB093
93	VB094
94	VB095
95	VB096
96	VB097
97	VB098
98	VB099
99	VB100
100	VB101
101	VB102
102	VB103
103	VB104
104	VB105
105	VB106
106	VB107
107	VB108
108	VB109
109	VB110
110	VB111
111	VB112
112	VB113
113	VB114
114	VB115
115	VB116

Table B.11 Ethernet DNP Binary Output Point Mapping (Sheet 4 of 8)

Numeric Reference (CPId)	Label Reference
116	VB117
117	VB118
118	VB119
119	VB120
120	VB121
121	VB122
122	VB123
123	VB124
124	VB125
125	VB126
126	VB127
127	VB128
128	RB01
129	RB02
130	RB03
131	RB04
132	RB05
133	RB06
134	RB07
135	RB08
136	RB09
137	RB10
138	RB11
139	RB12
140	RB13
141	RB14
142	RB15
143	RB16
144	RB17
145	RB18
146	RB19
147	RB20
148	RB21
149	RB22
150	RB23
151	RB24
152	RB25
153	RB26
154	RB27
155	RB28
156	RB29

Table B.11 Ethernet DNP Binary Output Point Mapping (Sheet 5 of 8)

Numeric Reference (CPId)	Label Reference
157	RB30
158	RB31
159	RB32
160	RB33
161	RB34
162	RB35
163	RB36
164	RB37
165	RB38
166	RB39
167	RB40
168	RB41
169	RB42
170	RB43
171	RB44
172	RB45
173	RB46
174	RB47
175	RB48
176	RB49
177	RB50
178	RB51
179	RB52
180	RB53
181	RB54
182	RB55
183	RB56
184	RB57
185	RB58
186	RB59
187	RB60
188	RB61
189	RB62
190	RB63
191	RB64
192	RB65
193	RB66
194	RB67
195	RB68
196	RB69
197	RB70

Table B.11 Ethernet DNP Binary Output Point Mapping (Sheet 6 of 8)

Numeric Reference (CPId)	Label Reference
198	RB71
199	RB72
200	RB73
201	RB74
202	RB75
203	RB76
204	RB77
205	RB78
206	RB79
207	RB80
208	RB81
209	RB82
210	RB83
211	RB84
212	RB85
213	RB86
214	RB87
215	RB88
216	RB89
217	RB90
218	RB91
219	RB92
220	RB93
221	RB94
222	RB95
223	RB96
224	RB01:RB02
225	RB03:RB04
226	RB05:RB06
227	RB07:RB08
228	RB09:RB10
229	RB11:RB12
230	RB13:RB14
231	RB15:RB16
232	RB17:RB18
233	RB19:RB20
234	RB21:RB22
235	RB23:RB24
236	RB25:RB26
237	RB27:RB28
238	RB29:RB30

Table B.11 Ethernet DNP Binary Output Point Mapping (Sheet 7 of 8)

Numeric Reference (CPId)	Label Reference
239	RB31:RB32
240	RB33:RB34
241	RB35:RB36
242	RB37:RB38
243	RB39:RB40
244	RB41:RB42
245	RB43:RB44
246	RB45:RB46
247	RB47:RB48
248	RB49:RB50
249	RB51:RB52
250	RB53:RB54
251	RB55:RB56
252	RB57:RB58
253	RB59:RB60
254	RB61:RB62
255	RB63:RB64
256	RB65:RB66
257	RB67:RB68
258	RB69:RB70
259	RB71:RB72
260	RB73:RB74
261	RB75:RB76
262	RB77:RB78
263	RB79:RB80
264	RB81:RB82
265	RB83:RB84
266	RB85:RB86
267	RB87:RB88
268	RB89:RB90
269	RB91:RB92
270	RB93:RB94
271	RB95:RB96
272	OC1
273	OC2
274	OC3
275	OC4
276	OC5
277	OC6
278	OC7
279	OC8

Table B.11 Ethernet DNP Binary Output Point Mapping (Sheet 8 of 8)

Numeric Reference (CPId)	Label Reference
280	OC9
281	OC10
282	OC11
283	OC12
284	OC13
285	OC14
286	OC15
287	OC16
288	OC17
289	OC18

Counters

In the SEL-487B-0, counters were referenced as points in the database. There is no direct equivalent in the SEL-487B-1, so this will need to be analyzed to determine the appropriate counter mapping.

Analog Inputs

In the SEL-487B-0, analog inputs were referenced as points in the database with optional "treat as" qualifiers and with per-point class selection. There is no direct equivalent in the SEL-487B-1, so this will need to be analyzed to determine the appropriate analog input mapping.

Table B.12 provides reference addresses and corresponding labels for the SEL-487B-0 METER database region.

Table B.12 Meter Database Labels and Addresses (Sheet 1 of 3)

Address	Label Reference
1004h	FREQ
1006h	VDC
1008h	I01FIM
100ah	I01FIA
100ch	I02FIM
100eh	I02FIA
1010h	I03FIM
1012h	I03FIA
1014h	I04FIM
1016h	I04FIA
1018h	I05FIM
101ah	I05FIA
101ch	I06FIM
101eh	I06FIA
1020h	I07FIM

Table B.12 Meter Database Labels and Addresses (Sheet 2 of 3)

Address	Label Reference
1022h	I07FIA
1024h	I08FIM
1026h	I08FIA
1028h	I09FIM
102ah	I09FIA
102ch	I10FIM
102eh	I10FIA
1030h	I11FIM
1032h	I11FIA
1034h	I12FIM
1036h	I12FIA
1038h	I13FIM
103ah	I13FIA
103ch	I14FIM
103eh	I14FIA
1040h	I15FIM
1042h	I15FIA
1044h	I16FIM
1046h	I16FIA
1048h	I17FIM
104ah	I17FIA
104ch	I18FIM
104eh	I18FIA
1068h	V01FIM
106ah	V01FIA
106ch	V02FIM
106eh	V02FIA
1070h	V03FIM
1072h	V03FIA
1080h	IOP1
1082h	IOP2
1084h	IOP3
1086h	IOP4
1088h	IOP5
108ah	IOP6
108ch	IRT1
108eh	IRT2
1090h	IRT3
1092h	IRT4
1094h	IRT5
1096h	IRT6

Table B.12 Meter Database Labels and Addresses (Sheet 3 of 3)

Address	Label Reference
1098h	IOPCZ1
109ah	IRTCZ1

Analog Outputs

In the SEL-487B-0, analog outputs were referenced by index (0–255). These mapped to remote analogs (RA001–RA256). In the SEL-487B-1, these same remote analogs are available. So if Index 0 was referenced in the SEL-487B-0 DNP3 map, the SEL-487B-1 DNP3 reference is RA001. Similarly index 1 goes to RA002, etc.

IEC 61850 Object Changes

The SEL-487B-0 implementation of the IEC 61850 protocol suite differs slightly from the SEL-487B-1 implementation. *Table B.13* lists the main functional changes between the two.

Table B.13 IEC 61850 Functional Differences

Topic	SEL-487B-0	SEL-487B-1
ICD File Version	Version 002	Version 004
Incoming GOOSE	Mappable to CCIN001–CCIN128 (binary data)	VB001–VB256 (binary data) and RA001–RA128 (analog data)
Outgoing GOOSE	Relay Word Bits mapped to CCOUT001 (binary data)	N/A (Relay Word bits can be sent directly without intermediate mapping; Analog outputs RAO01–RAO64 also available)
SER Timestamps	SER-quality timestamps available only for LNs included in the SER dataset (not editable)	Any points in the SER list (SET R) will have SER-quality time stamps. Otherwise, accuracy is within 500 ms of relay time.
Controls	Direct operate with normal security only	Direct operate with enhanced security and select-before operate (SBO) with enhanced security is also available.

Default datasets may be used for MMS Reports or for GOOSE message transmission. *Table B.14* lists the default dataset changes in the new ICD file version. Note that the contents of any data set may be modified via ACSELERATOR Architect SEL-5032 Software.

Table B.14 Default Dataset Differences

Default Dataset	SEL-487B-0	SEL-487B-1
DSet06, DSet12	Includes CCIN001–CCIN016	Includes VB001–VB016 instead
DSet13	CCOUT01–COUT08 Status	VB001–VB008 Status
SER1	List of LNs that have SER-quality time stamps (informational only, not editable)	N/A (Any point in the SER list will have SER-quality time stamps)

Most of the Logical Nodes and Attributes remain the same between the two implementations. *Table B.15* lists the mapping changes in the new ICD file.

Table B.15 Logical Node and Mapping Differences (Sheet 1 of 4)

LD	487B-0		487B-1	
	Path	Mapping	Path (If Different)	Mapping
PRO	T87CZPTRC25Trgeneral	87CZ1	NA	NA
PRO	BKRCSWI1PosOper$ctlVal	1:CONTROL:BR01		OC01:NOOP
PRO	BKRCSWI2PosOper$ctlVal	1:CONTROL:BR02		OC02:NOOP
PRO	BKRCSWI3PosOper$ctlVal	1:CONTROL:BR03		OC03:NOOP
PRO	BKRCSWI4PosOper$ctlVal	1:CONTROL:BR04		OC04:NOOP
PRO	BKRCSWI5PosOper$ctlVal	1:CONTROL:BR05		OC05:NOOP
PRO	BKRCSWI6PosOper$ctlVal	1:CONTROL:BR06		OC06:NOOP
PRO	BKRCSWI7PosOper$ctlVal	1:CONTROL:BR07		OC07:NOOP
PRO	BKRCSWI8PosOper$ctlVal	1:CONTROL:BR08		OC08:NOOP
PRO	BKRCSWI9PosOper$ctlVal	1:CONTROL:BR09		OC09:NOOP
PRO	BKRCSWI10PosOper$ctlVal	1:CONTROL:BR010		OC10:NOOP
PRO	BKRCSWI11PosOper$ctlVal	1:CONTROL:BR11		OC11:NOOP
PRO	BKRCSWI12PosOper$ctlVal	1:CONTROL:BR12		OC12:NOOP
PRO	BKRCSWI13PosOper$ctlVal	1:CONTROL:BR13		OC13:NOOP
PRO	BKRCSWI14PosOper$ctlVal	1:CONTROL:BR14		OC14:NOOP
PRO	BKRCSWI15PosOper$ctlVal	1:CONTROL:BR15		OC15:NOOP
PRO	BKRCSWI16PosOper$ctlVal	1:CONTROL:BR16		OC16:NOOP
PRO	BKRCSWI17PosOper$ctlVal	1:CONTROL:BR17		OC17:NOOP
PRO	BKRCSWI18PosOper$ctlVal	1:CONTROL:BR18		OC18:NOOP
MET	METMMXN1$Amp01$Mag$f	1:METER:I01[0]		I01FM
MET	METMMXN1$Amp02$Mag$f	1:METER:I02[0]		I02FM
MET	METMMXN1$Amp03$Mag$f	1:METER:I03[0]		I03FM
MET	METMMXN1$Amp04$Mag$f	1:METER:I04[0]		I04FM
MET	METMMXN1$Amp05$Mag$f	1:METER:I05[0]		I05FM
MET	METMMXN1$Amp06$Mag$f	1:METER:I06[0]		I06FM
MET	METMMXN1$Amp07$Mag$f	1:METER:I07[0]		I07FM
MET	METMMXN1$Amp08$Mag$f	1:METER:I08[0]		I08FM
MET	METMMXN1$Amp09$Mag$f	1:METER:I09[0]		I09FM
MET	METMMXN1$Amp10$Mag$f	1:METER:I10[0]		I10FM
MET	METMMXN1$Amp11$Mag$f	1:METER:I11[0]		I11FM
MET	METMMXN1$Amp12$Mag$f	1:METER:I12[0]		I12FM
MET	METMMXN1$Amp13$Mag$f	1:METER:I13[0]		I13FM
MET	METMMXN1$Amp14$Mag$f	1:METER:I14[0]		I14FM
MET	METMMXN1$Amp15$Mag$f	1:METER:I15[0]		I15FM
MET	METMMXN1$Amp16$Mag$f	1:METER:I16[0]		I16FM
MET	METMMXN1$Amp17$Mag$f	1:METER:I17[0]		I17FM
MET	METMMXN1$Amp18$Mag$f	1:METER:I18[0]		I18FM
MET	METMMXN1$Vol01$Mag$f	1:METER:V01[0]		V01FM
MET	METMMXN1$Vol02$Mag$f	1:METER:V02[0]		V01FM
MET	METMMXN1$Vol03$Mag$f	1:METER:V03[0]		V01FM

Table B.15 Logical Node and Mapping Differences (Sheet 2 of 4)

LD	487B-0		487B-1	
	Path	Mapping	Path (If Different)	Mapping
MET	IOPMMXN2$Amp01$Mag$f	1:METER:IOP1		IOP1F
MET	IOPMMXN2$Amp02$Mag$f	1:METER:IOP2		IOP2F
MET	IOPMMXN2$Amp03$Mag$f	1:METER:IOP3		IOP3F
MET	IOPMMXN2$Amp04$Mag$f	1:METER:IOP4		IOP4F
MET	IOPMMXN2$Amp05$Mag$f	1:METER:IOP5		IOP5F
MET	IOPMMXN2$Amp06$Mag$f	1:METER:IOP6		IOP6F
MET	IOPMMXN2$Amp06$Mag$f	1:METER:IOPCZ1	NA	NA
MET	IRTMMXN3$Amp01$Mag$f	1:METER:IRT1		IRT1F
MET	IRTMMXN3$Amp02$Mag$f	1:METER:IRT2		IRT2F
MET	IRTMMXN3$Amp03$Mag$f	1:METER:IRT3		IRT3F
MET	IRTMMXN3$Amp04$Mag$f	1:METER:IRT4		IRT4F
MET	IRTMMXN3$Amp05$Mag$f	1:METER:IRT5		IRT5F
MET	IRTMMXN3$Amp06$Mag$f	1:METER:IRT6		IRT6F
MET	IRTMMXN3$Amp07$Mag$f	1:METER:IRTCZ1	NA	NA
CON	RBGGIO1$SPSCO09$Oper$ctlVal	1:CONTROL:RB09	RBGGIO2$SPSCO09$Oper$ctlVal	RB09
CON	RBGGIO1$SPSCO10$Oper$ctlVal	1:CONTROL:RB10	RBGGIO2$SPSCO10$Oper$ctlVal	RB10
CON	RBGGIO1$SPSCO11$Oper$ctlVal	1:CONTROL:RB11	RBGGIO2$SPSCO11$Oper$ctlVal	RB11
CON	RBGGIO1$SPSCO12$Oper$ctlVal	1:CONTROL:RB12	RBGGIO2$SPSCO12$Oper$ctlVal	RB12
CON	RBGGIO1$SPSCO13$Oper$ctlVal	1:CONTROL:RB13	RBGGIO2$SPSCO13$Oper$ctlVal	RB13
CON	RBGGIO1$SPSCO14$Oper$ctlVal	1:CONTROL:RB14	RBGGIO2$SPSCO14$Oper$ctlVal	RB14
CON	RBGGIO1$SPSCO15$Oper$ctlVal	1:CONTROL:RB15	RBGGIO2$SPSCO15$Oper$ctlVal	RB15
CON	RBGGIO1$SPSCO16$Oper$ctlVal	1:CONTROL:RB16	RBGGIO2$SPSCO16$Oper$ctlVal	RB16
CON	RBGGIO1$SPSCO17$Oper$ctlVal	1:CONTROL:RB17	RBGGIO3$SPSCO17$Oper$ctlVal	RB17
CON	RBGGIO1$SPSCO18$Oper$ctlVal	1:CONTROL:RB18	RBGGIO3$SPSCO18$Oper$ctlVal	RB18
CON	RBGGIO1$SPSCO19$Oper$ctlVal	1:CONTROL:RB19	RBGGIO3$SPSCO19$Oper$ctlVal	RB19
CON	RBGGIO1$SPSCO20$Oper$ctlVal	1:CONTROL:RB20	RBGGIO3$SPSCO20$Oper$ctlVal	RB20
CON	RBGGIO1$SPSCO21$Oper$ctlVal	1:CONTROL:RB21	RBGGIO3$SPSCO21$Oper$ctlVal	RB21
CON	RBGGIO1$SPSCO22$Oper$ctlVal	1:CONTROL:RB22	RBGGIO3$SPSCO22$Oper$ctlVal	RB22
CON	RBGGIO1$SPSCO23$Oper$ctlVal	1:CONTROL:RB23	RBGGIO3$SPSCO23$Oper$ctlVal	RB23
CON	RBGGIO1$SPSCO24$Oper$ctlVal	1:CONTROL:RB24	RBGGIO3$SPSCO24$Oper$ctlVal	RB24
CON	RBGGIO1$SPSCO25$Oper$ctlVal	1:CONTROL:RB25	RBGGIO4$SPSCO25$Oper$ctlVal	RB25
CON	RBGGIO1$SPSCO26$Oper$ctlVal	1:CONTROL:RB26	RBGGIO4$SPSCO26$Oper$ctlVal	RB26
CON	RBGGIO1$SPSCO27$Oper$ctlVal	1:CONTROL:RB27	RBGGIO4$SPSCO27$Oper$ctlVal	RB27
CON	RBGGIO1$SPSCO28$Oper$ctlVal	1:CONTROL:RB28	RBGGIO4$SPSCO28$Oper$ctlVal	RB28
CON	RBGGIO1$SPSCO29$Oper$ctlVal	1:CONTROL:RB29	RBGGIO4$SPSCO29$Oper$ctlVal	RB29
CON	RBGGIO1$SPSCO30$Oper$ctlVal	1:CONTROL:RB30	RBGGIO4$SPSCO30$Oper$ctlVal	RB30
CON	RBGGIO1$SPSCO31$Oper$ctlVal	1:CONTROL:RB31	RBGGIO4$SPSCO31$Oper$ctlVal	RB31
CON	RBGGIO1$SPSCO32$Oper$ctlVal	1:CONTROL:RB32	RBGGIO4$SPSCO32$Oper$ctlVal	RB32
CON	RBGGIO1$SPSCO33$Oper$ctlVal	1:CONTROL:RB33	RBGGIO5$SPSCO33$Oper$ctlVal	RB33
CON	RBGGIO1$SPSCO34$Oper$ctlVal	1:CONTROL:RB34	RBGGIO5$SPSCO34$Oper$ctlVal	RB34

Table B.15 Logical Node and Mapping Differences (Sheet 3 of 4)

LD	487B-0		487B-1	
	Path	Mapping	Path (If Different)	Mapping
CON	RBGGIO1$SPSCO35$Oper$ctlVal	1:CONTROL:RB35	RBGGIO5$SPSCO35$Oper$ctlVal	RB35
CON	RBGGIO1$SPSCO36$Oper$ctlVal	1:CONTROL:RB36	RBGGIO5$SPSCO36$Oper$ctlVal	RB36
CON	RBGGIO1$SPSCO37$Oper$ctlVal	1:CONTROL:RB37	RBGGIO5$SPSCO37$Oper$ctlVal	RB37
CON	RBGGIO1$SPSCO38$Oper$ctlVal	1:CONTROL:RB38	RBGGIO5$SPSCO38$Oper$ctlVal	RB38
CON	RBGGIO1$SPSCO39$Oper$ctlVal	1:CONTROL:RB39	RBGGIO5$SPSCO39$Oper$ctlVal	RB39
CON	RBGGIO1$SPSCO40$Oper$ctlVal	1:CONTROL:RB40	RBGGIO5$SPSCO40$Oper$ctlVal	RB40
CON	RBGGIO1$SPSCO41$Oper$ctlVal	1:CONTROL:RB41	RBGGIO6$SPSCO41$Oper$ctlVal	RB41
CON	RBGGIO1$SPSCO42$Oper$ctlVal	1:CONTROL:RB42	RBGGIO6$SPSCO42$Oper$ctlVal	RB42
CON	RBGGIO1$SPSCO43$Oper$ctlVal	1:CONTROL:RB43	RBGGIO6$SPSCO43$Oper$ctlVal	RB43
CON	RBGGIO1$SPSCO44$Oper$ctlVal	1:CONTROL:RB44	RBGGIO6$SPSCO44$Oper$ctlVal	RB44
CON	RBGGIO1$SPSCO45$Oper$ctlVal	1:CONTROL:RB45	RBGGIO6$SPSCO45$Oper$ctlVal	RB45
CON	RBGGIO1$SPSCO46$Oper$ctlVal	1:CONTROL:RB46	RBGGIO6$SPSCO46$Oper$ctlVal	RB46
CON	RBGGIO1$SPSCO47$Oper$ctlVal	1:CONTROL:RB47	RBGGIO6$SPSCO47$Oper$ctlVal	RB47
CON	RBGGIO1$SPSCO48$Oper$ctlVal	1:CONTROL:RB48	RBGGIO6$SPSCO48$Oper$ctlVal	RB48
ANN	TLEDGGIO7$Ind19$stVal	1:TARGET:TARGET: TLED_17	NA	NA
ANN	TLEDGGIO7$Ind20$stVal	1:TARGET:TARGET: TLED_18	NA	NA
ANN	TLEDGGIO7$Ind21$stVal	1:TARGET:TARGET: TLED_19	NA	NA
ANN	TLEDGGIO7$Ind22$stVal	1:TARGET:TARGET: TLED_20	NA	NA
ANN	TLEDGGIO7$Ind23$stVal	1:TARGET:TARGET: TLED_21	NA	NA
ANN	TLEDGGIO7$Ind24$stVal	1:TARGET:TARGET: TLED_22	NA	NA
ANN	TLEDGGIO7$Ind25$stVal	1:TARGET:TARGET: TLED_23	NA	NA
ANN	TLEDGGIO7$Ind26$stVal	1:TARGET:TARGET: TLED_24	NA	NA
ANN	PBLEDGGIO8$Ind09$stVal	1:TARGET:TARGET: PB9_LED	NA	NA
ANN	PBLEDGGIO8$Ind10$stVal	1:TARGET:TARGET: PB10LED	NA	NA
ANN	PBLEDGGIO8$Ind11$stVal	1:TARGET:TARGET: PB11LED	NA	NA
ANN	PBLEDGGIO8$Ind12$stVal	1:TARGET:TARGET: PB12LED	NA	NA
ANN	CCINGGIO19$Ind001$stVal–CCINGGIO19$Ind001$stVal	CCIN001–CCIN128	NA	NA
ANN	CCOUTGGIO20$Ind01$stVal–CCOUTGGIO20$Ind32$stVal	CCOUT01–CCOUT32	NA	NA
ANN	RMBAGGIO21$Ind01$stVal–RMBAGGIO21$Ind08$stVal	RMB1A–RMB8A	NA	NA

Table B.15 Logical Node and Mapping Differences (Sheet 4 of 4)

LD	487B-0		487B-1	
	Path	Mapping	Path (If Different)	Mapping
ANN	TMBAGGIO22$Ind01$stVal–TMBAGGIO22$Ind08$stVal	TMB1A–TMB8A	NA	NA
ANN	RMBBGGIO23$Ind01$stVal–RMBBGGIO23$Ind08$stVal	RMB1B–RMB8B	NA	NA
ANN	TMBBGGIO24$Ind01$stVal–TMBBGGIO24$Ind08$stVal	TMB1B–TMB8B	NA	NA
ANN	MBOKGGIO25$Ind01$stVal	1:TARGET:TARGET:ROKA	NA	NA
ANN	MBOKGGIO25$Ind02$stVal	1:TARGET:TARGET:RBADA	NA	NA
ANN	MBOKGGIO25$Ind03$stVal	1:TARGET:TARGET:CBADA	NA	NA
ANN	MBOKGGIO25$Ind04$stVal	1:TARGET:TARGET:LBOKA	NA	NA
ANN	MBOKGGIO25$Ind05$stVal	1:TARGET:TARGET:ANOKA	NA	NA
ANN	MBOKGGIO25$Ind06$stVal	1:TARGET:TARGET:DOKA	NA	NA
ANN	MBOKGGIO25$Ind07$stVal	1:TARGET:TARGET:ROKB	NA	NA
ANN	MBOKGGIO25$Ind08$stVal	1:TARGET:TARGET:RBADB	NA	NA
ANN	MBOKGGIO25$Ind09$stVal	1:TARGET:TARGET:CBADB	NA	NA
ANN	MBOKGGIO25$Ind10$stVal	1:TARGET:TARGET:LBOKB	NA	NA
ANN	MBOKGGIO25$Ind11$stVal	1:TARGET:TARGET:ANOKB	NA	NA
ANN	MBOKGGIO25$Ind12$stVal	1:TARGET:TARGET:DOKB	NA	NA

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SEL-487B-1 Relay Command Summary

Command[a, b]	Description
2ACCESS	Go to Access Level 2 (full control)
AACCESS	Go to Access Level A (automation configuration)
ACCESS	Go to Access Level 1 (monitor relay)
BACCESS	Go to Access Level B (monitor relay and control circuit breakers)
BNAME	ASCII names of Fast Meter status bits
CASCII	Generate the Compressed ASCII response configuration message
CEVENT	Display Compressed ASCII event report
CFG CTNOM *i*	For TiDL (EtherCAT) relays, configure the nominal CT input value *i* to 1 or 5
CFG NFREQ *f*	In TiDL (EtherCAT) relays, set the nominal frequency, *f* (50 or 60)
CHISTORY	Display Compressed ASCII history report
COM *c*	Display relay-to-relay MIRRORED BITS communications data (*c* = A is Channel A; *c* = B is Channel B; *c* = M is either enabled single channel)
COM PTP	Display a report on PTP data sets and statistics
CONTROL *nn*	Set, clear, or pulse an internal remote bit (*nn* is the remote bit number from 01–96)
COPY *m n*	Copy settings between instances in the same class (*m* and *n* are instance numbers; for example: *m* = 1 is Group 1; *n* = 2 is Group 2)
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 date
DNAME X	ASCII names of all relay digital points reported via Fast Meter
ETHERNET	Display Ethernet port (Port 5) configuration and status
EVENT	Display and acknowledge event reports
EXIT	Terminates a Telnet session
FILE	Transfer files between the relay and external software
GOOSE	Displays transmit and receive GOOSE messaging information
GROUP	Display the active group number or select the active group
HELP	List and describe available commands at each access level
HISTORY	View event summaries/histories; 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 the MAC addresses
MAP 1	View the relay database organization
METER	Display metering data and internal relay operating variables
OACCESS	Go to Access Level O (output configuration)
OPEN *n*	Open the circuit breaker (*n* = 1–21)
PACCESS	Go to Access Level P (protection configuration)
PASSWORD *n*	Change relay password for Access Level *n*

Command[a, b]	Description
PING *addr*	Sends an ICMP echo request message to the provided IP address to confirm connectivity
PORT *p*	Connect to a remote relay via MIRRORED BITS virtual terminal for port number *p* (*p* = 1–3 and 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)
SER	View Sequential Events Recorder report
SET	Set or modify relay settings
SHOW	Display relay settings
SNS	Display Sequential Events Recorder settings name strings (Fast SER)
STATUS	Report 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 table
TEST DB	Display or place values in the communications card database (useful for Ethernet protocol read tests)
TEST DB2	Test all communications protocols except Fast Message
TEST FM	Display or place values in metering database (Fast Meter)
TIME	Display and set the internal clock
TRIGGER	Initiate a data capture and record an event report
VERSION	Display the relay hardware and software configurations
VIEW 1	View data from the Fast Message database
ZONE	Display the terminal and bus names associated with all active protective zones

[a] See Section 9: ASCII Command Reference.
[b] For help on a specific command, type **HELP [command] <Enter>** at an ASCII terminal communicating with the relay.

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GROUP	Display the active group number or select the active group
HELP	List and describe available commands at each access level
HISTORY	View event summaries/histories; 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 the MAC addresses
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ZONE	Display the terminal and bus names associated with all active protective zones

[a] See Section 9: ASCII Command Reference.
[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

SEL SCHWEITZER ENGINEERING LABORATORIES

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Part Number: PM400-01

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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	A ⎿ B	Output B asserts at the falling edge of Input A.
Rising Edge	A ⎾ B	Output B asserts at the rising edge of Input A.

Trademarks

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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 equa-

tions 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

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*.

NOTE: The following option is only available in the Admin Install. Skip Step 5 if you are running the User Install.

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.

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:

- *Inspecting a New Relay on page 3.1*
- *Establishing Communication on page 3.3*
- *Access Levels and Passwords on page 3.7*
- *Checking Relay Status on page 3.13*
- *Making Simple Settings Changes on page 3.15*
- *Examining Metering Quantities on page 3.34*
- *Examining Relay Elements on page 3.42*
- *Reading Oscillograms, Event Reports, and SER on page 3.46*
- *Operating the Relay Inputs and Outputs on page 3.55*
- *Configuring Timekeeping on page 3.64*
- *Readying the Relay for Field Application on page 3.65*

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:

- 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

NOTE: For the five-port Ethernet card, set EINTF to **CD** and/or **E**. Then, set ETELNET to **CD** and/or **E**.

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.

[1] Requires correct password for the requested access level
[2] Where n = 1, 2, 3, F, or 5

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:=I01FA <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:

- ➢ 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*.

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.

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*.

```
PASSWORD REQUIRED
_____________
A B C D E F G H
I J K L M N O P
Q R S T U V W X
Y Z a b c d e f
g h i j k l m n
o p q r s t u v
w x y z 0 1 2 3
4 5 6 7 8 9 _ .
ACCEPT  BACKSPACE
```

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
? LBO3 <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 := LBO3
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 on page 4.1*
- *Front-Panel Menus and Screens on page 4.14*
- *Front-Panel Automatic Messages on page 4.32*
- *Operation and Target LEDs on page 4.33*
- *Front-Panel Operator Control Pushbuttons on page 4.35*

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)

```
ALARM POINTS
 Circuit BK1 SF6 Gas

Press ↵ to acknldge
```

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*.

```
ALARM POINTS
 Circuit BK1 SF6 Gas

 Are you sure you
 want to clear
 inactive alarms?
 Press ↵ to clear

Press ↵ to acknldge
```

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*.

```
ALARM POINTS
NO ALARM POINTS
EXIST.
```

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

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.

⚠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.

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*).

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`.

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.

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*.

```
DATE   (MM/DD/YYYY)

  03/15/2001
```

```
TIME

  00:00:00
```

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*.

```
RELAY STATUS
SEL-421-R101-V0-
Z001001-D20010315

S/N=2001001234
RELAY ENABLED
NO FAILURES OR
WARNINGS
```

Normal

```
RELAY STATUS
SEL-421-R101-V0-
Z001001-D20010315

S/N=2001001234
RELAY ENABLED
TEMPERATURE WARNING
```

Status Warning

```
RELAY STATUS
SEL-421-R101-V0-
Z001001-D20010315

S/N=2001001234
RELAY DISABLED
MASTER OFFSET FAILED
```

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.

- *Circuit Breaker Status and Control on page 5.1*
- *Disconnect Logic on page 5.2*
- *Remote Bits on page 5.12*
- *Bay Control Front-Panel Operations on page 5.12*
- *Bay Control Screens on page 5.29*
- *Customizable Screens on page 5.36*
- *Bay Control Example Application on page 5.37*

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, con-

sider 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.

(a) Disconnect Control Screen (b) Disconnect Control Screen

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

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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:

- *Autoreclosing States on page 6.2*
- *One-Circuit-Breaker Autoreclosing on page 6.4*
- *Two-Circuit-Breaker Autoreclosing on page 6.10*
- *Autoreclose Logic Diagrams on page 6.26*
- *Manual Closing on page 6.39*
- *Voltage Checks for Autoreclosing and Manual Closing on page 6.42*
- *Settings and Relay Word Bits for Autoreclosing and Manual Closing on page 6.45*

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 • 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.

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.

NOTE: Some SEL-400 series relays use a BK_SEL setting to list enabled breakers, rather than the EBnMON settings shown here.

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 (ΣI^2t), 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:

$$\text{B1COSP1} = \frac{\sum I^2t}{(\text{B1KASP1})^2 \cdot t_{arc}} = \frac{750}{2^2 \cdot (0.01667 \cdot 1)} := 11250$$

Equation 8.1

$$\text{B1COSP2} = \frac{\sum I^2t}{(\text{B1KASP2})^2 \cdot t_{arc}} = \frac{750}{10^2 \cdot (0.01667 \cdot 1)} := 450$$

Equation 8.2

$$\text{B1COSP3} = \frac{\sum I^2t}{(\text{B1KASP3})^2 \cdot t_{arc}} = \frac{750}{40^2 \cdot (0.01667 \cdot 1)} := 28$$

Equation 8.3

In these equations, t_{arc} is the arcing time in seconds; $t_{arc} = (1/f_{NOM}) \cdot$ (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 Con-

trol 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:

- *Data Processing on page 9.1*
- *Triggering Data Captures and Event Reports on page 9.7*
- *Duration of Data Captures and Event Reports on page 9.9*
- *Oscillography on page 9.9*
- *Event Reports, Event Summaries, and Event Histories on page 9.13*
- *Sequential Events Recorder (SER) on page 9.28*
- *Signal Profiling on page 9.31*

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*.

```
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
```

Summary Event Information

```
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",
```

Relay Settings

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

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
                                    •
                                    •
                                    •
[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

[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

[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

[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
```

Header
Firmware ID in bold

1 Cycle of Data
See *Figure 9.9* and *Figure 9.10* to calculate phasors for the data in bold.

Trigger

Largest Current (to Event Summary)

Circuit Breaker Open

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:

$$\begin{aligned}\theta &= \angle VA \\ &= \arctan\left(\frac{Y}{X}\right) \\ &= \arctan\left(\frac{-288.0}{-223.7}\right) \\ &= -127.8°\end{aligned}$$

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.

$$\angle VA - \angle IA = -127.8° - (-105.9°) = -21.9°$$

Equation 9.4

IA leads VA; thus, the rms phasor for current IA at the present sample is 277.0 A ∠21.9°, 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 A ∠–105.9°.

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.

$$X = -76 = 277.0 \bullet \cos(-105.9°)$$

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
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
```

Digital Column Labels

```
[1]

 ... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
 ... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
 ... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
 ... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
```

1 Cycle of Data

```
                                    •
                                    •
                                    •

[6]
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
[7]
*** **.. ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....>
```

Trigger

```
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
[8]
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....*
```

Values used in the Event Summary

```
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
[9]
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
[10]
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** .... ... .... ... *.. .. .* .... .. ... .. ... .. ... .... ...... .. ....
*** .... ... .... ... *.. .. *. .... .. ... .. ... .. ... .... ...... .. ....
```

Circuit Breaker Open

```
[11]

*** .... ... .... ... *.. .. *. *.*. .. ... .. ... .. ... .... ...... .. ....
*** .... ... .... ... *.. .. *. .... .. ... .. ... .. ... .... ...... .. ....
*** .... ... .... ... *.. .. *. .... .. ... .. ... .. ... .... ...... .. ....
*** .... ... .... ... *.. .. *. .... .. ... .. ... .. ... .... ...... .. ....
```

Figure 9.11 Digital Section of the SEL-411L Event Report

```
                    IN201
                    #
                    RMBA5
                    Z2P
                    LBOKA
                    #
                    OUT203
                    OUT204
                    HALARM

                   00H
I  R    UUA
N  M L  TTL
2  BM0  22A
0  A2K  00R
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
```

Event Information

```
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
```

Pre-Fault Data

Fault Data

```
                 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
```

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
ZOMAG   := 14.50    ZOANG   := 75.70    EFLOC   := Y
  •
  •
  •
```

Active Group Settings

```
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
  •
  •
  •
```

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

RAO01   := NA
RAO02   := NA
  •
  •
  •
RAO61   := NA
RAO62   := NA
RAO63   := NA
RAO64   := 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_0/C_1_LINE_1","51S1_DROPOUT","09D2"
2,3,15,2001,00,32,00,114,"GROUND_0/C_1_LINE_1","51S1_RESET","08E7"
3,3,15,2001,00,30,03,221,"GROUND_0/C_1_LINE_1","51S1_TIMEOUT","09B0"
4,3,15,2001,00,30,00,021,"GROUND_0/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:

- *Testing Philosophy on page 10.1*
- *Testing Features and Tools on page 10.4*
- *Test Methods on page 10.7*
- *Relay Self-Tests on page 10.19*
- *Relay Troubleshooting on page 10.23*
- *Maintenance on page 10.27*
- *Technical Support on page 10.35*

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.

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

Perform the following steps to install SEL-400 series relay 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.

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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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 on page 11.1*
- *PTP Timekeeping on page 11.2*
- *Time Source Selection on page 11.5*
- *Time Quality Indications on page 11.5*
- *Time-Synchronized Events on page 11.9*

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 time-keeping 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.

$$S_{3\phi} = P_{3\phi} + jQ_{3\phi}$$
$$= \sqrt{3} \bullet V_{pp} \bullet I^*_L$$
$$= 3 \bullet V_p \bullet I^*_L$$

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:

$$S_S = (3 \bullet 288.675\ \text{kV}\angle 0°) \bullet (238.995\ \text{A}\angle -41.9°)$$
$$= 154.1\ \text{MW} - j138.2\ \text{MVAR}$$

The complex power generation supplied by Substation R is:

$$S_R = (3 \bullet 303.109\ \text{kV}\angle -0.2°) \bullet (234.036\ \text{A}\angle 44.2°)$$
$$= 152.6\ \text{MW} + j148.3\ \text{MVAR}$$

The load at Substation T supplied by Substation S is:

$$S_{T-S} = (3 \bullet 295.603\ \text{kV}\angle -1.6°) \bullet (238.995\ \text{A}\angle 138.1°)$$
$$= -153.7\ \text{MW} + j145.9\ \text{MVAR}$$

The load at Substation T supplied by Substation R is:

$$S_{T-R} = (3 \bullet 295.603\ \text{kV}\angle -1.6°) \bullet (234.036\ \text{A}\angle -135.8°)$$
$$= -152.8\ \text{MW} - j140.5\ \text{MVAR}$$

The total load at Substation T is:

$$S_T = S_{T-S} + S_{T-R}$$
$$= -306.5\ \text{MW} + j5.4\ \text{MVAR}$$

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.

SECTION 12

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 on page 12.1*
- *Multiple Setting Groups on page 12.4*
- *Port Settings on page 12.6*
- *DNP3 Settings—Custom Maps on page 12.19*
- *Front-Panel Settings on page 12.20*
- *Alias Settings on page 12.25*
- *Protection Freeform SELOGIC Control Equations on page 12.26*
- *Automation Freeform SELOGIC Control Equations on page 12.26*
- *Output Settings on page 12.26*
- *Report Settings on page 12.28*
- *Notes Settings on page 12.29*

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

The Global settings class contains the SELOGIC control equation settings SS1 through SS6, as shown in *Table 12.3*.

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.

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)

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: SV configuration settings are only available in SV relays.

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 := O.
[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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SECTION 13

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 on page 13.1*
- *SELOGIC Control Equation Setting Structure on page 13.2*
- *SELOGIC Control Equation Capacity on page 13.5*
- *SELOGIC Control Equation Programming on page 13.6*
- *SELOGIC Control Equation Elements on page 13.9*
- *SELOGIC Control Equation Operators on page 13.24*
- *Effective Programming on page 13.34*
- *SEL-311 and SEL-351 Series Users on page 13.36*

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*nn*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 DISNAM`*n* `(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 DISNAM`*n* `(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

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***).

NOTE: Not all SEL-400 series relays support the CEV L option.

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 informa-

tion 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

NOTE: Not all SEL-400 series relays support maximum/minimum metering.

Use the **MET M** command to view power system maximum and minimum quantities.

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

NOTE: Not all SEL-400 series relays support synchrophasors.

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*.

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`.

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.

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.

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:

- *Serial Communication on page 15.2*
- *Serial Port Hardware Protocol on page 15.4*
- *Ethernet Communications on page 15.6*
- *Virtual File Interface on page 15.21*
- *Software Protocol Selections on page 15.28*
- *SEL Protocol on page 15.29*
- *SEL MIRRORED BITS Communication on page 15.36*
- *SEL Distributed Port Switch Protocol (LMD) on page 15.43*
- *SEL-2600A RTD Module Operation on page 15.43*
- *Direct Networking Example on page 15.45*

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

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	

NOTE: Pins 5 and 9 are not intended to provide a chassis ground connection.

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.

- NETMODE := FAILOVER
- NETPORT := the preferred primary network port
- FTIME := desired time-out for the active port before failover to the backup port

NOTE: The process bus on the four-port Ethernet card uses FAILOVER operating mode with no time-out delay.

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*.

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.

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*).

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 on page 16.1*
- *DNP3 in the Relay on page 16.7*
- *DNP3 Documentation on page 16.12*
- *DNP3 Serial Application Example on page 16.26*
- *DNP3 LAN/WAN Application Example on page 16.31*

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]		Response[a]	
			Funct. Codes	Qual. Codes	Funct. Codes	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 ≤ time ≤ 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 gen-

erate 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: RBO4
14: RBO5
15: RBO6


Binary Output Map
(Binary Output Label)

1: RBO1
2: RBO2
.
.
.
5: RBO5
6: RBO6


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

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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.
- **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.
- **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.

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.

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.

This section presents the information you need to use the IEC 61850 features of the relay.

- *Introduction to IEC 61850 on page 17.2*
- *IEC 61850 Operation on page 17.3*
- *IEC 61850 Configuration on page 17.47*
- *Logical Nodes on page 17.53*
- *Protocol Implementation Conformance Statement on page 17.84*
- *ACSI Conformance Statements on page 17.89*

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 sec-

ondary 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:

$$\text{CH_DLY} = \text{MAX}(\text{SVND}mm) + (\text{N} + 1) \bullet (\text{Sample Period})$$

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
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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
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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
• • •			
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:

- *Synchrophasor Measurement on page 18.3*
- *Settings for Synchrophasors on page 18.6*
- *Synchrophasor Quantities on page 18.18*
- *View Synchrophasors by Using the MET PM Command on page 18.21*
- *IEEE C37.118 Synchrophasor Protocol on page 18.23*
- *SEL Fast Message Synchrophasor Protocol on page 18.29*
- *Control Capabilities on page 18.33*
- *PMU Recording Capabilities on page 18.42*

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 $-\pi < \text{angle} \leq \pi$.

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.

i7158c

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*-vy4*xx*.zds or s*nnn*-vy4*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*-vy4*xx*.s19, or s3*nn*-vy4*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*-vy4*xx*.s19 or r*nnn*-vy4*xx*.z19	SEL-400 series relay firmware
SEL-400 series relays with SELBOOT versions supporting .zds upgrade files	r*nnn*-vy4*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=xxxxxxxxxxxxxx","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.

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.

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.

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 MAXACC 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 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 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.