SEL-421 Relay

Protection and Automation System

Instruction Manual

20190325

SCHWEITZER ENGINEERING LABORATORIES, INC.

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Preface

This manual provides information and instructions for installing and operating the SEL-421 Relay. The three volumes that comprise this manual are for use by power engineers and others experienced in protective relaying applications. Included are detailed technical descriptions of the relay and application examples. While this manual gives reasonable examples and illustrations of relay uses, you must exercise sound judgment at all times when applying the SEL-421 in a power system.

SEL-421 Versions and Supported Features on page U.1.7 shows the relay features supported by versions SEL-421-0, SEL-421-1, SEL-421-2, and SEL-421-3. Throughout the manual, we provide margin notes next to the text explaining a feature to specify the availability of that feature in different versions of the relay.

Manual Overview

The SEL-421 Relay Manual consists of three volumes:

- User's Guide
- Applications Handbook
- Reference Manual

In addition, the SEL-421 Relay Manual contains a comprehensive Index that encompasses the entire manual. The index appears at the end of each printed volume. In the electronic version of the manual, the index appears once; hyperlinks take you to material referenced in the index. Also included is a glossary that lists and defines technical terms used throughout the manual.

The SEL-421 Relay Manual is a comprehensive work covering all aspects of relay application and use. Read the sections that pertain to your application to gain valuable information about using the SEL-421. For example, to learn about relay protection functions, read the protection sections of this manual and skim the automation sections, then 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.

User's Guide

Preface. Describes manual organization and conventions used to present information (appears once in the electronic form of the manual; repeated in each printed volume).

Section 1: Introduction and Specifications. Introduces SEL-421 features; summarizes relay functions and applications; lists relay specifications, type tests, and ratings.

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

Section 3: PC Software. Explains how to use the ACSELERATOR QuickSet® SEL-5030 software program.

Section 4: 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 SER (Sequential Events Recorder) records, operating relay control outputs and control inputs, and using relay features to make relay commissioning easier.

Section 5: 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 6: Testing and Troubleshooting. Describes techniques for testing, troubleshooting, and maintaining the SEL-421; includes the list of status notification messages and a troubleshooting chart.

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

Applications Handbook

Section 1: Protection Application Examples. Provides the following protection schemes with explanations and settings:

- Overhead single 230 kV transmission line
- Overhead parallel 500 kV transmission lines with zero-sequence mutual coupling
- Overhead tapped 345 kV transmission line
- Parallel 230 kV underground cables

This section also provides separate application examples for out-of-step blocking and tripping, circuit breaker failure protection, and automatic reclose and synchronism checking.

Section 2: Monitoring and Metering. Describes how to use the circuit breaker monitors and the substation dc battery monitors; provides information on viewing fundamental and rms metering quantities for voltages and currents, as well as power and energy metering data.

Section 3: Analyzing Data. 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 and alias settings.

Section 4: Time-Synchronized Measurements. Explains synchronized phasor measurements and estimation of power system states using the SEL-421 high-accuracy time-stamping capability; presents real-time load flow/power flow application ideas.

Section 5: Substation Automatic Restoration. Describes an example of automatic substation restoration; gives a real-world example of the programming ease and flexibility of free-form expanded SELOGIC® control equations.

Section 6: SEL Communications Processor Applications. Provides examples of how to use the SEL-421 with the SEL-2032, SEL-2030, and SEL-2020 Communications Processors for total substation automation solutions.

Section 7: Direct Network Communication. Explains how to use DNP3 (serial and LAN/WAN) and other Ethernet protocols such as Telnet, FTP, and IEC 61850.

Reference Manual

Section 1: 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.

Section 2: Auto-Reclosing and Synchronism Check. Explains how to operate the SEL-421 two-circuit breaker multi-shot recloser; describes how to set the SEL-421 for single-pole reclosing, three-pole reclosing, or both; shows selection of the lead and follow circuit breakers; explains how to set and apply synchronism-check elements for automatic and manual closing.

Section 3: 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 free-form equations.

Section 4: Communications Interfaces. Explains the physical connection of the SEL-421 to various communications network topologies.

Section 5: SEL Communications Protocols. Describes the various SEL software protocols and how to apply these protocols to substation integration and automation; includes details about SEL ASCII, SEL Compressed ASCII, SEL Fast Meter, SEL Fast Operate, SEL Fast SER, and enhanced MIRRORED BITS® communications.

Section 6: DNP3 Communications. 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 7: Synchrophasors. Describes the Phasor Measurement Unit (PMU) functions of the SEL-421; provides details on synchrophasor measurement; describes the IEEE C37.118 synchrophasor protocol settings; describes the SEL Fast Message synchrophasor protocol settings.

Section 8: IEC 61850 Communications. Describes the IEC 61850 protocol and how to apply this protocol to substation automation and integration. Includes IEC 61850 protocol compliance statements.

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

Section 10: Settings. Provides a list of all SEL-421 settings and defaults. The organization of the settings is similar to the settings organization in the relay and in the ACSELERATOR QuickSet software.

Appendix A: Relay Word Bits. Contains a summary of Relay Word bits.

Appendix B: Analog Quantities. Contains a summary of analog quantities.

CD-ROM

The CD-ROM contains the SEL-421 Relay Manual in an electronic form that you can search easily.

Conventions

Typographic Conventions

There are three ways to communicate with the SEL-421:

- ➤ Using a command line interface in a PC terminal emulation window.
- ➤ 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.
{CLOSE}	Relay front-panel pushbuttons.
ENABLE	Relay front- or rear-panel labels.
RELAY RESPONSE MAIN > METER	Relay front-panel LCD menus and relay responses visible on the PC screen. The > character indicates submenus.
U.3.1 A.3.1 R.3.1	Page numbers include a reference to the volume, section, and page number. U stands for User's Guide A stands for Applications Handbook R stands for Reference Manual.
SELOGIC control equations	SEL trademarks and registered trademarks contain the appropriate symbol on first reference in a section. In the SEL-421 Instruction Manual, certain SEL trademarks appear in small caps. These include SELOGIC control equations, MIRRORED BITS communications, and the ACSELERATOR QuickSet software program.
Modbus®	Registered trademarks of other companies include the registered trademark symbol with the first occurrence of the term in a section.

Examples

This instruction manual uses several example illustrations and instructions to explain how to effectively operate the SEL-421. These examples are for demonstration purposes only; the firmware identification information or settings values included in these examples may not necessarily match those in the current version of your SEL-421.

Notes

Margin notes serve two purposes in the SEL-421 Relay Manual. Notes present valuable or important points about relay features or functions. Use these notes as tips to easier and more efficient operation of the relay. Also in this manual, notes specify differences between the SEL-421-0, SEL-421-1, SEL-421-2, and SEL-421-3 models when these differences affect relay functions or operations.

Commands

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 the following:

ACC <Enter>

Numbers

This manual displays numbers as decimal values. Hexadecimal numbers include the letter h appended to the number. Alternatively, the prefix 0X can also indicate a hexadecimal number. For instance, 11 is the decimal number eleven, but 11h and 0X11 are hexadecimal representations of the decimal value seventeen.

Safety Information

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

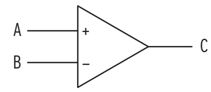
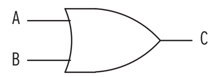
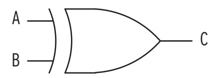
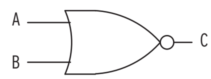
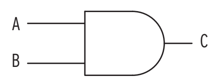
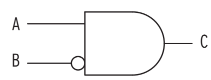
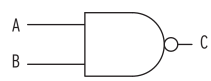
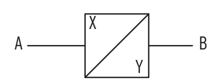
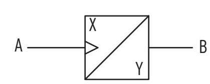
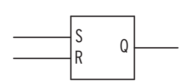
⚠CAUTION
Indicates a potentially hazardous situation that, if not avoided, may result in minor or moderate injury or equipment damage.

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

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

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 A is greater than B.
INPUT FLAG		Input A comes from other logic.
OR		Either input A or input B asserted cause output C to assert.
EXCLUSIVE OR		If either A or B is asserted, output C is asserted. If A and B are of the same state, C is deasserted.
NOR		If neither A nor B asserts, output C asserts.
AND		Input A and input B must assert to assert output C.
AND W/ INVERTED INPUT		If input A is asserted and input B is deasserted, output C asserts. Inverter "O" inverts any input or output on any gate.
NAND		If A and/or B are deasserted, output C is asserted.
TIME DELAYED PICK UP AND/OR TIME DELAYED DROP OUT		X is a time-delay-pickup value; Y is a time-delay-dropout value. B asserts time X after input A asserts; B will not assert if A does not remain asserted for time X. If X is zero, B will assert when A asserts. If Y is zero, B will deassert when A deasserts.
EDGE TRIGGER TIMER		Rising edge of A starts timers. Output B will assert time X after the rising edge of A. B will remain asserted for time Y. If Y is zero, B will assert 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 R asserts.
FALLING EDGE		B asserts at the falling edge of input A.

SEL-421 Cautions, Warnings, and Dangers

The following hazard statements appear in the body of this manual in English. See the following table for the English and French translation of these statements.

English	French
⚠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 There is danger of explosion if the battery is incorrectly replaced. Replace only with Ray-O-Vac® no. BR2335 or equivalent recommended by manufacturer. Dispose of used batteries according to the manufacturer's instructions.	⚠ATTENTION Il y a un danger d'explosion si la pile électrique n'est pas correctement remplacée. Utiliser exclusivement Ray-O-Vac® No. BR2335 ou un équivalent recommandé par le fabricant. Se débarrasser des piles usagées suivant les instructions du fabricant.
⚠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 (see Table 2.3 and Table 2.4 for board descriptions), first check the firmware version of the relay—see Firmware Version Number on page U.6.39. 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 (voit Table 2.3 et Table 2.4 pour la description de la carte), vérifiez en premier la version du logiciel du relais (voir l'indentification de la Version du logiciel [Firmware Version Number on page U.6.39]). 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.

English	French
⚠CAUTION Do not install a jumper on positions A or D of the main board J18 header. Relay misoperation can result if you install jumpers on positions J18A and J18D.	⚠ATTENTION Ne pas installer de cavalier sur les positions A ou D sur le connecteur J18 de la carte principale. Une opération intempestive du relais pourrait résulter suite à l'installation d'un cavalier entre les positions J18A et J18D.
⚠CAUTION Insufficiently rated insulation can deteriorate under abnormal operating conditions and cause equipment damage. For external circuits, use wiring of sufficiently rated insulation that will not break down under abnormal operating conditions.	⚠ATTENTION Un niveau d'isolation insuffisant peut entraîner une détérioration sous des conditions anormales et causer des dommages à l'équipement. Pour les circuits externes, utiliser des conducteurs avec une isolation suffisante de façon à éviter les claquages durant les conditions anormales d'opération.
⚠CAUTION Relay misoperation can result from applying other than specified secondary voltages and currents. Before making any secondary circuit connections, check the nominal voltage and nominal current specified on the rear-panel nameplate.	⚠ATTENTION Une opération intempestive du relais peut résulter par le branchement de tensions et courants secondaires non conformes aux spécifications. Avant de brancher un circuit secondaire, vérifier la tension ou le courant nominal sur la plaque signalétique à l'arrière.
⚠CAUTION Severe power and ground problems can occur on the communications ports of this equipment as a result of using non-SEL cables. Never use standard null-modem cables with this equipment.	⚠ATTENTION Des problèmes graves d'alimentation et de terre peuvent survenir sur les ports de communication de cet appareil si des câbles d'origine autre que SEL sont utilisés. Ne jamais utiliser de câble de modem nul avec cet équipement.
⚠CAUTION Do not connect power to the relay until you have completed these procedures and receive instruction to apply power. Equipment damage can result otherwise.	⚠ATTENTION Ne pas mettre le relais sous tension avant d'avoir complété ces procédures et d'avoir reçu l'instruction de brancher l'alimentation. Des dommages à l'équipement pourraient survenir autrement.
⚠CAUTION Use of controls or adjustments, or performance of procedures other than those specified herein, may result in hazardous radiation exposure.	⚠ATTENTION L'utilisation de commandes ou de réglages, ou l'application de tests de fonctionnement différents de ceux décrits ci-après peuvent entraîner l'exposition à des radiations dangereuses.
⚠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 (laser) ports/connectors.	⚠AVERTISSEMENT Ne pas regarder vers l'extremité des ports ou connecteurs de fibres pour laser.
⚠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.

English	French
⚠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.
⚠WARNING Incorporated components, such as LEDs, transceivers, and laser emitters, are not user serviceable. Return units to SEL for repair or replacement.	⚠AVERTISSEMENT Les composants internes tels que les leds (diodes électroluminescentes), émetteurs-récepteurs ou émetteurs pour rayon laser ne peuvent pas être entretenus par l'usager. Retourner ces unités à SEL pour toute réparation ou remplacement.
⚠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.

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SEL-421 Relay

Protection and Automation System

Instruction Manual

User's Guide

20190325

SCHWEITZER ENGINEERING LABORATORIES, INC.

PM421-01

Section 1
Introduction and Specifications

The SEL-421 Relay is a high-speed transmission line protection relay featuring single-pole and three-pole tripping and reclosing with synchronism check, circuit breaker monitoring, circuit breaker failure protection, and series-compensated line protection logic. The relay features extensive metering and data recording including high-resolution data capture and reporting.

NOTE: Not all features mentioned on this page are available in the SEL-421-1 and the SEL-421-2. See SEL-421 Versions and Supported Features on page U.1.7 for more details about the different versions of the relay and about differences among the SEL-421-0, SEL-421-1, SEL-421-2, and SEL-421-3.

The SEL-421 features expanded SELOGIC® control equation programming for easy and flexible implementation of custom protection and control schemes. The relay has separate protection and automation SELOGIC control equation programming areas with extensive protection programming capability and 1000 lines of automation programming capability. You can organize automation of SELOGIC control equation programming into 10 blocks of 100 program lines each.

The SEL-421 provides 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 the latest industry communications tools, including Telnet, FTP, IEC 61850, and DNP3 (serial and LAN/WAN) protocols.

Purchase of an SEL-421 includes the ACSELERATOR QuickSet® SEL-5030 Software program. ACSELERATOR QuickSet assists 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. ACSELERATOR Architect enables you to view and configure IEC 61850 settings via a GUI interface, tightly integrated with ACSELERATOR QuickSet.

Synchrophasor measurements are available when a high-accuracy time source is connected to the relay. The SEL-421 supports the IEEE C37.118, Standard for Synchrophasors for Power Systems.

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.

This section introduces the SEL-421 and provides information on the following topics:

Features

The SEL-421 contains many protection, automation, and control features. *Figure 1.1* presents a simplified functional overview of the relay.

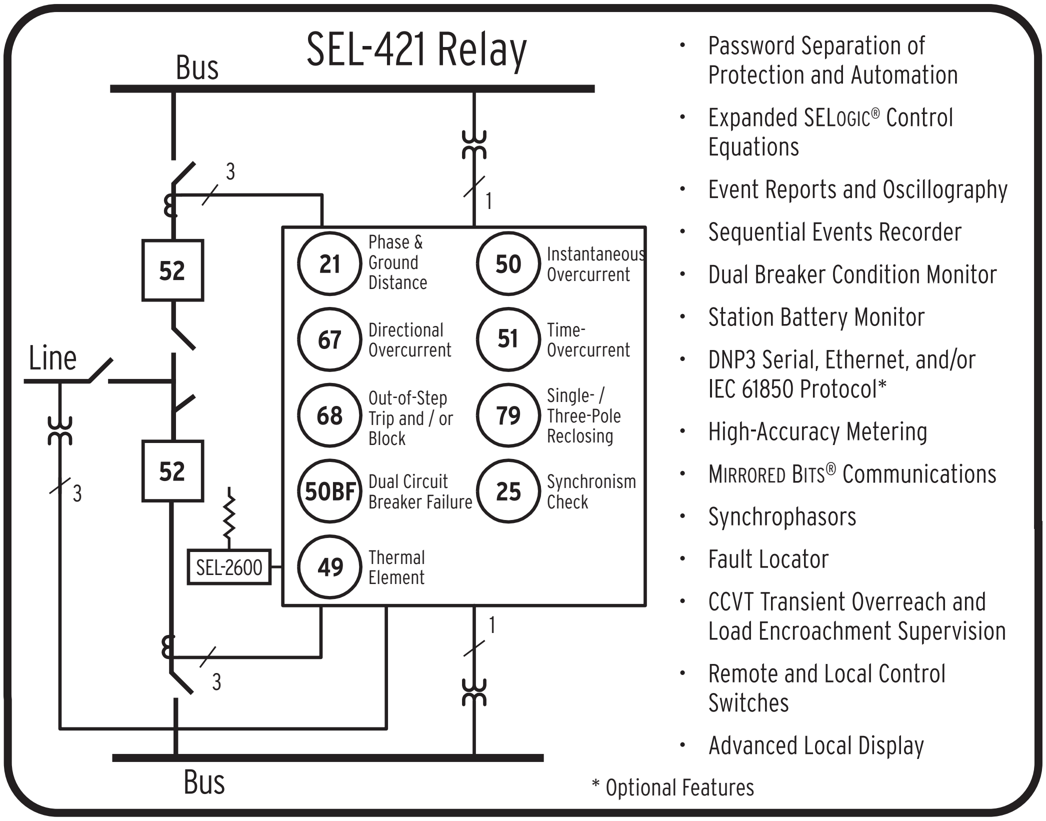


Figure 1.1 SEL-421 Functional Overview

SEL-421 features include the following:

NOTE: The SEL-421-1 and the SEL-421-2 do not provide series-compensated line protection logic.

Superior Protection. Combine five zones of phase distance and ground distance elements with directional overcurrent elements. Patented Coupling Capacitor Voltage Transformer (CCVT) transient overreach logic enhances Zone 1 distance element security. The Best Choice Ground Directional Element™ optimizes directional element performance and eliminates many settings. Additional logic prevents Zone 1 overreach on series-compensated lines.

NOTE: The SEL-421-1 and the SEL-421-2 do not provide high-speed directional elements and high-speed distance elements.

High-Speed Tripping. The SEL-421 uses the HSDPS (High-Speed Directional and Phase Selection) element and high-speed distance elements for subcycle detection of power system faults.

Reclosing. Incorporate programmable single-pole and three-pole tripping and reclosing of one and two circuit breakers into an integrated substation control system. Synchronism and voltage checks from multiple sources provide complete bay control.

Breaker Failure. The SEL-421 incorporates CT subsidence detection to produce element dropout in 5/8 cycle. Apply the SEL-421 to supply three-pole breaker failure for one or two breakers. Included is the necessary logic for single-pole and three-pole breaker failure retrip and initiation of transfer tripping.

Out-of-Step Blocking and Tripping. Select out-of-step blocking of distance elements or out-of-step tripping during power swings. The SEL-421 includes multizone elements and logic for detection of an out-of-step condition.

Switch-Onto-Fault. Relay switch-onto-fault (SOTF) logic permits specific protection elements to quickly trip after the circuit breaker closes, protecting maintenance personnel and substation equipment.

Fault Locator. Efficiently dispatch line crews to quickly repair line problems.

Primary Potential Redundancy. Multiple voltage inputs to the SEL-421 provide primary input redundancy. At loss-of-potential (LOP) detection, configure the relay to use inputs from an electrically equivalent source. Protection remains in service without compromising security.

Dual CT Input. Apply with ring bus, breaker-and-a-half, or other two-breaker schemes. Combine currents within the relay from two sets of CTs for protection functions, but keep them separately available for monitoring and station integration applications.

NOTE: The SEL-421-1 and the SEL-421-2 have only one 100-line automation programming block.

Automation. Take advantage of enhanced automation features that include 32 programmable elements for local control, remote control, protection latching, and automation latching. Local metering on the large format front-panel Liquid Crystal Display (LCD) eliminates the need for separate panel meters. Use serial and Ethernet links to efficiently transmit key information, including metering data, protection element and control I/O status, Sequential Events Recorder (SER) reports, breaker monitor, relay summary event reports, and time synchronization. Use expanded SELOGIC control equations with math and comparison functions in control applications. Incorporate up to 1000 lines of automation logic to speed and improve control actions.

Monitoring. Schedule breaker maintenance when accumulated breaker duty (independently monitored for each pole of two circuit breakers) indicates possible excess contact wear. Electrical and mechanical operating times are recorded for both the last operation and the average of operations since function reset. Alarm contacts provide notification of substation battery voltage problems (two independent battery monitors) even if voltage is low only during trip or close operations.

Comprehensive Metering. View metering information for Line, Circuit Breaker 1, and Circuit Breaker 2. SEL-421 metering includes fundamental and rms metering, as well as energy import/export, demand, and peak demand metering data. Synchrophasor data can be used for time-synchronized state measurements across the system.

Oscillography and Event Reporting. Record voltages, currents, and internal logic points at up to 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, power-ups, and selectable logic elements.

High-Accuracy Time Stamping. Time-tag 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. Enhanced MIRRORED BITS communications to monitor internal element conditions between relays within a station, or between stations, 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 using IEC 61850 or DNP3 LAN/WAN protocols directly or DNP3 through an SEL-2032 Communications Processor. Use file transfer protocol (FTP) for high-speed data collection.

Increased Security. The SEL-421 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.

Rules-Based Settings Editor. Communicate with and set the relay using an ASCII terminal, or use the PC-based ACSELERATOR QuickSet SEL-5030 Software to configure the SEL-421 and analyze fault records with relay element response. View real-time phasors.

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

Thermal Overload Modeling. Use the SEL-421 with the SEL-2600A RTD Module for dynamic overload protection using SELOGIC control equations. For more information, see SEL Application Guide *AG2003-06, Implementation of the SEL-49 Relay Line Thermal Protection Using the SEL-421 Relay SELOGIC Equations*.

Alias Settings. Use as many as 200 aliases to rename any digital or analog quantity in the relay. The aliases are now available for use in customized programming, making the initial programming and maintenance much easier.

Auxiliary {TRIP}/{CLOSE} Pushbuttons. The part number indicates whether the relay has auxiliary **{TRIP}** and **{CLOSE}** pushbuttons. These pushbuttons are shown in *Figure 5.2*. These features are electrically isolated from the rest of the relay. They function independently from the relay and do not need relay power.

Part numbers 0421*xxxxxxxxxx*3A*xxxxx*, 0421*xxxxxxxxxx*7A*xxxxx*, 0421*xxxxxxxxxx*3B*xxxxx*, and 0421*xxxxxxxxxx*7B*xxxxx* designate relays *with* the auxiliary **{TRIP}** and **{CLOSE}** pushbuttons.

The lowercase *x*s in the above part numbers represent fields that contain other values that are not important in determining the operator controls of the relay. Refer to the SEL-421 Model Option Table for complete part number details. These tables are available on the SEL website or from the factory.

Models and Options

Consider the following options when ordering and configuring the SEL-421.

- Chassis size
  - 3U, 4U, and 5U
    (U is one rack unit—1.75 inches or 44.45 mm)
- Main board I/O

NOTE: The SEL-421-0 and the SEL-421-1 do not support Main Board B.

  - Main Board A:

    Contact inputs: 5 independent and 2 common inputs (programmable pickup threshold);
    Contact outputs: 2 standard Form A, 3 standard Form C, and 3 High-Current Interrupting Form A outputs
  - Main Board B:

    Contact inputs: 5 independent and 2 common inputs (level sensitive and optoisolated);
    Contact outputs: 2 standard Form A, 3 standard Form C, and 3 High-Current Interrupting Form A outputs
- Additional I/O board (for 4U and 5U chassis)

NOTE: The SEL-421-0 and the SEL-421-1 do not support I/O boards INT2, INT3, INT7, and INT8.

  - INT1:

    Contact inputs: 8 independent inputs (programmable pickup threshold);
    Contact outputs: 13 standard Form A and 2 standard Form C outputs
  - INT2:

    Contact inputs: 8 independent inputs (level sensitive and optoisolated);
    Contact outputs: 13 standard Form A and 2 standard Form C outputs
  - INT3:

    Contact inputs: 18 common (2 groups of 9) and 6 independent inputs (level sensitive and optoisolated);
    Contact outputs: 4 high-current interrupting Form A outputs
  - INT4:

    Contact inputs: 18 common (2 groups of 9) and 6 independent inputs (level sensitive and optoisolated);
    Contact outputs: 6 Fast High-Current Interrupting Form A and 2 standard Form A outputs
  - INT5:

    Contact inputs: 8 independent inputs (programmable pickup threshold);
    Contact outputs: 8 Fast High-Current Interrupting Form A outputs

- INT6:

  Contact inputs: 8 independent inputs (programmable pickup threshold);
  Contact outputs: 13 High-Current Interrupting Form A and 2 standard Form C outputs
- INT7:

  Contact inputs: 8 independent inputs (level sensitive and optoisolated);
  Contact outputs: 13 High-Current Interrupting Form A and 2 standard Form C outputs
- INT8:

  Contact inputs: 8 independent inputs (level sensitive and optoisolated);
  Contact outputs: 8 Fast High-Current Interrupting Form A outputs

- Chassis orientation and type
  - Horizontal rack mount
  - Horizontal panel mount
  - Vertical rack mount
  - Vertical panel mount
- Power supply
  - 24/48 Vdc
  - 48/125 Vdc or 120 Vac
  - 125/250 Vdc or 120/230 Vac
- Secondary inputs
  - 1 A nominal or 5 A nominal CT inputs.
    300 V phase-to-neutral wye configuration PT inputs
- Communications card options
  - Ethernet card with combinations of 10/100BASE-T and 100BASE-FX media connections on each of two ports
- Communications protocols
  - Complete group of SEL protocols
    (SEL ASCII, SEL Compressed ASCII, SEL Settings File Transfer, SEL Fast Meter, SEL Fast Operate, SEL Fast SER, RTDs, Enhanced MIRRORED BITS Communications), and Synchrophasors (SEL Fast Message and IEEE C37.118 format).
  - Complete group of SEL protocols, Synchrophasors (SEL Fast Message and IEEE C37.118 format), plus DNP3
  - Complete group of SEL protocols, Synchrophasors (SEL Fast Message and IEEE C37.118 format), plus IEC 61850

- ➤ Connector type
  - ➢ Fixed PT and CT terminal block inputs
  - ➢ Plug-in/plug-out PT and shorting CT Connectorized® versions

Contact the SEL factory or your local Technical Service Center for particular part number and ordering information (see *Technical Support on page U.6.45*). You can also view the latest part number and ordering information on the SEL website at www.selinc.com.

SEL-421 Versions and Supported Features

SEL-421 Features	-0	-1	-2	-3
Protection				
21G Mho Ground Distance and 21P Mho Phase Distance	standard	standard	standard	standard
High-Speed Distance and High-Speed Directional	standard			standard
50N/G Ground, 50P Phase, and 50Q Negative-Sequence—O/C	standard	standard	standard	standard
51N/G Ground, 51P Phase, and 51Q Negative-Sequence Time—O/C	standard	standard	standard	standard
67N/G Ground, 67P Phase, and 67Q Neg.-Seq. Directional—O/C	standard	standard	standard	standard
Programmable Analog Math	standard	standard	standard	standard
Out-of-Step Trip and Block	standard	standard	standard	standard
Load-Encroachment Supervision	standard	standard	standard	standard
Switch-Onto-Fault	standard	standard	standard	standard
Single-Pole Trip	standard	standard	standard	standard
MIRRORED BITS Communications	standard	standard	standard	standard
Zone/Level Timers	standard	standard	standard	standard
Pilot Protection Logic	standard	standard	standard	standard
Series-Compensated Line Logic	standard			standard
Instrumentation and Control				
79 Automatic Reclosing, Voltage Check on Closing, 25 Synchronism Check	standard	standard	standard	standard
Fault Locating	standard	standard	standard	standard
SELOGIC Control Equations	standard	standard	standard	standard
Maximum Automation SELOGIC Control Equations	1000	100	100	1000
Substation Battery Monitor	standard	standard	standard	standard
Breaker Wear Monitor	standard	standard	standard	standard
Event Report (Multicycle Data) and Sequential Events Recorder	standard	standard	standard	standard
Instantaneous, RMS, and Demand Meter	standard	standard	standard	standard
DNP3 Level 2 Slave	standard	optional	optional	optional
Synchrophasors (IEEE C37.118 and SEL-Fast Message)[a]	standard	standard	standard	standard
Remote Synchrophasor Measurement[b]			standard	standard

SEL-421 Features	-0	-1	-2	-3
Contact Input Option				
Main Board A—User-Settable Level-Sensitive Contact Inputs	standard	standard	optional	optional
Main Board B—Optoisolated Level-Sensitive Contact Inputs[c]			optional	optional
INT1 Interface Board—User-Settable Level-Sensitive Contact Inputs	optional	optional	optional	optional
INT2 Interface Board—Optoisolated Level-Sensitive Contact Inputs[c]			optional	optional
INT3 Interface Board—Optoisolated Level-Sensitive Contact Inputs[d]			optional	optional
INT4 Interface Board—Optoisolated Level-Sensitive Contact Inputs[e]	optional	optional	optional	optional
INT5 Interface Board—User-Settable Level-Sensitive Contact Inputs	optional	optional	optional	optional
INT6 Interface Board—User-Settable Level-Sensitive Contact Inputs	optional	optional	optional	optional
INT7 Interface Board—Optoisolated Level-Sensitive Contact Inputs[c]			optional	optional
INT8 Interface Board—Optoisolated Level-Sensitive Contact Inputs[c]			optional	optional

a Firmware versions R102–R112 provide synchrophasors using the SEL Fast Message protocol in the SEL-421-0.
b Firmware versions R123 and older do not provide this feature.
c Firmware versions R115 and older do not provide support for Main Board B, INT2, INT7, and INT8 interface boards.
d Firmware versions R121 and older do not provide support for the INT3 interface board.
e Firmware versions R112 and older do not provide support for the INT4 interface board.

Applications

Use the SEL-421 in a variety of transmission line protection applications. For information on connecting the relay, see *Installation on page U.2.1*. See the *Applications Handbook* for thorough discussions of protection and automation applications using the SEL-421.

The figures in this subsection illustrate common relay application configurations. *Figure 1.3*, *Figure 1.4*, *Figure 1.5*, *Figure 1.6*, and *Figure 1.7* demonstrate relay versatility with Global setting ESS (Current and Voltage Source Selection). These figures show the power and simplicity of the four preprogrammed ESS options. For more information on setting ESS, see *Current and Voltage Source Selection on page R.1.2*.

The SEL-421 has two sets of three-phase analog current inputs, IW and IX, and two sets of three-phase analog voltage inputs, VY and VZ. The drawings that follow use a two-letter acronym to represent all three phases of a relay analog input. For example, IW represents IAW, IBW, and ICW for A-, B-, and C-phase current inputs on terminal W, respectively. The drawings list a separate phase designator if you need only one or two phases of the analog input set (VAZ for the A-phase voltage of the VZ input set, for example).

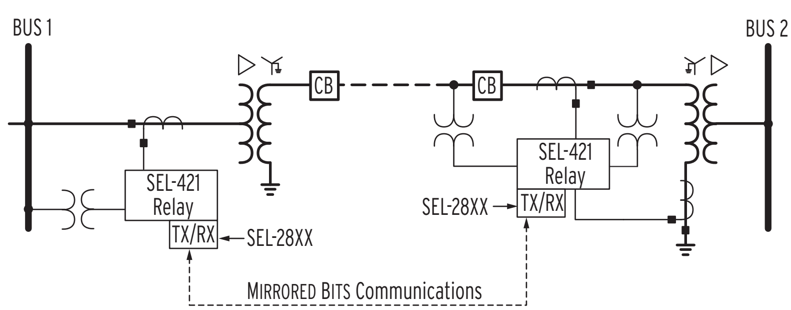
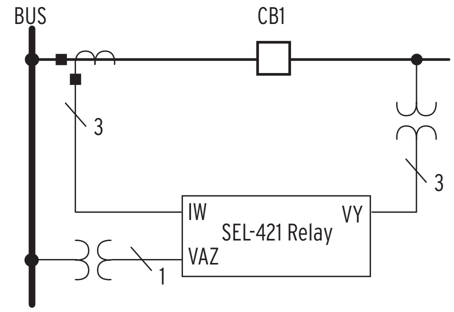
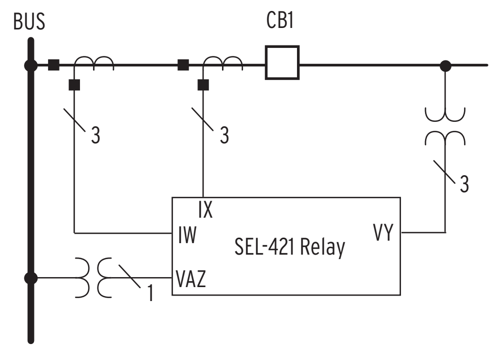


Figure 1.2 Protecting a Line Segment With MIRRORED BITS Communications on a Fiber Channel



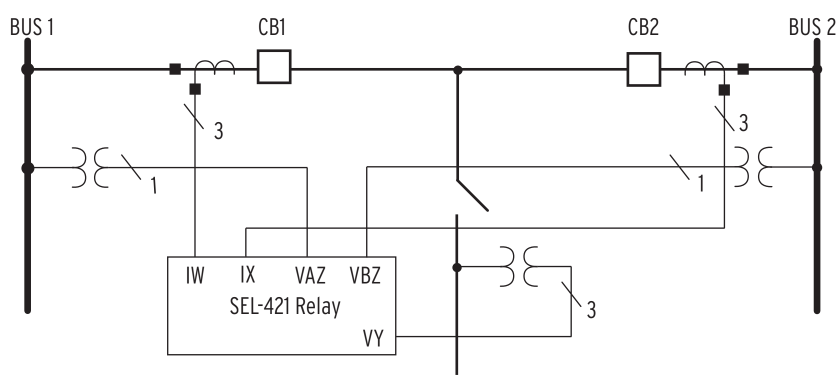
Analog Input	Function
IW	CB1 protection, line protection
VY	Line protection
VAZ	Synchronism check

Figure 1.3 Single Circuit Breaker Configuration (ESS := 1)



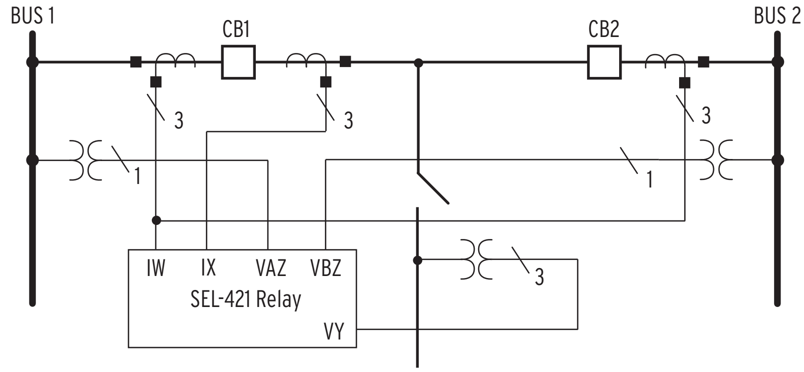
Analog Input	Function
IW	CB1 protection, line protection
IX	CB1 breaker failure
VY	Line protection
VAZ	Synchronism check

Figure 1.4 Single Circuit Breaker Configuration With Line Breaker CTs (ESS := 2)



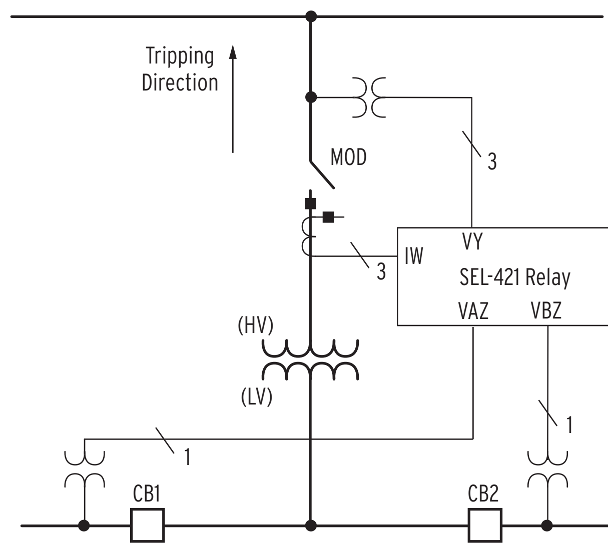
Analog Input	Function
IW+IX	Line Protection
IW	CB1 protection
IX	CB2 protection
VY	Line protection
VAZ	Synchronism check Circuit Breaker 1
VBZ	Synchronism check Circuit Breaker 2

Figure 1.5 Double Circuit Breaker Configuration (ESS := 3)



Analog Input	Function
IW+IX	CB2 protection
IW	Line protection
IX	CB1 protection
VY	Line protection
VAZ	Synchronism check Circuit Breaker 1
VBZ	Synchronism check Circuit Breaker 2

Figure 1.6 Double Circuit Breaker Configuration With Bus Protection (ESS := 4)



Analog Input	Function
IW	Line protection
VY	Line protection
VAZ	Synchronism check Circuit Breaker 1
VBZ	Synchronism check Circuit Breaker 2

Figure 1.7 Tapped Line (ESS := Y)

Application Highlights

Apply the SEL-421 in power system protection and control situations. *Table 1.1* lists applications and key features of the relay.

NOTE: The SEL-421-1 and the SEL-421-2 do not provide high-speed directional elements and high-speed distance elements.

NOTE: The SEL-421-1 and the SEL-421-2 do not provide series-compensated line protection logic.

Table 1.1 Application Highlights (Sheet 1 of 2)

Application	Key Features
Single-pole and three-pole tripping	High-speed distance elements Best Choice Ground Directional element Secure protection during open-pole interval Pole-discordance logic trips three-pole for excessive single-pole-open conditions
Multiple-breaker tripping	SPT one; 3PT other SPT both; 3PT both Breaker failure protection
Reclosing and synchronism check	2 shots SPT; 4 shots 3PT Leader/follower breaker arrangements Two-circuit-breaker universal synchronism check
Coupling-Capacitor Voltage Transformer (CCVT) transient detection logic	Detect CCVT transients to provide correct operation of the direct tripping (Zone 1) distance elements
Long lines	Load-encroachment elements prevent unwanted trips on load Voltage elements detect local bus overvoltages Sensitive negative-sequence and residual overcurrent elements provide sensitive backup protection
Tapped and three-terminal lines	Five zones Three zero-sequence compensation factors for more accurate ground-distance reach on either side of tap Independent reach settings for phase, ground mho, and ground quadrilateral elements Multiple settings groups cover any switching configurations
Bus-tie or transfer circuit breakers	Multiple setting groups Match relay settings group to each line substitution Eliminate current reversing switches Local or remote operator switches the setting groups
Subtransmission lines	Time-step distance protection Ground directional overcurrent protection Torque-controlled time-overcurrent elements
Lines with capacitors	Series-compensated line logic
Lines with transformers	Negative-sequence overcurrent protection
Short transmission lines	Directional overcurrent elements and communications-assisted tripping schemes
Permissive Overreaching Transfer Tripping (POTT) schemes	Current reversal guard logic Open breaker echo keying logic Weak-infeed and zero-infeed logic Time-step distance backup protection
Directional Comparison Unblocking Tripping (DCUB) schemes	Includes all POTT logic All loss-of-channel logic is inside the relay Time-step distance backup protection
Permissive Underreaching Transfer Tripping (PUTT) schemes	Supported by POTT logic Time-step distance backup protection

Table 1.1 Application Highlights (Sheet 2 of 2)

Application	Key Features
Directional Comparison Blocking Trip (DCB) schemes	Current reversal guard logic Carrier coordinating timers Carrier send and receive extend logic Zone 3 latch eliminates the need for offset three-phase distance elements Time-step distance backup protection
Direct Transfer Tripping (DTT) schemes	SELOGIC control equations program the elements that key direct tripping
SCADA applications	Analog and digital data acquisition for station wide functions
Communications capability	SEL ASCII Enhanced MIRRORED BITS communications SEL Fast Meter, SEL Fast Operate, SEL Fast SER SEL Compressed ASCII Phasor Measurement Unit (PMU) protocols RTD Optional Serial DNP3 Optional protocols: Ethernet, IEC 61850, DNP3 (Ethernet), FTP, Telnet
Customized protection and automation schemes	Separate protection and automation SELOGIC control equation programming areas Use timers and counters in expanded SELOGIC control equations for complete flexibility
Synchrophasors	The SEL-421 can function as a phasor measurement unit (PMU) at the same time as it provides best-in-class protective relay functions. C37.118 message format allows up to eight current and four voltage synchronized measurements, up to 60 messages per second (on a 60 Hz nominal power system). Two choices of filter response, settable angle correction, and choice of numeric representation makes the data usable for a variety of synchrophasor applications. SEL Fast Operate commands are available on the synchrophasor communications ports, allowing control actions initiated by the synchrophasor processor. SEL Fast Message Synchrophasor format is also available, with up to four current and four voltage synchronized measurements.

NOTE: Starting with SEL-421 firmware version R112, synchrophasors are available in the SEL-421-1.

Specifications

Important: Do not use the following specification information to order an SEL-421. Refer to the actual ordering information sheets.

General

AC Current Inputs (Secondary Circuits)

Note: Current transformers are Measurement Category II.

5 A nominal:	15 A continuous, linear to 100 A symmetrical 500 A for 1 second 1250 A for 1 cycle
Burden:	0.27 VA at 5 A 2.51 VA at 15 A
1 A nominal:	3 A continuous, linear to 20 A symmetrical 100 A for 1 second 250 A for 1 cycle
Burden:	0.13 VA at 1 A 1.31 VA at 3 A

AC Voltage Inputs

300 V_{L-N} continuous (connect any voltage up to 300 Vac)

600 Vac for 10 seconds

Burden:	0.03 VA at 67 V 0.06 VA at 120 V 0.8 VA at 300 V

Power Supply

125/250 Vdc or 120/230 Vac

Range:	85–300 Vdc <35 W or 85–264 Vac
Nominal Frequency:	50/60 Hz
Range:	30–120 Hz
Burden:	<120 VA

48/125 Vdc or 120 Vac

Range:	38–140 Vdc <35 W or 85–140 Vac
Nominal Frequency:	50/60 Hz
Range:	30–120 Hz
Burden:	<120 VA

24/48 Vdc

Range:	18–60 Vdc
Burden:	<35 W

Control Outputs

Standard

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

Break Capacity (10000 operations):

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 = 40 ms

Cyclic Capacity (2.5 cycle/second):

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 = 40 ms

Note: EA certified relays do not have MOV protected standard output contacts.

Hybrid (high current interrupting):

Make:	30 A
Carry:	6 A continuous carry at 70°C 4 A continuous carry at 85°C
1s Rating:	50 A
MOV Protection (maximum voltage):	330 Vdc
Pickup/Dropout Time:	6 ms, resistive load
Update Rate:	1/8 cycle

Break Capacity (10000 operations):

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 (4 cycles in 1 second, followed by 2 minutes idle for thermal dissipation):

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.

Fast Hybrid (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:	1/8 cycle

Break Capacity (10000 operations):

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 (4 cycles in 1 second, followed by 2 minutes idle for thermal dissipation):

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: Per IEC 60255-23:1994, using the simplified method of assessment.
Note: Make rating per IEEE C37.90-1989.

Auxiliary Trip/Close Pushbuttons (Select Models Only)

Resistive DC or AC Outputs with Arc Suppression Disabled:

Make:	30 A
Carry:	6 A continuous carry

1 s Rating:	50 A
MOV Protection:	250 Vac/330 Vdc/130 J

Breaking Capacity (1000 operations):

48 V	0.50 A	L/R = 40 ms
125 V	0.30 A	L/R = 40 ms
250 V	0.20 A	L/R = 40 ms

Note: Make per IEEE C37.90-1989.

High Interrupt DC Outputs with Arc Suppression Enabled:

Make:	30 A
Carry:	6 A continuous carry
1 s Rating:	50 A
MOV Protection:	330 Vdc/130 J

Breaking Capacity (10000 operations):

48 V	10 A	L/R = 40 ms
125 V	10 A	L/R = 40 ms
250 V	10 A	L/R = 20 ms

Note: Make per IEEE C37.90-1989.

Breaker Open/Closed LEDs:

250 Vdc:	on for 150–300 Vdc; 192–288 Vac
125 Vdc:	on for 80–150 Vdc; 96–144 Vac
48 Vdc:	on for 30–60 Vdc;
24 Vdc:	on for 15–30 Vdc

Note: With nominal control voltage applied, each LED draws 8 mA (max.). Jumpers may be set to 125 Vdc for 110 Vdc input and set to 250 Vdc for 220 Vdc input.

Control Inputs

Direct Coupled (for use with dc signals)

Main Board A:	5 inputs with no shared terminals 2 inputs with shared terminals
INT1, INT5, and INT6 interface boards:	8 inputs with no shared terminals
Range:	15–265 Vdc, independently adjustable
Accuracy:	±5% plus ±3 Vdc
Maximum Voltage:	300 Vdc
Sampling Rate:	1/16 cycle
Typical Burden:	0.24 W at 125 Vdc

Optoisolated (use with ac or dc signals)

Main Board B:	5 inputs with no shared terminals 2 inputs with shared terminals
INT2, INT7, and INT8 interface boards:	8 inputs with no shared terminals
INT3 and 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 V standard 48, 110, 125, 220, 250 V level sensitive

DC Thresholds (Dropout thresholds indicate level-sensitive option):

24 Vdc:	Pickup 15.0–30.0 Vdc rms
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 2.2*.):

24 Vac:	Pickup 12.8–30.0 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 150–264 Vac rms; Dropout <93.2 Vac rms
250 Vac:	Pickup 170.6–300 Vac rms; Dropout <106 Vac rms
Current Drawn:	5 mA at nominal voltage 8 mA for 110 V option
Sampling Rate:	1/16 cycle

Frequency and Rotation

System Frequency:	50/60 Hz
Phase Rotation:	ABC or ACB
Frequency Tracking Range:	40–65 Hz

Communications Ports

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

Communications Card Slot for optional Ethernet Processor

Fiber Optic (Optional)

Ordering Options:

Mode:	Multi	Multi
Wavelength (nm):	820	1300
Source:	LED	LED
Connector type:	ST	ST
Min. TX Pwr. (dBm):	–15.8	–19
Max. TX Pwr. (dBm):	12	–14
RX Sens. (dBm):	–34.4	–32
Sys. Gain (dB):	5	13

Time Inputs

IRIG-B Input—Serial Port 1

Input:	Demodulated IRIG-B
Nominal Voltage:	5 Vdc +10%
Maximum Voltage:	8 Vdc
Input Impedance:	333 ohms
Isolation:	500 Vdc

IRIG-B Input—BNC Connector

Input:	Demodulated IRIG-B
Nominal Voltage:	5 Vdc +10%
Maximum Voltage:	8 Vdc
Input Impedance:	2500 ohms

Operating Temperature

Without Ethernet: –40° to +85°C (–40° to +185°F)

With Ethernet: –40° to +75°C (–40° to +167°F)

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

Humidity

5% to 95% without condensation

Weight (Maximum)

3U Rack Unit: 8.0 kg (17.5 lbs)
4U Rack Unit: 9.8 kg (21.5 lbs)
5U Rack Unit: 11.6 kg (25.5 lbs)

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:

Connection Type	Minimum Wire Size	Maximum Wire Size
Grounding (Earthing) Connection	18 AWG (0.8 mm^2)	14 AWG (2.5 mm^2)
Current Connection	16 AWG (1.5 mm^2)	12 AWG (4 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)	14 AWG (2.5 mm^2)
Other Connection	18 AWG (0.8 mm^2)	14 AWG (2.5 mm^2)

Use wire with 0.4 mm-thick insulation for high-voltage connections to allow for contact between adjacent wires. If possible, use 0.4 mm insulated wires for all connections.

Routine Dielectric Strength Tests (Performed on Each Manufactured Relay)

AC Current Inputs, optoisolated inputs, and output contacts: 2500 Vac for 10 s

Power Supply: 3100 Vdc for 10 s

Type Tests

Electromagnetic Compatibility Emissions

Emissions: IEC 60255-25:2000

Electromagnetic Compatibility Immunity

Conducted RF Immunity: IEC 60255-22-6:2001
Severity Level: 10 Vrms
IEC 61000-4-6:2008
Severity Level: 10 Vrms

Electrostatic Discharge Immunity: IEC 60255-22-2:2008
Severity Level: 2, 4, 6, 8 kV contact; 2, 4, 8, 15 kV air
IEC 61000-4-2:2008
Severity Level: 2, 4, 6, 8 kV contact; 2, 4, 8, 15 kV air
IEEE C37.90.3-2001
Severity Level: 2, 4, 8 kV contact; 4, 8, 15 kV air

Fast Transient/Burst Immunity: IEC 60255-22-4:2008
Severity Level: Calss A: 4 kV, 5 kHz; 2 kV, 5 kHz on communication ports
IEC 61000-4-4:2011
Severity Level: 4 kV, 5 kHz

Magnetic Field Immunity: IEC 61000-4-8:2009
Severity Level: 900 A/m for 3 seconds, 100 A/m for 1 minute
IEC 61000-4-9:2001
Severity Level: 1000 A/m

Power Supply Immunity: IEC 60255-11:2008
IEC 61000-4-11:2004
IEC 61000-4-29:2000

Radiated Digital Radio Telephone RF Immunity: ENV 50204:1995
Severity Level: 10 V/m at 900 MHz and 1.89 GHz

Radiated Radio Frequency Immunity: IEC 60255-22-3:2007
Severity Level: 10 V/m
IEC 61000-4-3:2010
Severity Level: 10 V/m
IEEE C37.90.2-2004
Severity Level: 35 V/m

Surge Immunity: IEC 60255-22-5:2008
Severity Level: 1 kV Line-to-Line, 2 kV Line-to-Earth
IEC 61000-4-5:2005
Severity Level: 1 kV Line-to-Line, 2 kV Line-to-Earth

Surge Withstand Capability Immunity: IEC 60255-22-1:2007
Severity Level: 2.5 kV peak common mode, 1.0 kV peak differential mode
IEEE C37.90.1-2002
Severity Level: 2.5 kV oscillatory, 4 kV fast transient waveform

Environmental

Cold: IEC 60068-2-1:2007
Severity Level: 16 hours at –40°C

Damp Heat, Cyclic: IEC 60068-2-30:2005
Severity Level: 25°C to 55°C, 6 cycles, Relative Humidity: 95%

Dry Heat: IEC 60068-2-2:2007
Severity Level: 16 hours at +85°C

Vibration: IEC 60255-21-1:1988
Severity Level: Class 1 Endurance, Class 2 Response
IEC 60255-21-2:1988
Severity Level: Class 1–Shock withstand, Bump, and Class 2–Shock Response
IEC 60255-21-3:1993
Severity Level: Class 2 (Quake Response)

Safety

Dielectric Strength:	IEC 60255-5:2000 Severity Level: 2500 Vac on contact inputs, contact outputs, and analog inputs. 3100 Vdc on power supply. Type Tested for 1 minute. IEEE C37.90-2005 Severity Level: 2500 Vac on contact inputs, contact outputs, and analog inputs. 3100 Vdc on power supply. Type Tested for 1 minute.
Impulse:	IEC 60255-5:2000 Severity Level: 0.5 Joule, 5 kV IEEE C37.90-2005 Severity Level: 0.5 Joule, 5 kV

Safety Agency Certifications

Product Safety:	C22.2 No. 14 cUL Listed Protective Relay, Product Category NRGU7 UL 508 UL Listed Protective Relay, Product Category NRGU

Certifications

ISO 9001: This product was designed and manufactured under an ISO 9001 certified quality management system.

Product Safety:	IEC 60255-6:1988

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

Event Reports

Storage:	35 quarter-second events or 24 half-second events
Maximum Duration:	Record events as long as 5 seconds
Resolution:	8- or 4-samples/cycle

Event Summary

Storage:	100 summaries

Breaker History

Storage:	128 histories

Sequential Events Recorder

Storage:	1000 entries
Trigger Elements:	250 relay elements

Processing Specifications

AC Voltage and Current Inputs

8000 samples per second, 3 dB low-pass analog filter cut-off frequency of 3000 Hz.

Digital Filtering

Full-cycle cosine and half-cycle Fourier filters after low-pass analog and digital filtering.

Protection and Control Processing

8 times per power system cycle

Synchrophasors

Maximum data rate in messages per second

IEEE C37.118 protocol:	60 (nominal 60 Hz system) 50 (nominal 50 Hz system)
SEL Fast Message protocol:	20 (nominal 60 Hz system) 10 (nominal 50 Hz system)

Control Points

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

Relay Element Pickup Ranges and Accuracies

Mho Phase Distance Elements

Zones 1–5 Impedance Reach

Setting Range	
5 A Model:	OFF, 0.05 to 64 Ω secondary, 0.01 Ω steps
1 A Model:	OFF, 0.25 to 320 Ω secondary, 0.01 Ω steps
Sensitivity	
5 A Model:	0.5 A_{P-P} secondary
1 A Model:	0.1 A_{P-P} secondary (Minimum sensitivity is controlled by the pickup of the supervising phase-to-phase overcurrent elements for each zone.)
Accuracy (Steady State):	±3% of setting at line angle for SIR (source-to-line impedance ratio) < 30 ±5% of setting at line angle for 30 ≤ SIR ≤ 60
Zone 1 Transient Overreach:	<5% of setting plus steady-state accuracy
SEL-421-0 and SEL-421-3 Maximum Operating Time:	0.8 cycle at 70% of reach and SIR = 1
SEL-421-1 and SEL-421-2 Maximum Operating Time:	1.5 cycle at 70% of reach and SIR = 1

Mho Ground Distance Elements

Zones 1–5 Impedance Reach

Mho Element Reach	
5 A Model:	OFF, 0.05 to 64 Ω secondary, 0.01 Ω steps
1 A Model:	OFF, 0.25 to 320 Ω secondary, 0.01 Ω steps
Sensitivity	
5 A Model:	0.5 A secondary
1 A Model:	0.1 A secondary (Minimum sensitivity is controlled by the pickup of the supervising phase and residual overcurrent elements for each zone.)
Accuracy (Steady State):	±3% of setting at line angle for SIR < 30 ±5% of setting at line angle for 30 ≤ SIR ≤ 60
Zone 1 Transient Overreach:	<5% of setting *plus* steady-state accuracy

SEL-421-0 and SEL-421-3 Maximum Operating Time: 0.8 cycle at 70% of reach and SIR = 1

SEL-421-1 and SEL-421-2 Maximum Operating Time: 1.5 cycle at 70% of reach and SIR = 1

Quadrilateral Ground Distance Elements

Zones 1–5 Impedance Reach

Quadrilateral Reactance Reach

5 A Model: OFF, 0.05 to 64 Ω secondary, 0.01 Ω steps

1 A Model: OFF, 0.25 to 320 Ω secondary, 0.01 Ω steps

Quadrilateral Resistance Reach

5 A Model: OFF, 0.05 to 50 Ω secondary, 0.01 Ω steps

1 A Model: OFF, 0.25 to 250 Ω secondary, 0.01 Ω steps

Sensitivity

5 A Model: 0.5 A secondary

1 A Model: 0.1 A secondary (Minimum sensitivity is controlled by the pickup of the supervising phase and residual overcurrent elements for each zone.)

Accuracy (Steady State): ±3% of setting at line angle for SIR < 30
±5% of setting at line angle for 30 ≤ SIR ≤ 60

Transient Overreach: <5% of setting plus steady-state accuracy

Instantaneous/Definite-Time Overcurrent Elements

Phase, Residual Ground, and Negative-Sequence

Pickup 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 plus ±3% of setting

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

Transient Overreach: <5% of pickup

Time Delay: 0.000–16000.000 cycles, 0.125 cycle steps

Timer Accuracy: ±0.125 cycle plus ±0.1% of setting

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 plus ±3% of setting

1 A Model: ±0.01 A plus ±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 plus ±4% of curve time (for current between 2 and 30 multiples of pickup)

Reset: 1 power cycle or Electromechanical Reset Emulation time

Ground Directional Elements

Neg.-Seq. Directional Impedance Threshold (Z2F, Z2R)

5 A Model: –64 to 64 Ω

1 A Model: –320 to 320 Ω

Zero-Seq. Directional Impedance Threshold (Z0F, Z0R)

5 A Model: –64 to 64 Ω

1 A Model: –320 to 320 Ω

Supervisory Overcurrent Pickup 50FP, 50RP

5 A Model: 0.25 to 5.00 A 3I0 secondary
0.25 to 5.00 A 3I2 secondary

1 A Model: 0.05 to 1.00 A 3I0 secondary
0.05 to 1.00 A 3I2 secondary

Undervoltage and Overvoltage Elements

Pickup Ranges: Phase elements: 1–200 V secondary, 1 V steps

Phase-to-Phase Elements: 1.0–300.0 V secondary, 0.1 V steps

Accuracy (Steady State): ±1 V plus ±5% of setting

Transient Overreach: <5% of pickup

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

12 RTD Inputs via SEL-2600 RTD Module and SEL-2800 Fiber-Optic Transceiver

Monitor Ambient or Other Temperatures

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

Up to 500 m Fiber-Optic Cable to SEL-2600 RTD Module

Breaker Failure Instantaneous Overcurrent

Setting Range

5 A Model: 0.50–50.0 A, 0.01 A steps

1 A Model: 0.10–10.0 A, 0.01 A steps

Accuracy

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

1 A Model: ±0.01 A plus ±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, 0.125 cycle steps (All but BFIDO*n*, BFISP*n*)
0–1000 cycles, 0.125 cycle steps (BFIDO*n*, BFISP*n*)

Time Delay Accuracy: 0.125 cycle plus ±0.1% of setting

Synchronism-Check Elements

Slip Frequency Pickup Range:	0.005–0.500 Hz, 0.001 Hz steps
Slip Frequency Pickup Accuracy:	±0.0025 Hz plus ±2% of setting
Close Angle Range:	3–80°, 1° steps
Close Angle Accuracy:	±3°

Load-Encroachment Detection

Setting Range	
5 A Model:	0.05–64 Ω secondary, 0.01 Ω steps
1 A Model:	0.25–320 Ω secondary, 0.01 Ω steps
Forward Load Angle:	–90° to +90°
Reverse Load Angle:	+90° to +270°
Accuracy	
Impedance Measurement:	±3%
Angle Measurement:	±2°

Out-of-Step Elements

Blinders (R1) Parallel to the Line Angle	
5 A Model:	0.05 to 70 Ω secondary –0.05 to –70 Ω secondary
1 A Model:	0.25 to 350 Ω secondary –0.25 to –350 Ω secondary
Blinders (X1) Perpendicular to the Line Angle	
5 A Model:	0.05 to 96 Ω secondary –0.05 to –96 Ω secondary
1 A Model:	0.25 to 480 Ω secondary –0.25 to –480 Ω secondary
Accuracy (Steady State)	
5 A Model:	±5% of setting plus ±0.01 A for SIR (source to line impedance ratio) < 30 ±10% of setting plus ±0.01 A for 30 ≤ SIR ≤ 60
1 A Model:	±5% of setting plus ±0.05 A for SIR (source to line impedance ratio) < 30 ±10% of setting plus ±0.05 A for 30 ≤ SIR ≤ 60
Transient Overreach:	<5% of setting *plus* steady-state accuracy
Positive-Sequence Overcurrent Supervision	
Setting Range	
5 A Model:	1.0–100.0 A, 0.01 A steps
1 A Model:	0.2–20.0 A, 0.01 A steps
Accuracy	
5 A Model:	±3% of setting plus ±0.05 A
1 A Model:	±3% of setting plus ±0.01 A
Transient Overreach:	<5% of setting

Timer Specifications

Setting Ranges

Breaker Failure:	0–6000 cycles, 0.125 cycle steps (All but BFIDO*n*, BFISP*n*) 0–1000 cycles, 0.125 cycle steps (BFIDO*n*, BFISP*n*)
Communications-Assisted Tripping Schemes:	0.000–16000 cycles, 0.125 cycle steps
Out-of-Step Timers	
OSBD, OSTD:	0.500–8000 cycles, 0.125 cycle steps
UBD:	0.500–120 cycles, 0.125 cycle steps
Pole Open Timer:	0.000–60 cycles, 0.125 cycle steps
Recloser:	1–99999 cycles, 1 cycle steps
Switch-Onto-Fault	
CLOEND, 52AEND:	OFF, 0.000–16000 cycles, 0.125 cycle steps
SOTFD:	0.50–16000 cycles, 0.125 cycle steps
Synchronism Check Timers	
TCLSBK1, TCLSBK2:	1.00–30.00 cycles, 0.25 cycle steps
Zone Time Delay:	0.000–16000 cycles, 0.125 cycle steps

Station DC Battery System Monitor Specifications

Operating Range:	0–350 Vdc
Input Sampling Rate:	2 kHz
Processing Rate:	1/8 cycle
Maximum Operating Time:	≤1.5 cycles
Setting Range	
DC settings:	15–300 Vdc, 1 Vdc steps
AC ripple setting:	1–300 Vac, 1 Vac steps
Accuracy	
Pickup Accuracy:	±3% plus ±2 Vdc (all elements but DC1RP and DC2RP) ±10% plus ±2 Vac (DC1RP and DC2RP)

Metering Accuracy

All metering accuracy is at 20°C, and nominal frequency unless otherwise noted.

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 A sec)
Phase Current Angle	
All Models:	±0.2° in the current range 0.5 • I_{nom} to 3.0 • I_{nom}
Sequence Currents Magnitude	
5 A Model:	±0.3% plus ±4 mA (2.5–15 A sec)
1 A Model:	±0.3% plus ±0.8 mA (0.5–3 A sec)
Sequence Current Angle	
All Models:	±0.3° in the current range 0.5 • I_{nom} to 3.0 • I_{nom}

Voltages

Phase and Phase-to-Phase Voltage Magnitude:	±0.1% (33.5–200 V_{L-N})
Phase and Phase-to-Phase Angle:	±0.05° (33.5–200 V_{L-N})
Sequence Voltage Magnitude:	±0.15% (33.5–200 V_{L-N})
Sequence Voltage Angle:	±0.1° (33.5–200 V_{L-N})

Frequency (Input 40–65 Hz)

Accuracy:	±0.01 Hz

Power and Energy

Real Power, P (MW), Three Phase

At 0.1 • I_{nom}

Power factor unity:	±0.4%
Power factor 0.5 lag, 0.5 lead:	±0.7%

At 1.0 • I_{nom}

Power factor unity:	±0.4%
Power factor 0.5 lag, 0.5 lead:	±0.4%

Reactive Power, Q (MVAR), Three Phase

At 0.1 • I_{nom}

Power factor 0.5 lag, 0.5 lead:	±0.5%

At 1.0 • I_{nom}

Power factor 0.5 lag, 0.5 lead:	±0.4%

Energy (MWh), Three Phase

At 0.1 • I_{nom}

Power factor unity:	±0.5%
Power factor 0.5 lag, 0.5 lead:	±0.7%

At 1.0 • I_{nom}

Power factor unity:	±0.4%
Power factor 0.5 lag, 0.5 lead:	±0.4%

Synchrophasors

See *Accuracy on page R.7.8* for test exclusions and details.

TVE (total vector error):	≤1%
Frequency Range:	±5 Hz of nominal (50 or 60 Hz)
Voltage Range:	30 V–150 V
Current Range:	(0.1–2) • I_{nom} (I_{nom} = 1 A or 5 A)
Phase Angle Range:	–179.99° to 180°

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Section 2
Installation

The first steps in applying the SEL-421 Relay are installing and connecting the relay. This section describes common installation features and particular installation requirements for the many physical configurations of the SEL-421. You can order the relay in horizontal and vertical orientations, and in panel-mount and rack-mount versions. SEL also provides various expansion I/O (input/output) interface boards to tailor the relay to your specific needs.

To install and connect the relay safely and effectively, you must be familiar with relay configuration features and options and relay jumper configuration. You should carefully plan relay placement, cable connection, and relay communication. Consider the following when installing the SEL-421:

➤ *Shared Configuration Attributes on page U.2.1*

➤ *Plug-In Boards on page U.2.12*

➤ *Jumpers on page U.2.18*

➤ *Relay Placement on page U.2.30*

➤ *Connection on page U.2.31*

➤ *AC/DC Connection Diagrams on page U.2.50*

It is also very important to limit access to the SEL-421 settings and control functions by using passwords. For information on relay access levels and passwords, see *Changing the Default Passwords: Terminal on page U.4.9*.

Shared Configuration Attributes

There are common or shared attributes among the many possible configurations of SEL-421 relays. This section discusses the main shared features of the relay.

Relay Sizes

SEL produces the SEL-421 in horizontal and vertical rack-mount versions and horizontal and vertical panel-mount versions. Relay sizes correspond to height in rack units, U, where U is approximately 1.75 inches or 44.45 mm. The SEL-421 is available in 3U, 4U, and 5U sizes.

Front-Panel Templates

The horizontal front-panel template shown in *Figure 2.1* is the same for all 3U, 4U, and 5U horizontal versions of the relay. The vertical front-panel template (shown in *Figure 2.1*) is the same for all 3U, 4U, and 5U vertical versions of the relay.

The SEL-421 front panel has three pockets for slide-in labels: one pocket for the target LED label, and two pockets for the operator control labels. *Figure 2.1* shows the front-panel pocket areas and openings for typical horizontal and vertical relay orientations; dashed lines denote the pocket areas. Refer to the instructions included in the Configurable Label kit for information on reconfiguring front-panel LED and pushbutton labels.

Rear Panels

Rear panels are identical for the horizontal and the vertical configurations of the relay. *Figure 2.2* is an example of a rear panel for a 3U relay with fixed terminal block analog inputs. *Figure 2.3* shows a rear panel for a 3U relay with Connectorized® analog inputs. See *Rear-Panel Layout on page U.2.32* for representative 3U, 4U, and 5U relay rear panels (large drawings are in *Figure 2.28*, *Figure 2.29*, *Figure 2.30*, and *Figure 2.33*).

Connector Types

Screw Terminal Connectors—I/O and Monitor/Power

Connect to the relay I/O and Monitor/Power terminals on the rear panel 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 2.37*), so you can replace the screw terminal connector on the rear panel only at the location from which you removed the screw terminal connector. In addition, the receptacle key prevents you from inverting the screw terminal connector, making removal and replacement easier.

Secondary Circuit Connectors

Fixed Terminal Blocks

Connect PT and CT inputs to the fixed terminal blocks in the bottom row 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-421 features receptacles that accept plug-in/plug-out connectors for terminating PT and CT inputs; this requires ordering a wiring harness (SEL-WA0421) with mating plugs and wire leads. *Figure 2.3* shows the relay 3U chassis with Connectorized CT and PT analog inputs (see *Connectorized on page U.2.42* for more information).

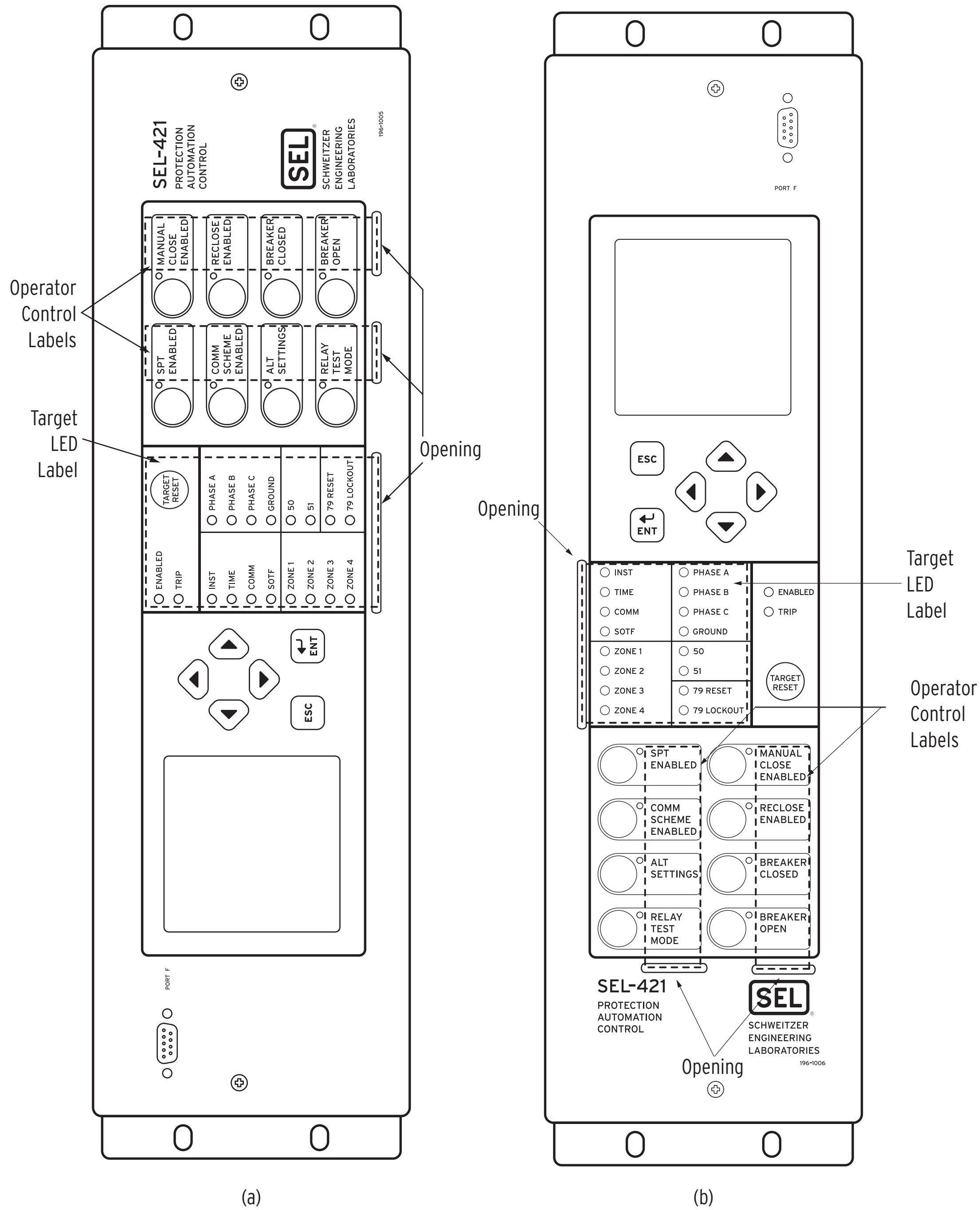


Figure 2.1 Horizontal Front-Panel Template (a); Vertical Front-Panel Template (b)

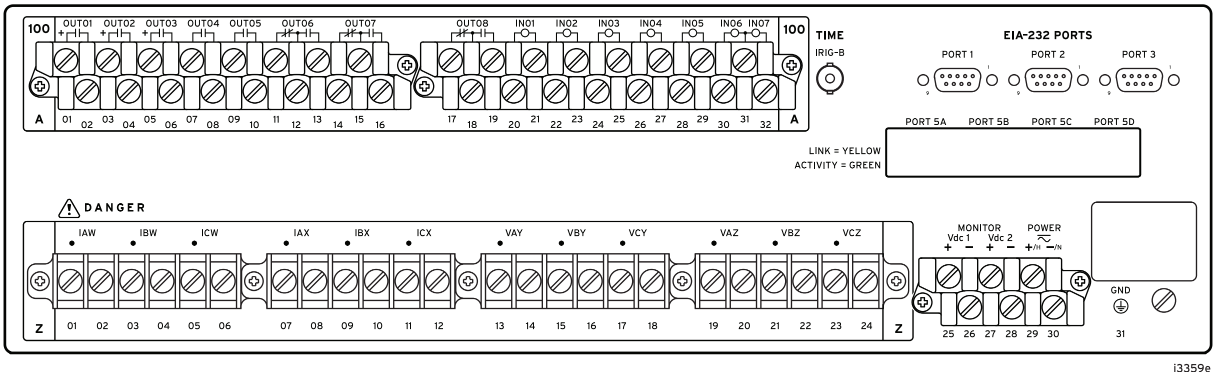


Figure 2.2 Rear 3U Template, Fixed Terminal Block Analog Inputs

(In a vertical-mount relay, the right rear side is at the top.)

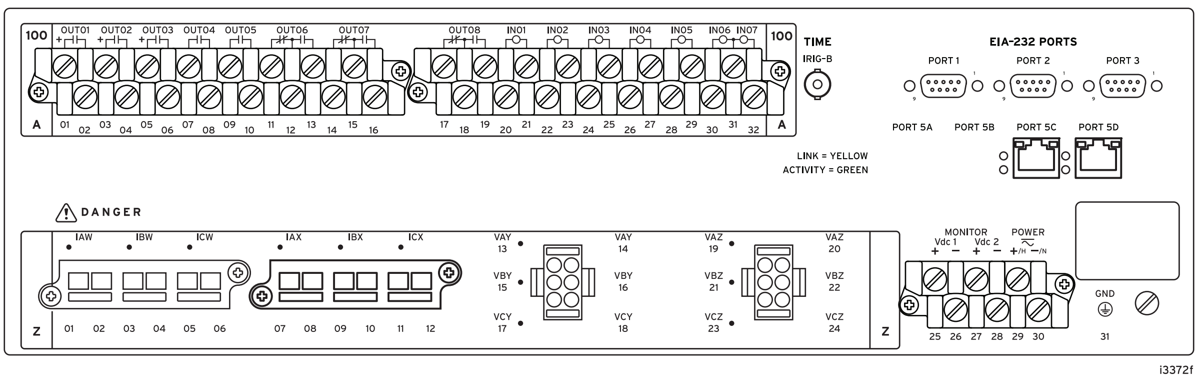


Figure 2.3 Rear 3U Template, Connectorized Analog Inputs

(In a vertical-mount relay, the right rear side is at the top.)

Secondary Circuits

The SEL-421 is a very low burden load on the CT secondaries and PT secondaries. For both the CT and PT inputs, the frequency range is 40–65 Hz.

The relay accepts two sets of three-phase currents from power system CT inputs:

- IAW, IBW, and ICW
- IAX, IBX, and ICX

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.

Input current for both relay types can range to 20 • I_{nom}. The CT burden for each relay is the following:

- 5 A relay: 0.27 VA @ 5A and 2.51 VA @ 15 A
- 1 A relay: 0.13 VA @ 1 A and 1.31 VA @ 3A

See the *AC Current Inputs (Secondary Circuits) on page U.1.13* for complete CT input specifications.

The relay also accepts two sets of three-phase, four-wire (wye) potentials from power system PT or CCVT (coupling-capacitor voltage transformer) secondaries:

- VAY, VBY, and VCY
- VAZ, VBZ, and VCZ

The nominal line-to-neutral input voltage for the PT inputs is 67 volts with a range of 0–300 volts. The PT burden is less than 0.5 VA at 67 volts, L-N. See *AC Voltage Inputs on page U.1.13* for complete PT input specifications.

Some applications do not use all three phases of a source; for example, voltage synchronization sources can be single phase. See *Section 1: Protection Application Examples in the Applications Handbook* for examples of connections to the potential inputs.

See *Secondary Circuit Connections on page U.2.41* for information on connecting power system secondary circuits to these inputs.

Control Inputs

Direct Coupled

NOTE: The SEL-421 Main Board A and the INT1, INT5, and INT6 I/O interface boards have polarity-sensitive inputs, and the terminals are identified with a polarity mark.

The SEL-421 Main Board A inputs, and the inputs on the optional I/O interface boards (INT1, INT5, or INT6 I /O boards—see *Models and Options on page U.1.5*), are direct-coupled, high-impedance control inputs. Use these inputs for monitoring on/off and logical change-of-state conditions of power system equipment. These high-isolation control inputs are polarity-sensitive circuits. You cannot damage these inputs with a reverse polarity connection, although the relay will not detect input changes with a reverse-polarity input. For more information on control input specifications, see *Control Inputs on page U.1.14*.

Inputs can be independent or common. Independent inputs have two separate ground-isolated connections to a high-isolation ADC (analog to digital converter). There are no internal connections among independent inputs. Common inputs share one input leg in common; all input legs of common inputs are ground-isolated. Each pair of common inputs is isolated from all other pairs.

Nominal current draw for these inputs is very low (4 mA or less) with an input voltage range of 15 Vdc to 265 Vdc. You can adjust the level at which these inputs assert (and deassert) and can also debounce the control inputs. See *Global Settings on page R.10.4* for the default settings and more information.

To ensure secure performance of the control inputs, set the control input pickup level according to the battery voltage level. *Table 2.1* lists some of the common DC voltage levels and appropriate settings.

Table 2.1 Recommended Control Input Pickup Settings (Sheet 1 of 2)

Substation DC Voltage Level	Recommended Settings	
	Pickup: GINP[a]	Dropout: GINDF
24	18 Vdc	85%
48	36 Vdc	85%
110	88 Vdc	80%
125	100 Vdc	80%

Table 2.1 Recommended Control Input Pickup Settings (Sheet 2 of 2)

Substation DC Voltage Level	Recommended Settings	
	Pickup: GINP[a]	Dropout: GINDF
220	176 Vdc	80%
250	200 Vdc	80%

[a] Applies to IN1nnP, IN2nnP, IN3nnP when global setting EICIS := Y.

The control input accuracy is ±5 percent of the applied signal plus ±3 Vdc. The maximum voltage input is 300 Vdc, and the relay samples the control inputs 16 times per cycle. See *Raw and Filtered Data on page A.3.2*.

Optoisolated

The SEL-421 Main Board B inputs, and the inputs on the optional I/O interface boards (INT2, INT3, INT4, INT7, or INT8 I/O boards—see *Models and Options on page U.1.5*), are fixed pickup threshold, optoisolated, control inputs. The pickup voltage level is determined for each board at ordering time.

NOTE: The SEL-421 Main Board B and the INT2, INT3, INT4, INT7, and INT8 I/O interface boards have optoisolated contact inputs that can be used in either polarity.

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. In other words, the relay will detect input changes with voltage applied at either polarity.

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 6 voltage options covering a wide range of voltages, as listed in *Control Inputs on page U.1.14*. You can debounce the control input pickup delay and dropout delay separately for each input, or you can use a single debounce setting that applies to all the contact input pickup and dropout times—see *Global Settings on page R.10.4*.

AC Control Signals

Optoisolated control inputs can be used with ac control signals, within the ratings shown in *Control Inputs on page U.1.14*. Specific pickup and dropout time-delay settings are required to achieve the specified ac thresholds, as shown in *Table 2.2*.

NOTE: Only the optoisolated control inputs can be used to detect ac control signals. Direct-coupled control inputs can only be used with dc control signals.

It is possible to mix ac and dc control signal detection on the same interface board with optoisolated contact inputs, 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 2.2 Required Settings for Use with AC Control Signals[a]

Global Settings	Description	Entry[b]	Relay Recognition Time for AC Control Signal state change
IN*nmm*PU[c]	Pickup Delay	0.1250 cycles	0.625 cycles maximum (assertion)
IN*nmm*DO[c]	Dropout Delay	1.0000 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.
[b] These are the only setting values that SEL recommends for detecting ac control signals. Other values may result in inconsistent operation.
[c] Where n is 1 for Main Board, 2 for Interface Board 1, and 3 for Interface Board 2; mm is number of available contact inputs depending on the type of board.

The recognition times listed in *Table 2.2* 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 *Optoisolated (use with ac or dc signals) on page U.1.14*.
- The signal contains no dc offset.

The SEL-421 samples the optoisolated inputs 16 times per cycle—see *Raw and Filtered Data on page A.3.2*.

Control Outputs

NOTE: EA certified relays do not have MOV protected standard output contacts.

I/O control outputs from the relay include Standard outputs, Hybrid (high-current-interrupting) outputs, and Fast Hybrid (fast high-current-interrupting) outputs. Fast Hybrid outputs are available only on the optional INT4, INT5, or INT8 I/O interface boards. An MOV (metal-oxide varistor) 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 eight times per cycle. Updating of relay control outputs does not occur when the relay is disabled. When the relay is reenabled, the control outputs assume the state that reflects the 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 contacts rated for tripping duty. Ratings for Standard outputs are 30 A make, 6 A continuous, and 0.5 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 2.4* shows a representative connection for a Form A Standard control output on the main board I/O terminals.

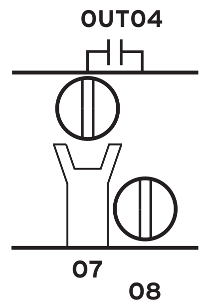


Figure 2.4 Standard Control Output Connection

See *Control Outputs on page U.1.13* 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 IGBT (Insulated Gate Bipolar Junction Transistor) 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 pickup time for the Hybrid control outputs is 6 ms. *Figure 2.5* shows a representative connection for a Form A Hybrid control output on the main board I/O terminals.

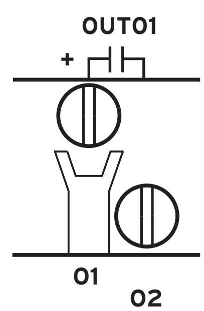


Figure 2.5 Hybrid Control Output Connection

See *Section 1: Introduction and Specifications*, for complete Hybrid control output specifications.

Fast Hybrid (Fast High-Current-Interrupting) Control Outputs

NOTE: You can use ac or dc circuits with Fast Hybrid (fast high-current-interrupting) outputs.

In addition to the Standard control outputs and the Hybrid control outputs, the INT4, INT5, and INT8 I/O interface boards offer Fast Hybrid (fast high-current-interrupting) control outputs. These control outputs have a resistive load pickup time of 10 µs (microseconds), which is much faster than the 6 ms pickup time of the Standard and Hybrid control outputs. The Fast Hybrid control outputs drop out at a maximum time of 8 ms. The maximum voltage rating is 250 Vac/330 Vdc. See *Control Outputs on page U.1.13*, for complete Fast Hybrid control output specifications.

Figure 2.6 shows a representative connection for a Form A Fast Hybrid control output on the INT5 (INT8) I/O interface terminals.

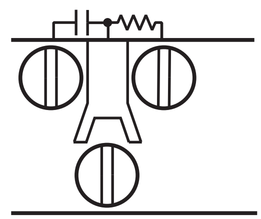


Figure 2.6 Fast Hybrid Control Output Connection, INT5 (INT8)

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

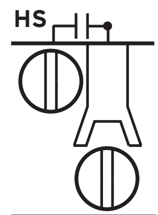


Figure 2.7 Fast Hybrid Control Output Connection, INT4

The INT5 (INT8) Fast Hybrid control output uses three terminal positions, while the INT4 Fast Hybrid uses two. The third terminal of each INT5 (INT8) Fast Hybrid control output is connected to precharge resistors that can be used to mitigate transient inrush current conditions, as explained below. A similar technique can be used with INT4 board Fast Hybrid control outputs using external resistors.

Short transient inrush current can flow at the closing of an external switch in series with open Fast Hybrid 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 pick-up transient occurs when the capacitance of the Fast Hybrid output circuitry charges (creating a momentary short circuit that a fast, sensitive device sees as a contact closure). A third terminal (03 in *Figure 2.8*) provides an internal path for precharging the Fast Hybrid output circuit capacitance when the circuit is open.

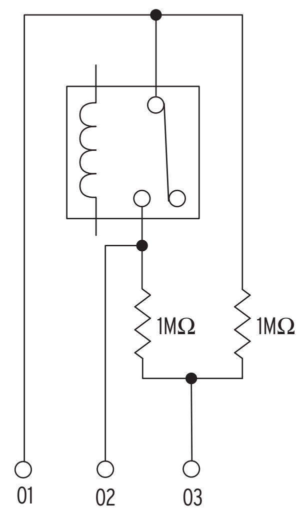


Figure 2.8 Fast Hybrid Control Output Typical Terminals, INT5 (INT8)

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

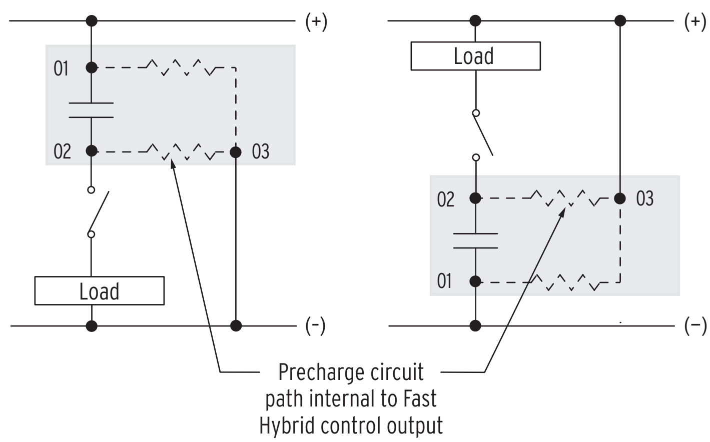


Figure 2.9 Precharging Internal Capacitance of Fast Hybrid Output Contacts, INT5 (INT8)

For wiring convenience, on the INT5 (INT8) I/O Interface Board, the precharge resistors shown in *Figure 2.8* are built-in to the I/O board, and connected to a third terminal. On the INT4 I/O Interface Board, there are no built-in precharge resistors, and each Fast Hybrid control output has only two terminal connections.

Main Board I/O

The SEL-421 base model is a 3U chassis with I/O interface on the main board (the top board). See *Figure 2.27* and *Figure 2.28* for representative rear-panel views of the 3U chassis rear panel. There are two options for the main board depending on the type of contact inputs. The Main Board A I/O interface has direct coupled contact inputs. The Main Board B I/O interface has optoisolated contact inputs.

Every SEL-421 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 high-isolation control inputs (five independent and two with a common leg)

TIME Inputs

The SEL-421 has a regular IRIG timekeeping mode, and a high-accuracy IRIG (HIRIG) timekeeping mode, as described in *Configuring High-Accuracy Timekeeping on page U.4.71*.

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.

There are two IRIG-B inputs on the SEL-421 rear panel, but only one is capable of supporting the HIRIG mode. For input specifications, see *Time Inputs on page U.1.14*.

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 (see *Table 4.9*), the relay enters the HIRIG mode, which has a timing accuracy of 1 µs.

If both inputs are connected, the SEL-421 will use the IRIG-B BNC connector signal if a signal is detected.

SEL-421 Time Inputs Changed

If you are upgrading the firmware in an existing SEL-421 relay, you may need to remove or reconnect your time-source cables. Beginning with the release of SEL-421 firmware version R112, the rear-panel TIME inputs have been changed. There is no longer a 1k PPS time input—see *1k PPS Connection Not Required on page U.4.72* for details.

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, Ray-O-Vac® No. BR2335 or equivalent. If power is lost or disconnected, the battery discharges to power the clock. At room temperature (25°C), the battery will operate for approximately 10 years at rated load.

When the SEL-421 is operating with power from an external source, the self-discharge rate of the battery only is very small. Thus, battery life can extend well beyond the nominal 10-year period because the battery rarely discharges after the relay is installed. The battery cannot be recharged. *Figure 2.19* 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 U.2.46*).

Communications Interfaces

The SEL-421 has several communications interfaces you can use to communicate with other IEDs (intelligent electronic devices) via EIA-232 ports: **PORT 1**, **PORT 2**, **PORT 3**, and **PORT F**. See *Section 4: Communications Interfaces in the Reference Manual* for more information and options for connecting your relay to the communications interfaces.

An optional communications card provides Ethernet capability for the SEL-421. A communications 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 6: DNP3 Communications in the Reference Manual*. For more information on IEC 61850 applications, see *Section 8: IEC 61850 Communications in the Reference Manual*.

Other Shared Configuration Attributes

All versions of the SEL-421 also feature ground, power, and battery monitor connections. See *Connection on page U.2.31* for information on these relay interface features.

Plug-In Boards

NOTE: The SEL-421-0 and the SEL-421-1 do not support Main Board B I/O and INT2, INT3, INT7, and INT8 I/O interface boards. See SEL-421 Versions and Supported Features on page U.1.7 for details.

NOTE: Ordering the 4U and 5U relay with partial or no extra I/O allows for future system expansion and future use of additional relay features.

The SEL-421 is available in many input/output configuration options. The relay base model is a 3U chassis with Main Board A or Main Board B I/O and screw terminal connector connections (see *Figure 2.2*). Other ordering options include versions of the relay in larger enclosures (4U or 5U) with all, partial, or no extra I/O boards installed.

Plug-in communications cards are also available for the SEL-421. The optional Ethernet card allows you to use TCP/IP, FTP, Telnet, DNP3 LAN/WAN, and IEC 61850 applications on an Ethernet network. This card is only available at the time of purchase of a new SEL-421 as a factory-installed option or as a factory-installed conversion to an existing relay.

I/O Interface Boards

You can choose among seven input/output interface boards for the I/O slots of the 4U and 5U chassis. These I/O interface boards are in addition to the main board I/O described in *Shared Configuration Attributes on page U.2.1*. The I/O interface boards are INT1, INT2, INT3, INT4, INT5, INT6, INT7, and INT8. *Figure 2.10*. *Figure 2.11*, *Figure 2.12*, *Figure 2.13*, *Figure 2.14*, *Figure 2.15*, *Figure 2.16*, and *Figure 2.17* show the rear screw terminal connectors associated with these interface boards.

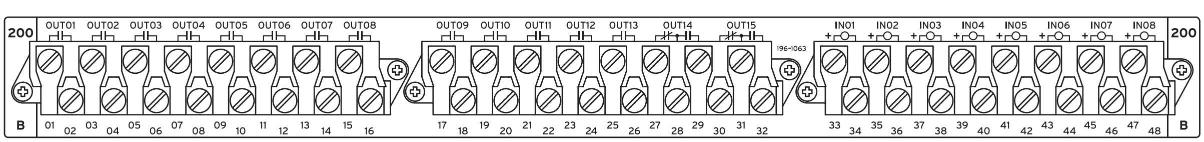


Figure 2.10 INT1 I/O Interface Board

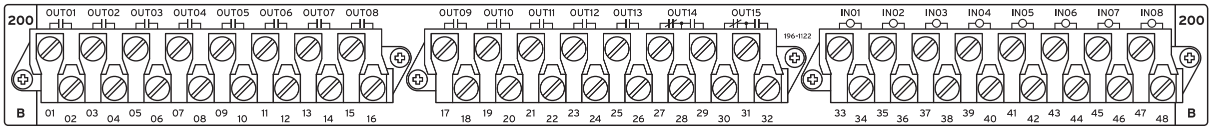


Figure 2.11 INT2 I/O Interface Board

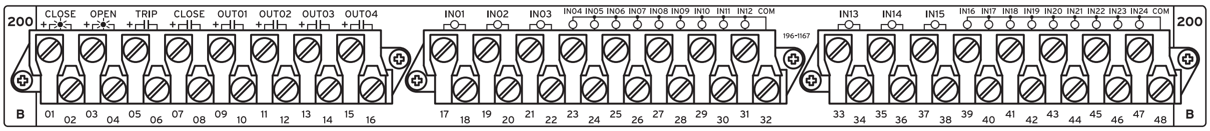


Figure 2.12 INT3 I/O Interface Board

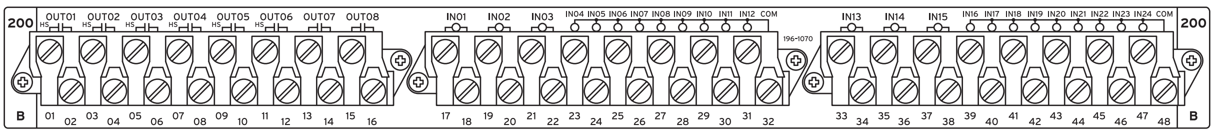


Figure 2.13 INT4 I/O Interface Board

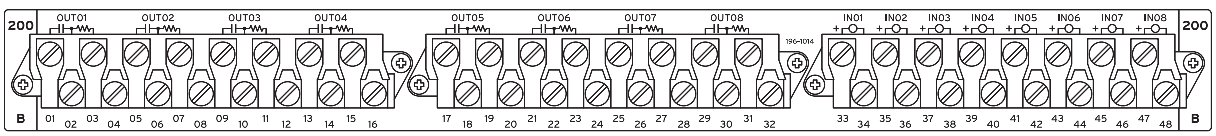


Figure 2.14 INT5 I/O Interface Board

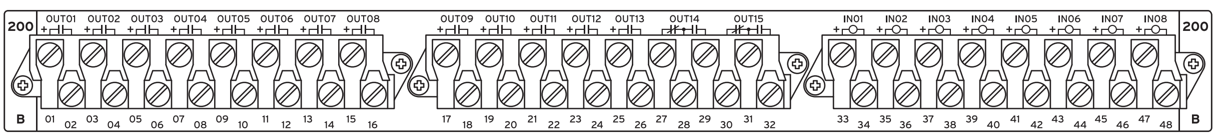


Figure 2.15 INT6 I/O Interface Board

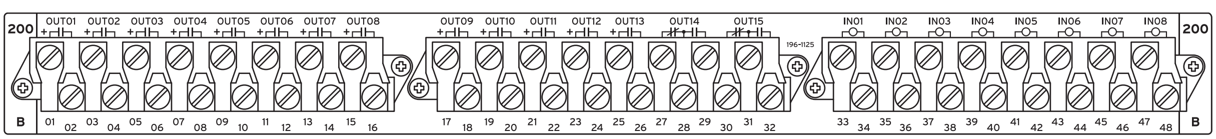


Figure 2.16 INT7 I/O Interface Board

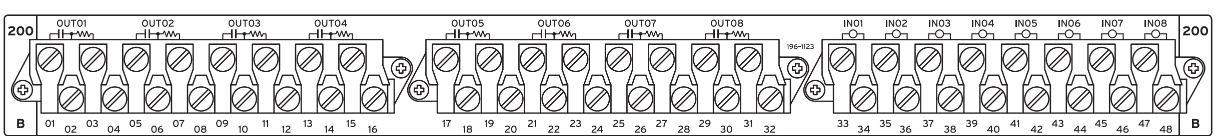


Figure 2.17 INT8 I/O Interface Board

The I/O interface boards carry jumpers that identify the board location (see *Jumpers on page U.2.18*).

I/O Interface Board Inputs

⚠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.

The INT1, INT5, and INT6 I/O interface boards have eight independent control inputs. All independent inputs are isolated from other inputs. These high-isolation control inputs are direct coupled and hence polarity-sensitive. You cannot damage these inputs with a reverse polarity connection; though, the relay will not detect input changes with a reverse-polarity input.

The INT3 and INT4 I/O interface board has two groups of nine (9) common contacts (18 total) and six (6) independent control inputs. The INT2, INT7, and INT8 I/O interface boards have eight independent control inputs. All independent inputs are isolated from other inputs. These control inputs are optoisolated and hence are not polarity sensitive, i.e., the relay will detect input changes with voltage applied at either polarity, or ac signals (when properly configured, see *Optoisolated on page U.2.6*).

Table 2.3 is a comparison of the I/O board input capacities; the table also shows the I/O inputs on Main Board A or Main Board B. See *Control Inputs on page U.1.14* for complete control input specifications.

NOTE: The SEL-421-0 and the SEL-421-1 do not support Main Board B I/O and INT2, INT3, INT7, and INT8 I/O interface boards. See SEL-421 Versions and Supported Features on page U.1.7 for details.

Table 2.3 I/O Interface Boards Control Inputs

Board Number	Independent Contact Pairs	Common Contacts
INT1[a]	8	
INT2[b]	8	
INT3[b]	6	Two sets of 9
INT4[b]	6	Two sets of 9
INT5[a]	8	
INT6[a]	8	
INT7[b]	8	
INT8[b]	8	
Main Board A[a]	5	2
Main Board B[b]	5	2

[a] Main Board A, INT1, INT5, and INT6 control inputs are direct coupled and are polarity sensitive.
[b] Main Board B, INT2, INT3, INT4, INT7, and INT8 control inputs are optoisolated and are not polarity sensitive.

I/O Interface Board Outputs

NOTE: Form A control outputs cannot be jumpered to Form B.

The I/O interface boards vary by the type and amount of output capabilities. *Table 2.4* lists the outputs of the additional I/O interface boards; the table also shows the I/O outputs on the main board. Information about the Standard and Hybrid (high-current interrupting) control outputs is in *Control Outputs on page U.2.7*.

NOTE: The SEL-421-0 and the SEL-421-1 do not support Main Board B I/O and INT2, INT3, INT7, and INT8 I/O interface boards. See SEL-421 Versions and Supported Features on page U.1.7 for details.

Table 2.4 I/O Interface Boards Control Outputs

Board Number	Standard		Fast Hybrid[a]	Hybrid[b]
	Form A	Form C	Form A	Form A
INT1	13	2		
INT2	13	2		
INT3				4
INT4	2		6	
INT5			8	
INT6		2		13
INT7		2		13
INT8			8	
Main Board A	2	3		3
Main Board B	2	3		3

[a] High-Speed/High-Current Interrupting.
[b] High-Current Interrupting.

Installing Optional I/O Interface Boards

Perform the following steps to expand the capability of the SEL-421 with additional I/O interface boards:

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

Step 2. Disconnect power from the SEL-421.

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

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

Step 5. Loosen the four front-panel screws (they remain attached to the front panel), and remove the relay front panel.

⚠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.

Step 6. Remove the 34-pin ribbon cable from the front panel by pushing the extraction ears away from the connector.

Step 7. Disconnect the power, the interface board, and the analog input board cables from the main board.

Step 8. Confirm proper installation of address jumpers on the interface board (see *Jumpers on page U.2.18*).

Step 9. Confirm drawout tray keying.

The relay chassis and the drawout trays for the 200-addresses slot and the 300-addresses slot are keyed (see *Figure 2.18*).

The keys are two round plug-in/plug-out discs on the bottom of the drawout tray.

The 200-addresses slot keys go to the left, and the 300-addresses slot keys go to the right (when viewed from the top and front of the drawout tray).

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

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

⚠CAUTION
If you are planning to install an INT4 I/O Interface Board in your relay (see Table 2.3 and Table 2.4 for board descriptions), first check the firmware version of the relay—see Firmware Version Number on page U.6.39. 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.

⚠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.

Step 10. Move a key on the bottom of the drawout tray to the correct position by prying the key from the tray and reinserting the key in the proper position.

Do this for both keys.

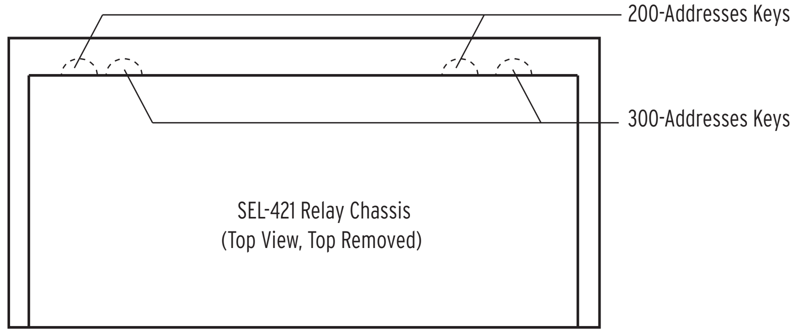


Figure 2.18 Chassis Key Positions for I/O Interface Boards

Step 11. Install the drawout tray with the I/O interface board, using the following precautions:

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 SEL-421 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 12. If this is a new I/O interface board installation, remove the INTERFACE BOARD EXPANSION SLOT self-sticking label from the rear panel.

Lift a corner of the label with a sharp tool and peel away the label from the rear panel.

Step 13. Confirm screw terminal connector keying.

SEL supplies three new screw terminal connectors with new I/O interface boards.

a. Inspect the screw terminal connector receptacles on the rear of the I/O interface board.

b. Refer to *Figure 2.38* for the corresponding key positions inside the receptacle.

c. If the keys inside the I/O interface board receptacles are not in the positions indicated in *Figure 2.38*, 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 (see *Figure 2.37*).

Step 14. Attach the screw terminal connector.

a. Mount the screw terminal connectors to the rear panel of the SEL-421.

Refer to *Figure 2.10* and *Figure 2.14* for screw terminal connector placement.

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 15. Reinstall the SEL-421 main board, and reconnect the power, the interface board, and the analog input board cables.

Step 16. Reconnect the cable removed in *Step 6* and reinstall the relay front-panel cover.

Step 17. Reconnect any serial cables that you removed from the **EIA-232 PORTS** in the disassembly process.

Step 18. Apply power.

Step 19. Enter Access Level 2 (see *Making Simple Settings Changes on page U.4.13*).

Step 20. Issue the **STA** command and answer **Y <Enter>** to accept the new hardware configuration (see *STATUS on page R.9.48*).

Step 21. Inspect the relay targets to confirm that the relay reads the added I/O interface board(s).

You can see the new control inputs in the target listings by using a terminal, the ACSELERATOR QuickSet® SEL-5030 software program, or the front panel.

Step 22. Use a communications terminal to issue the commands **TAR IN201 <Enter>** (for the 200-addresses slot) or **TAR IN301 <Enter>** (for the 300-addresses slot).

Alternatively, from the front panel `MAIN` menu, select `RELAY ELEMENTS`, and press the **{Down Arrow}** pushbutton to go to `ROW 101` (for the 200-addresses slot) or `ROW 104` (for the 300-addresses slot).

Step 23. Follow your company standard procedure to return the relay to service.

Communications Card

You can add communications protocols to the SEL-421 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-421 and a LAN (local area network).

Jumpers

The SEL-421 contains jumpers that configure the relay for certain operating modes. The jumpers are located on the main board (the top board) and the I/O interface boards (one or two boards located immediately below the main board).

Main Board Jumpers

The jumpers on the main board of the SEL-421 perform these functions:

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

Figure 2.19 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

⚠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.

You can access the password disable jumper and circuit breaker control jumper without removing the main board from the relay cabinet. Remove the SEL-421 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, located immediately left of power connector J17 (see *Figure 2.19*).

The J18 header is denoted A, B, C, and D from right to left (position A is on the right). Position B is the password disable jumper; position C is the circuit breaker control enable jumper. Positions A and D are not used. *Figure 2.20* 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 2.5* lists the J18 jumper positions and functions.

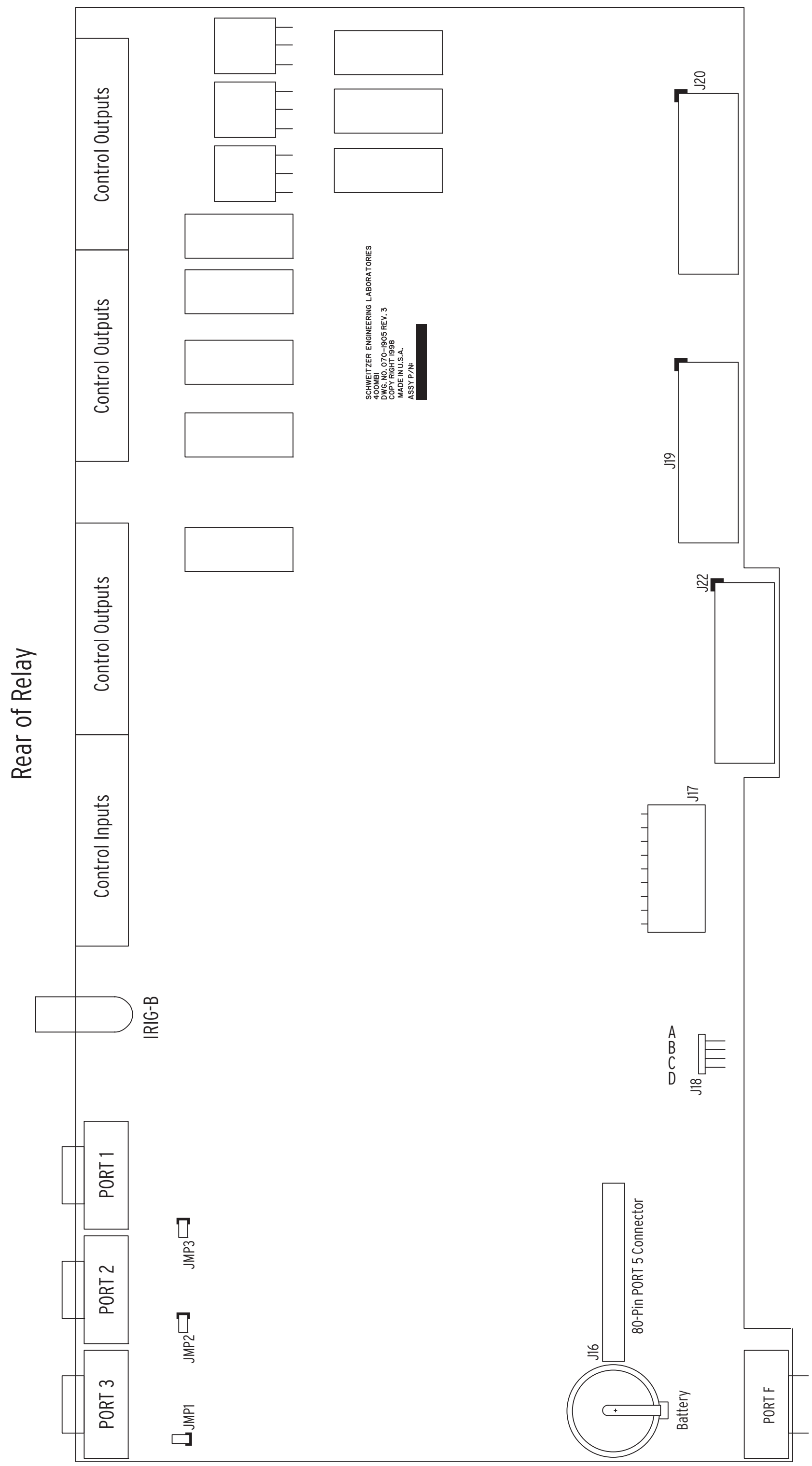


Figure 2.19 Major Component Locations on the SEL-421 Main Board A (or B)

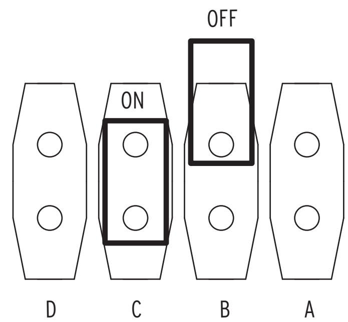


Figure 2.20 J18 Header—Password and Breaker Jumpers

Table 2.5 Main Board Jumpers[a]

Jumper	Jumper Location	Jumper Position	Function
J18A	Front	OFF	For SEL use only
J18B	Front	OFF	Enable password protection (normal and shipped position)
		ON	Disable password protection (temporary or emergency only)
J18C	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]
J18D	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 the Fast Operate Breaker Control Messages and the front-panel LOCAL CONTROL > BREAKER CONTROL, and front-panel LOCAL CONTROL > OUTPUT TESTING screens.

The password disable jumper, J18B, is for temporary or emergency suspension of the relay password protection mechanisms. Under no circumstance should you install J18B on a long-term basis. The SEL-421 ships with password disable jumper J18B OFF (passwords enabled).

For temporary unprotected access to a particular access level, use the **PAS *n* DISABLE** command (***n*** is the access level: ***n*** = **1**, **B**, **P**, **A**, **O**, **2**). For more information on this command and setting passwords, see *Passwords on page U.4.9*.

The circuit breaker control enable jumper, Jumper J18C, supervises the **CLOSE *n*** command, the **OPEN *n*** command, the **PULSE OUT*nnn*** command, and front-panel local bit control. To use these functions, you must install jumper J18C.

The relay checks the status of the circuit breaker control jumper when you issue **CLOSE *n***, **OPEN *n***, **PULSE OUT*nnn***, and when you use the front panel to close or open circuit breakers, control a local bit, or pulse an output.

The SEL-421 ships with circuit breaker jumper J18C OFF. For commissioning and testing of the SEL-421 contact outputs, it may be convenient to set J18C ON, so that the **PULSE OUT*nnn*** commands can be used to check output wiring. J18C must also be set ON if SCADA control of the circuit breaker via Fast Operate is required, or if the LOCAL CONTROL > BREAKER CONTROL screens are going to be used.

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 2.6* describes the JMP1, JMP2, and JMP3 positions. Refer to *Figure 2.19* for the locations of these jumpers. The SEL-421 ships with JMP1, JMP2, and JMP3 OFF (no +5 Vdc on Pin 1).

Table 2.6 Main Board Jumpers—JMP1, JMP2, and JMP3[a]

Jumper	Jumper Location	Jumper Position	Function
JMP1	Rear	OFF	Serial **PORT 3**, Pin **1** = not connected
		ON	Serial **PORT 3**, Pin **1** = +5 Vdc
JMP2	Rear	OFF	Serial **PORT 2**, Pin **1** = not connected
		ON	Serial **PORT 2**, Pin **1** = +5 Vdc
JMP3	Rear	OFF	Serial **PORT 1**, Pin **1** = not connected
		ON	Serial **PORT 1**, Pin **1** = +5 Vdc

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

Changing Serial Port Jumpers

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

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

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

You must remove the main board to access the serial port jumpers. Perform the following steps to change the JMP1, JMP2, and JMP3 jumpers in an SEL-421:

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

Step 2. Disconnect power from the SEL-421.

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

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

Step 5. Remove the rear-panel **EIA-232 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.

Step 6. Loosen the four front-panel screws (they remain attached to the front panel), and remove the relay front panel.

Step 7. Remove the 34-pin ribbon cable from the front panel by pushing the extraction ears away from the connector.

Step 8. Disconnect the power, the interface board, and the analog input board cables from the main board.

Step 9. Remove the screw terminal connectors.

a. Loosen the attachment screws at each end of the 100-addresses screw terminal connectors.

b. Pull straight back to remove.

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

Step 11. Locate the jumper you want to change.

Jumpers JMP1, JMP2, and JMP3 are located at the rear of the main board, directly in front of **PORT 3**, **PORT 2**, and **PORT 1**, respectively (see *Figure 2.19*).

Step 12. Install or remove the jumper as needed (see *Table 2.6* for jumper position descriptions).

Step 13. Reinstall the SEL-421 main board, and reconnect the power, the interface board, and the analog input board cables.

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

Step 15. Reattach the rear-panel connections.

Step 16. Affix the screw terminal connectors to the appropriate 100-addresses locations on the rear panel.

Step 17. Reconnect any serial cables that you removed from the **EIA-232 PORTS** in the disassembly process.

Step 18. Follow your company standard procedure to return the relay to service.

I/O Interface Board Jumpers

Jumpers on the I/O interface boards identify the particular I/O board configuration and I/O board control address. Eight I/O interface boards are available: INT1, INT2, INT3, INT4, INT5, INT6, INT7, and INT8 (see *I/O Interface Boards on page U.2.12* 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 2.21*, *Figure 2.22*, *Figure 2.23*, *Figure 2.24*, and *Figure 2.25*.

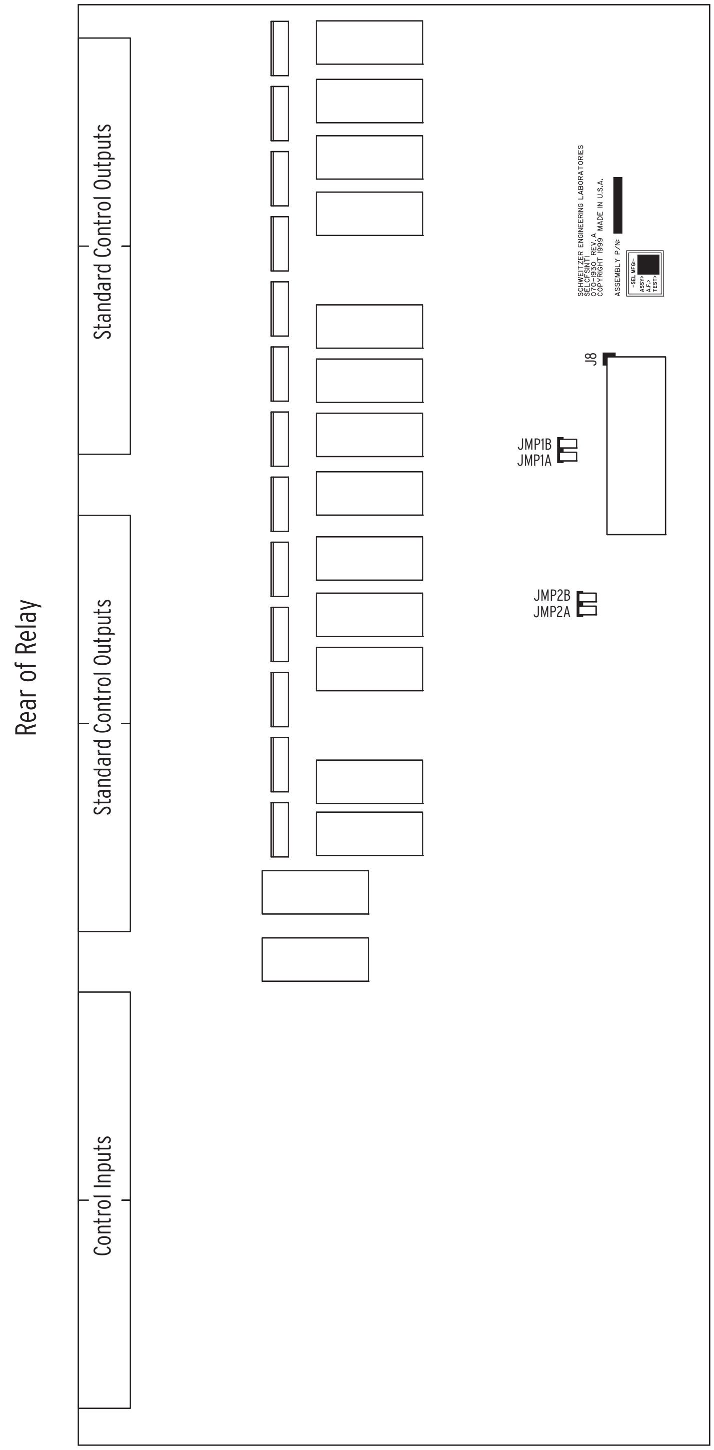


Figure 2.21 Major Component Locations on the SEL-421 INT1 (or INT2) I/O Board

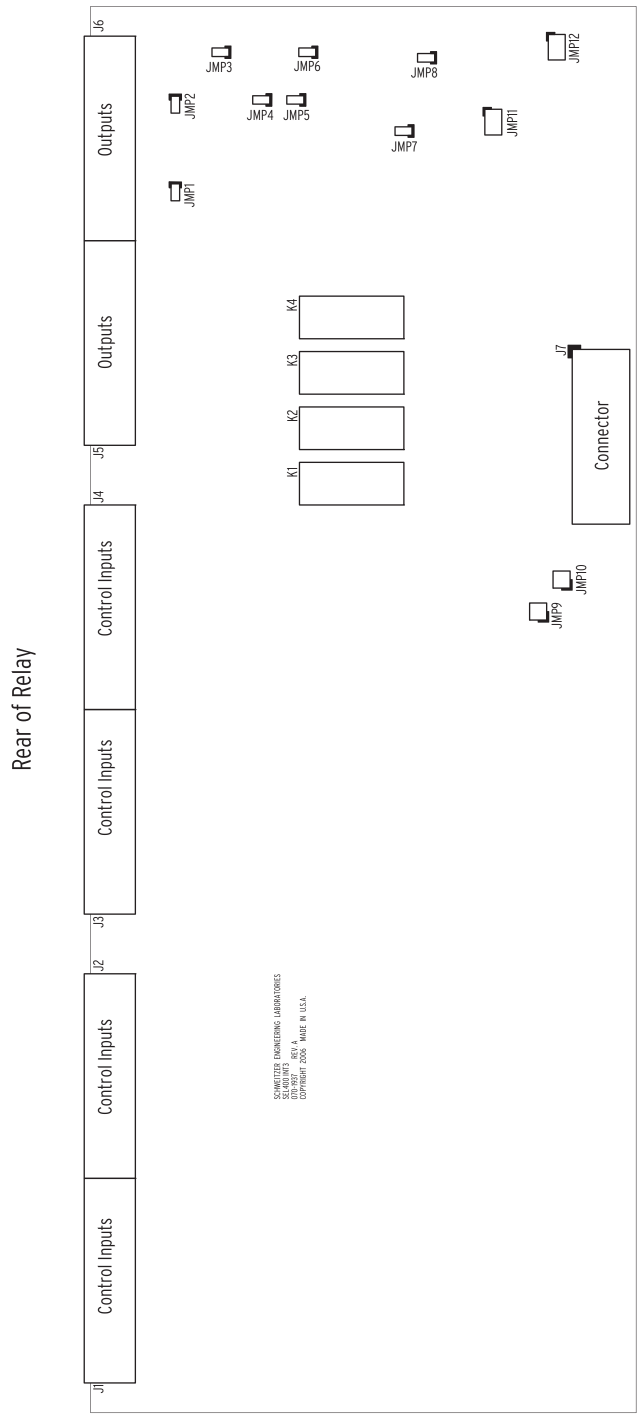


Figure 2.22 Major Component Locations on the SEL-421 INT3 I/O Board

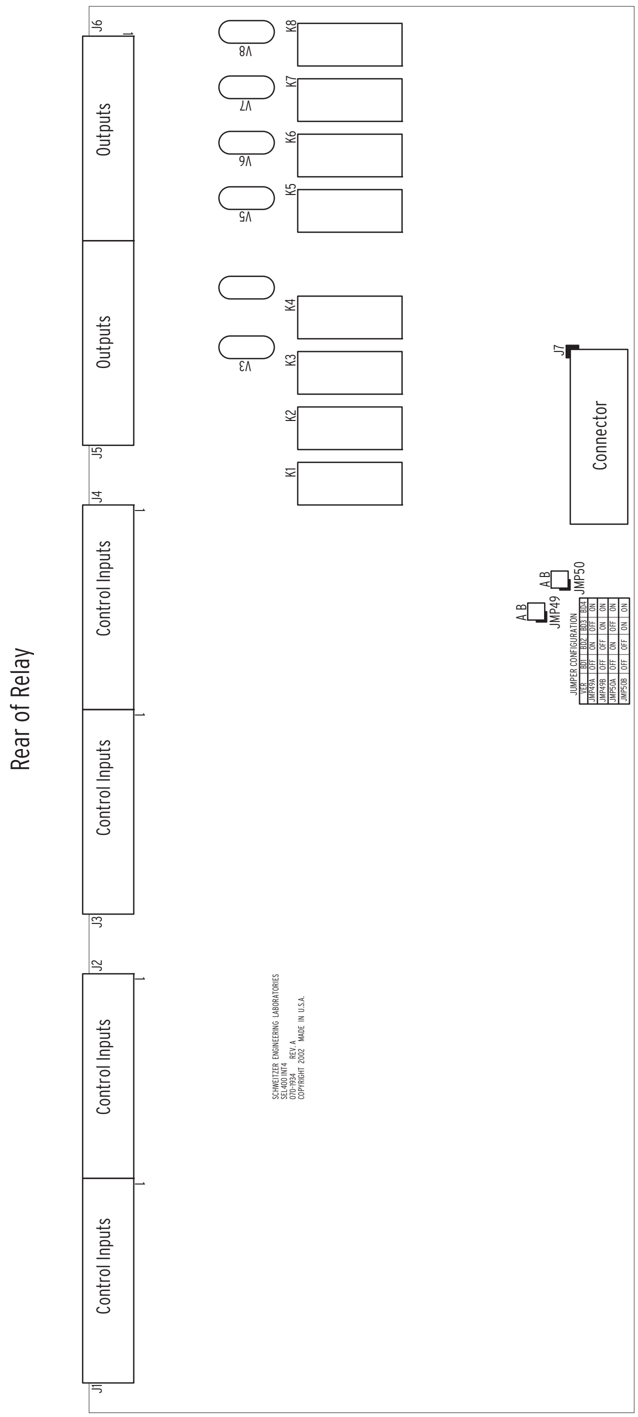


Figure 2.23 Major Component Locations on the SEL-421 INT4 I/O Board

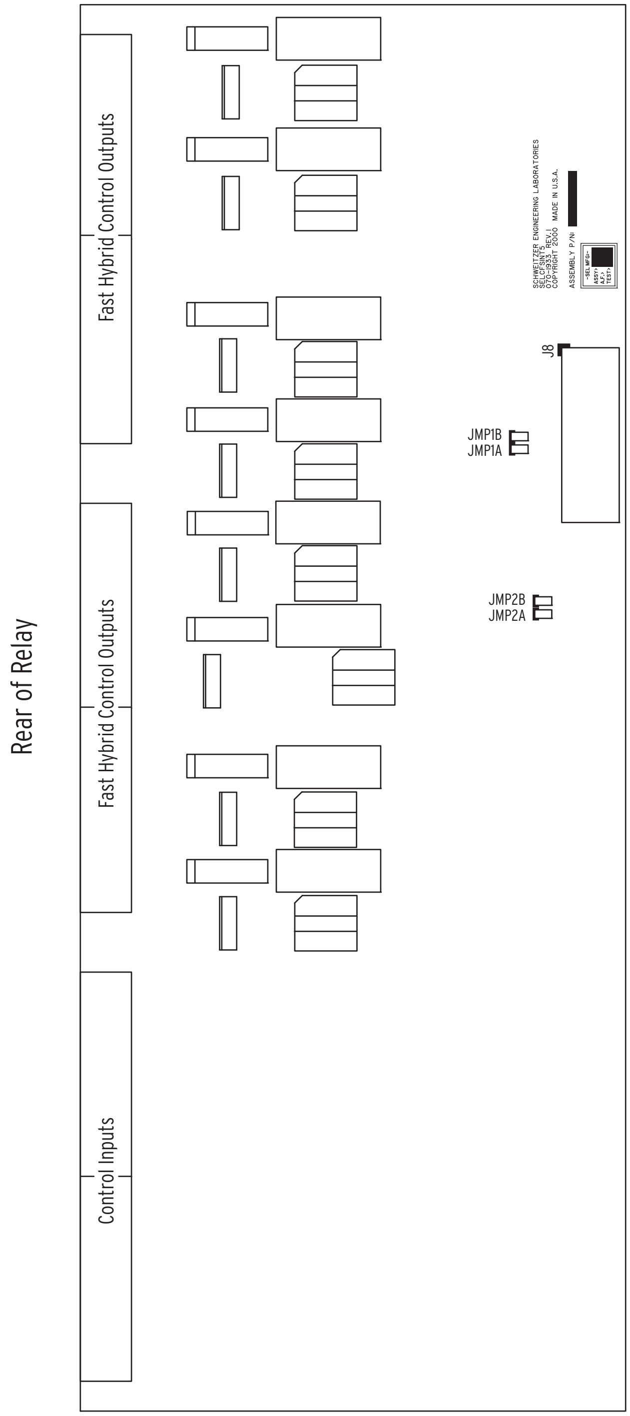


Figure 2.24 Major Component Locations on the SEL-421 INT5 (or INT8) I/O Board

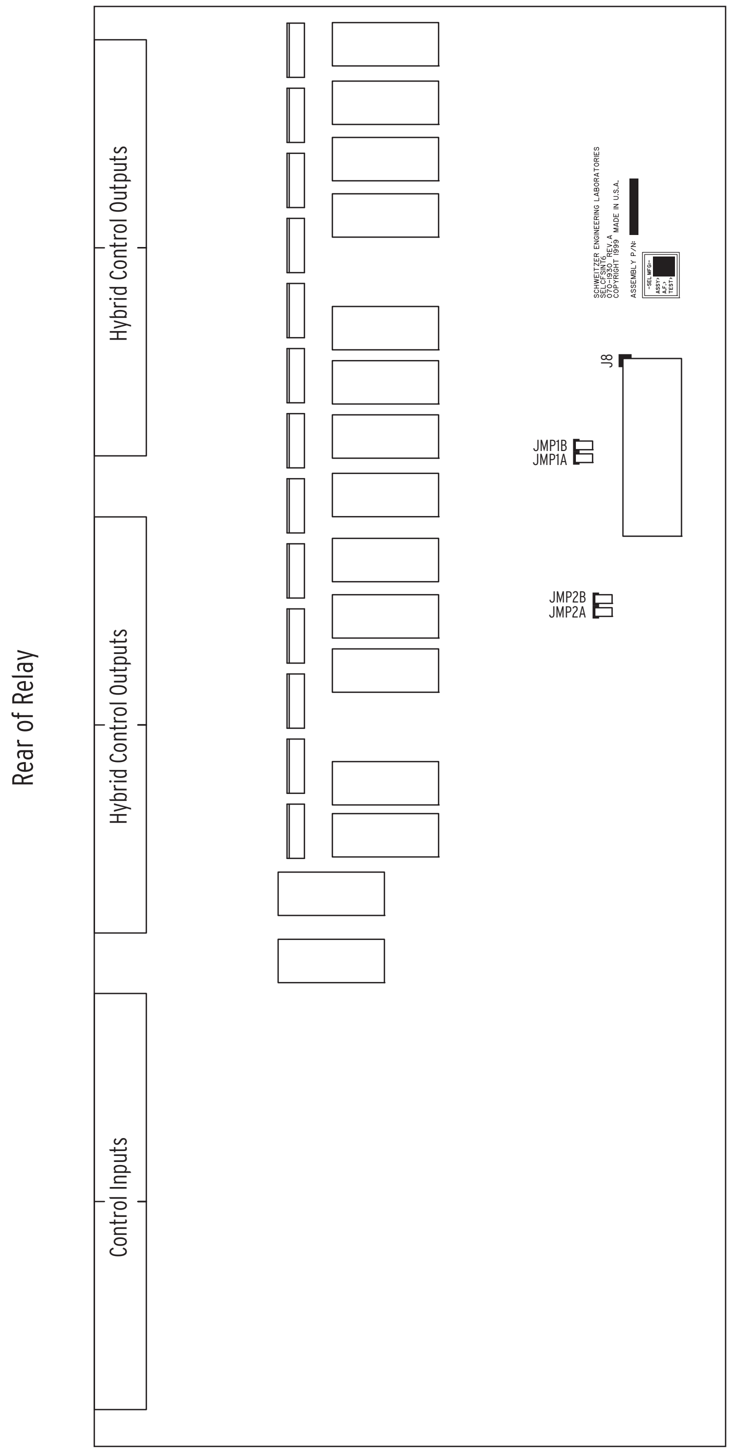


Figure 2.25 Major Component Locations on the SEL-421 INT6 (or INT7) I/O Board

To confirm the positions of your I/O board jumpers, remove the front panel and visually inspect the jumper placements. *Table 2.7* lists the four jumper positions for I/O interface boards. Refer to *Figure 2.21*, *Figure 2.23*, *Figure 2.24*, and *Figure 2.25* 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 4U chassis has a 200-addresses slot for inputs IN201, IN202, etc., and outputs OUT201, OUT202, etc. A 5U chassis has a 200-addresses slot and a 300-addresses slot.

The drawout tray on which each I/O board is mounted is keyed. See *Installing Optional I/O Interface Boards on page U.2.15* for information on the key positions for the 200-addresses slot trays and the 300-addresses slot trays.

Table 2.7 I/O Board Jumpers

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

[a] INT4 I/O Interface Board jumper numbering.

Changing I/O Interface Board Jumpers

Change the I/O interface board jumpers only when you move the slot position of an I/O board. You must remove the I/O interface boards to access the jumpers. Perform the following steps to change jumpers on an SEL-421 I/O interface board:

⚠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.

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

Step 2. Disconnect power from the SEL-421.

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

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

Step 5. Loosen the four front-panel screws (they remain attached to the front panel), and remove the relay front panel.

Step 6. Remove the 34-pin ribbon cable from the front panel by pushing the extraction ears away from the connector.

Step 7. Disconnect the power, the interface board, and the analog input board cables from the main board.

Step 8. Pull out the drawout assembly containing the I/O interface board.

Step 9. Locate the jumper you want to change.

The I/O interface board jumpers are located near the front of each I/O board, and near the interface board connector, as shown for each type of interface board in *Figure 2.21* through *Figure 2.25*.

Step 10. Install or remove the jumper as needed (see *Table 2.7* for jumper position descriptions).

Step 11. Reinstall the interface board, and reconnect the power, the interface board, and the analog input board cables.

Step 12. Reconnect the cable removed in *Step 6* and reinstall the relay front-panel cover.

Step 13. Replace any cables previously removed from serial ports.

Step 14. Follow your company standard procedure to return the relay to service.

Step 15. At relay power-up, confirm that the relay does not display a status warning about I/O board addresses. For information on this status warning, see *Relay Self-Tests on page U.6.38*.

Auxiliary {TRIP}/{CLOSE} Pushbutton and Breaker Status LED Jumpers (select models only)

The jumpers listed in *Table 2.8* are used to select the proper control voltage for breaker open/closed indicating LEDs on the front panel of the relay. *Figure 2.22* shows the jumper locations on the magnetics/auxiliary pushbutton board. The jumpers come preset from the factory with the voltage range set the same as the control input voltage, as determined by the part number at order time.

The voltage setting can be different for each LED. To access these jumpers, the relay front cover, top cover, main board, and any additional I/O board (if present) must first be removed. See instructions and precautions in the subsection *Changing Serial Port Jumpers on page U.2.21*.

Table 2.8 Jumper Positions for Breaker OPEN/CLOSE Indication

	BREAKER OPEN LED			BREAKER CLOSED LED		
	JMP4	JMP5	JMP7	JMP3	JMP6	JMP8
24 V	Installed	Installed	Installed	Installed	Installed	Installed
48 V	Installed	Installed	Not Installed	Installed	Installed	Not Installed
110/125 V	Installed	Not Installed	Not Installed	Installed	Not Installed	Not Installed
220/250 V	Not Installed	Not Installed	Not Installed	Not Installed	Not Installed	Not Installed

Table 2.9 shows how to enable or disable the arc suppression feature of the {TRIP} and {CLOSE} pushbuttons. If ac control power is used to operate the breaker, then the corresponding arc suppression jumper must be removed. If dc control power is used to operate the breaker, then the arc suppression is strongly recommended to break inductive loads. The arc suppression comes enabled from the factory. *Figure 2.22* shows the jumper locations on the magnetics/auxiliary pushbutton board.

NOTE: With arc suppression enabled, the corresponding output polarity marks must be followed when wiring the control.

Table 2.9 Jumper Positions for Arc Suppression

Option	{TRIP} pushbutton	{CLOSE} pushbutton
	JMP2	JMP1
Arc Suppression Enabled	Installed	Installed
Arc Suppression Disabled	Not Installed	Not Installed

Table 2.10 Front-Panel LED Option

JMP11, JMP12[a]	LED Color
BRIDGE Pins 1 and 3 Pins 2 and 4	Red
BRIDGE Pins 3 and 5 Pins 4 and 6	Green

[a] JMP11 Open; JMP12 Closed.

Relay Placement

Proper placement of the SEL-421 helps make certain that you receive years of trouble-free power system protection. Use the following guidelines for proper physical installation of the SEL-421.

Physical Location

You can mount the SEL-421 in a sheltered indoor environment (a building or an enclosed cabinet) that does not exceed the temperature and humidity ratings for the relay.

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

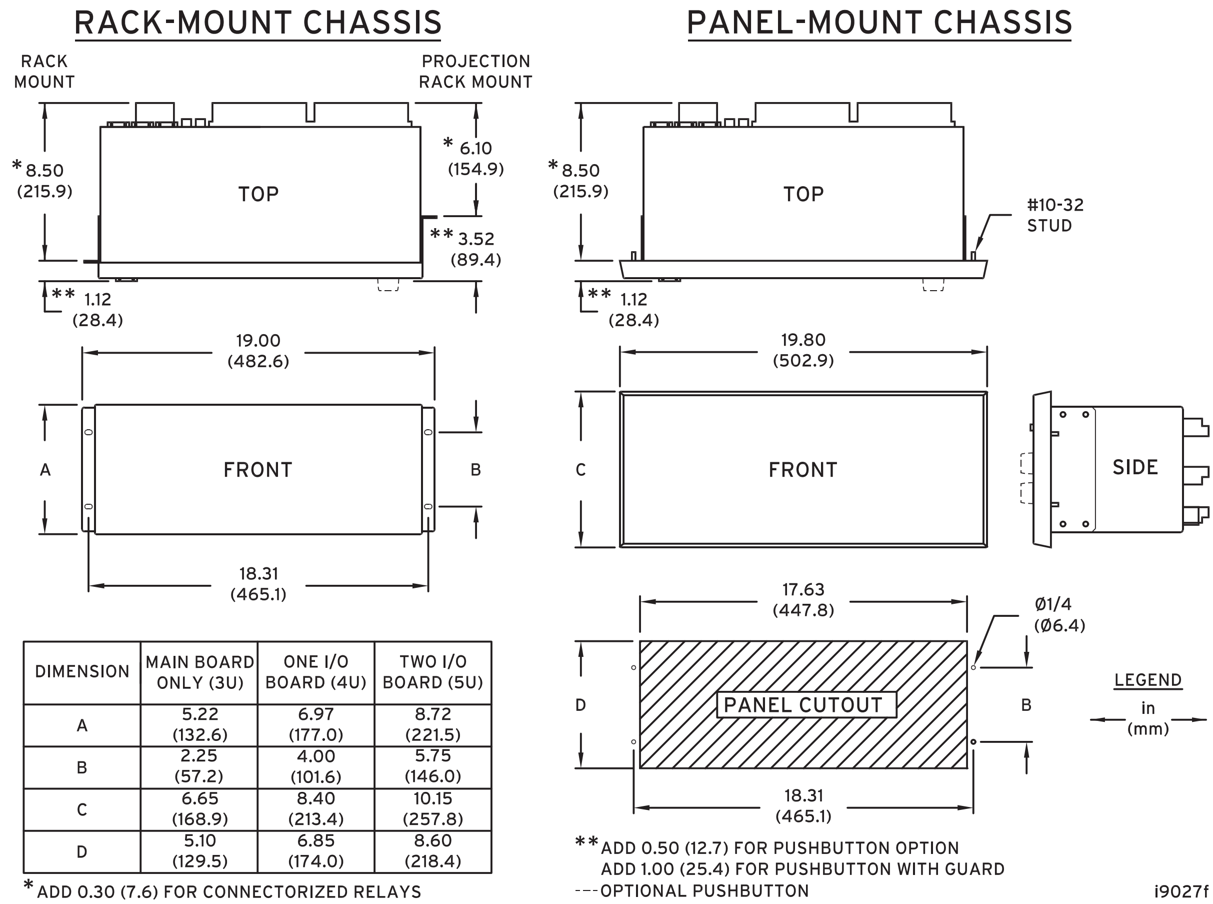
You can place the relay in extreme temperature and humidity locations. The temperature range over which the relay operates is –40° to +185°F (–40° to +85°C, see *Operating Temperature on page U.1.15*). The relay operates in a humidity range from 5 percent to 95 percent, no condensation, and is rated for installation at a maximum altitude of 2000 m (6560 feet) above mean sea level.

Rack Mounting

When mounting the SEL-421 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 in. or 27.9 mm. The projection mount places the front panel approximately 3.5 in. or 88.9 mm in front of the relay rack rails.

See *Figure 2.26* for exact mounting dimensions for both the horizontal and vertical rack-mount relays. Use four screws of the appropriate size for your rack.



DIMENSION	MAIN BOARD ONLY (3U)	ONE I/O BOARD (4U)	TWO I/O BOARD (5U)
A	5.22 (132.6)	6.97 (177.0)	8.72 (221.5)
B	2.25 (57.2)	4.00 (101.6)	5.75 (146.0)
C	6.65 (168.9)	8.40 (213.4)	10.15 (257.8)
D	5.10 (129.5)	6.85 (174.0)	8.60 (218.4)

*ADD 0.30 (7.6) FOR CONNECTORIZED RELAYS

**ADD 0.50 (12.7) FOR PUSHBUTTON OPTION
ADD 1.00 (25.4) FOR PUSHBUTTON WITH GUARD
---OPTIONAL PUSHBUTTON

Figure 2.26 SEL-421 Chassis Dimensions

Panel Mounting

Place the panel-mount versions of the SEL-421 in a switchboard panel. See the drawings in *Figure 2.26* for panel cut and drill dimensions (these dimensions apply to both the horizontal and vertical panel-mount relay versions). Use the supplied mounting hardware to attach the relay.

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-421 is available in many different configurations, depending on the number and type of control inputs, control outputs, and analog input termination you specified at ordering. This subsection presents a representative sample of relay rear-panel configurations and the connections to these rear panels. Only horizontal chassis are shown; rear panels of vertical chassis are identical to horizontal chassis rear panels for each of the 3U, 4U, and 5U sizes.

When connecting the SEL-421, 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 2.27, *Figure 2.28*, *Figure 2.29*, and *Figure 2.30*, and *Figure 2.33* show some of the available SEL-421 rear panels.

NOTE: The SEL-421-0 and the SEL-421-1 do not support Main Board B I/O and INT2, INT3, INT7, and INT8 I/O interface boards. See SEL-421 Versions and Supported Features on page U.1.7 for details.

All relay versions have screw terminal connectors for I/O, power, and battery monitor. You can order the relay with fixed terminal blocks for the CT and PT connections, or you can order SEL Connectorized rear-panel configurations that feature plug-in/plug-out PT connectors and shorting CT connectors for relay analog inputs. *Figure 2.28* shows the Connectorized 3U horizontal configuration of the SEL-421. For clarity, the figures do not show a communications card installed in **PORT 5**.

The screw terminal connections for the INT1 (or INT2) and the INT6 (or INT7) I/O interface boards are the same. The INT5 (or INT8) I/O interface board has control output terminals grouped in threes, with the fourth terminal as a blank additional separator (terminals 4, 8, 12, 16, 20, 24, 28, and 32). The INT3, INT4 and INT5 (or INT8) I/O interface boards both contain fast hybrid control outputs, but use a different terminal layout—see *Control Outputs on page U.2.7* for details.

For more information on the main board control inputs and control outputs, see *Main Board I/O on page U.2.10*. For more information on the I/O interface board control inputs and control outputs, see *I/O Interface Board Jumpers on page U.2.22*.

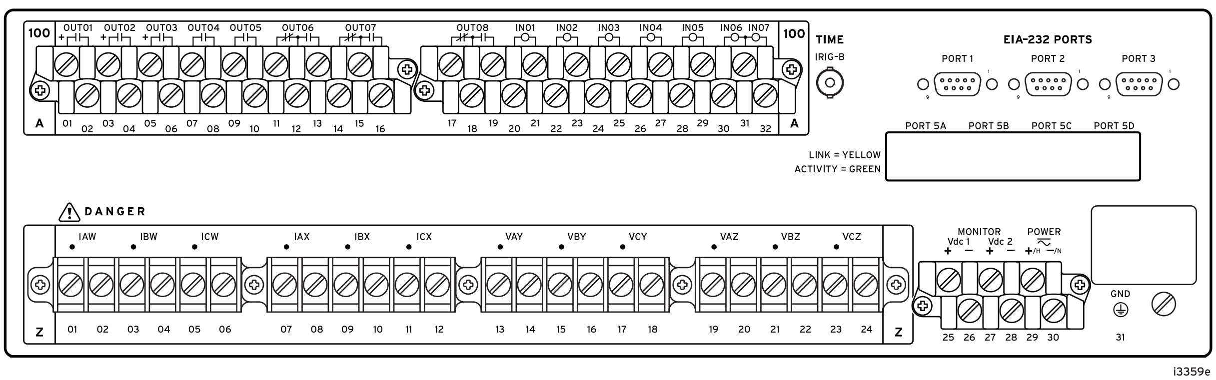


Figure 2.27 3U Rear Panel, Main Board A

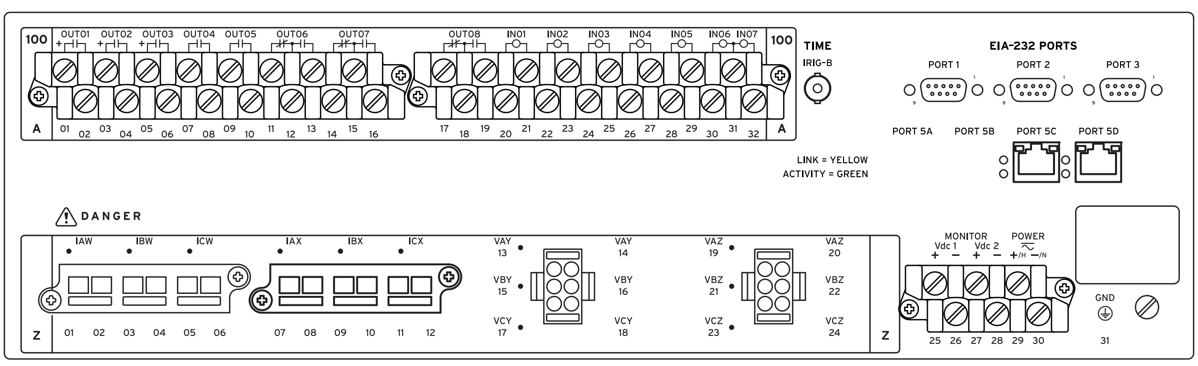
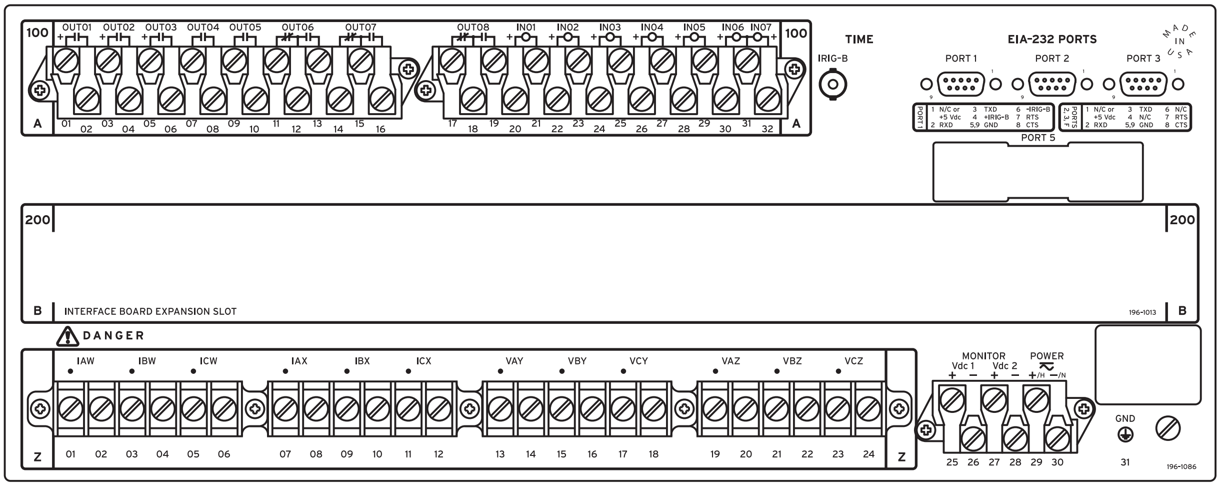
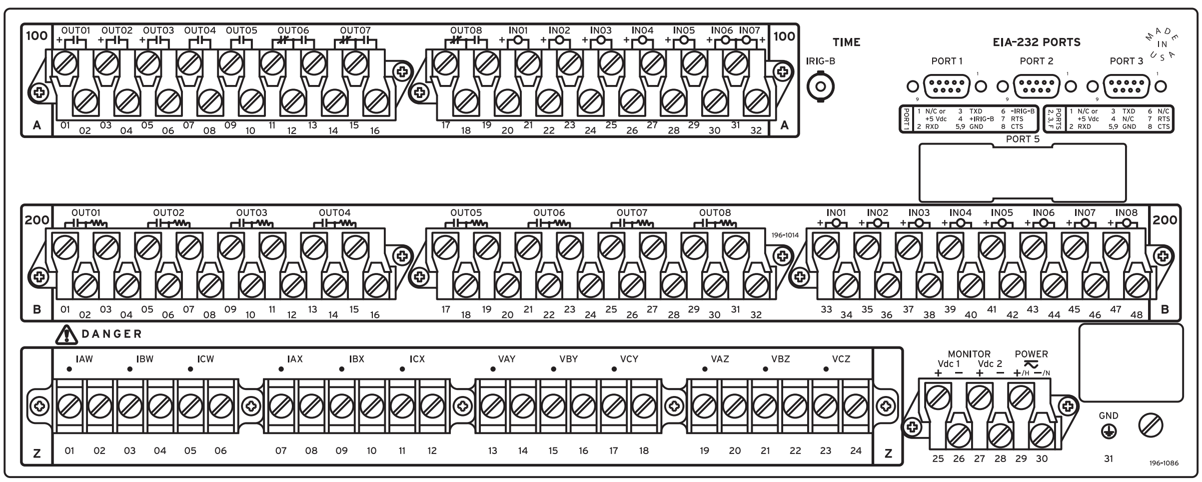


Figure 2.28 3U Rear Panel, Main Board A, Connectorized



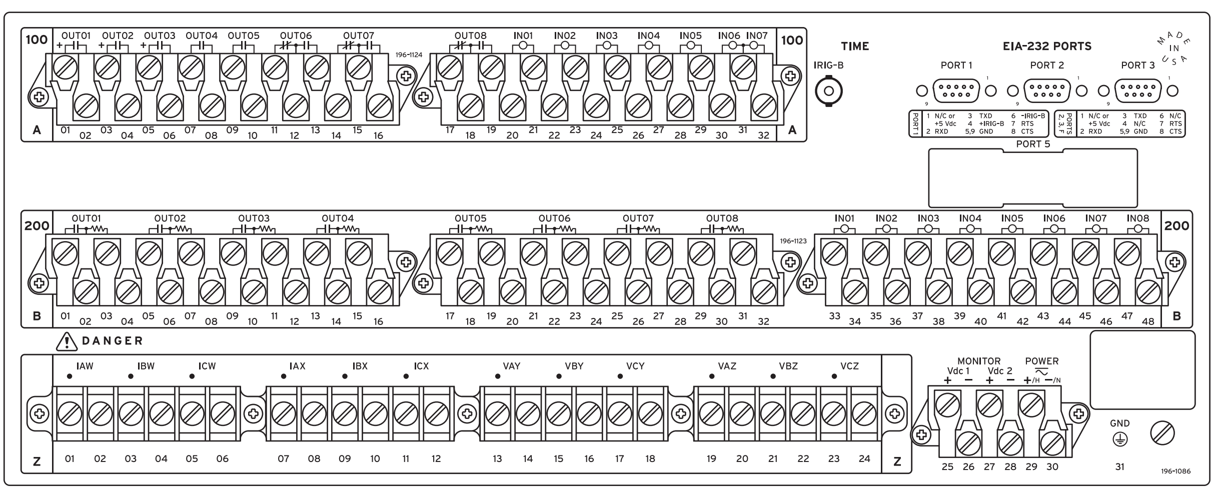
i3360d

Figure 2.29 4U Rear Panel, Main Board A, Without Optional I/O



i3362e

Figure 2.30 4U Rear Panel, Main Board A, INT5 I/O Interface Board



i3928a

Figure 2.31 4U Rear Panel, Main Board B, INT8 I/O Interface Board

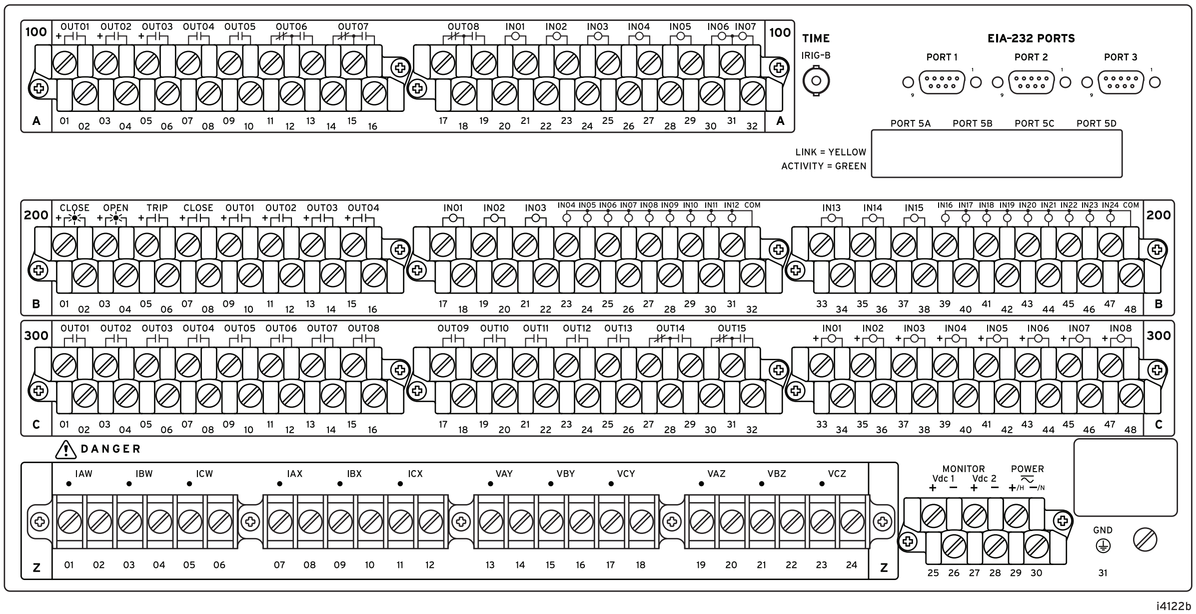


Figure 2.32 5U Rear Panel, Main Board B, INT3 and INT1 I/O Interface Board

(The INT3 board is the 200-addresses slot; the INT1 board is the 300-addresses slot.)

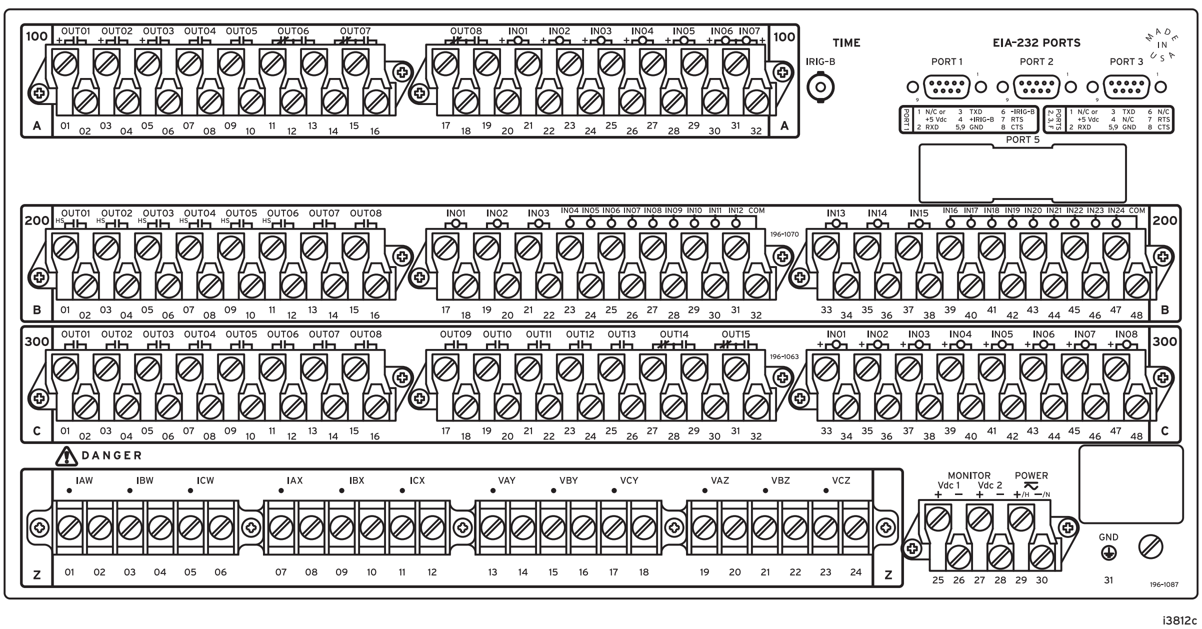
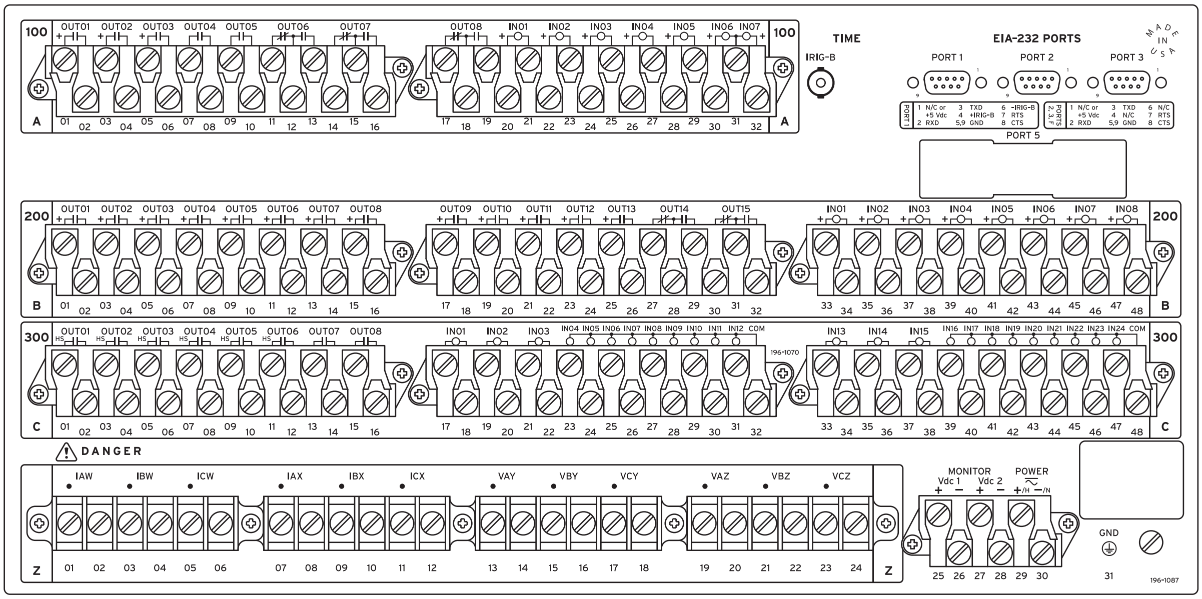


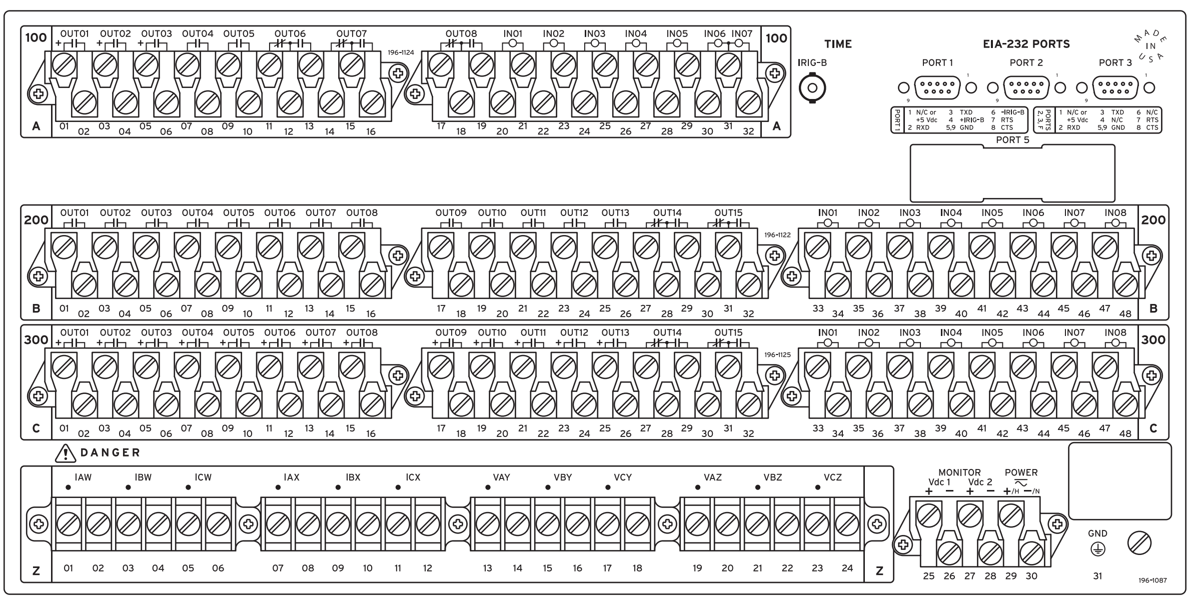
Figure 2.33 5U Rear Panel, Main Board A, INT4 and INT1 I/O Interface Board

(The INT4 board is the 200-addresses slot; the INT1 board is the 300-addresses slot.)



i3926a

Figure 2.34 5U Rear Panel, Main Board A, INT6 and INT4 I/O Interface Board



i3927a

Figure 2.35 5U Rear Panel, Main Board B, INT2 and INT7 I/O Interface Board

Rear-Panel Symbols

There are important safety symbols on the rear of the SEL-421 (see *Figure 2.36*). 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.

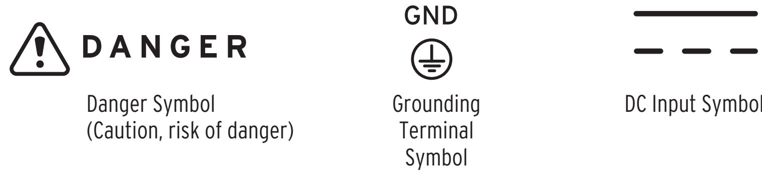


Figure 2.36 Rear-Panel Symbols

Screw Terminal Connectors

Terminate connections to the SEL-421 screw terminal connectors with ring-type crimp lugs. Use a #8 ring lug with a maximum width of 0.360 in. (9.1 mm). 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 9 in-lb. to 18 in-lb. (1.0 Nm to 2.0 Nm).

You can remove the screw terminal connectors from the rear of the SEL-421 by unscrewing the screws at each end of the connector block. Perform the following steps to remove a screw terminal connector:

Step 1. Remove the connector by pulling the connector block straight out.

Note that the receptacle on the relay circuit board is keyed; you can insert each screw terminal connector in only one location on the rear panel.

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

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

Changing Screw Terminal Connector Keying

You can rotate a screw terminal connector so that the connector wire dress position is the reverse of the factory-installed position (for example, wires entering the relay panel from below instead of from above). In addition, you can move similar function screw terminal connectors to other locations on the rear panel. To move these connectors to other locations, you must change the screw terminal connector keying.

Inserts in the circuit board receptacles key the receptacles for only one screw terminal connector in one orientation. Each screw terminal connector has a missing web into which the key fits (see *Figure 2.37*).

If you want to move a screw terminal connector to another circuit board receptacle or reverse the connector orientation, you must rearrange the receptacle keys to match the screw terminal connector block. Use long-nosed pliers to move the keys.

Figure 2.38 shows the factory default key positions.

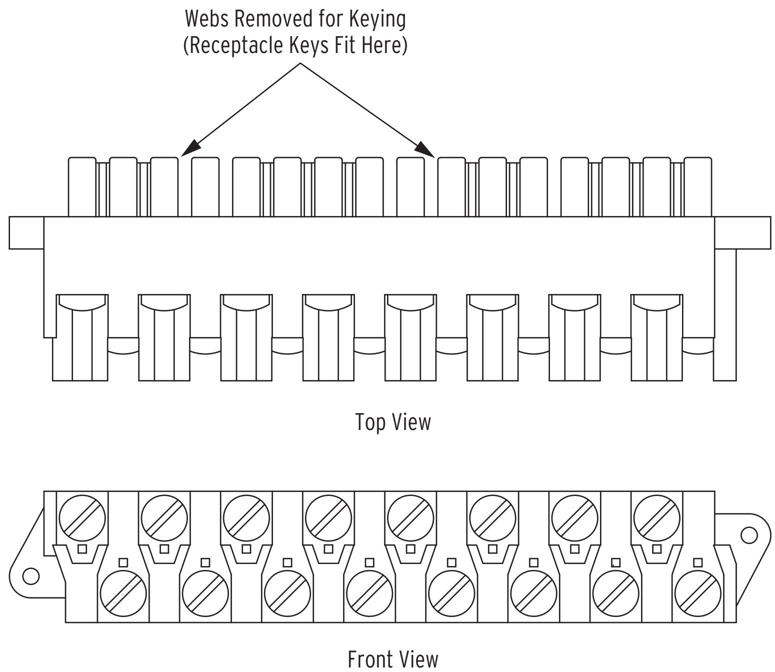


Figure 2.37 Screw Terminal Connector Keying

Grounding

Connect the grounding terminal (#Z31) 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 2.27*, *Figure 2.28*, *Figure 2.29*, and *Figure 2.30*, and *Figure 2.33*). The symbol that indicates the grounding terminal is shown in *Figure 2.36*.

Use 12–10 AWG (4 mm^2–6 mm^2) wire less than 6.6 feet (2 m) in length for this connection. This terminal connects directly to the internal chassis ground of the SEL-421.

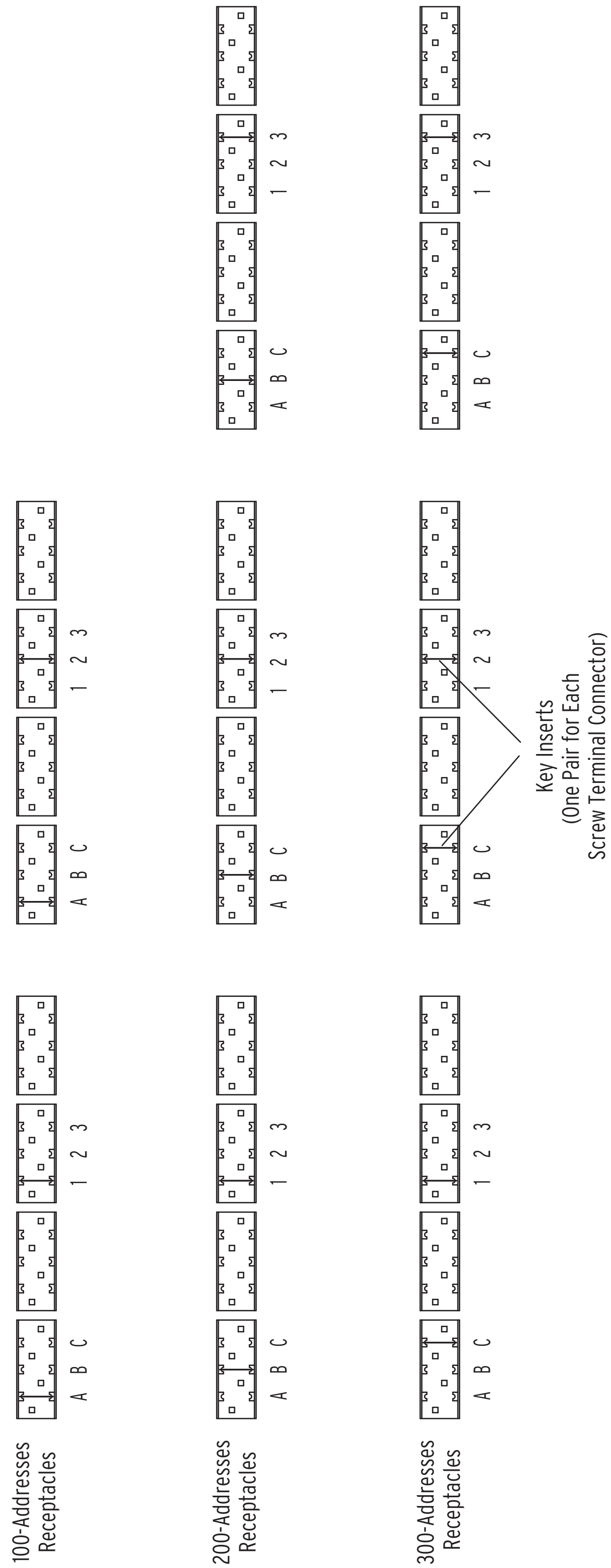


Figure 2.38 Rear-Panel Receptacle Keying, SEL-421

Power Connections

The terminals labeled **POWER** on the rear panel (#**Z29** and #**Z30**) must connect to a power source that matches the power supply characteristics that your SEL-421 specifies on the rear-panel serial number label. (See *Power Supply*

on page U.1.13, for complete power input specifications.) For the relay models that accept dc input, the serial number label specifies dc with the symbol shown in Figure 2.36.

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 16–14 AWG (1.5 mm^2–2.1 mm^2) 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, switch/fuse combination, or circuit breaker in the **POWER** leads for the SEL-421; 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. Be sure to locate this device within 9.8 feet (3.0 m) of the relay.

Operational power is internally fused by power supply fuse F1. Table 2.11 lists the SEL-421 power supply fuse requirements. Be sure to use fuses that comply with IEC 127-2.

You can order the SEL-421 with one of three operational power input ranges listed in Table 2.11. Each of the three supply voltage ranges represents a power supply ordering option.

As noted in Table 2.11, model numbers for the relay with these power supplies begin 04210*n* (or 04211*n*), where *n* is 2, 4, or 6, to indicate low, middle, and high voltage input power supplies, respectively.

Note that each power supply range covers two widely used nominal input voltages. The SEL-421 power supply operates from 30 Hz to 120 Hz when ac power is used for the **POWER** input.

Table 2.11 Fuse Requirements for the SEL-421 Power Supply

Nominal Power Supply Voltage Rating	Power Supply Voltage Range	Fuse F1	Fuse Description	Model Number
24/48 V	18–60 Vdc	T6.3AH250V	5x20 mm, time-lag, 6.3 A, high break capacity, 250 V	042102 or 042112
48/125 V	38–140 Vdc or 85–140 Vac (30–120 Hz)	T3.15AH250V	5x20 mm, time-lag, 3.15 A, high break capacity, 250 V	042104 or 042114
125/250 V	85–300 Vdc or 85–264 Vac (30–120 Hz)	T3.15AH250V	5x20 mm, time-lag, 3.15 A, high break capacity, 250 V	042106 or 042116

The SEL-421 accepts dc power input for all three power supply models. The 48/125 Vdc supply also accepts 120 Vac; the 125/250 Vdc supply also accepts 120/240 Vac. When connecting a dc power source, you must connect the source with the proper polarity, as indicated by the **+** (terminal #**Z29**) and **–** (terminal #**Z30**) symbols on the power terminals. When connecting to an ac power source, the **+** terminal #Z29 is hot (**H**), and the **–** terminal #**Z30** is neutral (**N**).

Each model of the SEL-421 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 U.1.13.

Power Supply Fuse Replacement

You can replace a bad fuse in an SEL-421 power supply, or you can return the SEL-421 to SEL for fuse replacement. If you decide to replace the fuse, perform the following steps to replace the power supply fuse:

⚠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.

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

Step 2. Disconnect power from the SEL-421.

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.

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 2.39*).

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 *Table 2.11* for the proper fuse for your power supply).

Step 18. Reinstall the interface board.

Step 19. Reinstall the SEL-421 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.

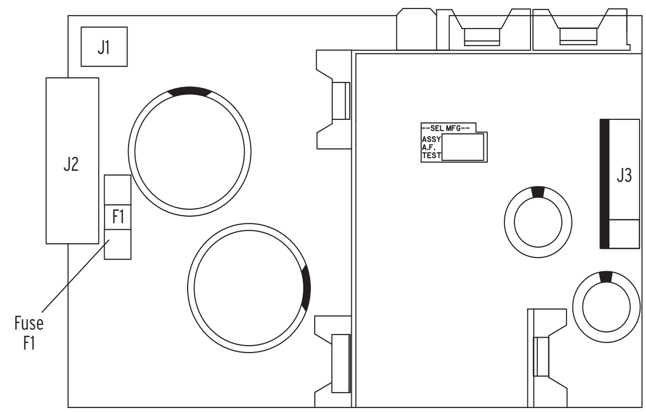


Figure 2.39 PS30 Power Supply Fuse Location

Monitor Connections (DC Battery)

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

The SEL-421 monitors two dc battery systems. For information on the battery monitoring function, see *Station DC Battery System Monitor on page A.2.21*.

Connect the positive lead of Battery System 1 to Terminal #**Z25** and the negative lead of Battery System 1 to Terminal #**Z26**. (Usually Battery System 1 is also connected to the rear-panel **POWER** input terminals.) For Battery System 2, connect the positive lead to Terminal #**Z27**, and the negative lead to Terminal #**Z28**.

Secondary Circuit Connections

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

The SEL-421 has two sets of three-phase current inputs and two sets of three-phase voltage inputs. *Shared Configuration Attributes on page U.2.1* describes these inputs in detail. The alert symbol and the word **DANGER** on the rear panel indicate that you should use all safety precautions when connecting secondary circuits to these terminals.

To verify these connections, use SEL-421 metering (see *Examining Metering Quantities on page U.4.33*). You can also review metering data in an event report that results when you issue the **TRIGGER** command (see *Triggering Data Captures and Event Reports on page A.3.4*).

Fixed Terminal Blocks

Connect the secondary circuits to the **Z** terminal blocks on the relay rear panel. Note the polarity dots above the odd-numbered terminals #**Z01**, #**Z03**, #**Z05**, #**Z07**, #**Z09**, and #**Z11** for CT inputs. Similar polarity dots are above the odd-numbered terminals #**Z13**, #**Z15**, #**Z17**, #**Z19**, #**Z21**, and #**Z23** for PT inputs.

Connectorized

⚠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.

For the Connectorized SEL-421, order the wiring harness kit, SEL-WA0421. The wiring harness contains four 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 #**Z06** for the **IW** inputs, and #**Z07** through #**Z12** for the **IX** inputs, 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 #**Z13** to #**Z18** for the VY inputs, and #**Z19** to #**Z24** for the VZ inputs, as appropriate.

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

Control Circuit Connections

You can configure the SEL-421 with many combinations of control inputs and control outputs. See *Main Board I/O on page U.2.10* and *I/O Interface Boards on page U.2.12* for information about I/O configurations. This subsection provides details about connecting these control inputs and outputs. Refer to *Figure 2.2*, *Figure 2.10*, and *Figure 2.14* for representative rear-panel screw terminal connector locations.

Control Inputs

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

Table 2.3 lists the control inputs available with the SEL-421, and notes that some are Direct-Coupled, and some are Optoisolated.

Direct-Coupled

Direct-coupled control inputs are polarity sensitive. These inputs use direct-coupled circuitry, and have terminal markings to indicate polarity: a + mark appears for each input. Connect the positive sense of the control input to the **+** terminal. Although you cannot damage these inputs with a reverse polarity connection, a reverse polarity connection will cause the relay internal A/D converter to measure the input voltage incorrectly and the relay will no longer detect input changes (see *Control Inputs on page U.2.5*).

Note that the Main Board A 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**.

Optoisolated

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

Note that the Main Board B I/O control inputs have one set of two inputs that share a common input leg and INT3 and INT4 I/O interface boards have two sets of nine inputs that share a common leg (see *Figure 2.13*).

Assigning

To assign the functions of the control inputs, see *Operating the Relay Inputs and Outputs on page U.4.56*, or *SET G on page R.9.41* for more details. You can also use ACSELERATOR QuickSet to set and verify operation of the inputs.

Control Outputs

The SEL-421 has three types of outputs:

- Standard outputs (example: main board OUT104)
- Hybrid (high-current-interrupting) outputs (example: main board OUT101)
- Fast Hybrid (fast high-current-interrupting) outputs (example: INT4 or INT5 (or INT8) board OUT201, or OUT301)

See *Control Outputs on page U.2.7* for more information.

You can connect the Standard outputs and the Fast Hybrid (fast high-current-interrupting) outputs in either ac or dc circuits. Connect the Hybrid (high-current-interrupting) outputs to dc circuits only. The screw terminal connector legends alert you about this requirement by showing polarity marks on the Hybrid (high-current-interrupting) contacts.

Form A (SPST NO) contacts comprise the majority of the control outputs. Two pairs of Form C (DPST CO) contacts are on the main board, the INT1 (INT2) I/O interface board, and the INT6 (INT7) I/O interface board.

The INT4 and INT5 (INT8) I/O interface boards feature high-speed operation capability using Fast Hybrid control outputs. To limit the false pickup indications with digital inputs and light duty high-speed auxiliary relays, precharging resistors are available on the screw terminal connector for each pair of control output contacts for INT5 boards. See *Fast Hybrid (Fast High-Current-Interrupting) Control Outputs on page U.2.9* for further information, and *Figure 2.8* and *Figure 2.9* for resistor connection details.

Alarm Output

The SEL-421 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 2.40* shows the configuration of the a and b contacts of control output OUT108.

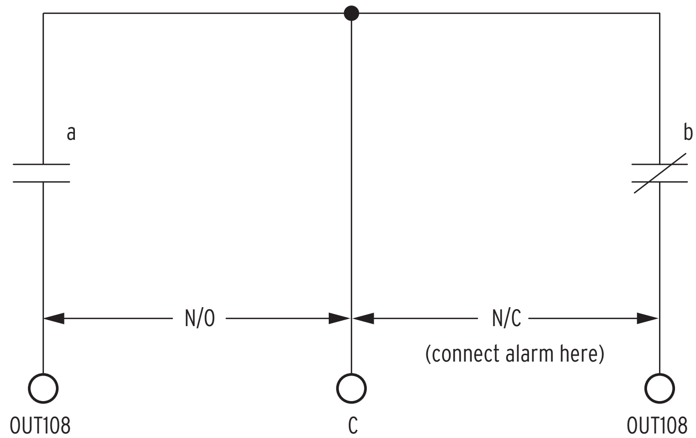


Figure 2.40 Control Output OUT108

Program OUT108 to respond to NOT HALARM by entering the following SELOGIC® control equation with a communications terminal, with ACSELERATOR QuickSet:

OUT108 := **NOT HALARM**

When the relay is operating normally, the NOT HALARM signal is at logical 1 and the b contacts of control output OUT108 are open.

When a status warning condition occurs, the relay pulses the NOT HALARM signal to logical 0 and the b contacts of OUT108 close momentarily to indicate an alarm condition.

For a status failure, the relay disables all control outputs and the OUT108 b contacts close to trigger an alarm. Also, when relay power is off, the OUT108 b contacts close to generate a power-off alarm. See *Relay Self-Tests on page U.6.38* for information on relay self-tests.

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

The SEL-421 also pulses the BADPASS Relay Word bit after three unsuccessful password entry attempts.

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

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

Tripping and Closing Outputs

To assign the control outputs for tripping and closing, see *Setting Outputs for Tripping and Closing on page U.4.62*. In addition, you can use the **SET O** command (see *SET on page R.9.40* for more details). You can also use the front panel to set and verify operation of the outputs (see *Set/Show on page U.5.28*).

Auxiliary {TRIP}/{CLOSE} Pushbuttons and OPEN/CLOSED LEDs (select models only)

Select relay models feature auxiliary **{TRIP}** and **{CLOSE}** pushbuttons and **OPEN** and **CLOSED** LED indicators. These features are electrically isolated from the rest of the relay. They function independently from the relay and do not need relay power.

The pushbuttons and LEDs can be hard-wired into a substation trip and close control circuit and operate the same as a separate installation of external trip/close switches and LED indicators. *Figure 2.48* shows example trip and close circuit connections for a control scheme configuration with a dc substation voltage source. The pushbutton switches come set from the factory for dc operation (arc suppression enabled). To use an ac trip or close potential, the arc suppression must be disabled for one or both pushbuttons (see *Table 2.9*). The voltage operating ranges of the LEDs are selected by jumpers (see *Table 2.8*).

⚠**WARNING**
SEL-421 features such as Hot Line Tag and Synchronism Check do not supervise the auxiliary close pushbutton.

Since the trip and close buttons are functionally separate from the relay, a manual trip or close cannot be distinguished from an external protection or automation-initiated operation. Unless provisions are made in the control wiring, the action of the close pushbutton is unsupervised.

TIME Input Connections

IRIG-B Input Connection

NOTE: The position of the IRIG-B BNC connector changed when SEL-421 firmware version R112 was released. See 1k PPS Connection Not Required on page U.4.72 for details.

The SEL-421 accepts a demodulated IRIG-B signal through two types of rear-panel connectors. These **IRIG-B** inputs are through the BNC connector labeled **TIME IRIG-B** or through Pin **4** (+) and Pin **6** (–) of the rear-panel 9-pin D-subminiature connector **PORT 1** (see *Communications Ports Connections on page U.2.47* for other DB-9 connector pinouts and additional details).

These inputs accept the dc shift time code generator output (demodulated) IRIG-B signal with positive edge on the time mark. For more information on IRIG-B and the SEL-421, see *TIME Inputs on page U.2.11*.

The **PORT 1 IRIG-B** input circuit connects to a 330 Ω resistor in series with an optocoupler input diode. The optocoupler input diode forward voltage drop is about 1.5 V. Driver circuits should source approximately 10 mA through the circuit for the ON state. When you are using the **PORT 1** input, ensure that you connect Pins **4** and **6** with the proper polarity.

Where distance between the SEL-421 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. Use the SEL-2810 transceiver to provide long distance delivery of the IRIG-B signal to the SEL-421. The SEL-2810 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.

Use the IRIG-B BNC connector for synchrophasor and high-accuracy timekeeping applications—see *Configuring High-Accuracy Timekeeping on page U.4.71*. Make the connection using a 50 Ω coaxial cable assembly with a male BNC connector.

Obsolete TIME Input Connection

Previous SEL-421 relays had a **TIME 1k PPS** input BNC connector. When relay firmware version R112 was released, the rear-panel **TIME** inputs were reconfigured. If you have upgraded the firmware in a previous SEL-421, see *Using New SEL-421 Firmware in an Existing Relay on page U.4.73* for retrofit information.

The previous **1k PPS** BNC connector is the new **IRIG-B** connector. The previous **IRIG-B** BNC connector is not used. See *1k PPS Connection Not Required on page U.4.72* for details.

Replacing the Lithium Battery

You can replace a bad lithium battery in the SEL-421. Perform the following steps to replace the lithium battery.

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

Step 2. Disconnect power from the SEL-421.

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 PORTS** mating connectors.

Step 7. Unscrew the keeper screws and disconnect any serial cables connected to the **PORT 1**, **PORT 2**, and **PORT 3** rear-panel receptacles.

Step 8. Loosen the four front-panel screws (they remain attached to the front panel), and remove the relay front panel.

Step 9. Remove the 34-pin ribbon cable from the front panel by pushing the extraction ears away from the connector.

Step 10. Disconnect the power, the interface board, and the analog input board cables from the main board.

Step 11. Pull out the drawout tray containing the main board.

Step 12. Locate the lithium battery.

The lithium battery is at the front of the main board (see *Figure 2.19*).

Step 13. Remove the spent battery from beneath the clip of the battery holder.

Step 14. Replace the battery with an exact replacement.

Use a 3 V lithium coin cell, Ray-O-Vac® No. BR2335 or equivalent. The positive side (+) of the battery faces up.

Step 15. Reinstall the SEL-421 main board, and reconnect the power, the interface board, and the analog input board cables.

Step 16. Reconnect the cable removed in *Step 9* and reinstall the relay front-panel cover.

Step 17. Reconnect any serial cables that you removed from the **EIA-232 PORTS** in the disassembly process.

⚠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.

⚠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.

⚠CAUTION
There is danger of explosion if the battery is incorrectly replaced. Replace only with Ray-O-Vac® no. BR2335 or equivalent recommended by manufacturer. Dispose of used batteries according to the manufacturer's instructions.

Step 18. Set the relay date and time via the communications ports or front panel (see *Making Simple Settings Changes on page U.4.13*).

Step 19. Follow your company standard procedure to return the relay to service.

Communications Ports Connections

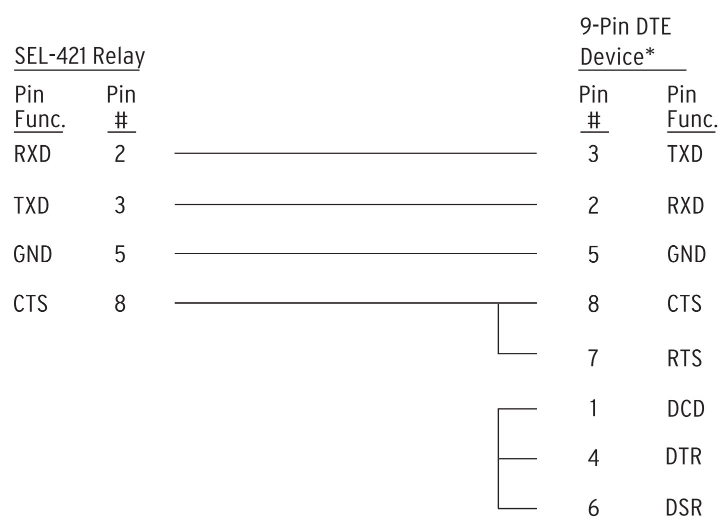
The SEL-421 has three rear-panel EIA-232 serial communications ports labeled **PORT 1**, **PORT 2**, and **PORT 3** and one front-panel port, **PORT F**. For information on serial communications, see *Establishing Communication on page U.4.4*, *Serial Communication on page R.4.2*, and *Serial Port Hardware Protocol on page R.5.1*.

In addition, the rear panel features a **PORT 5** for an optional communications card. For additional information about communications topologies and standard protocols that are available in the SEL-421, see *Network Connections on page U.2.48*, *Section 6: SEL Communications Processor Applications in the Applications Handbook*, *Section 7: Direct Network Communication in the Applications Handbook*, *Section 6: DNP3 Communications in the Reference Manual*, and *Section 8: IEC 61850 Communications in the Reference Manual*.

Serial Ports

The SEL-421 serial communications ports use EIA-232 standard signal levels in a D-subminiature 9-pin connector. To establish communication between the relay and a DTE device (a computer terminal, for example) with a D-subminiature 9-pin connector, use an SEL Cable C234A (see *Making an EIA-232 Serial Port Connection on page U.4.5*).

Figure 2.41 shows the configuration of SEL Cable C234A that you can use for basic ASCII and binary communication with the relay. A properly configured ASCII terminal, terminal emulation program, or ACSELERATOR QuickSet along with the C234A cable provide communication with the relay in most cases. See *Section 4: Communications Interfaces in the Reference Manual* for a list of hardware interfaces to the SEL-421.



*DTE = Data Terminal Equipment (Computer, Terminal, etc.)

Figure 2.41 SEL-421 to Computer—D-Subminiature 9-Pin Connector

Serial Cables

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

Using an improper cable can cause numerous problems or failure to operate, so you must be sure to specify the proper cable for application of your SEL-421. Several standard SEL communications cables are available for use with the relay. See *EIA-232 Communications Cables on page R.4.3* for information on recommended serial cables.

The following list provides additional rules and practices you should follow for successful communication using EIA-232 serial communications devices and cables:

- Route communications cables well away from power and control circuits. Switching spikes and surges in power and control circuits can cause noise in the communications circuits if power and control circuits are not adequately separated from communications cables.
- Keep the length of the communications cables as short as possible to minimize communications circuit interference and also to minimize the magnitude of hazardous ground potential differences that can develop during abnormal power system conditions.
- Ensure that EIA-232 communications cable lengths never exceed 50 feet, and always use shielded cables for communications circuit lengths greater than 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-28XX-series transceivers).
- Lower data speed communication is less susceptible to interference and will transmit greater distances over the same medium than higher data speeds. Use the lowest data speed that provides an adequate data transfer rate.

Network Connections

The optional Ethernet card for the SEL-421 can use either the connection on Port A or Port B to operate on a network. These ports work together to provide a primary and backup interface, as described in *Network Port Fail-Over Operation on page R.4.6*. 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 RJ-45 connector
- 100BASE-FX. 100 Mbps communications over multimode fiber-optic cable using an ST connector

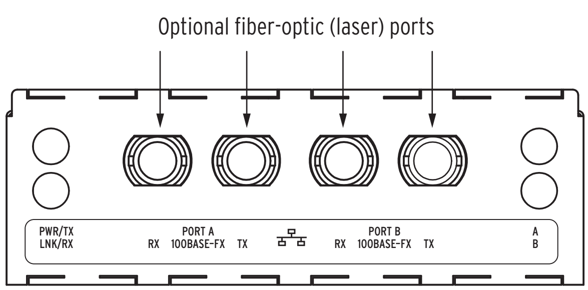


Figure 2.42 Example Ethernet Panel With Fiber-Optic Ports

Ethernet Card Rear-Panel Layout

Rear-panel layouts for the three Ethernet card port configurations are shown in *Figure 2.43–Figure 2.45*.

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

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

⚠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.

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

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

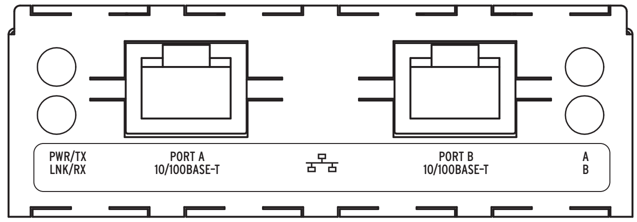


Figure 2.43 Two 10/100BASE-T Port Configuration

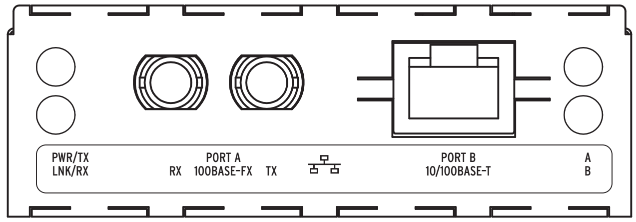


Figure 2.44 100BASE-FX and 10/100BASE-T Port Configuration

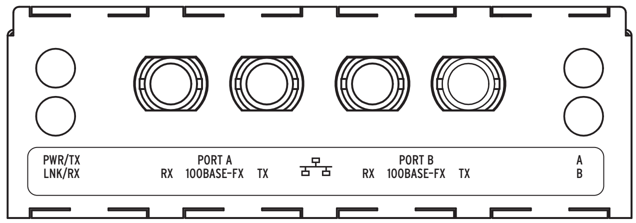


Figure 2.45 Two 100BASE-FX Port Configuration

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-421 Ethernet card is compatible with standard UTP cables for Ethernet networks as well as STP cables for Ethernet networks.

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

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

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

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

Some industrial Ethernet network devices use 9-pin connectors for STP cables. The Ethernet card RJ-45 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-421 in many power system protection schemes. *Figure 2.46* shows one particular application scheme with connections that represent typical interfaces to the relay for a single circuit breaker connection. *Figure 2.47* depicts typical connections for a dual circuit breaker protection scheme.

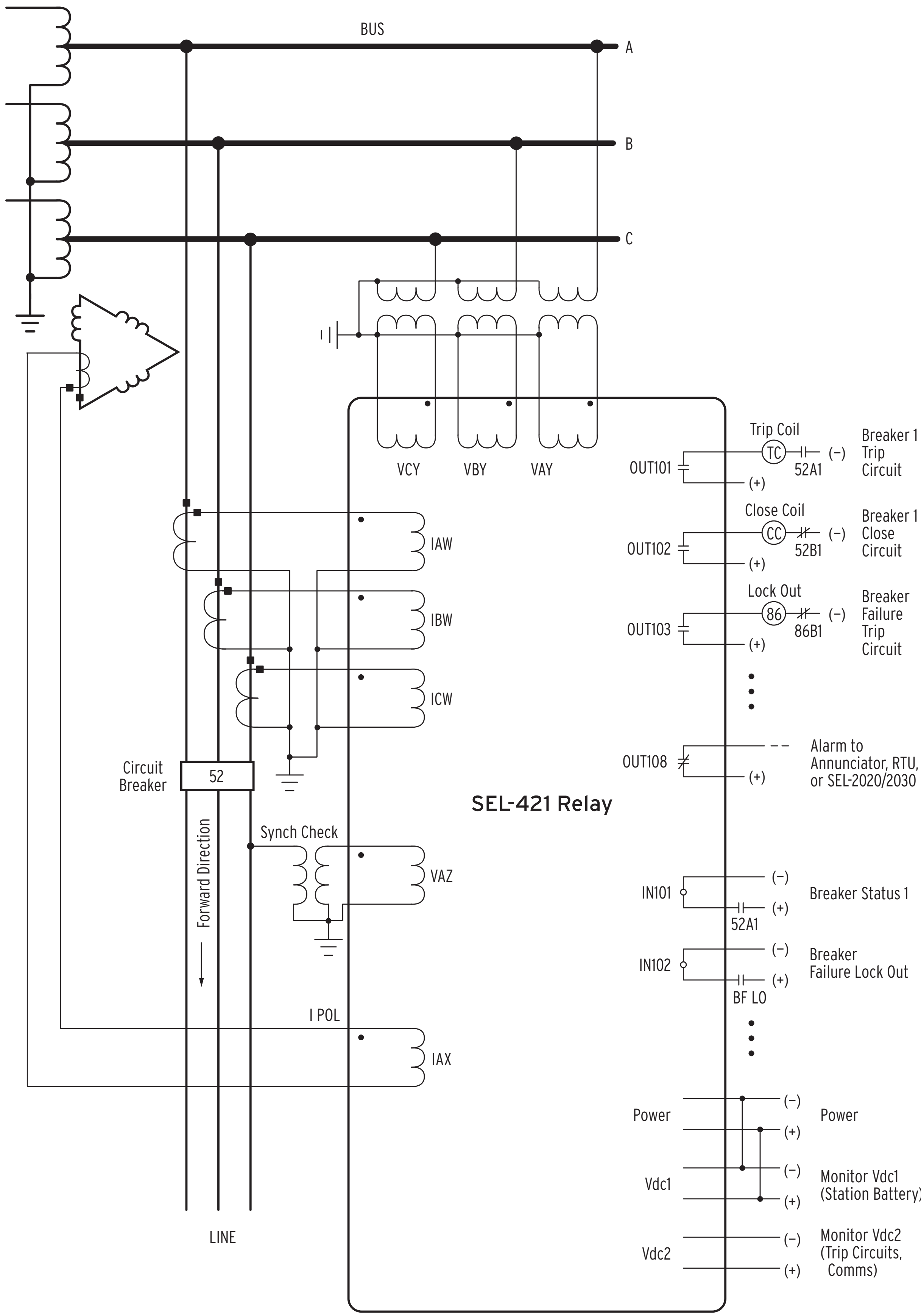


Figure 2.46 Typical External AC/DC Connections—Single Circuit Breaker

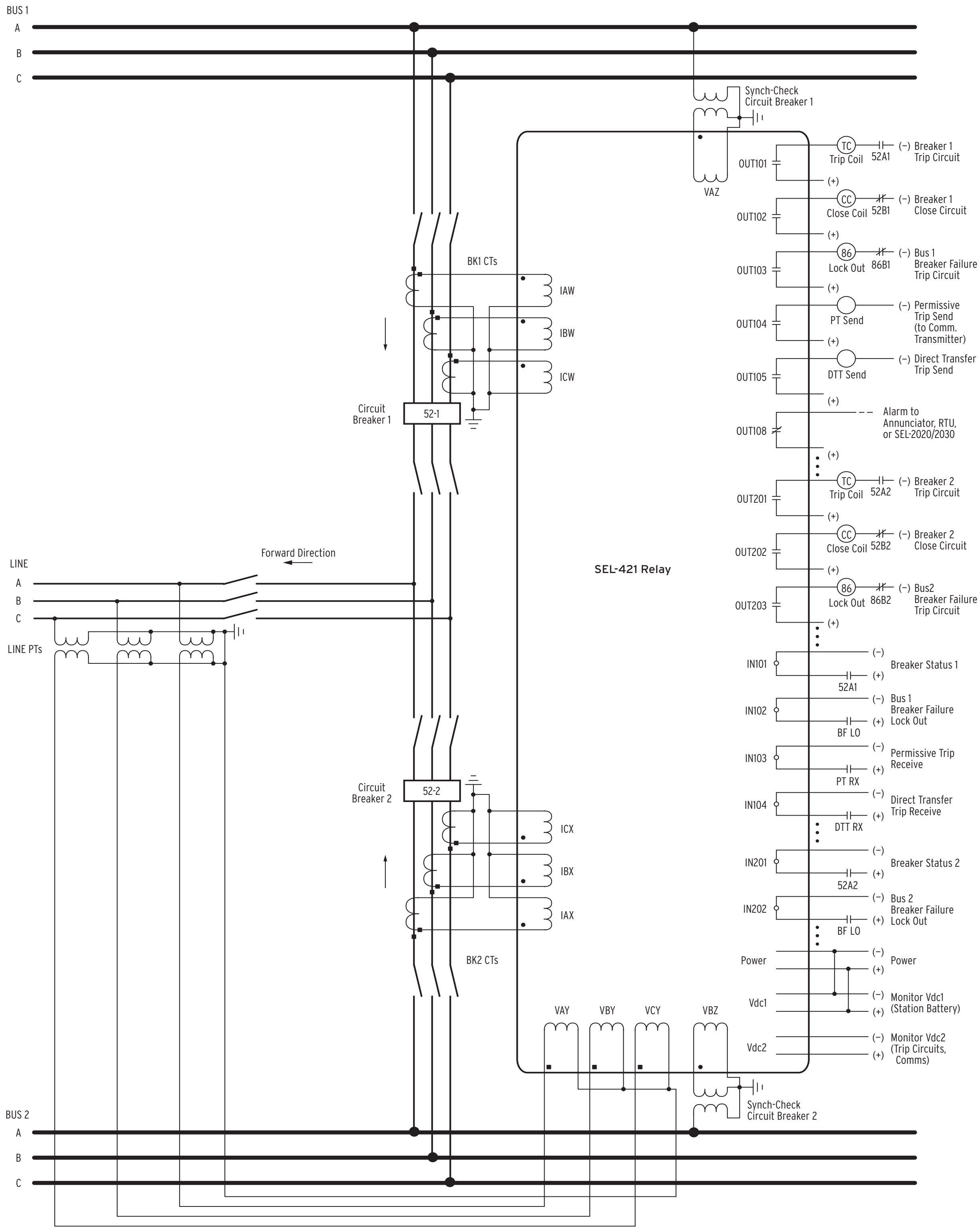


Figure 2.47 Typical External AC/DC Connections—Dual Circuit Breaker

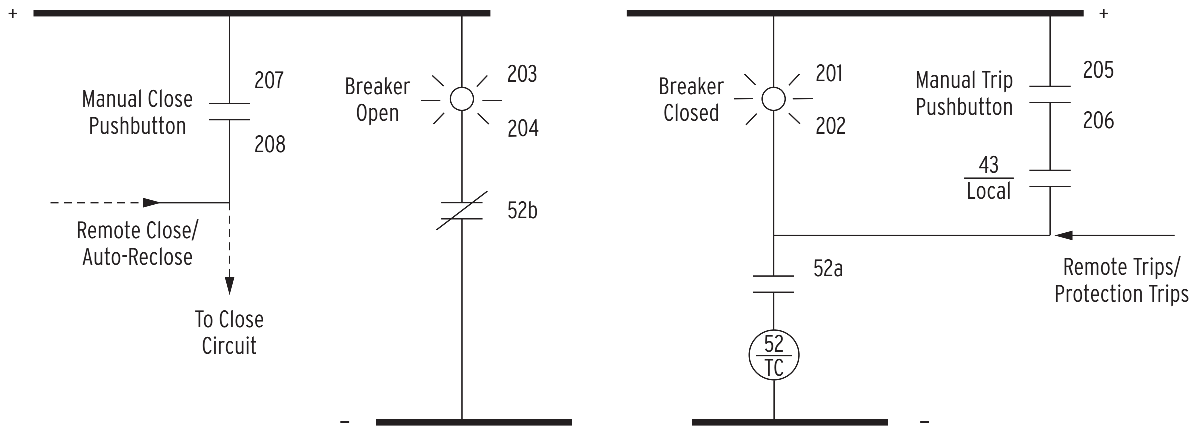


Figure 2.48 SEL-421 Example Wiring Diagram Using the Auxiliary {TRIP}/{CLOSE} Pushbuttons

Section 3
PC Software

This section provides information on the following topics:

The SEL-421 Relay includes ACSELERATOR QuickSet® SEL-5030 software, a powerful relay settings, analysis, and measurement tool to aid you in applying and using the relay. ACSELERATOR QuickSet reduces engineering costs for relay settings, logic programming, and system analysis. ACSELERATOR QuickSet also makes it easier for you to do the following:

- Create and manage relay settings
  - Create settings for one or more SEL-421 relays
  - Store and retrieve settings with an IBM-compatible personal computer (PC)
  - Upload and download relay settings files to and from SEL-421 relays
- Analyze events
  - Use the integrated waveform and harmonic analysis tools
- Monitor real-time and relay-stored power system data
  - Use the human machine interface (HMI) to view metering, Relay Word bits, and circuit breaker monitor data
- Control the relay
  - Command relay operation through use of a graphical user interface (GUI) environment
  - Execute relay serial port commands in terminal mode
- Configure the serial port and passwords

SEL provides ACSELERATOR QuickSet for easier, more efficient configuration of relay settings, metering, and control. ACSELERATOR QuickSet gives you the advantages of rules-based settings checks, SELOGIC® control equation Expression Builder, operator control and metering HMI, and event analysis.

However, you do not have to use ACSELERATOR QuickSet to configure the SEL-421; you can continue to use an ASCII terminal or a computer running terminal emulation software to access all relay settings and metering.

Installing the Computer Software

Load ACSELERATOR QuickSet on an IBM-compatible PC. If you encounter any difficulties installing ACSELERATOR QuickSet, contact your Technical Service Center or the SEL factory for assistance. See *Technical Support on page U.6.45* for contact information.

System Requirements

To successfully install and use ACSELERATOR QuickSet, your PC must have the minimum resources listed in *Table 3.1*.

Table 3.1 System Requirements for ACSELERATOR QuickSet

Item	Description
Processor	Pentium® class, ≥ 90 MHz
Operating System/RAM	Microsoft® Windows® 98/ME/XP—64 MB RAM Microsoft Windows 2000—64 MB RAM Microsoft Windows NT®—32 MB RAM (64 MB recommended)
Hard drive	At least 100 MB available storage space
Communications Port	One EIA-232 serial port or one Ethernet port
Drives	CD-ROM for software installation
Monitor	SVGA 800 x 600 pixel resolution or greater (1024 x 768 pixel resolution recommended)
Pointing Device	Mouse or other pointing device

Installation

You can load ACSELERATOR QuickSet automatically if your computer autorun feature is enabled; this is Method A.

If autorun is not enabled on your computer, use the Windows **Run** command to load ACSELERATOR QuickSet; this is Method B.

Method A

Load ACSELERATOR QuickSet automatically:

Step 1. Turn on your PC and run the Windows operating environment.

Step 2. Close all other applications on your PC.

Step 3. Place the ACSELERATOR QuickSet CD-ROM in the PC CD-ROM drive.

The setup software runs automatically and the SEL **Software License Agreement** appears, as in *Figure 3.1*.

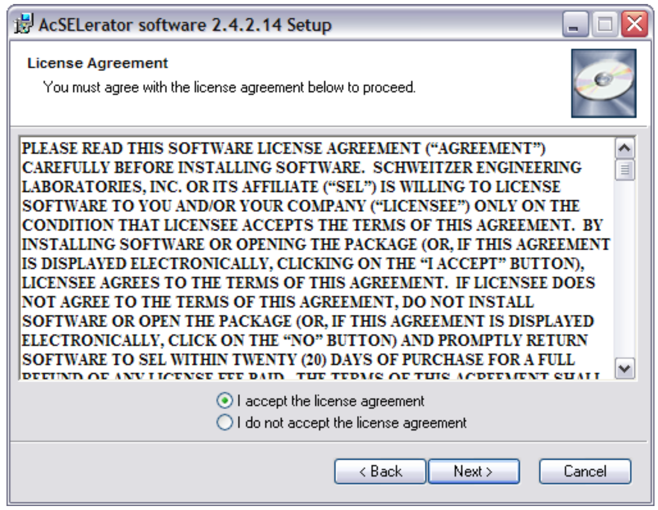


Figure 3.1 SEL Software License Agreement (Sample)

Method B

Load ACSELERATOR QuickSet with the Windows **Run** Command:

Step 1. If the **Setup** program does not start automatically, click **Start** > **Run** to load ACSELERATOR QuickSet.

Step 2. Type the command shown in *Figure 3.2*, being certain to use the correct drive letter for the CD-ROM drive in your PC (the CD-ROM drive in the *Figure 3.2* example is drive **D:**\).

Step 3. The SEL **Software License Agreement** appears (*Figure 3.1*).

Figure 3.2 Windows Run Command Line to Load ACSELERATOR QuickSet

Step 4. Complete the software loading process.

Step 5. Read the **Software License Agreement** and follow the loading instructions as these instructions appear on the PC screen.

Starting ACSELERATOR QuickSet

You can use the Windows **Start** menu to open ACSELERATOR QuickSet:

Step 1. If you installed ACSELERATOR QuickSet to the **Program Manager** group, click **Start** > **Programs**.

Step 2. Click SEL **Applications** > ACSELERATOR QuickSet.

Step 3. If you used a custom program group, click **Start** and click ACSELERATOR QuickSet in the custom group.

You can also create a shortcut on the Windows Desktop (see your Windows documentation for instructions on creating a shortcut). Double-click the shortcut icon to start ACSELERATOR QuickSet from the shortcut.

Communications Setup

ACSELERATOR QuickSet uses the relay communications ports to communicate with the SEL-421. Configure the ACSELERATOR QuickSet **Communication Parameters** menu settings to communicate effectively with the relay.

You can also use a basic terminal emulation window any time you run ACSELERATOR QuickSet. Use the **Communication** menu to view and clear a **Connection Log**. For a step-by-step procedure using ACSELERATOR QuickSet to communicate with the relay, see *Checking Relay Status: acSELerator QuickSet on page U.4.11*.

Communication Parameters

Use the **Communication Parameters** dialog box to configure relay communications settings. Select the **Communication** > **Parameters** from the top ACSELERATOR QuickSet toolbar to open this dialog box.

Figure 3.3 shows the ACSELERATOR QuickSet **Communication Parameters** dialog box.

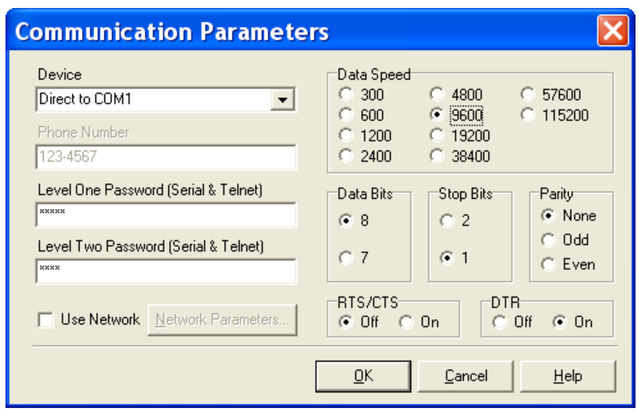


Figure 3.3 ACSELERATOR QuickSet Communication Parameters Dialog Box

Serial Setup

You can use serial communication via PORT 1, PORT 2, PORT 3, and PORT F (front panel). *Figure 3.3* shows the default serial port parameters (**9600**, **8**, **N**, **1**). Enter your relay **Level One** and **Level Two** passwords in the respective text boxes. (For complete information on passwords, see *Changing the Default Passwords: Terminal on page U.4.9*.)

If you choose a device from the **Device** text box that is a telephone modem, enter the dial-up telephone number in the **Phone Number** text box.

FTP Setup

Click the **Use Network** check box to access the **Network Parameters**. *Figure 3.4* shows the **Network Parameters** dialog box. For **FTP** (File Transfer Protocol) use **Telnet Port number 23**.

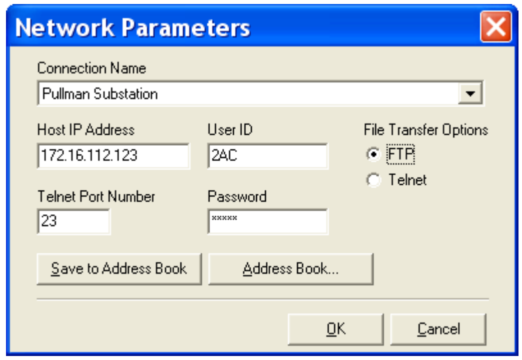


Figure 3.4 ACSELERATOR QuickSet Network Parameters Dialog Box: FTP

When you connect to a relay to use FTP, you must specify the access level and password.

Enter the access level command (**ACC**, **2AC**, for example) in the **User ID** text box and the corresponding access level password in the **Password** text box to control the relay at a specific access level (see *Changing the Default Passwords: Terminal on page U.4.9*).

Telnet Setup

Click the **Telnet** option button in the **Network Parameters** dialog box (see *Figure 3.5*) to connect to a relay for a **Telnet** session. The **Telnet** session uses the relay passwords in the **Communication Parameters** dialog box (*Figure 3.3*).

The default **Telnet Port Number** for accessing the relay is **T1PNUM := 23**. The default **Telnet Port Number** for communicating directly with an installed Ethernet card is **T2PNUM := 1024**.

See *Section 7: Direct Network Communication in the Applications Handbook* for information on changing the **Telnet Port Number**.

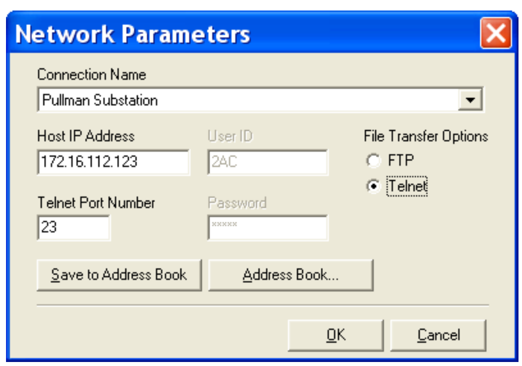


Figure 3.5 ACSELERATOR QuickSet Network Parameters Dialog Box: Telnet

Terminal Mode

The terminal emulation window is an ASCII interface between you and the relay. This is a basic terminal emulation with no file transfer capabilities. Many third-party terminal emulation programs are available with file transfer encoding schemes.

Click **Communication** > **Terminal** to start the terminal emulation window. Another convenient method to start the terminal is to type **<Ctrl+T>**.

Terminal Logging

When you check the **Terminal Logging** item in the **Communication** menu, ACSELERATOR QuickSet records communications events and errors in a log.

Click **Communication > Connection Log** to view the log.

Clear the log by selecting **Communication > Clear Connection Log**.

Settings Database Management and Drivers

Database Manager

ACSELERATOR QuickSet uses a relay database to save relay settings. ACSELERATOR QuickSet contains sets of all settings files for each relay that you specify in the **Database Manager**. See *Virtual File Interface on page R.5.11* for a list of the settings files in the SEL-421.

Choose appropriate storage backup methods and a secure location for storing your relay database files. Use the **File > Active Database** menu to retrieve a relay database from computer memory.

Relay Database

The default relay database file already configured in ACSELERATOR QuickSet is **Relay.rdb**. This database may contain example settings files for the SEL products with which you can use ACSELERATOR QuickSet.

Perform the following steps to access and/or modify the database:

Step 1. Open the **Database Manager**.

Step 2. Click **File > Database Manager** in the ACSELERATOR QuickSet top toolbar.

A dialog box similar to *Figure 3.6* appears.

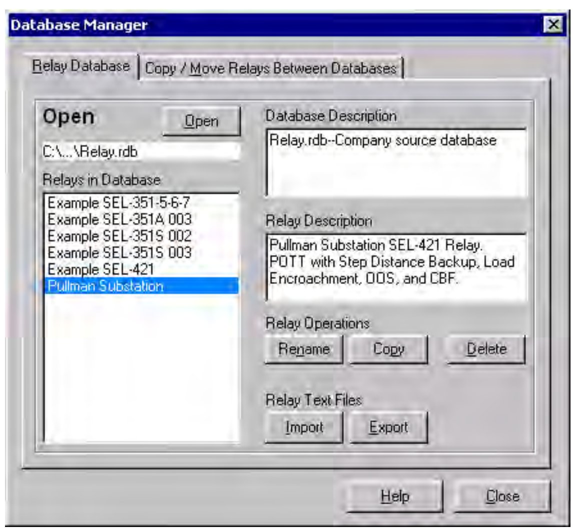


Figure 3.6 Database Manager Relay Database in ACSELERATOR QuickSet

Step 3. Enter descriptions for the database and for each relay in the database in the **Database Description** and **Relay Description** dialog boxes.

Type in the **Relay Description** dialog box special operating characteristics that describe the relay settings. These can include the protection scheme settings and communications settings.

Perform the following steps to create a new collection of relay settings:

Step 1. Highlight one of the relays listed in **Relays in Database** and click **Copy**.

ACSELERATOR QuickSet prompts you to provide a new name.

Step 2. Enter a new description in **Relay Description**.

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.

Perform the following steps to copy or move a relay between databases:

Step 1. Select the **Copy / Move Relays Between Databases** tab to access the dialog box shown in *Figure 3.7*.

Step 2. Click **Open B** to open a relay database.

Step 3. Select or type a filename and click **Open**; for example, **Relay2.rdb** is the B relay database in *Figure 3.7*.

Step 4. Highlight a relay in the **Database A** list, select **Copy** or **Move**, and click the > button to create a new relay in **Database B**.

- ➢ **Copy** creates an identical relay that appears in both databases.
- ➢ **Move** removes the relay from one database and places the relay in another database.

Step 5. Reverse this process to copy or move relays from **Database B** to **Database A**.

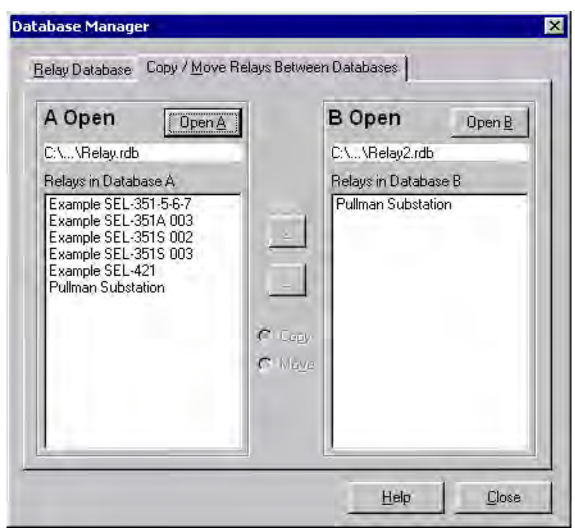


Figure 3.7 Database Manager Copy/Move in ACSELERATOR QuickSet

Create a New Database

Perform the following steps to create and copy an existing database of relays to a new database:

Step 1. Select the **File > Database Manager** to access the **Database Manager** dialog box.

Step 2. Select the **Copy / Move Relays Between Databases** tab in the **Database Manager** dialog box.

ACSELERATOR QuickSet opens the last active database and assigns it as **Database A** (see *Figure 3.7*).

Step 3. Click the **Open B** button.

ACSELERATOR QuickSet prompts you for a file location.

Step 4. Type a new database name, click the **Open** button, and answer **Yes.**

The program creates a new empty database.

Step 5. Load relays into the new database as in *Copy/Move Relays Between Databases on page U.3.7*.

Drivers

Relay settings folders in ACSELERATOR QuickSet are closely associated with the ACSELERATOR QuickSet relay driver that you used to create the settings. The relay settings and the ACSELERATOR QuickSet drivers must match.

Perform the following steps to ensure that the relay settings and ACSELERATOR QuickSet drivers match:

Step 1. Use any of the following methods to view the relay FID information:

- ➤ Enter the **STATUS** command.
- ➤ Click the **Status** button in the HMI tree view. See *Checking Relay Status on page U.4.10* for more information on viewing relay status.
- ➤ At a terminal (**<Ctrl+T>** from ACSELERATOR QuickSet), type **ID <Enter>**.

Step 2. View the ACSELERATOR QuickSet settings driver information at the bottom of the **Relay Editor** window (see *Figure 3.14*).

Step 3. Compare the ACSELERATOR QuickSet driver number and the relay FID number. The ACSELERATOR QuickSet driver Z-number and the corresponding part of the relay FID must match.

The first portion of the Z-number is the ACSELERATOR QuickSet settings driver version number (see *Figure 3.8*).

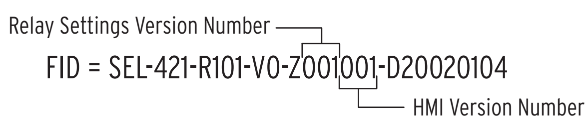


Figure 3.8 ACSELERATOR QuickSet Driver Information in the FID String

ACSELERATOR QuickSet reads the latter portion of the Z-number (ZXXX001, for example) to determine the correct HMI to display when you select the HMI **Meter and Control** menu. View the bottom of the HMI window to check the HMI driver number (see *Figure 3.9*).

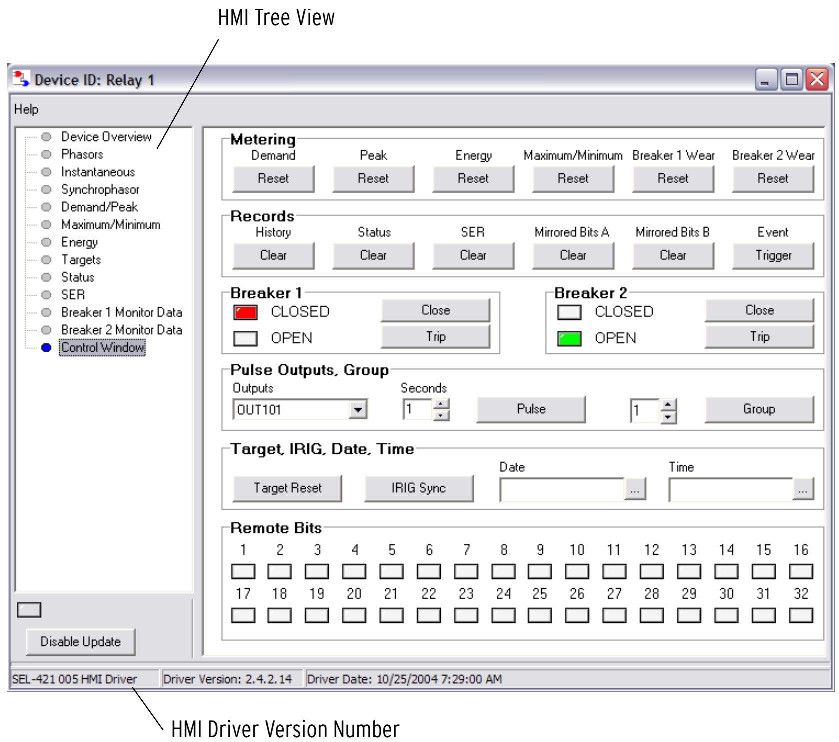


Figure 3.9 HMI Driver Version Number in the HMI Window

As SEL develops new drivers, you can update your existing ACSELERATOR QuickSet software with specific relay drivers for each SEL product that uses ACSELERATOR QuickSet. Contact your local Technical Service Center or the SEL factory for the latest ACSELERATOR QuickSet drivers.

Create and Manage Relay Settings

ACSELERATOR QuickSet gives you the ability to create settings for one or more SEL-421 relays. You can store existing relay settings downloaded from SEL-421 relays with ACSELERATOR QuickSet, creating a library of relay settings (see *Database Manager on page U.3.6*). You can then modify and upload these settings from your settings library to an SEL-421.

ACSELERATOR QuickSet makes setting the relay easy and efficient. For an example of setting the SEL-421 with ACSELERATOR QuickSet, see *Making Initial Global Settings: ACSELERATOR QuickSet on page U.4.25*.

Collected Settings

ACSELERATOR QuickSet arranges relay settings in easy-to-understand categories (for an explanation of settings organization, see *Making Simple Settings Changes on page U.4.13*). These categories of collected settings help you quickly set the relay.

Figure 3.10 is an example of relay settings categories in the **Relay Editor Settings** tree view. (Use the procedures described in *Settings Menu on page U.3.10* to view the tree views in *Figure 3.10*.)

ACSELERATOR 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 click the tree view to access the settings in a disabled category, the disabled settings are dimmed.

For example, select the **Group 1 > Set 1 > Relay Configuration** branch of the **Settings** tree view and choose **N** for **E50Q**.

Click the **Negative-Sequence O/C** branch and observe that the **Negative-Sequence Overcurrent Elements** settings are dim.

If you select **1** for **E50Q**, then only the level 1 overcurrent element settings are active and the remainder of the **Negative-Sequence Overcurrent Element** settings are dim.

Figure 3.10 illustrates this feature of ACSELERATOR QuickSet.

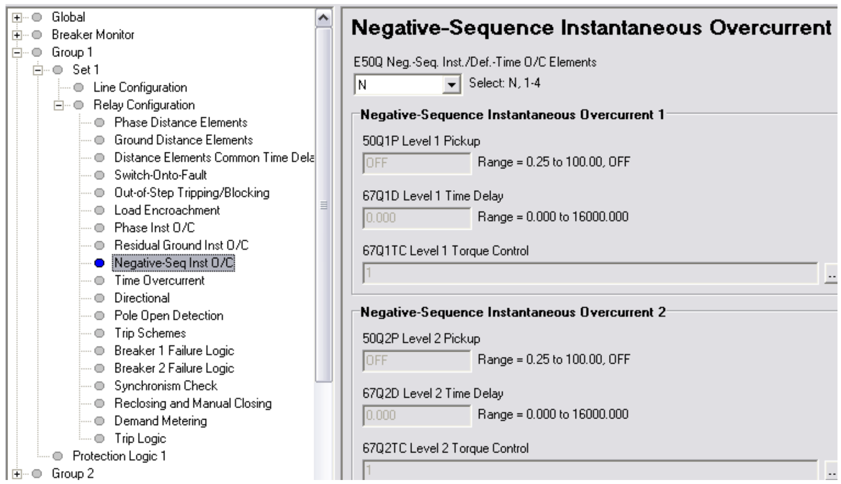


Figure 3.10 Sample Settings in ACSELERATOR QuickSet

Settings Menu

The **Settings** menu on the top ACSELERATOR QuickSet toolbar is the starting point for all settings entries. The menu items on the **Settings** menu are **New**, **Open**, and **Read**. All of these menu items open the **Relay Editor** (see *Relay Editor on page U.3.11*).

New

Selecting the **New** menu item creates new relay settings files. ACSELERATOR QuickSet makes the new settings files from the relay drivers that you specify in the **Settings Editor Selection** dialog box (see *Figure 3.11*).

ACSELERATOR QuickSet uses the Z-number in the relay FID string to create a particular version of relay settings (see *Drivers on page U.3.8*).

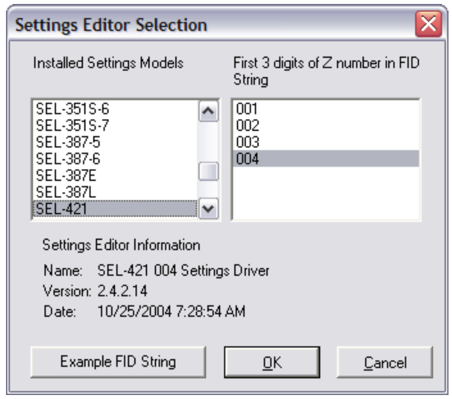


Figure 3.11 Selecting a Settings Driver in ACSELERATOR QuickSet

After selecting the relay model and settings driver, ACSELERATOR QuickSet presents the **Relay Part Number** dialog box. Use this dialog box to configure the **Relay Editor** to produce settings for a relay with options determined by the part number (see *Relay Part Number on page U.3.12*).

Open

The **Open** menu item opens an existing relay from the active database folder (see *Figure 3.12*). ACSELERATOR QuickSet prompts you for a folder containing relay settings to load into the **Relay Editor**.

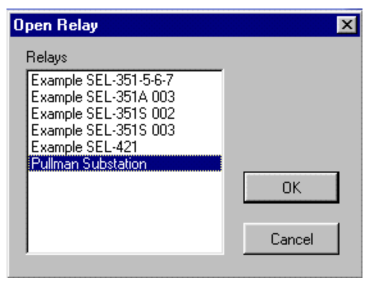


Figure 3.12 Opening Relay Settings in ACSELERATOR QuickSet

Read

When you select the **Read** menu item, ACSELERATOR QuickSet reads the relay settings from a connected relay. As ACSELERATOR QuickSet reads the relay, and a dialog box similar to *Figure 3.13* appears.

ACSELERATOR QuickSet uses serial protocols at a serial port or FTP from an Ethernet port to read settings from SEL devices.

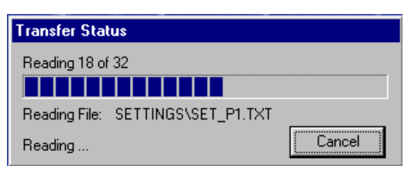


Figure 3.13 Reading Relay Settings in ACSELERATOR QuickSet

Relay Editor

Use the **Relay Editor** to enter relay settings. *Figure 3.14* illustrates the important features of the editor. These features include the ACSELERATOR QuickSet settings driver version number (the first three digits of the Z-number) in the lower left corner of the **Relay Editor**.

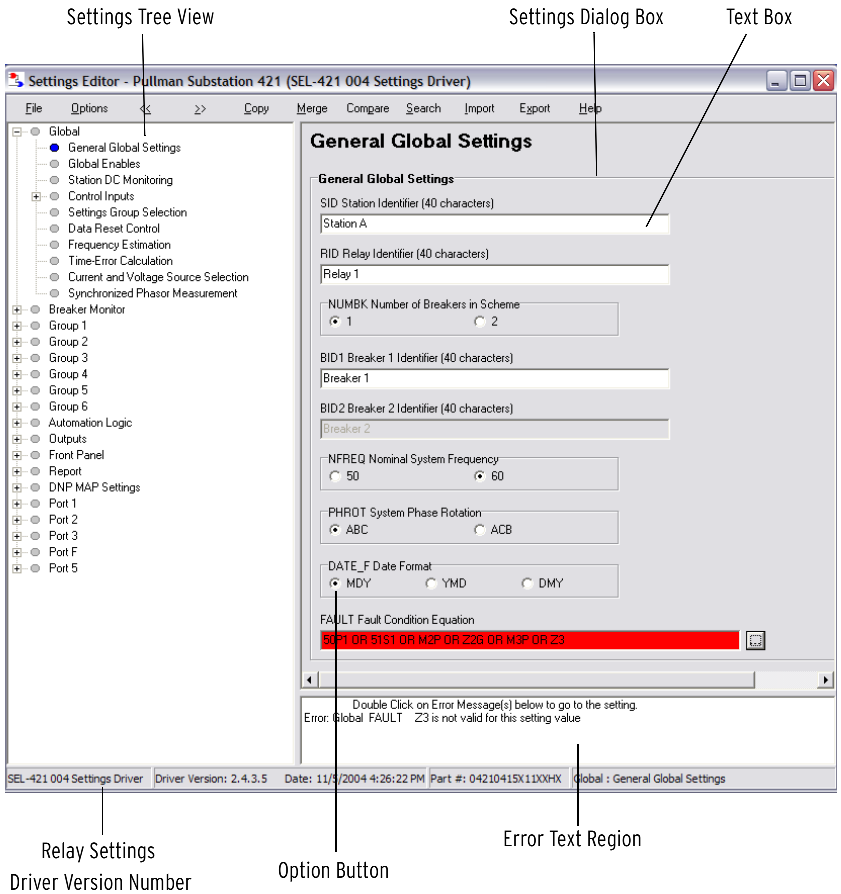


Figure 3.14 ACSELERATOR QuickSet Relay Editor

Entering Settings

Click the + marks and the buttons in the **Settings Tree View** to expand and select the settings class, instance, and category that you want to change.

Use **<Tab>** or click in a dialog box to edit a setting.

The right-click mouse button performs two special functions when you are editing settings: **Previous Value** and **Default Value**. To restore the previous value for a setting, right-click the setting and select **Previous Value**. Right-click the setting dialog box and select **Default Value** if you want to restore the factory default setting value.

If you enter a setting that is out of range or has an error, ACSELERATOR QuickSet shows the error at the bottom of the **Relay Editor**. Double-click the error listing to go to the setting to enter a valid input.

Relay Part Number

The relay part number determines the settings that ACSELERATOR QuickSet displays and the functions that the software controls. When configuring ACSELERATOR QuickSet to control a particular relay, you should confirm that the ACSELERATOR QuickSet part number matches the relay part number so that you can access all of the settings you need for your relay.

Configuring the Part Number

Perform the following steps to configure the part number:

Step 1. Select the **Settings** menu on the ACSELERATOR QuickSet top toolbar and click **New**, **Open**, or **Read** to start the **Relay Editor** (see *Settings Menu on page U.3.10*).

Step 2. Once in the **Relay Editor**, click the **Options** menu on the **Relay Editor** toolbar (see *Figure 3.15*).

Step 3. Click **Part Number**.

Figure 3.15 Retrieving the Relay Part Number

The **Relay Part Number** dialog box appears, as shown in *Figure 3.16*.

Step 4. Use the arrows inside the text boxes to match corresponding portions of the **Relay Part Number** dialog box to your relay.

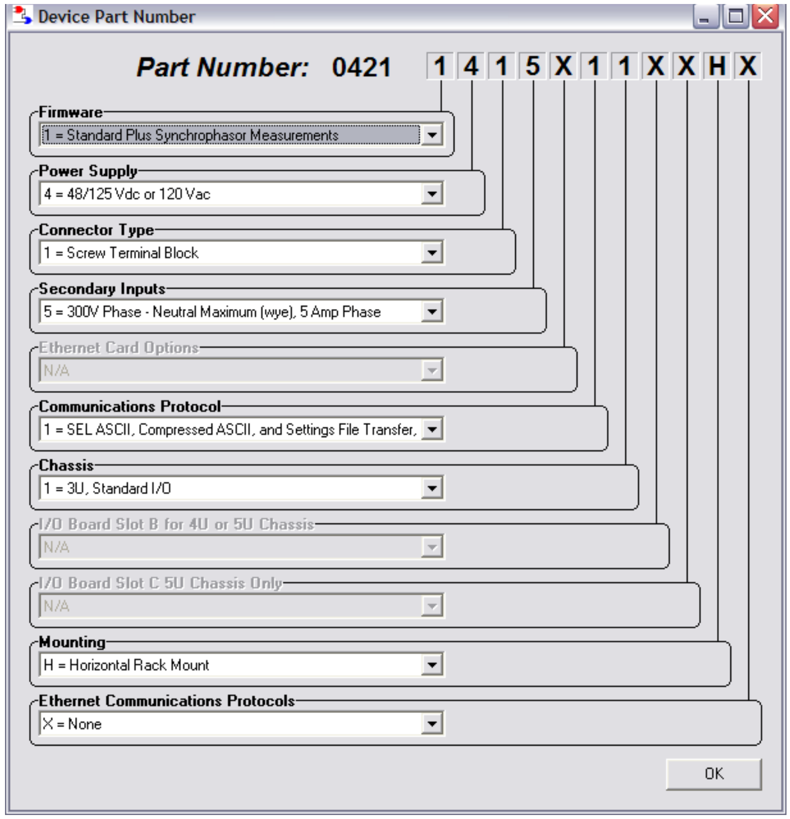


Figure 3.16 Setting the Relay Part Number in ACSELERATOR QuickSet

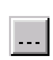
Expression Builder

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.

ACSELERATOR 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. The **Expression Builder** checks basic rules and flags mistakes in SELOGIC control equation settings.

Access the Expression Builder

Settings dialog boxes (see *Figure 3.17*) in the **Relay Editor** window show the following (ellipsis) button:



Click this button of a SELOGIC equation to use the **Expression Builder**.

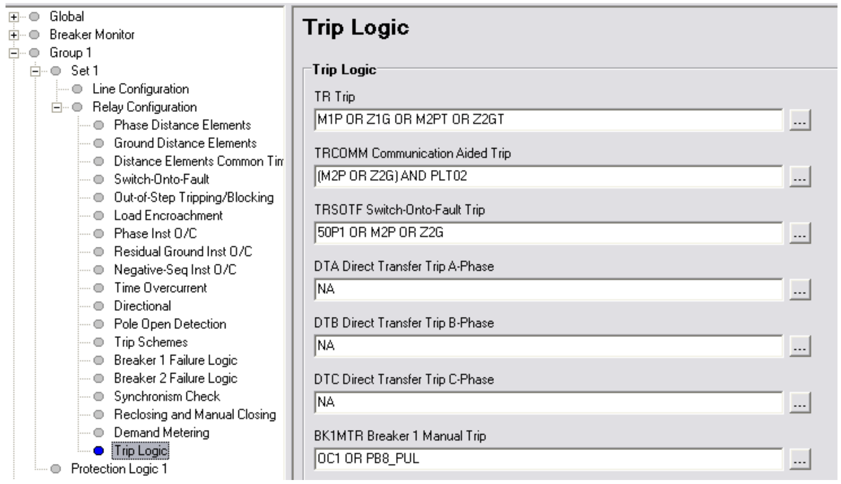


Figure 3.17 Location of the Expression Builder Option Buttons

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 settings; see *Fixed SELOGIC Control Equations on page R.3.4*.)

Figure 3.18 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 left and right sides.

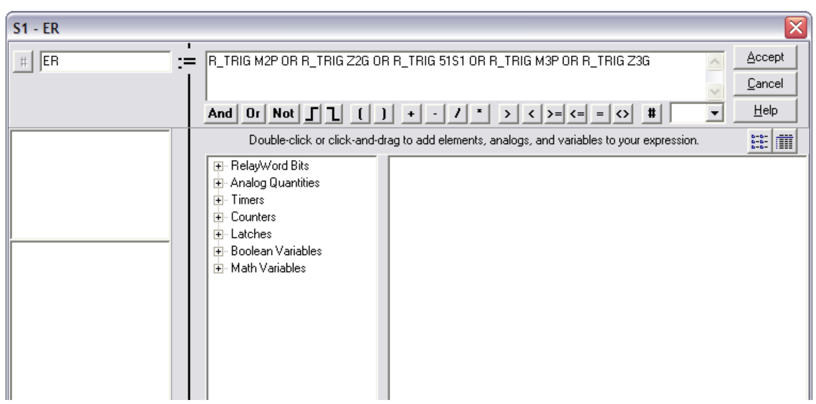


Figure 3.18 The ACSELERATOR QuickSet Expression Builder

Using the Expression Builder

For Protection Free-Form SELOGIC and Automation Free Form SELOGIC, select the type of result (LVALUE) for the SELOGIC control equation to use the **Expression Builder**. ACSELERATOR QuickSet shows these possibilities in the file box directly underneath the left side of the equation. The program shows the relay elements for each type of SELOGIC control equation (Boolean Variables, Math Variables, etc.).

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. Select a category in the RVALUE tree view, and the **Expression Builder** displays all elements for that category in the list box 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 3: SELOGIC Control Equation Programming in the Reference Manual*.

Analyze Events

ACSELERATOR QuickSet has integrated analysis tools that help you retrieve information about protection system operations quickly and easily. Use the protection system event information that the SEL-421 stores to evaluate the performance of a protection system.

Event Waveforms

The SEL-421 records power system events for all trip situations and for other operating conditions that you program with SELOGIC control equations (see *SELOGIC Control Equation ER on page A.3.4*).

The relay provides two types of event data captures: high-resolution oscillography that uses raw sample per second data and event report oscillography that uses filtered sample per cycle data. See *Triggering Data Captures and Event Reports on page A.3.4* and *Generating an Event on page U.4.42* for information on recording events.

Use ACSELERATOR QuickSet to view high resolution and event report oscillograms, phasor diagrams, harmonic analyses, and settings.

Read History

You can retrieve event files stored in the relay and transfer these files to your PC. For information on the types of event files and data capture, see *Triggering Data Captures and Event Reports on page A.3.4*.

To download event files from the relay, open the ACSELERATOR QuickSet **Analysis** menu at the top ACSELERATOR QuickSet toolbar and click **View Event History**. The **Event History** dialog box appears (*Figure 3.19* is similar).

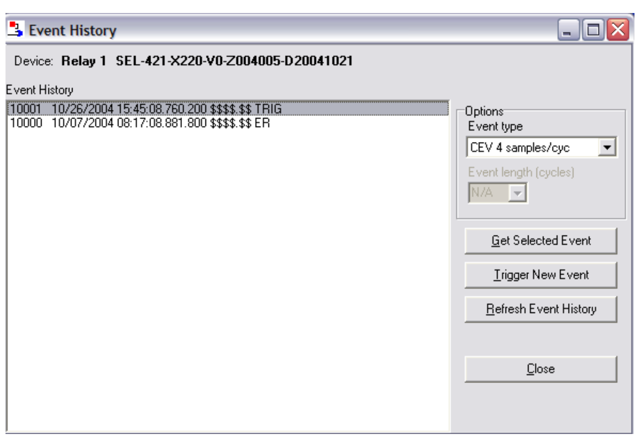


Figure 3.19 Retrieving Relay Event History

Get Event

Perform the following steps to view events:

Step 1. Highlight the event you want to view and click the **Get Selected Event** button.

For this exercise, choose Binary COMTRADE in the **Event Type** dialog box to select high-resolution oscillography. The other choices are CEV 4 samples/cyc and CEV 8 samples/cyc, which correspond to relay event reports of four or eight samples per cycle, respectively.

Step 2. When downloading is complete, ACSELERATOR QuickSet asks you to save the file on your PC.

Step 3. Once the file is saved, press the **Close** button, and then select the **Analysis** menu and click **View Event Files**.

Step 4. Open the oscillography file you just saved. It may be necessary to change the **Files of Type** selection to see the COMTRADE files in the file list.

NOTE: If your PC is loaded with SEL-5601 Analytic Assistant software (purchased separately), ACSELERATOR QuickSet® SEL-5030 Software automatically uses SEL-5601 to provide event analysis functionality. Some of the screen captures and related information may differ from the examples shown in this manual.

Step 5. ACSELERATOR QuickSet displays the **Event Waveform** dialog box and the event oscillogram (see *Figure 3.20* and *Figure 3.21*).

You can see high-accuracy time-stamp information on the event oscillogram.

When viewing the event oscillogram, use keyboard function keys to measure the time of oscillogram occurrences. These function keys and related functions help in event analysis

<F2>: go to trigger

<F3>: Cursor 1

<F4>: Cursor 2

The display shows the time difference between the **<F3>** and **<F4>** cursors.

Step 6. Click the **Pref** button at the bottom of the oscillogram and select **Time** (under **Time Units, Starting/Ending Row**).

Step 7. Click **OK**.

Step 8. Click on any point in a graph to observe the **Event Time** in microseconds of that data point at the bottom of the oscillogram.

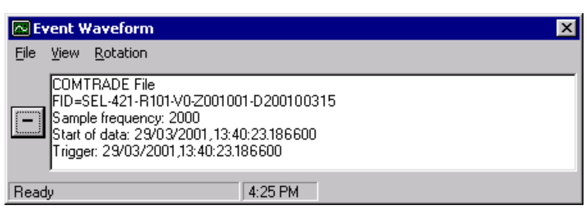


Figure 3.20 ACSELERATOR QuickSet Event Waveform Window

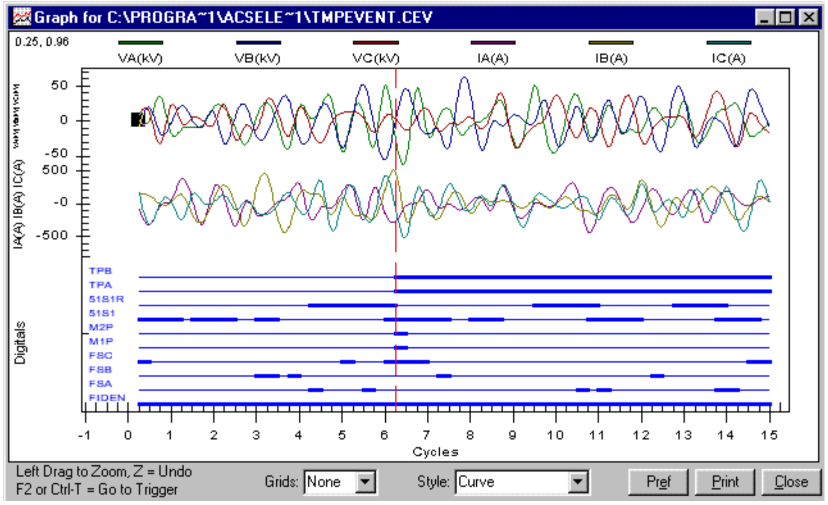


Figure 3.21 Sample Event Oscillogram

NOTE: The Phasors display is designed for 4 or 8-sample per cycle event reports. A warning message is displayed if you are viewing a COMTRADE file that cannot be properly represented in the phasor display.

You can also view other event displays:

Step 9. From the **Event Waveform** dialog box, select the **View** menu.

Step 10. Click **Phasors**, as shown in *Figure 3.22*, to view a sample-by-sample phasor display.

A phasor display similar to *Figure 3.23* appears.

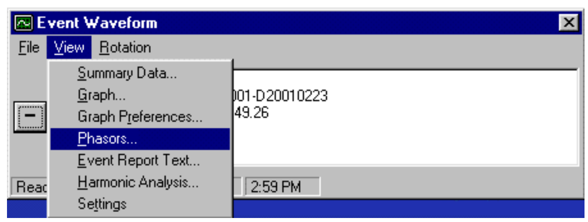


Figure 3.22 Retrieving Event Report Waveforms

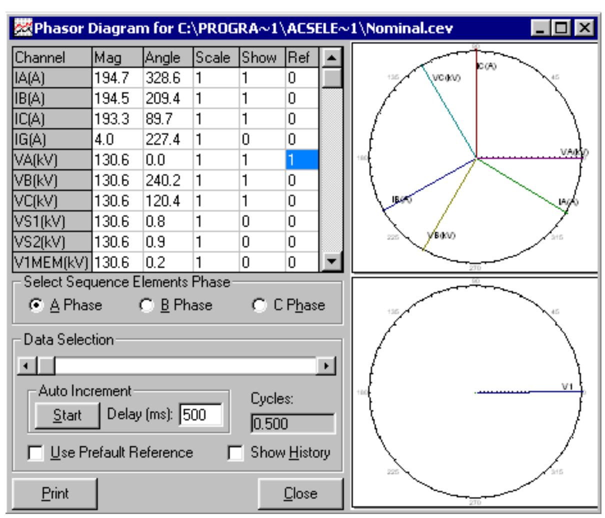


Figure 3.23 Sample Phasors Event Waveform Screen

ACSELERATOR QuickSet also presents a harmonic analysis of power system data for raw data binary COMTRADE event captures.

Step 1. From the **Event Waveform View** menu, click **Harmonic Analysis**.

A window similar to *Figure 3.24* appears.

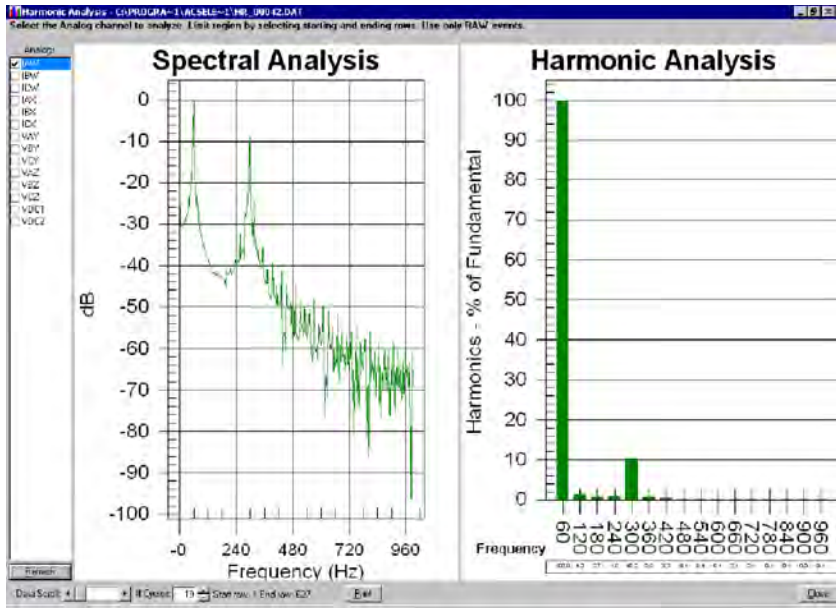


Figure 3.24 Sample Harmonic Analysis Event Waveform Screen

Step 2. On the left side of the **Harmonic Analysis** screen, choose the relay voltage and current channels to monitor for harmonic content.

You can view both a spectral analysis plot and a harmonic analysis bar chart.

Step 3. Click the arrows of the **Data Scroll** box or the **# Cycles** box to change the data analysis range.

Step 4. Click **Summary Data** on the **Event Waveform View** menu to see event summary information and to confirm that you are viewing the correct event.

Figure 3.25 shows a sample ACSELERATOR QuickSet **Event Report Summary** screen.

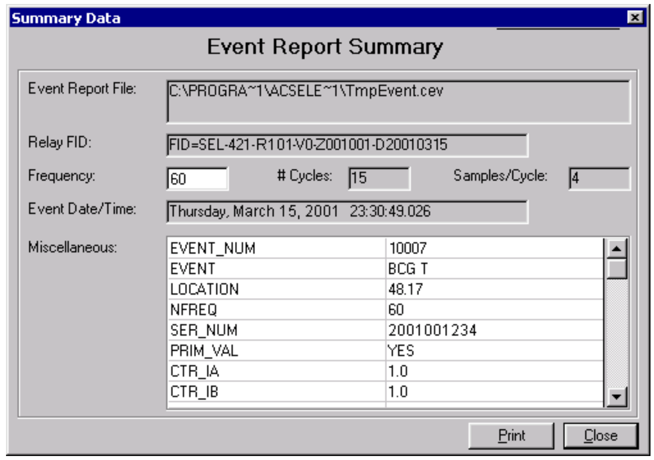


Figure 3.25 Sample Event Report Summary Screen

Step 5. Click **Settings** on the **Event Waveform View** menu to view the relay settings that were active at the time of the event.

Figure 3.26 shows a sample CEV-type event **Settings** screen.

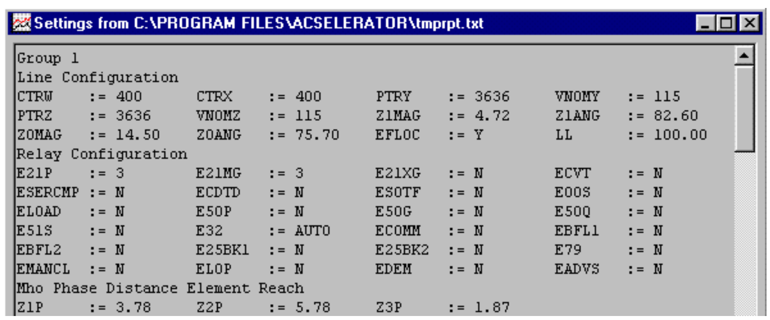


Figure 3.26 Sample Event Waveform Settings Screen

Open File

Computer-stored data captures are available as COMTRADE files (*.DAT) or compressed event report files (*.CEV).

Perform the following steps to open these files:

Step 1. Open the ACSELERATOR QuickSet **Analysis** menu and click **View Event Files** to view the waveforms in an event file stored on your computer.

The **Event Waveform** dialog box (similar to *Figure 3.20*) and an oscillographic event screen (similar to *Figure 3.21*) appear.

Step 2. At the **Event Waveform** dialog box, you can select the **Phasors** display, the **Harmonic Analysis** display, the **Summary Data** display, and the **Settings** display from the **Event Waveform** window (see *Read History on page U.3.16*).

HMI Meter and Control

Use the ACSELERATOR QuickSet HMI feature to view real-time relay information in a graphical format. Use the virtual relay front panel to read metering and targets and to operate the relay.

Open the ACSELERATOR QuickSet HMI

On the HMI menu, click **Meter and Control**.

ACSELERATOR QuickSet opens the HMI window and downloads the interface data. See the detailed examples in *View Metering: ACSELERATOR QuickSet on page U.4.37* for step-by-step instructions.

ACSELERATOR QuickSet HMI Features

You can use ACSELERATOR QuickSet to access many types of relay information and relay controls.

Step 1. Click the HMI menu at the top ACSELERATOR QuickSet toolbar and then click **Meter and Control** to access the ACSELERATOR QuickSet HMI.

Figure 3.27 shows the HMI tree view.

Table 3.2 lists the functions in the HMI tree view and a brief explanation of each function.

In the ACSELERATOR QuickSet HMI, an LED representation shows that a color is asserted or "on."

The flashing LED representation in the lower left of each HMI screen indicates an active data update via the communications channel.

Step 2. Click the button marked **Disable Update** to suspend HMI use of the communications channel.

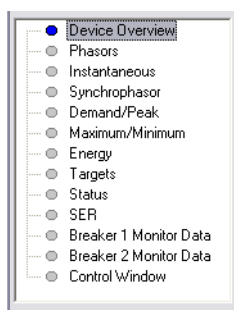


Figure 3.27 ACSELERATOR QuickSet HMI Features

Table 3.2 ACSELERATOR QuickSet HMI Tree View Functions

Function	Description
Device Overview	View general metering, selected targets, control input, control outputs, and the virtual front panel.
Phasors	A graphical and textual representation of phase and sequence voltage and current phasors.
Instantaneous	A table of instantaneous voltages, currents, powers, frequency, and dc monitor voltages.
Synchrophasors	A table showing synchrophasor data, if enabled.
Demand/Peak	A table showing demand and peak demand values. Reset buttons are in this display.
Max/Min	A table showing maximum/minimum metering quantities. A reset button is in this display.
Energy	A table showing energy import/export. A reset button is in this display.
Targets	View selected Relay Word bits in a row/column format.
Status	A list of relay status conditions.
SER	Sequential Events Recorder data listed oldest to newest, top to bottom. Set the range of SER records with the dialog boxes at the bottom of the display.
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.

Section 4
Basic Relay Operations

The SEL-421 Relay is a powerful tool 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 SEL-421, organized by task. These tasks help you become familiar with the relay and include the following:

Perform these tasks to gain a good understanding of relay operation, be able to confirm that the relay is properly connected, and be more effective when using the relay.

Inspecting a New Relay

⚠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.

The following items are included in your shipment from SEL:

- SEL-421 Relay
- Printed volume of the entire SEL-421 User's Guide
- CD-ROM containing the electronic version of the entire SEL-421 Relay Manual and the Customer Label Templates
- CD-ROM containing the ACSELERATOR QuickSet® SEL-5030 software program
- SEL Contact Card
- Configurable Front-Panel Label Kit

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 SEL-421.

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.

Cleaning

Perform the following steps and use care when cleaning the SEL-421:

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 4.1* shows a sample rear-panel serial number label.

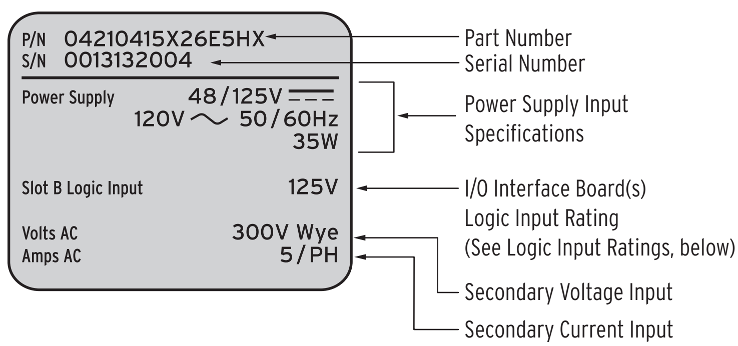


Figure 4.1 SEL-421 Serial Number Label

Figure 4.1 shows a serial number label for an SEL-421 with additional I/O in a 5U horizontal chassis. This example serial number label is for a 5 A-per-phase secondary current transformer input relay. For information on CT and PT inputs, see *Secondary Circuits on page U.2.4*.

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: Initial Global Settings on page U.4.17* for details on setting these parameters.

The power supply specification in *Figure 4.1* indicates that this relay is equipped with a power supply that accepts a nominal 48/125 Vdc input. This power supply also accepts a 120 Vac input. Other power supply options include nominal 24/48 Vdc and 125/250 Vdc power supplies. The 125/250 Vdc power supply also accepts a 120/230 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. See *Power Supply on page U.1.13* for more information on power supply specifications.

Logic Input Ratings

The serial number label in *Figure 4.1* only lists control input voltages for I/O Interface Boards that have 24 optoisolated inputs, which is determined at ordering time. In the sample shown, only Slot B contains an INT4 I/O Interface board, so only one input rating appears. 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 U.4.65* for more information.

Connecting and Applying Power

Connect external power to the SEL-421 to perform the initial checkout and familiarization procedures in this section. For complete information on power connections, see *Power Connections on page U.2.38*.

Figure 4.2 shows the portion of the relay rear panel where you connect the power input.

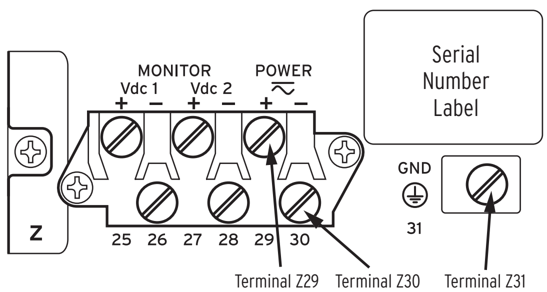


Figure 4.2 Power Connection Area of the Rear Panel

You can order the SEL-421 with one of three power supplies with nominal operating voltages: 24/48 Vdc, 48/125 Vdc, and 125/250 Vdc. The two higher voltage supplies, 48/125 Vdc and 125/250 Vdc, use ac input and dc input. The relay serial number label on the back of the relay lists voltage ranges that encompass the nominal voltages.

Table 4.1 shows the nominal voltage inputs and power supply voltage ranges for dc input, and ac inputs if applicable.

Table 4.1 Power Supply Voltage Inputs

Nominal DC Voltage Input	DC Input Range	AC Input Range (30–120 Hz)
24/48 Vdc	18–60 Vdc <35 W	N/A
48/125 Vdc	38–140 Vdc <35 W	120 Vac <120 VA
125/250 Vdc	85–300 Vdc <35 W	120/230 Vac <120 VA

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

Observe the following precautions when connecting power to the SEL-421:

Step 1. Always attach a safety ground as the first connection you make to the SEL-421.

Step 2. Connect the grounding terminal (#**Z31**) labeled **GND** on the rear panel to a rack frame ground or main station ground for proper safety and performance.

Step 3. Use 16 AWG (1.5 mm^2) wire (or heavier) to connect to the **POWER** terminals, observing the following:

- ➤ When you use a dc power source, you must connect the source with the proper polarity, as indicated by the **+** (Terminal #**Z29**) and **–** (Terminal #**Z30**) symbols on the power terminals.
- ➤ You can use ac input for the 48/125 Vdc power supply and the 125/250 Vdc power supply.
- ➤ The relay operates from 30 to 120 Hz (nominal 50/60 Hz) when alternating current supplies the **POWER** input.

Upon connecting power, you will see information on the front-panel LCD (liquid crystal display) and the **ENABLED** LED (light-emitting diode) will illuminate.

For complete information on the SEL-421 front panel, see *Front-Panel Operations on page U.5.1*.

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 4.3*. For complete instructions on using the front-panel menu system, see *Navigating the Menus on page U.5.4*.

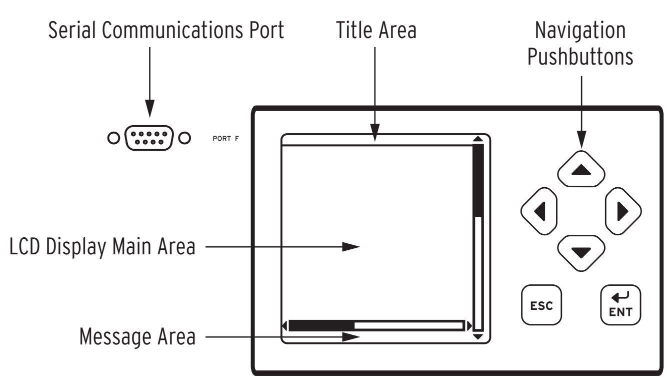


Figure 4.3 PORT F, LCD Display, and Navigation Pushbuttons

Fast and efficient communication with the relay is available through communications ports such as **PORT F**, also shown in *Figure 4.3*. 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 4: Communications Interfaces in the Reference Manual* 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 <Enter>** becomes **EVE 1 <Enter>**. Use upper- and lower-case characters without distinction, except in passwords, which are case sensitive. For a list of ASCII commands see *Section 9: ASCII Command Reference in the Reference Manual*.

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 ACSELERATOR QuickSet, press **<F1>** to get help, or select the **Help** menu from the ACSELERATOR QuickSet toolbars. The help information in ACSELERATOR 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 SEL-421.

Use an SEL Cable C234A to connect a 9-pin computer serial port to the SEL-421. Use an SEL Cable C227A to connect a 25-pin computer serial port to the relay. See *Section 4: Communications Interfaces in the Reference Manual* 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. Connect the computer and the SEL-421 using the serial communications cable.

Use the 9-pin serial port labeled 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 SEL-421 communications port settings are listed in *Table 4.2*.

Also set the terminal program to emulate either VT100 or VT52 terminals. These terminal emulations work best with SEL relays.

Table 4.2 General Serial Port Settings

Name	Description	Default
PROTO	Protocol (SEL, DNP[a], MBA, MBB, RTD, PMU)	SEL
SPEED	Data speed (300 to 57600, SYNC[b])	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

[a] DNP protocol is an ordering option.
[b] SYNC setting only available when PROTO := MBA or MBB.

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 for the default communications parameters of *Table 4.2* in your terminal emulation program.

Step 6. Type **QUIT <Enter>** to view the relay report header.

You will see a computer screen display similar to *Figure 4.4*. (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: 03/15/2001  Time: 00:01:05.209
Station A                                       Serial Number: 2001001234
=
```

Figure 4.4 Report Header

When you communicate with the relay at the Access Level 0 = prompt, you are in security Access Level 0. You cannot 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: Terminal on page U.4.9*.

Changing the Default Passwords

NOTE: Perform the password-change steps described in Changing the Default Passwords: Terminal on page U.4.9.

It is extremely important that you change the factory default passwords programmed in the SEL-421. Setting unique passwords for the relay access levels increases the security of your substation and the power system.

This subsection begins with information on the access level/password system in the SEL-421 and includes an example of changing the default passwords.

Access Levels

Access levels control whether you can perform different operations within the SEL-421. These security levels are labeled 0, 1, B, P, A, O, 2, and C. *Figure 4.5* presents an overview of the general access level structure in the relay.

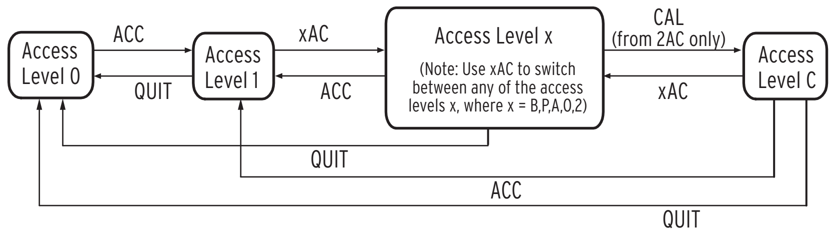


Figure 4.5 Access Level Structure

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. (Access Level C is reserved for SEL factory operations. Only go to Access 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.

Table 4.3 lists access levels and operator functions for the SEL-421.

Table 4.3 SEL-421 Access Levels

Access Level	Prompt	Allowed Operations
0	=	Log in to Access Level 1; some test diagnostics.
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 calibration-specific functions. For a list of commands available, contact SEL.

The SEL-421 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 4.4* lists the access level commands with corresponding passwords.

Table 4.4 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 SEL-421 times out, the relay reduces the access level to Access Level 0 for that communications port connection.

The MAXACC port setting can be used to limit the maximum access level permitted on a port. This can be useful to restrict what remote users can do.

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 U.5.14*.)

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. See Section 9: ASCII Command Reference in the Reference Manual 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 SEL-421 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 4.4* 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 SEL-421 to prompt you to type the Access Level 2 password. If the present level is Access Level 0, the SEL-421 responds with `Invalid Access Level`. The relay asserts alarm Relay Word bit SALARM when entering Access Level B, P, A, O, and 2 from a lower access level.

If you are unable to enter the correct password after the third failed attempt, the SEL-421 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), and MIRRORED BITS® communications virtual terminal mode. For more information on these protocols, see *Section 5: SEL Communications Protocols in the Reference Manual* and *Section 6: DNP3 Communications in the Reference Manual*.

If your connection to the SEL-421 has an inactivity time-out (in the **SET P** port settings), the SEL-421 automatically closes the communications connection and changes to Access Level 0 when the time-out occurs.

Passwords

Valid passwords are character sequences of as many as twelve characters. Valid password characters are any printable ASCII character. HMI password entry is limited to upper- and lower-case 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.

⚠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.

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: Terminal

Step 1. Confirm that the relay is operating (see *Connecting and Applying Power on page U.4.3*).

Step 2. Establish communication with the SEL-421 (see *Making an EIA-232 Serial Port Connection on page U.4.5* to learn how to use a terminal to communicate with the relay).

Step 3. Enter Access Level C (level 2 is sufficient except when changing the 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>**.

d. At the password prompt, type **TAIL <Enter>**.

e. Type **CAL <Enter>**.

f. At the password prompt, type **Sel-1 <Enter>**.

You will see the Access Level C ==>> prompt.

NOTE: Passwords are case sensitive; you must enter passwords exactly as set.

Step 4. To set a new password for Access Level 2, type the following:

PAS 2 nE2Pw- <Enter>

(**nE2Pw-** becomes the new strong password.)

The relay will return the word `Set` and the Access Level 2 =>> prompt.

Step 5. Set new passwords for each access level.

In a similar manner as the previous step, create new strong passwords for each access level.

Step 6. 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.

Using **DISABLE** is not recommended. Always set a unique, strong password in the relay for each access level. Failure to do this can severely jeopardize the security of your substation and the power system.

After you enter a new password, the relay pulses the Relay Word bit SALARM for one second and responds `Set`. The relay responds with the message `Password Disabled` if you used the **DISABLE** parameter.

If you forget a password, or encounter difficulty changing the default passwords in *Changing the Default Passwords: Terminal on page U.4.9*, you can temporarily disable password verification. See *Jumpers on page U.2.18* for information on the password disable jumper J18B.

Checking Relay Status

With continual self-testing, the SEL-421 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 U.6.38*.

You can check relay status through a communications port by using a terminal, terminal emulation computer program, or ACSELERATOR QuickSet. In addition, you can use the relay front panel to view status information.

Checking Relay Status: 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 U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* 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 4.6*.

```
=>STA <Enter>

Relay 1                                          Date: 03/15/2001  Time:07:02:50.776
Station A                                         Serial Number: 000101234

FID=SEL-421-R101-V0-Z001001-D20010315             CID=0x9aed

Failures
  No Failures

Warnings
  No Warnings

SELogic Relay Programming Environment Errors
  No Errors

Relay Enabled
=>
```

Figure 4.6 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 R.9.48*.

Checking Relay Status: ACSELERATOR QuickSet

You can use ACSELERATOR QuickSet to check relay status. Use the **HMI** > **Meter Control** menu to view status conditions.

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 U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords). You should also be familiar with ACSELERATOR QuickSet (see *Section 3: PC Software*).

NOTE: The DTR parameter has no effect on communications with the SEL-421 relay.

Step 1. Configure the communications port.

a. Start ACSELERATOR QuickSet.

b. On the top toolbar, click **Communication** > **Communication Parameters**.

You will see the **Communication Parameters** dialog box similar to *Figure 4.7*.

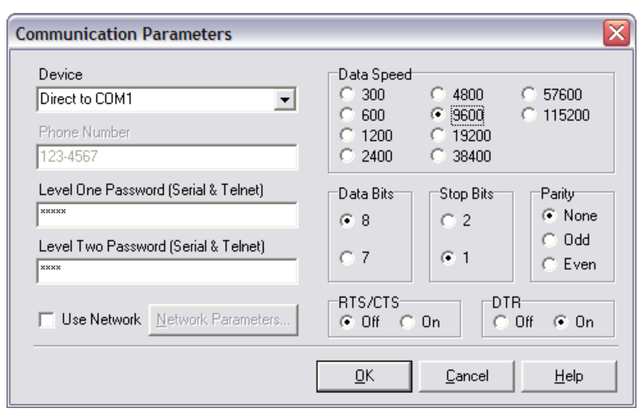


Figure 4.7 ACSELERATOR QuickSet Port Parameters and Password Entry

c. Select the **Data Speed**, **Data Bits**, **Stop Bits**, **Parity**, and **RTS/CTS** that match the relay settings.

The defaults are **9600**, **8**, **1**, **None**, and **Off**, respectively.

d. Click **OK** to update the ACSELERATOR QuickSet communications parameters and connect to the relay.

e. Confirm that the **Communications Status** bar at the bottom of the ACSELERATOR QuickSet window says **Connected**.

Step 2. Confirm that you have loaded the correct passwords in ACSELERATOR QuickSet.

a. Enter your Access Level 1 password in the **Level One Password** text box, and your Access Level 2 password in the **Level Two Password** text box.

b. Click **OK** to accept changes and close the dialog box.

Step 3. Click **Meter and Control** in the top toolbar HMI menu to start the ACSELERATOR QuickSet operator interface.

Step 4. Click the **Status** button of the HMI tree view (see *Figure 4.8*).

ACSELERATOR QuickSet displays the relay status with a display similar to that in *Figure 4.6*.

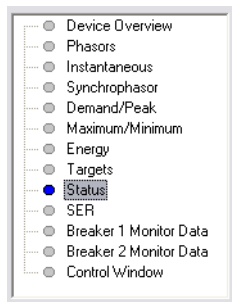


Figure 4.8 Retrieving Relay Status: ACSELERATOR QuickSet

Checking Relay Status: Front Panel

Use the front-panel display and navigation pushbuttons to check SEL-421 status. See *Section 5: 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 of *Figure 4.9*.

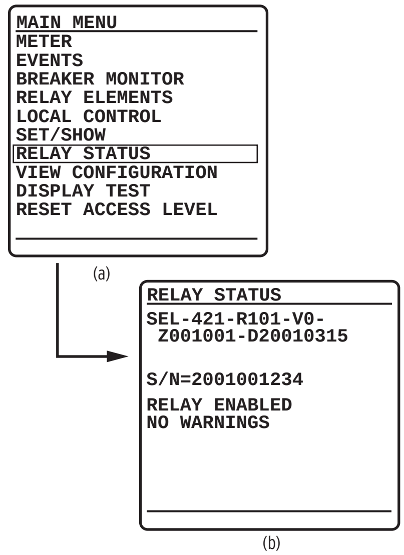


Figure 4.9 Checking Relay Status: Front-Panel LCD

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 4.9*).

b. Press the **{ENT}** pushbutton.

You will see the RELAY STATUS screen (the second screen of *Figure 4.9*).

Step 4. Press the **{ESC}** key to return to the MAIN MENU.

Step 5. Press **{ESC}** again to return to the ROTATING DISPLAY.

For more information on the front-panel screen presentations and the items in the STATUS screens, see *Relay Status on page U.5.32*.

Making Simple Settings Changes

The SEL-421 settings structure makes setting the relay easy and efficient. Settings are grouped logically, and you do not see relay elements that are not used in your selected protection scheme.

For example, if you select only three levels of a particular type of overcurrent protection, the corresponding Level 4 overcurrent element settings do not appear on the communications terminal screen. Hiding unused elements and settings that you have not enabled greatly simplifies the task of setting the SEL-421.

ACSELERATOR QuickSet uses a similar method to focus your attention on the active settings. Unused relay elements and inactive settings are dimmed (grayed) in the ACSELERATOR QuickSet menus. See *Section 3: PC Software* for more information on ACSELERATOR QuickSet.

Settings Structure

The SEL-421 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 4.10* to understand the settings structure in the SEL-421. 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-421 are listed in *Table 4.5*.

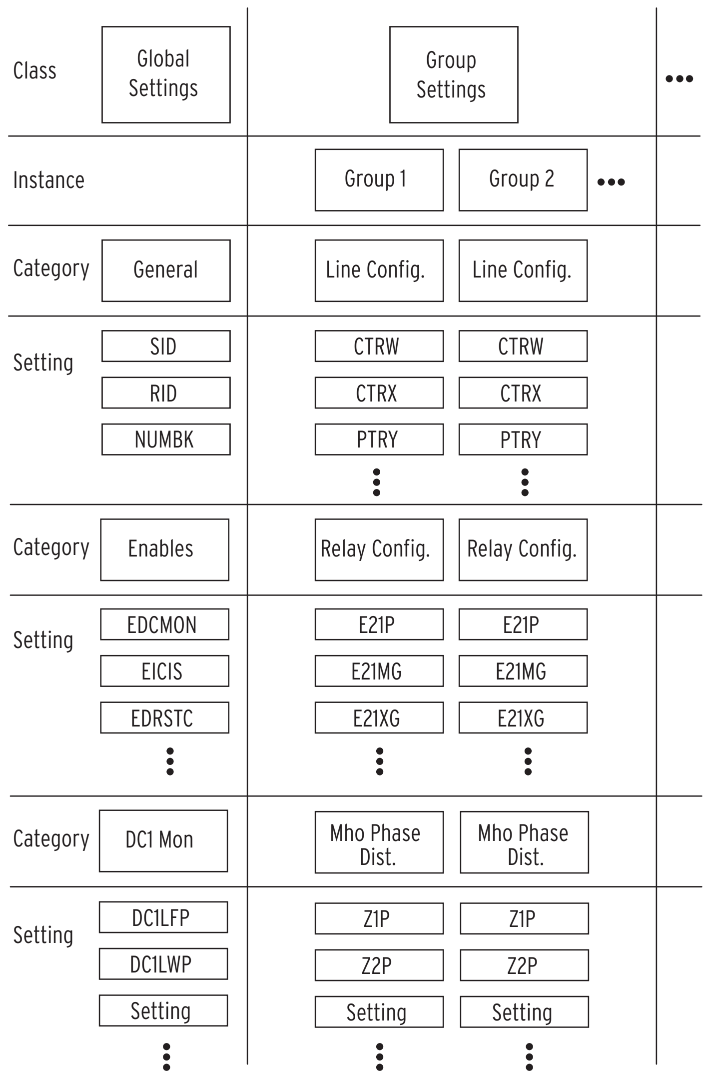


Figure 4.10 Relay Settings Structure Overview

Table 4.5 Settings Classes and Instances

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
Port	Communications port settings	PORT F PORT 1 • • • PORT 3 PORT 5	Front-panel port PORT 1 settings • • • PORT 3 settings Communications card settings	SET P F SET P 1 • • • SET P 3 SET P 5	P, A, O, 2
Report	Event report and SER[a] 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[b] • • • Block 10	Block 1 automation SELOGIC control equations • • • Block 10 automation SELOGIC control equations	SET A 1 • • • SET A 10	A, 2
DNP	Direct Network Protocol data remapping	DNP		SET D	P, A, O, 2
Output SELOGIC control equations	Relay control output settings and MIRRORED BITS communication transmit equations	Output		SET O	O, 2
Alias	Set aliases	Analog or digital quantities		SET T	P, A, O, 2

[a] SER is the Sequential Events Recorder; see SER (Sequential Events Recorder) on page A.3.34.
[b] The SEL-421-1 and SEL-421-2 have only one block of automation SELOGIC control equations.

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 4.5*. 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.

Settings: 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 4.11 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 `?` action prompt.

Table 4.6 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)                              Present       Action
RID := "Relay 1"                        Prompt                 Value        Prompt
? <Enter>
Number of Breakers in Scheme (1,2)                 NUMBK    := 1        ? <Enter>
```

Figure 4.11 Components of SET Commands

Table 4.6 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, `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: Initial Global Settings

You must configure the SEL-421 for specific conditions found in the power system where you are connecting the relay. In particular, 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 U.4.5* for a step-by-step procedure. In addition, you must be familiar with relay access levels and passwords. See *Changing the Default Passwords: Terminal on page U.4.9* 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 2 => prompt.

c. Type the **2AC <Enter>** command.

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 the beginning of *Figure 4.12*.

```
=>>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 := 50P1 OR 51S1 OR M2P OR Z2G OR M3P OR Z3G
?  END <Enter>
.
.
.

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

Figure 4.12 Initial Global Settings

Step 3. Accept the default settings.

a. For a 60 Hz system, simply 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 SEL-421 reports 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 4.12*, 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 4.6* 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) ?` prompt

(In *Figure 4.12*, 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 SEL-421 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 U.4.19* 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 4.7* lists the commands for text-edit mode.

Table 4.7 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.

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. You 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 SEL-421. See *Display Points on page U.5.10* for information on programming display points.

For this example, use inputs IN101, IN102, and IN105. You can use other inputs for your particular application. See *Control Inputs on page U.2.5* for more information on control inputs.

This procedure assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*) In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9*) 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 the **2AC <Enter>** command.

d. Type the correct password to go to Access Level 2.

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 and Aliases** category.

Figure 4.13 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 4.14*).

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 4.14*).

Step 5. At the **Display Points and Aliases** prompt, use the text-edit mode line editing commands to list the active display points. Type the following:

NOTE: Use quotation marks when entering alias strings that contain spaces or punctuation marks, as shown in the IN105 example, Step 6.

LIST <Enter>.

After showing the active display points, the relay returns to line `3:` followed by the settings `?` prompt.

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 4.13*).

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 4.13* 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 and Aliases
(Boolean) : RWB Name, “Alias”, “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 and Aliases
(Boolean) : RWB Name, “Alias”, “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 4.13 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 assertion level (setting IN105P) and the debounce time (setting 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 these settings:

EICIS := **Y** Independent Control Input Settings (Y, N)

IN105P := **80** Input IN105 Pickup Level (15–265 Vdc)

IN105PU := **0.3750** Input IN105 Pickup Delay (0.0000–5 cyc)

IN105DO := **0.3750** Input IN105 Dropout Delay (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. See *Control Inputs on page U.2.5* for more information on SEL-421 control inputs.

Deleting a Display Point

This example shows how you can 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 U.4.19*). You can use other inputs for your particular application. See *Control Inputs on page U.2.5* for more information on control inputs.

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 U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9*).

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 the **2AC <Enter>** command.

d. Type the correct password to go to Access Level 2.

You will see the Access Level 2 =>> prompt.

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 4.14 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 and Aliases
(Boolean) : RWB Name, "Alias", "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 and Aliases
(Boolean) : RWB Name, "Alias", "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 4.14 Using Text-Edit Mode Line Editing to Delete a Display Point

Step 3. List the present display points.

a. Type **LIST <Enter>** at the **Control Points and Aliases** 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.

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 4.14*, 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.

Alias Settings

Rename, or assign up to 200 alias names to any Relay Word bit or analog quantity in the relay. This is very useful when programming using SELOGIC® control equations or analyzing SER and event report data. Assigning alias names is also a text-edit type entry, with the same syntax as the display point entries.

Use the **SHO T** command to view the default settings, as shown in *Figure 4.15*.

```
=>>SHO T <Enter>
Alias

Relay Aliases
(RW Bit or Analog Qty. 7 Character Alias [0-9 A-Z _])
1: EN,"RLY_EN"
=>>
```

Figure 4.15 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 `=>` 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 4.16 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 4.16 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 4.17* shows an example of an alias used in protection logic programming.

```
=>>SET L <Enter>

Protection 1

1: PLT02S := PB2_PUL AND NOT PLT02 #COMM SCHEME ENABLED
?  > <Enter>
9:
?  THETA:=IO1FA <Enter>
10:
?  TAN:=SIN(THETA)/COS(THETA) <Enter>
11:
?  END <Enter>
Protection 1
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 4.17 Using Text-Edit Mode Line Editing to Set Protection Logic

Settings: ACSELERATOR QuickSet

You can use ACSELERATOR QuickSet to develop settings for the SEL-421 offline. ACSELERATOR QuickSet automatically checks interrelated settings and alerts you to out-of-range settings. Upload the off-line ACSELERATOR QuickSet settings to the relay via the communications ports. See *Checking Relay Status: ACSELERATOR QuickSet on page U.4.11* for an introductory tutorial on using ACSELERATOR QuickSet.

You can also use ACSELERATOR QuickSet as a terminal program to interact in real time with the relay. For an introduction to ACSELERATOR QuickSet and all of features of this software, see *Section 3: PC Software*.

Making Initial Global Settings: ACSELERATOR QuickSet

ACSELERATOR QuickSet makes setting the relay an easy task. The purpose of the procedure in the following steps is to familiarize you with reading, modifying, and sending settings with ACSELERATOR QuickSet.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords). You should also be familiar with ACSELERATOR QuickSet; see *Section 3: PC Software* and *Checking Relay Status: ACSELERATOR QuickSet on page U.4.11*.

Step 1. Configure the communications port.

a. Start ACSELERATOR QuickSet.

b. On the top toolbar, open the **Communication** menu, and then click **Communication Parameters**.

   You will see the **Communication Parameters** dialog box similar to *Figure 4.7*.

c. Select the **Data Speed**, **Data Bits**, **Stop Bits**, **Parity**, and **RTS/CTS** that match the relay settings.

   The defaults are **9600**, **8**, **1**, **None**, and **Off**, respectively.

d. Click **OK** to update the ACSELERATOR QuickSet communications parameters.

e. Type **<Ctrl+T>** to open the ACSELERATOR QuickSet terminal window.

f. Type **<Enter>** to see whether the communications link is active between ACSELERATOR QuickSet and the relay.

You will see the Access Level 0 = prompt in the terminal window.

g. Exit the terminal window.

Step 2. Confirm the correct ACSELERATOR QuickSet passwords.

a. Reopen the **Communication** menu and click **Port Parameters**.

b. Enter your Access Level 1 password in the **Level One Password** text box, and your Access Level 2 password in the **Level Two Password** text box.

c. Click **OK** to accept changes and close the dialog box.

Step 3. On the **Settings** menu, click **Read** to read the present configuration in the SEL-421.

The relay sends all configuration and settings data to ACSELERATOR QuickSet.

Step 4. Select **Global** settings.

a. Click the plus mark (+) next to the **Global** branch of the left-hand ACSELERATOR QuickSet tree structure shown in *Figure 4.18*.

b. Click **Global Settings/Enables**.

You will see the **Global Settings/Enables** window with **General Global Settings** and **Global Enables** (see *Figure 4.19*).

Step 5. Change settings.

a. Click the button for the correct option for NFREQ and PHROT to specify your system frequency and phase rotation.

When you tab or click to the next field, the relay validates the new setting.

b. The right-click mouse button performs two special functions when you are editing settings: **Previous Value** and **Default Value**.

➢ Right-click in the setting dialog box and select **Previous Value** if you want to revert to the setting value before you made a change.

➢ Right-click in the setting dialog box and select **Default Value** if you want to restore the factory default setting value.

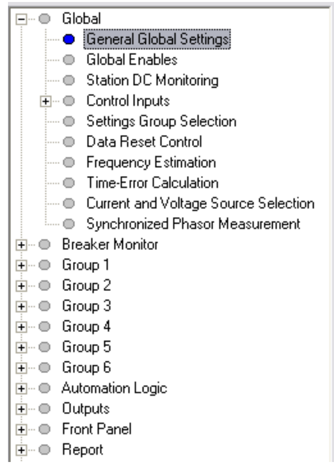


Figure 4.18 Selecting Global Settings in ACSELERATOR QuickSet

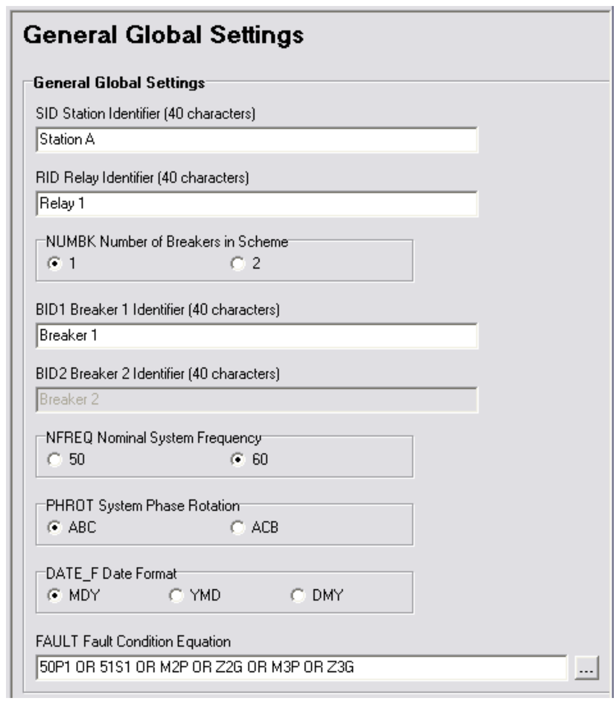


Figure 4.19 ACSELERATOR QuickSet Global Settings Window

Step 6. Save the new settings in ACSELERATOR QuickSet.

a. On the **Relay Editor File** menu, click **Save**.

b. Specify a **Relay Name**.

c. Click **OK**.

Step 7. Upload the new settings to the SEL-421.

a. On the **File** menu, click **Send**.

ACSELERATOR QuickSet prompts you for the settings class or instance you want to send to the relay, as shown in the first dialog box of *Figure 4.20*.

b. Click the check box for **Global**.

c. Click **OK**.

ACSELERATOR QuickSet responds with the second dialog box of *Figure 4.20*.

> **NOTE:** The **Relay Editor** dialog boxes shown in Figure 4.20 are for the SEL-421. The SEL-421-1 and SEL-421-2 dialog boxes do not contain Automation 2 through Automation 10 setting instances.

If you see no error message, the new settings are loaded in the relay.

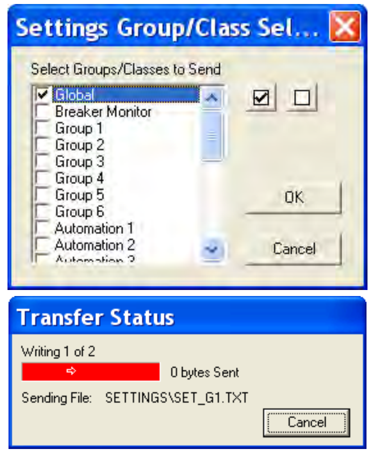


Figure 4.20 Uploading Global Settings to the SEL-421

Settings: Front Panel

You can use the relay front panel to enter some of the relay settings. The SEL-421 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 U.5.28*.

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 SEL-421 front panel. Refer to *Connecting and Applying Power on page U.4.3* before performing this example.

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 4.21*.

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 4.21*).

b. Press the **{ENT}** pushbutton.

You will see the `SET/SHOW` submenu (the second screen in *Figure 4.21*).

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 4.21*, second screen).

b. Press the **{ENT}** pushbutton.

The relay next displays the DATE/TIME submenu (the third screen of *Figure 4.21*).

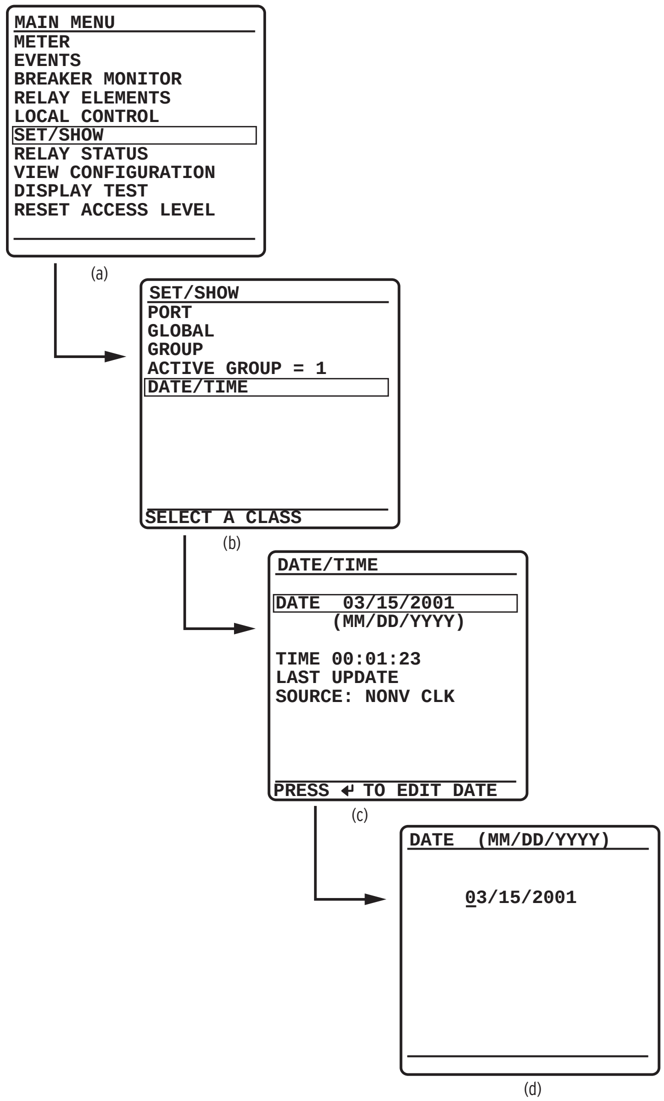


Figure 4.21 DATE and TIME Settings: Front-Panel LCD

Step 5. Set the date.

a. Press the **{ENT}** pushbutton.

The relay shows the last screen of *Figure 4.21*, 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.

The first screen of *Figure 4.22* 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 (see *Figure 4.22*).

b. Press the **{ENT}** pushbutton. You will see the SET/SHOW submenu (the second screen in *Figure 4.22*).

Step 3. Select PORT F.

a. Highlight PORT and press the **{ENT}** pushbutton.

The relay displays the PORT instances (the third screen of *Figure 4.22*).

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 shows the fourth screen of *Figure 4.22*, the PORT F category screen. 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 fifth screen of *Figure 4.22*, the Communications Settings screen.

Step 5. Change settings.

a. Highlight the SPEED setting.

b. Press **{ENT}**.

(The relay possibly requires a password here; see *Passwords on page U.4.9* and *Section 5: Front-Panel Operations*.)

The LCD displays the SPEED selection submenu that has all the possible choices for serial data speeds.

The highlight in the sixth screen of *Figure 4.22* 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 (the third screen of *Figure 4.22*).

Step 7. Press **{ESC}** repeatedly to return to the MAIN MENU.

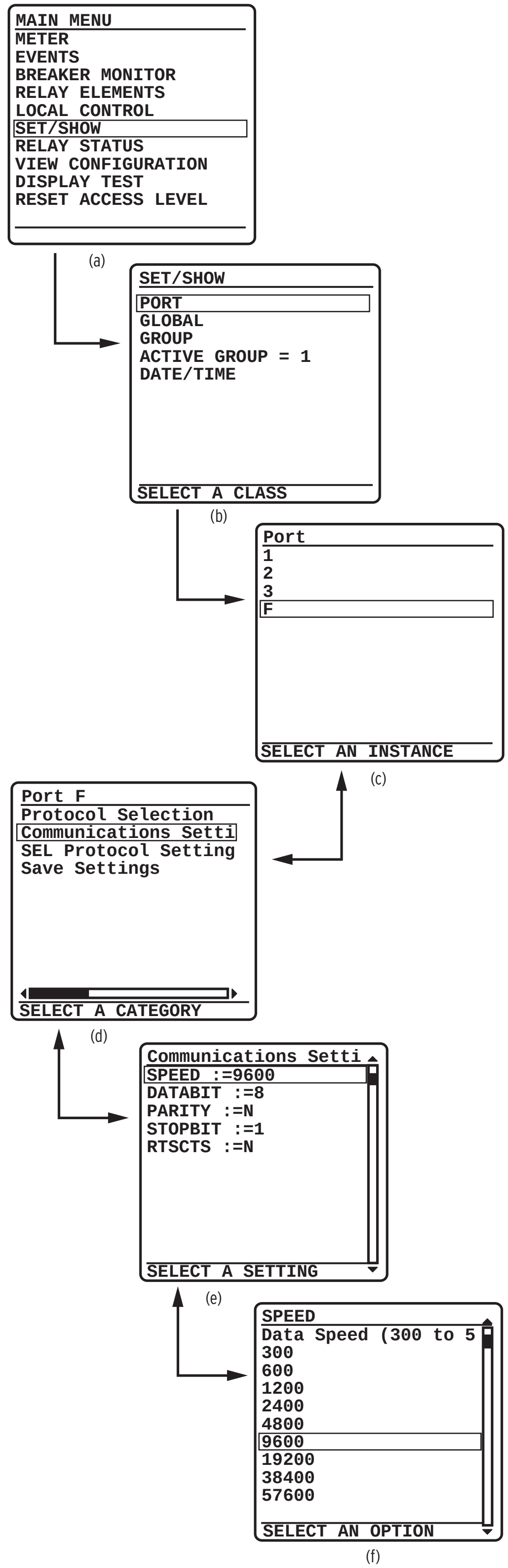


Figure 4.22 SETTINGS Menus

Examining Metering Quantities

The SEL-421 features high-accuracy power system metering. You can view fundamental and rms quantities by using a communications terminal, ACSELERATOR QuickSet, or the front panel. For more information on SEL-421 metering, see *Metering on page A.2.26*.

View Metering: 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. For more information on testing the relay and making test connections, see *Section 6: Testing and Troubleshooting*.

NOTE: If the relay is in service, disable any output circuits (such as trip and close) to avoid an unintended relay operation caused by test signals.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* 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 the **2AC <Enter>** command.

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: Initial Global Settings on page U.4.17*.

b. Set the relay for 60-Hz operation, ABC phase rotation.

Step 3. Set the relay for a basic voltage and current configuration (see *Figure 4.23*). Use the terminal to set global settings ESS := 1.

a. Type **SET G ESS TERSE <Enter>**.

b. Type **1 <Enter>** if the ESS setting is not 1.

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 4.23 Setting ESS: Terminal

Step 4. Set CT and PT ratios. Use the terminal to confirm that Group 1 setting CTRW := 200 (the current transformer W-input ratio), and PTRY := 2000 (the potential transformer 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 4.24* to PTRY and change PTRY to 2000, 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   := 1000   ? 200 <Enter>
Current Transformer Ratio - Input X (1-50000)      CTRX   := 1000   ? <Enter>
Potential Transformer Ratio - Input Y (1-10000)    PTRY   := 2000   ? END <Enter>

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

Figure 4.24 Setting CTRW and PTRY: Terminal

Step 5. Turn the relay power off.

Step 6. Connect analog inputs.

a. If three voltage sources and three current sources are available, connect the sources to the relay as shown in *Figure 4.25*.

If three voltage sources and two current sources are available, use the connection diagram of *Figure 4.26*.

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.

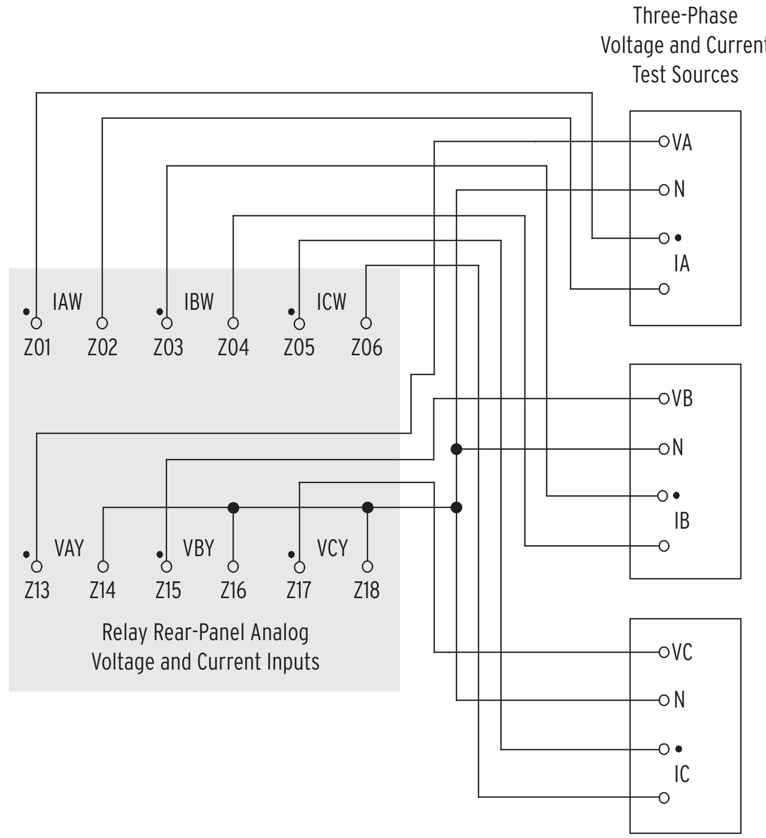


Figure 4.25 Test Connections Using Three Voltage Sources/Three Current Sources

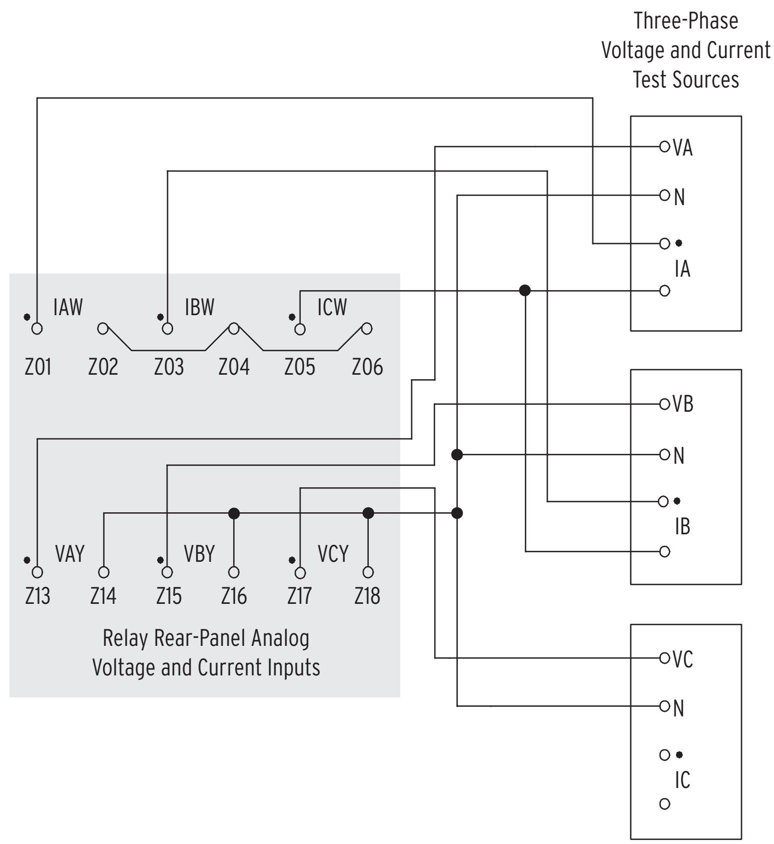


Figure 4.26 Test Connections Using Two Current Sources for Three-Phase Faults and METER Test

Step 7. Turn the relay power on.

Step 8. View metering.

a. Type **ACC <Enter>** to log-in to relay Access Level 1.

b. Type your 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 in *Figure 4.27*.

```
=>>MET <Enter>

Relay 1                                    Date: 02/26/2004  Time: 01:35:05.221
Station A                                  Serial Number: 0000000000

                      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 4.27 Terminal Screen MET Metering Quantities

The metering quantities of *View Metering: Terminal on page U.4.33* are the fundamental line quantities. Other variants of the **MET** command give different relay metering quantities. For example, you can see the line rms (harmonics-included) quantities by issuing the **MET RMS** command. See *Metering on page A.2.26* and *METER on page R.9.28* for more information on the **MET** command.

View Metering: ACSELERATOR QuickSet

Use the procedures in the following steps to examine the SEL-421 metering with the ACSELERATOR QuickSet HMI.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords). You should also be familiar with ACSELERATOR QuickSet (see *Checking Relay Status: ACSELERATOR QuickSet on page U.4.11* and *Section 3: PC Software*).

Step 1. Configure the communications port.

a. Start ACSELERATOR QuickSet.

b. On the top toolbar, open the **Communication** menu, and then click **Port Parameters**.

You will see the **Port Parameters** dialog box similar to *Figure 4.7*.

c. Select the **Data Speed**, **Data Bits**, **Stop Bits**, **Parity**, and **RTS/CTS** that match the relay settings. The defaults are **9600**, **8**, **1**, **None**, **Off**, respectively.

d. Click **OK** to update the ACSELERATOR QuickSet communications parameters.

e. Confirm that the **Communications Status** bar at the bottom of the ACSELERATOR QuickSet window says **Connected**.

Step 2. Confirm the correct ACSELERATOR QuickSet passwords.

a. Reopen the **Communication** menu and click **Port Parameters**.

b. Enter your Access Level 1 password in the **Level One Password** text box, and your Access Level 2 password in the **Level Two Password** text box.

c. Click **OK** to accept changes and close the dialog box.

Step 3. Set the relay to a nominal operation mode. Perform the initial global settings relay setup of *Making Initial Global Settings: ACSELERATOR QuickSet on page U.4.25* to set the relay for 60-Hz operation, ABC phase rotation.

Step 4. Set a basic voltage and current configuration.

a. In the ACSELERATOR QuickSet **Settings** tree view, double-click the **Global** entry of the **Settings** tree view to expand the **Global** branch (see *Figure 4.28*).

b. Click the **Current and Voltage Source Selection** branch.

You will see the **Current and Voltage Source Selection** dialog box of *Figure 4.28*.

c. Click the down button to select **1** for **ESS Current and Voltage Source Selection**.

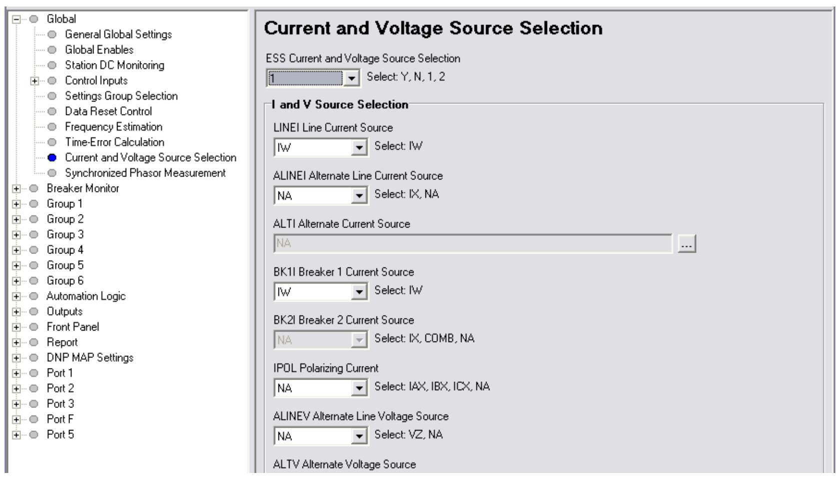


Figure 4.28 Global Alternate Source Selection Settings in ACSELERATOR QuickSet

Step 5. Set PT and CT ratios.

a. In the ACSELERATOR QuickSet **Settings** tree view, click the **+** mark next to **Group 1** to expand this branch (see *Figure 4.29*).

b. Click the plus (+) mark next to **Set 1**.

c. Click **Line Configuration**.

You will see the **Line Configuration** window similar to *Figure 4.29*.

d. Confirm that setting **CTRW Current Transformer Ratio - Input W** is **200**, and the **PTRY Potential Transformer Ratio - Input Y** is **2000**.

e. Save the settings and send the **Group 1** settings if you change the settings (see *Step 6* and *Step 7*).

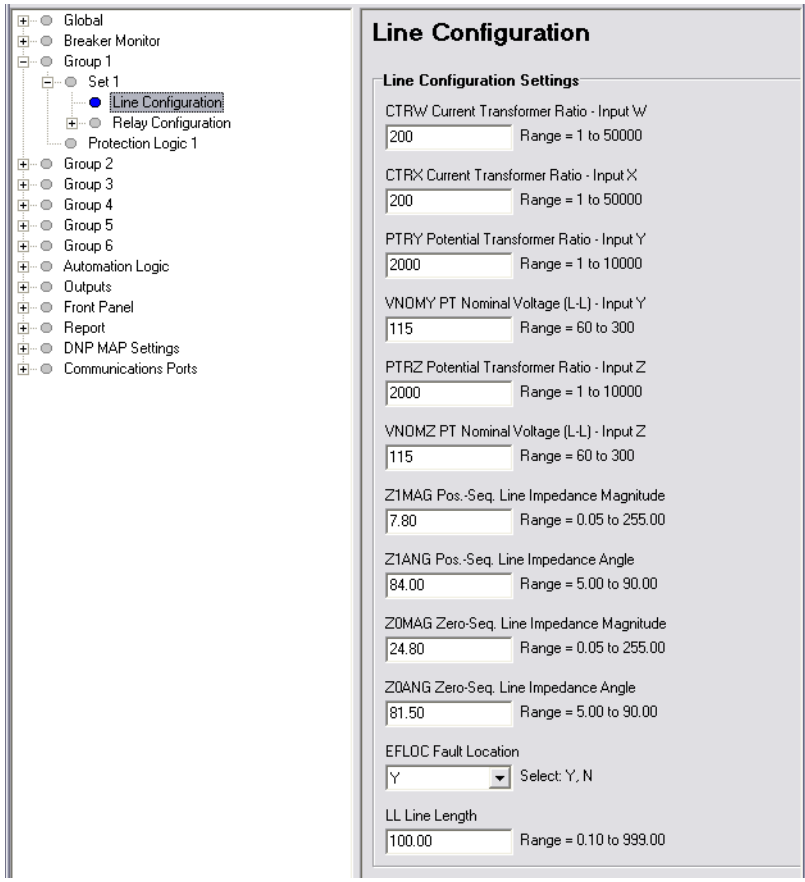


Figure 4.29 Group 1 Terminal Configuration Settings: ACSELERATOR QuickSet

Step 6. Start the ACSELERATOR QuickSet operator interface.

Step 7. In the top toolbar HMI menu, click **Meter and Control**.

Step 8. Click the **Phasors** button of the HMI tree view (see *Figure 4.30*) to view phasors.

ACSELERATOR QuickSet displays fundamental line metering quantities with a display similar to *Figure 4.31*. (The test setup is adjusted for an approximately 30-degree lagging current.)

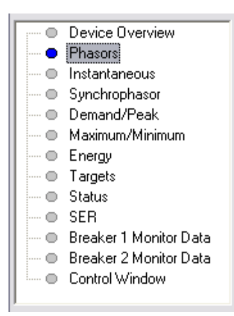


Figure 4.30 HMI Tree View: ACSELERATOR QuickSet

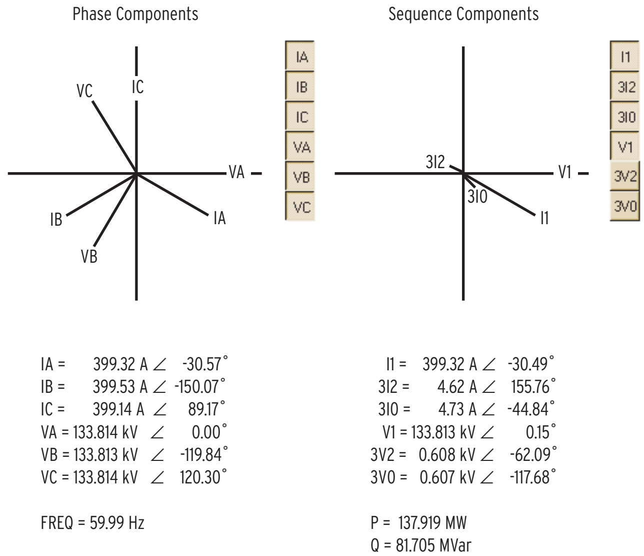


Figure 4.31 Phasor Metering Quantities: ACSELERATOR QuickSet HMI

Step 9. Click the **Instantaneous** button of the HMI tree view to see metering information similar to the terminal display of *Figure 4.27*. Click the Synchrophasors, Demand/Peak, Maximum/Minimum, or Energy buttons in the HMI tree view to see more types of metering, with displays similar to the terminal commands **MET PM**, **MET D**, **MET M**, and **MET E**, respectively.

View Metering: Front Panel

You can use the front-panel display and navigation pushbuttons to view the metering quantities of the SEL-421 (see *Meter on page U.5.15* for more information on viewing metering on the relay front panel). The screens in this procedure are for one circuit breaker, and this example assumes that you have not enabled the demand metering and 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 4.32*.

Step 3. View the metering selection screen.

a. Highlight the METER action item (see the first screen of *Figure 4.32*).

b. Press the **{ENT}** pushbutton.

The relay displays the METER submenu (the second screen in *Figure 4.32*).

Step 4. View the metering screens.

a. Press the **{Up Arrow}** and **{Down Arrow}** navigation pushbuttons to highlight the FUNDAMENTAL METER action item (see *Figure 4.32*, middle screen).

b. Press the **{ENT}** pushbutton.

The relay displays the first FUNDAMENTAL METER screen (the third screen of *Figure 4.32*).

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.

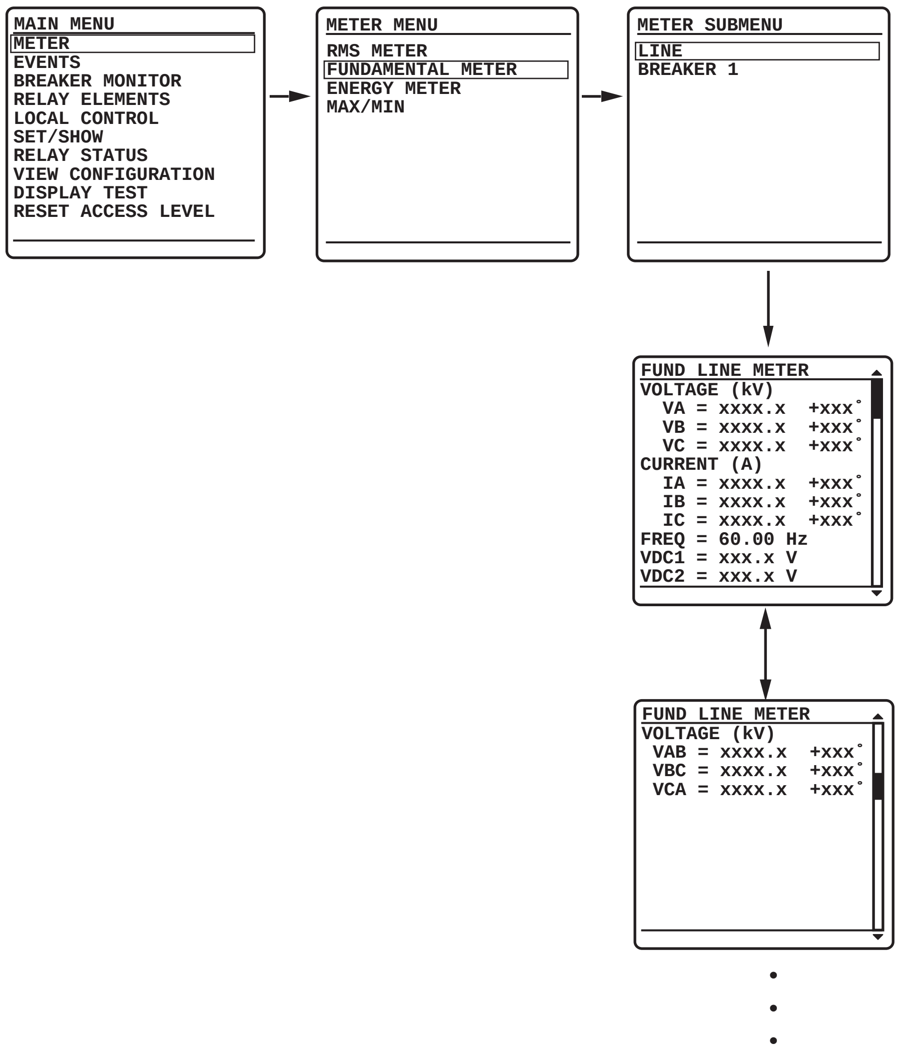


Figure 4.32 Front-Panel Screens for METER

Reading Oscillograms, Event Reports, and SER

The SEL-421 has 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 subsection give step-by-step procedures to acquaint you with these features. *Section 3: Analyzing Data in the Applications Handbook* gives 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 three sources to initiate a data capture: Relay Word bit TRIP asserts, SELOGIC control equation ER (event report trigger), and the **TRI** command. (Factory default setup no longer includes 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; see *Test Commands on page U.6.5*.)

Triggering an Event

You can use an event trigger to initiate capturing power system data. The procedure in the following steps shows how to use the ACSELERATOR QuickSet HMI to generate the **TRI** command, 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 pretrigger or prefault 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 A.3.5* 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 U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords). You should also be familiar with ACSELERATOR QuickSet (see *Checking Relay Status: ACSELERATOR QuickSet on page U.4.11* and *Section 3: PC Software*). In addition, you should perform *View Metering: Terminal on page U.4.33* to connect secondary test voltages and currents, and to set the relay to meter these quantities correctly.

Step 1. Connect voltage and current sources to the relay secondary voltage and secondary current inputs (use the connections of *View Metering: Terminal on page U.4.33* and *Figure 4.25* or *Figure 4.26*).

Step 2. Apply power to the relay and establish communication.

a. Start ACSELERATOR QuickSet.

b. On the top toolbar, open the **Communication** menu, and click **Port Parameters**.

You will see the **Port Parameter**s dialog box similar to *Figure 4.7*.

c. Select the **Data Speed**, **Data Bits**, **Stop Bits**, **Parity**, and **RTS/CTS** that match the relay settings. The defaults are **9600**, **8**, **1**, **None**, **Off**, respectively.

d. Click **OK** to update the ACSELERATOR QuickSet communications parameters.

e. Confirm that the **Communications Status** bar at the bottom of the ACSELERATOR QuickSet window says **Connected**.

Step 3. Confirm the correct ACSELERATOR QuickSet software passwords.

a. Reopen the **Communication** menu and click **Port Parameters**.

b. Enter your Access Level 1 password in the **Level One Password** text box, and your Access Level 2 password in the **Level Two Password** text box.

c. Click **OK** to accept changes and close the dialog box.

NOTE: The **Trigger New Event** button in the Event History dialog box may also be used. See Figure 4.36.

Step 4. In the top toolbar HMI menu, click **Meter and Control** to start the ACSELERATOR QuickSet operator interface.

Step 5. Click the **Control Window** button of the HMI tree view (see *Figure 4.33*).

ACSELERATOR QuickSet displays the **Control Window** similar to that in *Figure 4.34*.

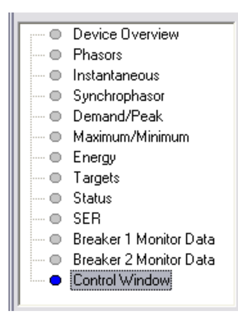


Figure 4.33 ACSELERATOR QuickSet HMI Tree View

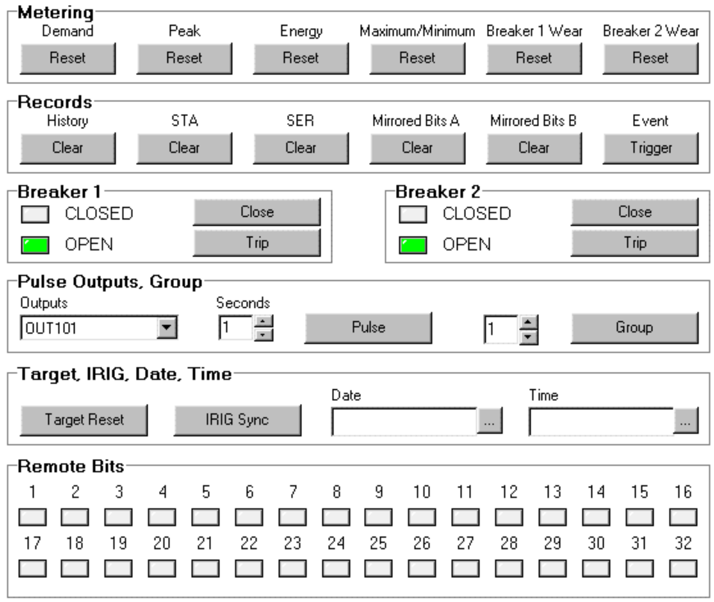


Figure 4.34 ACSELERATOR QuickSet HMI Control Window

Step 6. Trigger an Event.

a. Click the **Event Trigger** box to trigger an event.

ACSELERATOR QuickSet displays a prompt in a dialog box similar to that in *Figure 4.35*.

b. Click **Yes** to trigger an event.

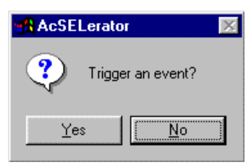


Figure 4.35 Event Trigger Prompt: ACSELERATOR QuickSet

Reading the Event History

The SEL-421 has two convenient methods for checking whether you successfully captured power system data. You can view the event history data with ACSELERATOR QuickSet, or you can examine internal relay file folders for the recorded data.

Reading the Event History: ACSELERATOR QuickSet

The procedure in the following steps shows how to use the ACSELERATOR QuickSet HMI to gather relay event history information. See *Event History on page A.3.31* for more information on event history.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords). You should also be familiar with ACSELERATOR QuickSet (see *Checking Relay Status: ACSELERATOR QuickSet on page U.4.11* and *Section 3: PC Software*).

Step 1. Configure the communications port.

a. Start ACSELERATOR QuickSet.

b. On the top toolbar, open the **Communication** menu, and then click **Port Parameters**.

You will see the **Port Parameters** dialog box similar to *Figure 4.7*.

c. Select the **Data Speed**, **Data Bits**, **Stop Bits**, **Parity**, and **RTS/CTS** that match the relay settings. The defaults are **9600**, **8**, **1**, **None**, **Off**, respectively.

d. Click **OK** to update the ACSELERATOR QuickSet communications parameters.

e. Confirm that the **Communications Status** bar at the bottom of the ACSELERATOR QuickSet window says **Connected**.

Step 2. Confirm that you have loaded the correct passwords in ACSELERATOR QuickSet.

a. Enter your Access Level 1 password in the **Level One Password** text box, and your Access Level 2 password in the **Level Two Password** text box.

b. Click **OK** to accept changes and close the dialog box.

Step 3. To view the event history report, open the ACSELERATOR QuickSet **Analysis** menu and click **View Event History**.

You will see the **Event History** dialog box similar to that in *Figure 4.36*.

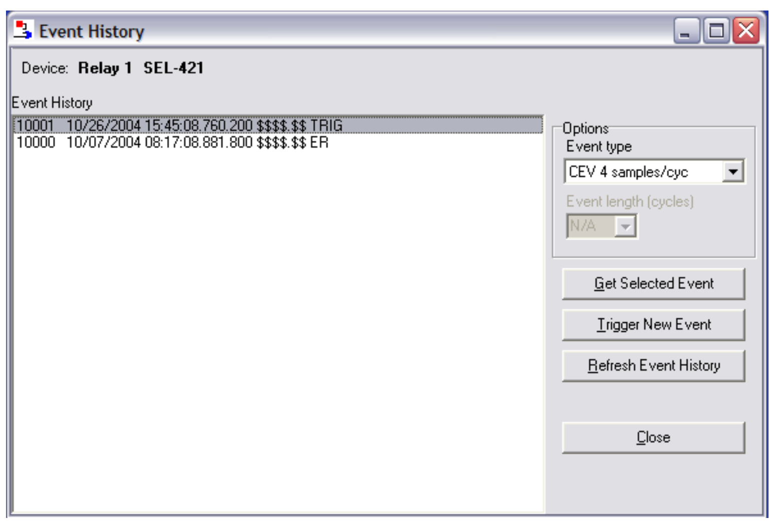


Figure 4.36 Relay Event History Dialog Box

Reading the Event History: Terminal

The procedure in the following steps shows how to use the SEL-421 file structure 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 U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* 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 4.37*.

```
=>HIS <Enter>

Relay 1                                      Date: 10/27/2004  Time: 10:22:23.895
Station A                                    Serial Number: 0000000000

#        DATE         TIME      EVENT  LOCAT    CURR GRP TARGETS
10001 10/26/2004 15:45:08.760 TRIG  $$$$.$$   638  1
10000 10/07/2004 08:17:08.881 ER    $$$$.$$     0  1
=>
```

Figure 4.37 Sample HIS Command Output: Terminal

For more information on the event history, see *Event History on page A.3.31*.

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 SEL-421 outputs high-resolution oscillography data in the binary COMTRADE file format (*IEEE/ANSI standard C37.111-1999*). File transfer is the only mechanism for retrieving high-resolution COMTRADE data from the relay.

The SEL-5601 Analytic Assistant 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: Terminal

The relay recorded the event triggered in *Triggering an Event on page U.4.42*. 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 *Triggering an Event on page U.4.42* before executing the instructions in this example. For this procedure, you must use a communications terminal emulation computer program capable of file transfers (this function is not available in ACSELERATOR QuickSet).

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 SEL-421 events file directory.

The relay lists file names for recently recorded events in a manner similar to that shown in *Figure 4.38*.

The relay shows three high-resolution oscillography files with the file extensions .HDR, .CFG, and .DAT for each event.

This procedure uses HR_10001 as the number of the event that you recently triggered; use the event number corresponding to your triggered event.

```
=>>FILE DIR EVENTS <Enter>

C4_10000.TXT                     R   10/07/2004 08:17:08
C4_10001.TXT                     R   10/26/2004 15:45:08
C8_10000.TXT                     R   10/07/2004 08:17:08
C8_10001.TXT                     R   10/26/2004 15:45:08
CHISTORY.TXT                     R
E4_10000.TXT                     R   10/07/2004 08:17:08
E4_10001.TXT                     R   10/26/2004 15:45:08
E8_10000.TXT                     R   10/07/2004 08:17:08
E8_10001.TXT                     R   10/26/2004 15:45:08
HISTORY.TXT                      R
HR_10000.CFG                     R   10/07/2004 08:17:08
HR_10000.DAT                     R   10/07/2004 08:17:08
HR_10000.HDR                     R   10/07/2004 08:17:08
HR_10001.CFG                     R   10/26/2004 15:45:08
HR_10001.DAT                     R   10/26/2004 15:45:08
HR_10001.HDR                     R   10/26/2004 15:45:08
=>>
```

Figure 4.38 EVENTS Folder Files

Step 3. Type **FILE READ EVENTS HR_10001.* <Enter>** to ready the relay to transfer the HR_10001.HDR, HR_10001.CFG, and HR_10001.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 **Y-Modem** (if this transfer type is not already enabled).
- ➢ Click **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 the SEL-5601 Analytic Assistant, ACSELERATOR 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.

Retrieving High Resolution COMTRADE Data: ACSELERATOR QuickSet

The procedure in the following steps shows how to use ACSELERATOR QuickSet to view the event that you triggered in *Triggering an Event on page U.4.42*. You can use this procedure to view other events stored in the SEL-421.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords). You should also be familiar with ACSELERATOR QuickSet (see *Checking Relay Status: ACSELERATOR QuickSet on page U.4.11* and *Section 3: PC Software*).

Step 1. Configure the communications port.

a. Start ACSELERATOR QuickSet.

b. On the top toolbar, open the **Communication** menu, and then click **Port Parameters**.

You will see the **Port Parameters** dialog box similar to *Figure 4.7*.

c. Select the **Data Speed**, **Data Bits**, **Stop Bits**, **Parity**, and **RTS/CTS** that match the relay settings. The defaults are **9600**, **8**, **1**, **None**, **Off**, respectively.

d. Click **OK** to update the ACSELERATOR QuickSet communications parameters.

e. Confirm that the **Communications Status** bar at the bottom of the ACSELERATOR QuickSet window says **Connected**.

Step 2. Confirm the correct ACSELERATOR QuickSet passwords.

a. Reopen the **Communication** menu and click **Port Parameters**.

b. Enter your Access Level 1 password in the **Level One Password** text box, and your Access Level 2 password in the **Level Two Password** text box.

c. Click **OK** to accept changes and close the dialog box.

Step 3. Open the ACSELERATOR QuickSet **Analysis** menu and click **View Event History** to view the Event History.

You will see the **Event History** dialog box similar to that shown in *Figure 4.39*.

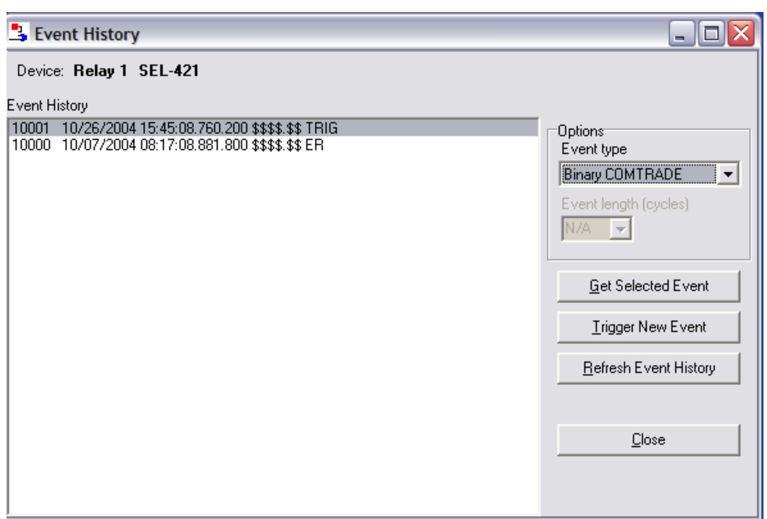


Figure 4.39 Relay Event History Dialog Box in ACSELERATOR QuickSet

Step 4. Get the event.

a. Select Binary COMTRADE in the **Event Type** dialog box.

b. Highlight the event you want to view and click the **Get Selected Event** button.

c. After getting the event ACSELERATOR QuickSet prompts you to save the event file (.DAT) in a directory.

d. Click Analysis > View Event Files and select the saved event file (.DAT).

e. Press Open.

ACSELERATOR QuickSet then presents the window similar to that in *Figure 4.40* and the sample event oscillogram of *Figure 4.41*.

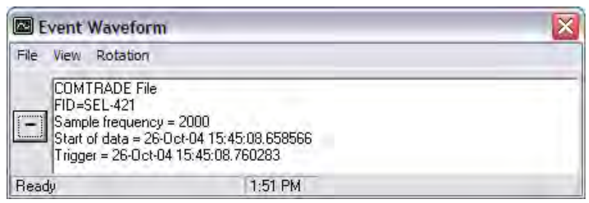


Figure 4.40 ACSELERATOR QuickSet Event Waveform Window

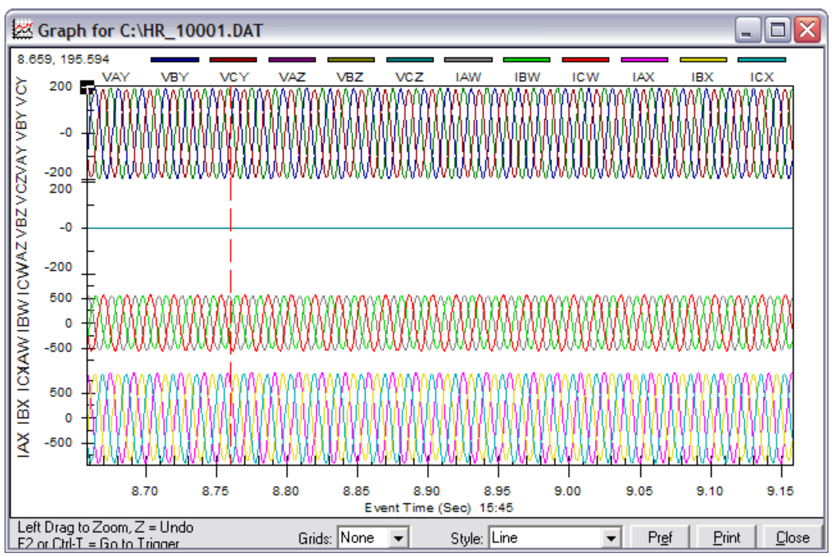


Figure 4.41 Sample Event Oscillogram

You can also examine a phasors display, an event harmonic analysis display, and the event summary from the **Event Waveform View** menu. See *Analyze Events on page U.3.16* and *Section 3: Analyzing Data in the Applications Handbook* for more information.

Viewing Event Report Data

Examine relay event reports to inspect the operating quantities the SEL-421 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 A.3.12*.

Retrieving Event Report Data Files: Terminal

The relay recorded the event triggered in *Triggering an Event on page U.4.42*. The procedure in the following steps shows you how to retrieve the event report data files for this event. Perform the steps listed in *Triggering an Event on page U.4.42* 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 4.38*.

In the figure, the relay shows two event report files: E4_10001.TXT and E8_10001.TXT, and two Compressed ASCII event report files: C4_10001.TXT and C8_10001.TXT.

Step 3. Type **FILE READ EVENTS C8_10001.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 **Y-Modem** (if not already enabled).
- ➢ Click **Receive**.

You will usually see a confirmation message when the file transfer is complete.

Step 5. When this file has transferred successfully, use the SEL-5601 Analytic Assistant to play back the event report oscillograms of the 8-samples/cycle event report file you just transferred.

Use the ASCII command **CEVENT** to retrieve event report files in Compressed ASCII format. See *SEL Compressed ASCII Commands on page R.5.4* and *CEVENT on page R.9.5* for more information.

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 SEL-421 stores the latest 1000 entries to a nonvolatile record. Use the relay communications ports or ACSELERATOR QuickSet to view the SER records. For more information on the SER, see *Section 3: Analyzing Data in the Applications Handbook*.

The latest 200 SER events are viewable from the front panel. For more information, see *Section 5: Front-Panel Operations*.

Setting the SER and Examining an SER Record: ACSELERATOR QuickSet

The procedure in the following steps shows you how to use ACSELERATOR QuickSet to program relay elements into the SER. Also, use these procedures to review SER records with ACSELERATOR QuickSet.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords). You should also be familiar with ACSELERATOR QuickSet (see *Section 3: PC Software*).

Step 1. Configure the communications port.

a. Start ACSELERATOR QuickSet.

b. On the top toolbar, open the **Communication** menu, and then click **Port Parameters**.

You will see the **Port Parameters** dialog box similar to *Figure 4.7*.

c. Select the **Data Speed**, **Data Bits**, **Stop Bits**, **Parity**, and **RTS/CTS** that match the relay settings. The defaults are **9600**, **8**, **1**, **None**, **Off**, respectively.

d. Click **OK** to update the ACSELERATOR QuickSet communications parameters.

e. Confirm that the **Communications Status** bar at the bottom of the ACSELERATOR QuickSet window says **Connected**.

Step 2. Confirm the correct ACSELERATOR QuickSet passwords.

a. Reopen the **Communication** menu and click **Port Parameters**.

b. Enter your Access Level 1 password in the **Level One Password** text box, and your Access Level 2 password in the **Level Two Password** text box.

c. Click **OK** to accept changes and close the dialog box.

Step 3. Download the present configuration in the SEL-421 by clicking **Settings > Read**.

The relay sends all configuration and settings data to ACSELERATOR QuickSet.

Step 4. Click the **Report** branch of the ACSELERATOR QuickSet **Settings** tree view structure (see *Figure 4.42*) to view the SER settings entry screen.

You will see the **SER Points and Aliases** window similar to *Figure 4.43*.

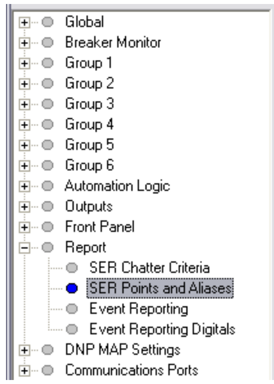


Figure 4.42 Selecting SER Points and Aliases Settings: ACSELERATOR QuickSet

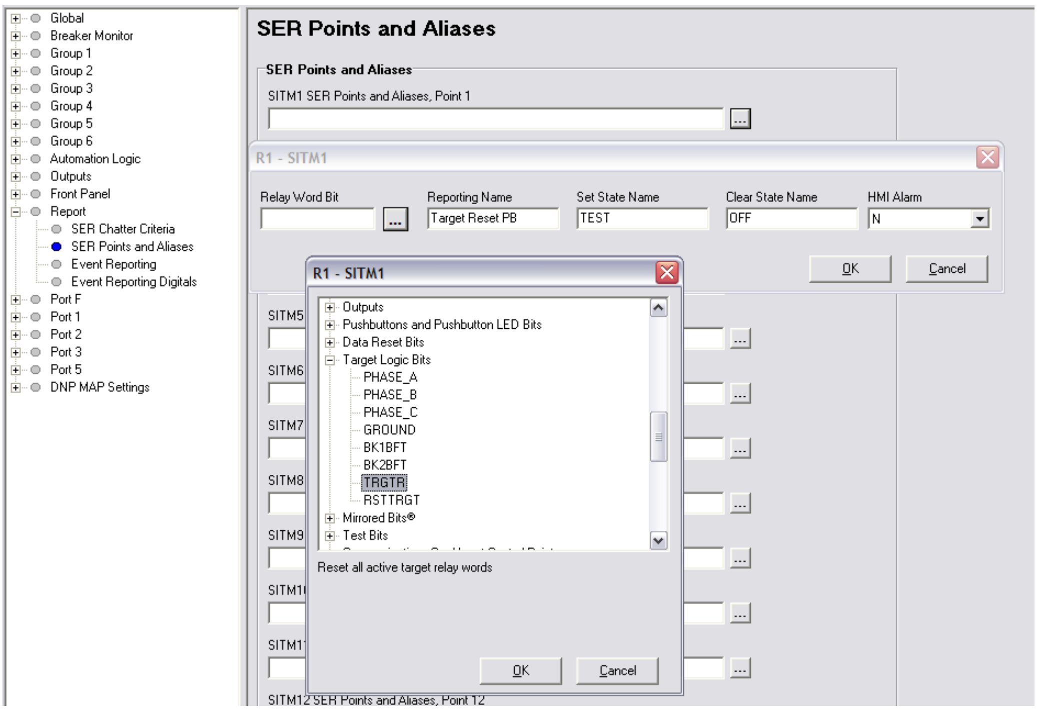


Figure 4.43 SER Points and Aliases Settings: ACSELERATOR QuickSet

Step 5. Enter SER trigger settings.

a. For this example, open the entry form by clicking the ... button beside the **SITM1 SER Points and Aliases, Point 1** entry field. We will set this SER point to report the operation of the Target Reset pushbutton.

b. Click the ... button beside the **Relay Word Bit** entry field.

c. Select Target Logic Bits, and then double-click on TRGTR to copy the TRGTR name into the **Relay Word Bit** field. This also copies TRGTR to the Alias Name field.

d. Type **Target Reset PB** in the **Reporting Name** field.

e. Type **TEST** in the **Set State Name** field.

f. Type **OFF** in the **Clear State Name** field.

g. Click **OK**.

Step 6. Click **File** > **Save** to save the new settings in ACSELERATOR QuickSet.

Step 7. Upload the new settings to the SEL-421.

a. Click **File** > **Send**.

ACSELERATOR QuickSet prompts you for the settings class you want to send to the relay, as shown in the first dialog box of *Figure 4.44*.

b. Click the **Report** check box.

c. Click **OK**.

ACSELERATOR QuickSet responds with the second dialog box of *Figure 4.44*.

If you see no error message, the new settings are loaded in the relay.

NOTE: The **Relay Editor** dialog boxes shown in Figure 4.44 are for the SEL-421. The SEL-421-1 and SEL-421-2 dialog boxes do not contain Automation 2 through Automation 10 setting instances.

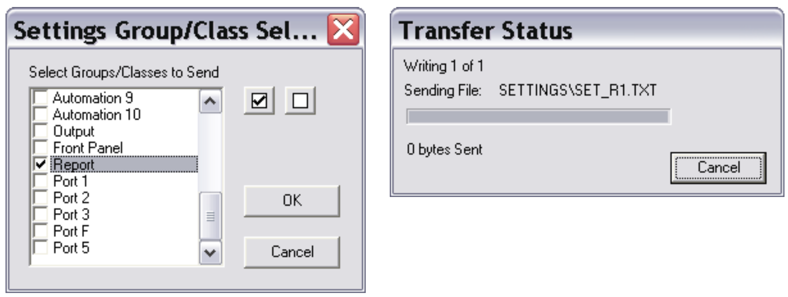


Figure 4.44 Uploading Report Settings to the SEL-421

Step 8. Press and release the front-panel {TARGET RESET} pushbutton to generate an SER record.

Step 9. View the SER report.

a. Start the ACSELERATOR QuickSet operator interface.

b. In the top toolbar HMI menu, click **Meter and Control**.

c. Click the **SER** button of the HMI tree view (see *Figure 4.45*).

ACSELERATOR QuickSet displays the SER records with a display similar to *Figure 4.46*.

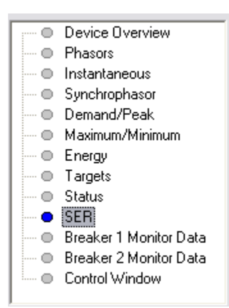


Figure 4.45 Retrieving SER Records With ACSELERATOR QuickSet

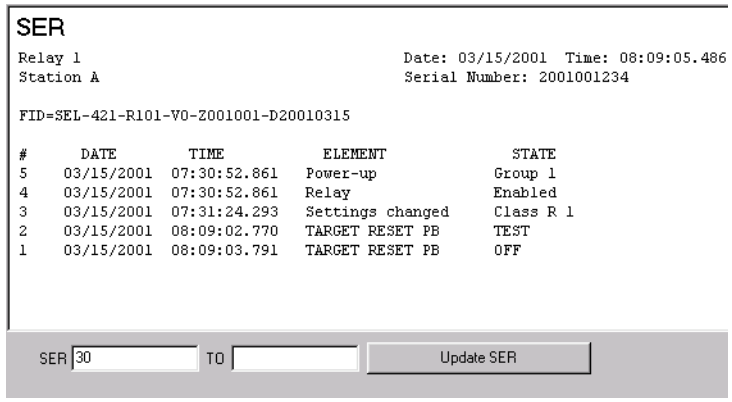


Figure 4.46 SER Records in the ACSELERATOR QuickSet HMI

The relay lists the SER records in chronological order from top to bottom as shown in *Figure 4.46*. 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 (**Group 1** in *Figure 4.46*). 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 first press the pushbutton. When you release the pushbutton, the SER records the pushbutton release. For more information on the Sequential Events Recorder, see *SER (Sequential Events Recorder) on page A.3.34*.

Setting the SER and Examining the SER Record: Terminal

The procedure in the following steps shows how to use a terminal connected to an SEL-421 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 U.4.18*). Also included is a procedure for viewing the SER report with a terminal. For more information on the SER, see *SER (Sequential Events Recorder) on page A.3.34*.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* 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 the **2AC <Enter>** command.

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 4.47*).

b. Type **<Enter>** to move past the **SER Chatter Criteria** setting.

c. At the **SER Points and Aliases** 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
2:
? END <Enter>

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

Figure 4.47 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 4.46*.

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. For more information on the SER, see *SER (Sequential Events Recorder) on page A.3.34*.

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 4.48*.

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
CSER.TXT                          R
HISTORY.TXT                       R
SER.TXT                           R
=>
```

Figure 4.48 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 **Y-Modem** (if not already enabled).
- ➢ Click **Receive**.

You will usually see a confirmation message when the file transfer is complete.

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 is no data available for subsequent SER or CSER transfers from the same port.

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 4.46*.

The CSER.TXT file viewed with a word-processing program is similar to the example in CSER, SER (Sequential Events Recorder), in *CSER on page A.3.35*.

Operating the Relay Inputs and Outputs

The SEL-421 gives 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 subsection is an introduction to operating the SEL-421 control outputs and control inputs. For more information on connecting and applying the control outputs and control inputs, see *Section 2: Installation*.

Control Output

The SEL-421 features Standard, Hybrid (High-Current Interrupting), and Fast Hybrid (Fast High-Current Interrupting) control outputs that you can use to control circuit breakers and other devices in an equipment bay or substation control house. See *Control Outputs on page U.2.7* for more information on control outputs.

Pulsing a Control Output: 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 R.9.37*.

This example assumes that you have successfully established communication with the relay; see *Making an EIA-232 Serial Port Connection on page U.4.5* for a step-by-step procedure. In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords).

NOTE: To PULSE an output, the circuit breaker control enable jumper, J18C, 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 the **BAC <Enter>** command.

d. Type the correct password to go to Access Level B.

You will see the Access Level 1 => 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.

For more information on connecting control outputs, see *Control Outputs on page U.2.7*.

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 4.49*.

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 4.49 Terminal Display for PULSE Command

You can also pulse an output for longer than the default 1-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 3 seconds.

Pulsing a Control Output: 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 SEL-421 control outputs. See *Section 5: 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.

For more information on connecting control outputs, see *Control Outputs on page U.2.7*.

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 at the top of *Figure 4.50*.

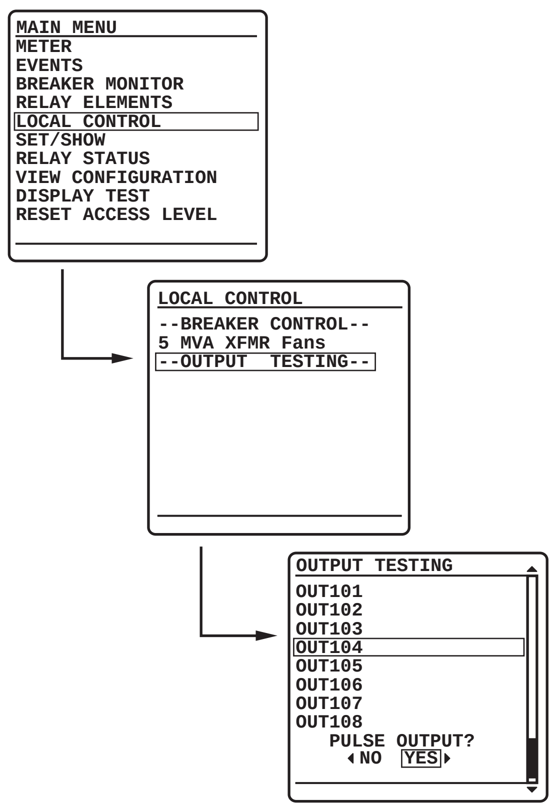


Figure 4.50 Front-Panel Menus for Pulsing OUT104

Step 4. View the local control screen.

a. Press the **{Up Arrow}** and **{Down Arrow}** navigation pushbuttons to highlight the `LOCAL CONTROL` action item (see *Figure 4.50*).

b. Press the **{ENT}** pushbutton.

You will see the `LOCAL CONTROL` submenu (the middle screen in *Figure 4.50*).

Step 5. View the output testing screen.

a. Press the **{Up Arrow}** and **{Down Arrow}** navigation pushbuttons to highlight the `--OUTPUT TESTING--` action item (see *Figure 4.50*, middle screen).

b. Press the **{ENT}** pushbutton.

The relay next displays the `OUTPUT TESTING` submenu (the last screen of *Figure 4.50*).

Step 6. Command the relay to pulse the control output.

a. Press the **{Up Arrow}** and **{Down Arrow}** navigation pushbuttons to highlight `OUT104` (see *Figure 4.50*, last screen).

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 of *Figure 4.51*.

Figure 4.51 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: 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-421. 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 U.5.24*.

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. See *Control Outputs on page U.2.7* for more information on SEL-421 control outputs.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* 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 the **2AC <Enter>** command.

d. Type the correct password to go to Access Level 2.

You will see the Access Level 1 =>> prompt.

Step 2. Access the local control settings.

a. Type **SET F <Enter>** command.

b. Repeatedly type > and then **<Enter>** to advance through the front-panel settings until you reach the **Display Points and Aliases** category.

c. Press **<Enter>** to access the **Control Points and Aliases Category**.

Figure 4.52 shows a representative terminal screen.

```
Control Points and Aliases
(Local Bit, Alias Name, Alias for Set State, Alias for Clear State,
Pulse Enable)
 1:
? LIST <Enter>

1:
? LB03,"5 MVA XFMR Fans",ON,OFF,N <Enter>
2:
? END <Enter>
              .
              .
              .
Control Points and Aliases
(Local Bit, Alias Name, Alias for Set State, Alias for 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 4.52 Using Text-Edit Mode Line Editing to Set Local Bit 3

NOTE: Use quotation marks when entering alias strings that contain spaces or punctuation marks, as shown in the LB03 example, Step 4.

Step 3. Type **LIST <Enter>** at the **Local Control and Aliases** 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 1 prompt:

1: LB03,"5 MVA XFMR Fans",ON,OFF,N <Enter>

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 scrolls a readback of all the front-panel settings, eventually displaying the `Save settings (Y,N) ?` prompt. (In *Figure 4.52* 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. Answer **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 4.53*).

b. At the `?` prompt, type **LB03 <Enter>**.

c. At the next `?` prompt, type **END <Enter>**.

d. When prompted to save settings, answer **Y <Enter>**.

```
=>>SET O OUT105 <Enter>
Output

Main Board

OUT105 := NA
? LB03 <Enter>

OUT106 := NA

? END <Enter>
Output

Main Board

OUT101 := 3PT AND NOT PLT04
OUT102 := 3PT AND NOT PLT04
OUT103 := BK1 CL AND NOT PLT04
OUT104 := KEY AND PLT02 AND NOT PLT04
OUT105 := LB03
OUT106 := NA
OUT107 := PLT04
OUT108 := NOT (HALARM OR SALARM)

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

Figure 4.53 Setting Control Output OUT105: 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 (see *Figure 4.54*).

c. Select 5 MVA XFMR Fans on the LOCAL CONTROL screen as shown in *Figure 4.54*.

d. Press **{ENT}** to see the last screen of *Figure 4.54*.

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.

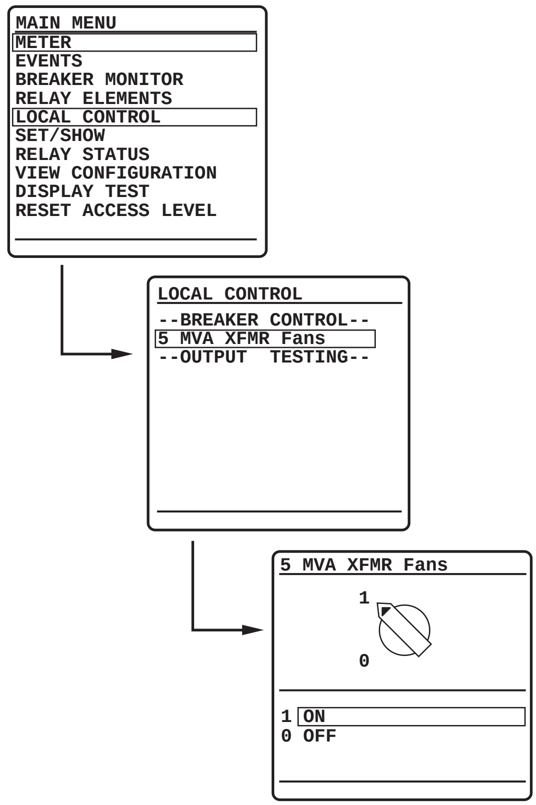


Figure 4.54 Front-Panel LOCAL CONTROL Screens

Setting Outputs for Tripping and Closing

To actuate power system circuit breakers, you must configure the SEL-421 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

The SEL-421 is capable of single-pole tripping and three-pole tripping. There are many Relay Word bits (e.g., TPA1, TPA2, RTA1, and 3PT) that you can program to drive control outputs to trip circuit breakers. See *Section 1: Protection Functions in the Reference Manual* for complete information on tripping equations and settings. For target illumination at tripping, see *Section 5: Front-Panel Operations*.

Close Output Signals

The SEL-421 features an automatic recloser for single circuit breaker and two circuit breaker applications. The relay provides as many as two single-pole and four three-pole reclose shots. See *Section 2: Auto-Reclosing and Synchronism Check in the Reference Manual* for more information.

Close the circuit breakers using Relay Word bits BK1CLS and BK2CLS for Circuit Breaker 1 and Circuit Breaker 2, respectively.

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. Relay factory defaults assign control outputs OUT101 and OUT102 to the trip bus and OUT103 to the close bus for a three-pole tripping circuit breaker. This procedure assigns an additional close output at OUT106.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords). You should also be familiar with ACSELERATOR QuickSet (see *Section 3: PC Software*).

Step 1. Configure the communications port.

a. Start ACSELERATOR QuickSet.

b. On the top toolbar, open the **Communication** menu, and then click **Port Parameters**.

You will see the **Port Parameters** dialog box similar to *Figure 4.7*.

c. Select the **Data Speed**, **Data Bits**, **Stop Bits**, **Parity**, and **RTS/CTS** that match the relay settings. The defaults are **9600**, **8**, **1**, **None**, **Off**, respectively.

d. Click **OK** to update the ACSELERATOR QuickSet communications parameters.

e. Confirm that the **Communications Status** bar at the bottom of the ACSELERATOR QuickSet window says **Connected**.

Step 2. Confirm the correct ACSELERATOR QuickSet passwords.

a. Reopen the **Communication** menu and click **Port Parameters**.

b. Enter your Access Level 1 password in the **Level One Password** text box, and your Access Level 2 password in the **Level Two Password** text box.

c. Click **OK** to accept changes and close the dialog box.

Step 3. Click **Settings > Read**.

The relay sends all configuration and settings data to ACSELERATOR QuickSet.

Step 4. Access the **Main Board** output settings.

a. Expand the **Outputs** branch of the **Settings** tree view.

b. Click **Main Board** (see *Figure 4.55*).

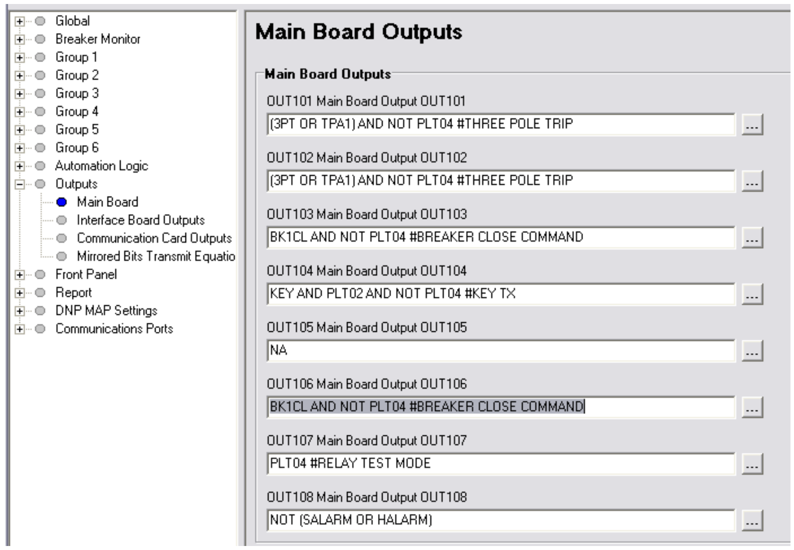


Figure 4.55 Assigning an Additional Close Output: ACSELERATOR QuickSet

Step 5. Assign a control output for the close bus.

a. In the **Main Board Outputs** dialog box, click the **OUT106** text box and type the following:

BK1CL AND NOT PLT04 #BREAKER CLOSE COMMAND

(The # indicates that a comment follows.)

b. Click or tab to another text box.

ACSELERATOR QuickSet checks that your entry is valid.

Step 6. Click **File > Save** to save the new settings in ACSELERATOR QuickSet.

Step 7. Upload the new settings to the SEL-421.

a. Click **File** > **Send**.

ACSELERATOR QuickSet prompts you for the settings class or instance you want to send to the relay.

b. Click the check box for **Outputs** as shown in the first dialog box of *Figure 4.56*.

c. Click **OK**.

ACSELERATOR QuickSet responds with the second dialog box of *Figure 4.56*.

If you see no error message, the new settings are loaded in the relay.

NOTE: The **Relay Editor** dialog boxes shown in Figure 4.56 are for the SEL-421. The SEL-421-1 and SEL-421-2 dialog boxes do not contain Automation 2 through Automation 10 setting instances.

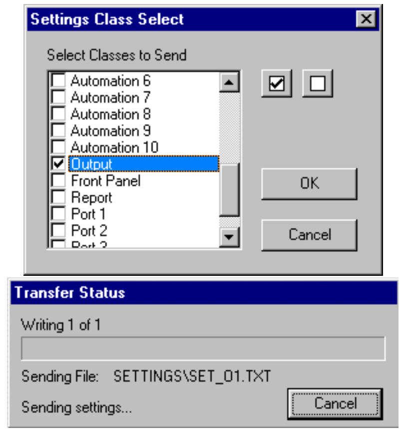


Figure 4.56 Uploading Output Settings to the SEL-421

Control Input Assignment

The SEL-421 relay has control inputs on the main board (IN101–IN107), and on one or two optional I/O interface boards (IN201–IN2xx, IN301–IN3xx), if so equipped. See *Control Inputs on page U.2.5* for detailed information.

There are two types of input circuitry: Direct Coupled and Optoisolated. *Table 4.8* lists the main differences between the two types of control inputs.

Table 4.8 Control Inputs in the SEL-421

	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:	➤ SEL-421 Main Board A (IN101–IN107) ➤ INT1, INT5, and INT6 I/O Interface Boards (IN201–IN208; IN301–IN308)	➤ SEL-421 Main Board B (IN101–IN107) ➤ INT2, INT7, and INT8 I/O Interface Boards (IN201–IN208; IN301–IN308) ➤ INT4 I/O Interface Board (IN201–IN224; IN301–IN324)

[a] With appropriate debounce settings—see Table 2.4.

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. For information on the Global settings related to control inputs, see *Table 9.3 on page R.9.2*, and *Table 9.5 on page R.9.2* through *Table 9.10 on page R.9.4*.

The following exercises use Direct-Coupled control inputs on Main Board A.

Setting a Control Input: Circuit Breaker Auxiliary Contacts (52A): 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 SEL-421. This example is for a 125 Vdc system; the open state of the auxiliary contacts is 0 Vdc (circuit breaker open), and the closed state of the auxiliary contacts is approximately 125 Vdc (circuit breaker closed). The voltage drop in the connecting wires from the auxiliary contacts through the station battery to the relay gives a slightly lower voltage than the station battery at the relay control input terminals. Make the control input pickup, dropout, and debounce timer settings as explained in *Control Inputs on page U.2.5*.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* 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 => action prompt.

c. Type the **2AC <Enter>** command.

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 4.57*).

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).

c. At the BK1TYP setting, type **3 <Enter>** for a three-pole circuit breaker for this particular example.

(Use the setting BK1TYP appropriate for your circuit breaker(s).)

d. At the BK2TYP setting, type **3 <Enter>** for a three-pole circuit breaker for this example.

The relay displays the 52AA1 SELOGIC control equation action prompt.

e. Type **IN101 <Enter>** at the ? prompt to specify input IN101 as the control input that represents the close/open state of Circuit Breaker 1.

The relay next displays the 52AA2 SELOGIC control equation action prompt.

f. 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 Trip Type (Single Pole=1,Three Pole=3) BK1TYP  := 1 ? 3 <Enter>
Breaker 2 Trip Type (Single Pole=1,Three Pole=3) BK2TYP  := 1 ? 3 <Enter>

Breaker 1 Inputs

N/O Contact Input -BK1 (SELogic Equation)
52AA1 := NA
?  IN101 <Enter>

Breaker 2 Inputs

A-Phase N/O Contact Input -BK2 (SELogic Equation)
52AA2 := NA
?  IN102 <Enter>
Breaker Monitor

Breaker Configuration

EB1MON  := N        EB2MON  := N        BK1TYP  := 3        BK2TYP  := 3

Breaker 1 Inputs

52AA1   := IN101

Breaker 2 Inputs

52AA2   := IN102

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

Figure 4.57 Setting 52AA1: Terminal

Setting a Control Input for Circuit Breaker Auxiliary Contacts (52A): ACSELERATOR QuickSet

The procedure in the following steps shows how to program the SEL-421 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 have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords). You should also be familiar with ACSELERATOR QuickSet (see *Section 3: PC Software*).

Step 1. Configure the communications port.

a. Start ACSELERATOR QuickSet.

b. On the top toolbar, open the **Communication** menu, and then click **Port Parameters**.

You will see the **Port Parameters** dialog box similar to *Figure 4.7*.

c. Select the **Data Speed**, **Data Bits**, **Stop Bits**, **Parity**, and **RTS/CTS** that match the relay settings. The defaults are **9600**, **8**, **1**, **None**, **Off**, respectively.

d. Click **OK** to update the ACSELERATOR QuickSet communications parameters.

e. Confirm that the **Communications Status** bar at the bottom of the ACSELERATOR QuickSet window says **Connected**.

Step 2. Confirm the correct ACSELERATOR QuickSet passwords.

a. Reopen the **Communication** menu and click **Port Parameters**.

b. Enter your Access Level 1 password in the **Level One Password** text box, and your Access Level 2 password in the **Level Two Password** text box.

c. Click **OK** to accept changes and close the dialog box.

Step 3. On the **Settings** menu, click **Read**.

The relay sends all configuration and settings data to ACSELERATOR QuickSet.

Step 4. Access the **Control Inputs** settings.

a. Click the **+** mark next to the **Global** branch of the **Settings** tree view.

b. Click the + mark next to the **Control Inputs** branch of the **Settings** tree view, and click the **Control Inputs** branch (see *Figure 4.58*).

Step 5. Set **EICIS Independent Control Input Settings** to **Y**.

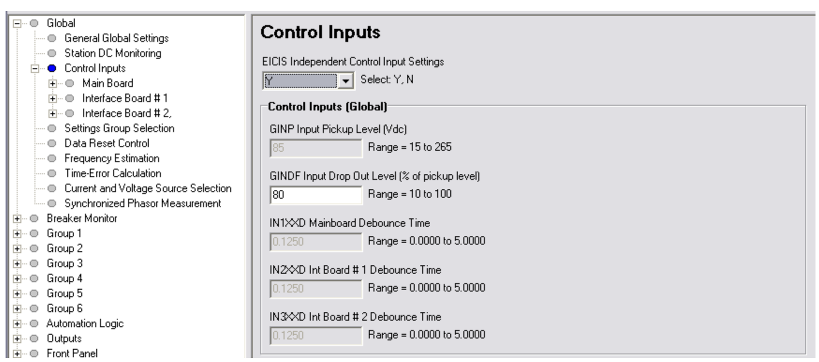


Figure 4.58 Accessing Global Enable Setting EICIS in ACSELERATOR QuickSet

Step 6. Access the **Control Inputs** settings.

a. Expand the **Main Board** branch by clicking the **+** button next to **Main Board**.

b. Click **Mainboard Pickup Levels**. You will see the input window similar to that in *Figure 4.59*.

c. Click **Mainboard Pickup and Dropout Delays**. You will see the input window similar to that in *Figure 4.60*.

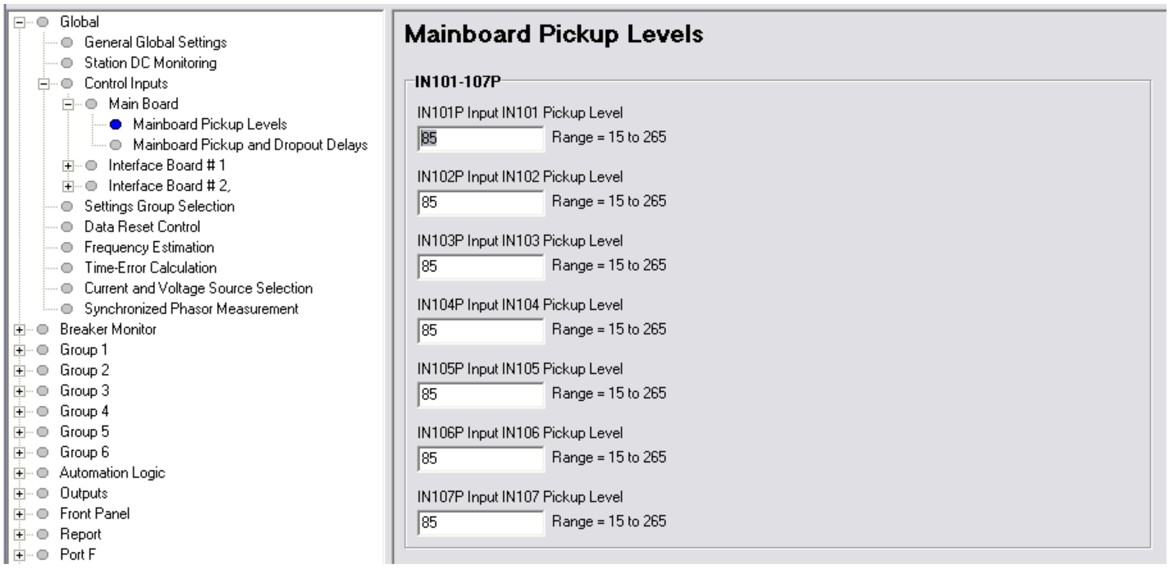


Figure 4.59 Control Input Pickup Level Settings in ACSELERATOR Quickset SEL-5030 Software

Step 7. Set the control input IN101 pickup threshold.

For this example, a 125 Vdc station battery is providing the control voltage. Referring to *Table 2.1*, the appropriate pickup voltage settings is 100 Vdc. Click the mouse cursor (or press **<Tab>**) to highlight **IN101P Main Board Input 101 Assertion Level**.

a. Delete the present setting by pressing **<Delete>**.

b. Type **100**, and then click or **<Tab>** to another value.

The relay checks the new value and enters the value in the ACSELERATOR QuickSet database.

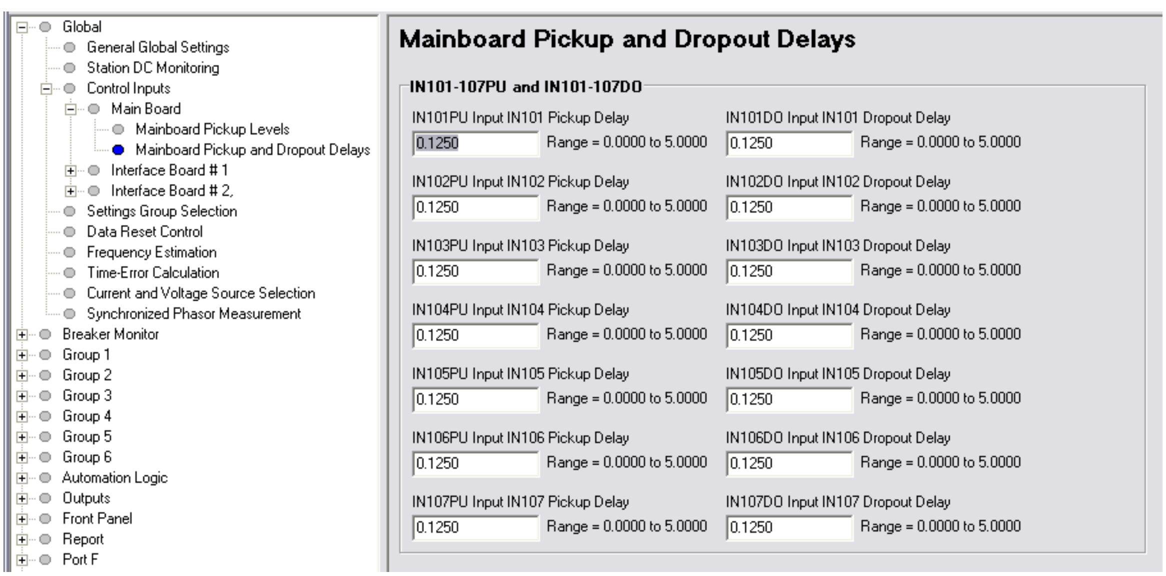


Figure 4.60 Control Input Pickup and Dropout Delay Settings in ACSELERATOR QuickSet

Step 8. 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 Input IN101 pickup delay**.

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 relay checks the new value and enters the value in the ACSELERATOR QuickSet database.

Step 9. Configure the relay to read the circuit breaker auxiliary contact.

a. Expand the **Breaker Monitor** branch of the **Settings** tree view by clicking the **+** button (see *Figure 4.61*).

b. In the tree view, click **Breaker 1** to select circuit breaker monitor settings for Circuit Breaker 1.

c. At the **BK1TYP** setting, click **3** for the three-pole circuit breaker of this particular example.

(Use the setting BK1TYP appropriate for your circuit breaker(s).)

d. Set the 52AA1 SELOGIC control equation by clicking in the text box labeled **N/O Contact Input -BK1**.

e. Type **IN101**, and then click or **<Tab>** to another field to specify input IN101 as the control input that represents the close/open state of Circuit Breaker 1.

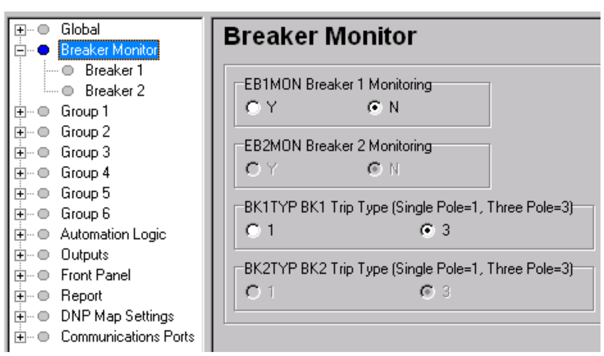


Figure 4.61 Setting BK1TYP in ACSELERATOR QuickSet

Step 10. Click **File > Save** to save the new settings in ACSELERATOR QuickSet.

Step 11. Upload the new settings to the SEL-421.

a. Click **File** > **Send**.

ACSELERATOR QuickSet prompts you for the settings class or instance you want to send to the relay

b. Click the **Global** check box and the **Breaker Monitor** check box, as shown in the first dialog box of *Figure 4.62*.

c. Click **OK**.

d. ACSELERATOR QuickSet responds with the second dialog box of *Figure 4.62*.

If you see no error message, the new settings are loaded in the relay.

NOTE: The **Relay Editor** dialog boxes shown in Figure 4.62 are for the SEL-421. The SEL-421-1 and SEL-421-2 dialog boxes do not contain Automation 2 through Automation 10 setting instances.

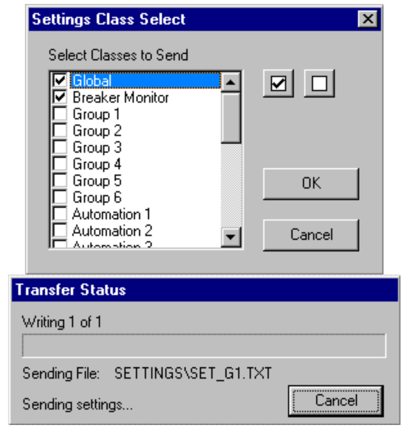


Figure 4.62 Uploading Global and Breaker Monitor Settings to the SEL-421

Configuring High-Accuracy Timekeeping

The SEL-421 features high-accuracy timekeeping when supplied with an IRIG-B signal. When the supplied clock signal is sufficiently accurate, the SEL-421 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 using the high-accuracy time stamp. See *Synchrophasors on page R.7.1*, *Oscillography on page A.3.7*, and *Time-Synchronized Measurements on page A.4.1* for details on these applications.

IRIG-B

The SEL-421 has two input connectors that accept IRIG-B (Inter-Range Instrumentation Group-B) demodulated time-code format: the IRIG-B pins of Serial Port 1, and the IRIG-B BNC connector—see *TIME Input Connections on page U.2.45*.

The IRIG-B BNC connector can be used for high-accuracy timekeeping purposes, with up to 1 µs accuracy with an appropriate time source. Either input can be used for general-purpose timekeeping, and the relay will have up to 500 µs accuracy. See *Table 4.9* for SEL-421 timekeeping mode details.

NOTE: The SEL-2407 Satellite Synchronized Clock meets both the SEL-421 accuracy and IEEE C37.118 requirements for a high-accuracy time source.

Table 4.9 SEL-421 Timekeeping Modes (Sheet 1 of 2)

Item	Internal Clock	IRIG	HIRIG (or High-Accuracy IRIG)
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]

Table 4.9 SEL-421 Timekeeping Modes (Sheet 2 of 2)

Item	Internal Clock	IRIG	HIRIG (or High-Accuracy IRIG)
IRIG-B Connection Required	None	BNC connector (preferred), or Serial Port 1	BNC connector
Relay Word bits	TIRIG = logical 0 TSOK = logical 0	TIRIG = logical 1 TSOK = logical 0	TIRIG = logical 1 TSOK = logical 1

[a] The SEL-421 internal clock can be synchronized via DNP3, Ethernet card, SEL-2030 Communications Processor, or MIRRORED BITS communications.
[b] The time source must include the IEEE C37.118 IRIG-B control bit assignments to provide the Time Error estimate for the clock.

NOTE: If the time-code signal connected to the BNC connector degrades in quality, the SEL-421 will not switch-over to the IRIG-B pins of serial port 1. The SEL-421 will only switch to Serial Port 1 if the signal on the BNC connector completely fails (e.g. the cable is un-plugged).

Only one IRIG-B time source can be used by the SEL-421, and the signal connected to the IRIG-B BNC connector (shown in *Figure 4.64*) 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.

The SEL-421 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).

The SEL-421 will assert Relay Word bit TSOK only when these two tests are met, indicating HIRIG mode. The TQUAL Analog Quantity can be viewed with the **MET PM** command, and is shown beside the label

`Time Quality   Maximum time synchronization error:`. See *Figure 7.13 on page R.7.25* for a sample.

The IRIG-B control field is defined in the IEEE C37.118 standard. The SEL-421 places the raw time quality information in Relay Word bits TQUAL1, TQUAL2, TQUAL4, and TQUAL8; and the decoded maximum clock error in Analog Quantity TQUAL, in seconds.

If the clock signal is determined to be of low quality, with more than 500 ns of jitter, the SEL-421 will not assert the TIRIG Relay Word bit.

1k PPS Connection Not Required

SEL-421 Relays Changed

Previous versions of the SEL-421 Relay required a 1k PPS clock signal in addition to the IRIG-B signal to allow HIRIG mode (high-accuracy IRIG timekeeping). The previous SEL-421 hardware included two BNC connectors for timekeeping: 1k PPS and IRIG-B (see *Figure 4.64*). On newer SEL-421 relays, there is only one BNC connector, IRIG-B, as shown in *Figure 4.63*.

Starting with SEL-421 firmware version R112, HIRIG mode is available if a sufficiently accurate IRIG-B time source is connected to the IRIG-B BNC connector (see *Table 4.9*). A 1k PPS time source *cannot be used*.

Firmware version R112 redefines the meaning of the BNC connectors on the rear panel of the SEL-421. Pay close attention to the following instructions if you are upgrading your SEL-421 firmware.

Using New SEL-421 Firmware in an Existing Relay

In new SEL-421 relays, the IRIG-B BNC connector is in the same location as the 1k PPS BNC connector on previous relays. If you upgrade a previously installed SEL-421 relay to firmware version R112 or later, you will be provided with a retrofit kit that includes a new rear-panel label for the TIME inputs (see *Figure 4.65*). Follow the instructions included in the firmware upgrade package, and be sure to remove any 1k PPS time source cables that were previously connected.

Additionally, if the IRIG-B signal was previously supplied to the SEL-421 via Serial Port 1, and HIRIG mode operation is desired, connect the IRIG-B source to the IRIG-B BNC connector instead.

Time and Date Management Settings Not Required

SEL-421 Relays Changed

Previous firmware versions (R111 and earlier) of the SEL-421 relay provided Global Settings ETPPS and ETIRIG to enable or disable the 1k PPS and IRIG-B time sources. Beginning in firmware version R112, these settings are no longer part of Global Settings, because there is no 1k PPS input connector. Relay Word bit TPPS has also been removed from the relay.

Connecting High-Accuracy Timekeeping

The procedure in the following steps assumes that you have a modern high-accuracy GPS receiver with a BNC connector output for an IRIG-B signal. Use a communications terminal to send commands and receive data from the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*).

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords).

Step 1. Confirm that the relay is operating (see *Connecting and Applying Power on page U.4.3*).

Step 2. 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.

NOTE: Consult the specific GPS Clock (IRIG-B time source) instruction manual for the IRIG-B cable requirements, termination resistor requirements, antenna installation, and clock configuration details.

Step 3. Connect the cable.

Attach the IRIG-B signal with a BNC-to-BNC coaxial jumper cable from the GPS receiver IRIG-B output to the SEL-421 **TIME IRIG-B** BNC connector (see *Figure 4.63*).

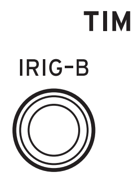


Figure 4.63 TIME BNC Connector, new hardware

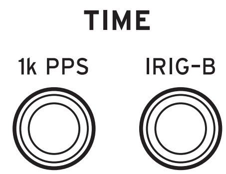


Figure 4.64 TIME BNC Connectors, old hardware

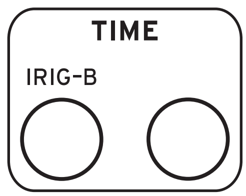


Figure 4.65 Retrofit Sticker

Step 4. Confirm/Enable automatic detection of high-accuracy timekeeping.

a. Wait at least 20 seconds for the SEL-421 to acquire the clock signal, and then, at a communications terminal, type **TAR TIRIG <Enter>**

The relay will return one row from the Relay Word, as shown in *Figure 4.66*. 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 SEL-421 internal clock is presently being updated by the HIRIG source, and TSYNCA, which acts as an alarm bit that asserts when the SEL-421 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 4.66 Confirming the High-Accuracy Timekeeping Relay Word Bits

b. The TIRIG and TSOK Relay Word bits should be asserted (logical 1), indicating that the relay is in the High-Accuracy IRIG timekeeping mode (HIRIG).

If TSOK is not asserted, but TIRIG is asserted, the relay is in regular IRIG timekeeping mode. Here 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.
- ➢ If the time-source clock is reporting that its time error is greater than 1 µs.
- ➢ The IRIG-B clock source is connected via Serial Port 1 instead of the IRIG-B BNC connector.
- ➢ The IRIG-B clock source is connected to the unlabeled BNC connector on older relay hardware (the previous location of the IRIG-B BNC connector).

NOTE: If the firmware in an already installed SEL-421 is upgraded to version R112 or later, and the previous IRIG-B BNC cable is not moved to the new location (see Figure 4.63), the SEL-421 cannot enter High-Accuracy mode.

If neither TSOK nor TIRIG are asserted, the relay is not in an IRIG time-source mode. Here is a list of possible reasons for not entering IRIG mode:

- ➢ The IRIG-B clock signal is not of sufficient accuracy or is improperly configured.
- ➢ The termination resistor, required by some IRIG clocks, is not installed.
- ➢ The time source clock is not connected to an antenna.
- ➢ An IRIG-B clock source is connected both to serial port 1 and the unlabeled BNC connector on older relay hardware (the previous location of the IRIG-B BNC connector).
- ➢ A 1k PPS cable is still connected to the relay.

NOTE: If the firmware in an already installed SEL-421 is upgraded to version R112 or later, and the previous 1k PPS BNC cable is not removed (see Figure 4.63), the SEL-421 cannot use the IRIG time inputs.

Step 5. Type **TIME Q <Enter>** to confirm that the relay is operating in the high-accuracy IRIG (HIRIG) mode.

The relay displays information similar to *Figure 4.67*.

The Time Source will be HIRIG, indicating that the relay internal clock is locked to the high-accuracy IRIG input signal.

```
=>TIME Q <Enter>

Relay 1                                       Date: 10/06/2004  Time: 15:44:30.840
Station A                                     Serial Number: 0000000000

Time Source: HIRIG
Last Update Source: HIRIG

IRIG Time Mark Period:  1000.000000 ms

Internal Clock Period:  24.999995 ns

=>
```

Figure 4.67 Results of the TIME Q Command

TIME Q Descriptions

The **TIME Q** command provides details about relay timekeeping (see *Figure 4.67*). The SEL-421 internal clock is initially calibrated at the SEL factory. An external IRIG source is required to eliminate clock drift. For high-accuracy timekeeping functions such as synchrophasor measurement, the connected clock must support IEEE C37.118—Annex F, IRIG-B Control Bit assignments. The Time Source field provides the present high-accuracy timing input source; entries for this line are HIRIG and 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 4.10* lists the possible Last Update Source values for the SEL-421.

NOTE: When EPMU := Y, the relay year is updated automatically from the connected clock IEEE C37.118–Annex F, IRIG-B Control Bit information.

Table 4.10 Date/Time Last Update Sources

Time Input Source Mode (QQQQQ)	Priority	Time Source	Front Panel Editing?
HIRIG	High	Time/date from the high-accuracy IRIG-B input.	No
IRIG	High	Time/date from the IRIG-B format time base signal	No
COMM CARD	Low	Time/date signal from the communications card	Date and Time
DNP	Low	Time/date from the DNP communications port	Date and Time
MIRRORED BITS	Low	Time/date from the MIRRORED BIT port	Date and Time
ASCII TIME	Low	Time from the relay serial ports	Time only
ASCII DATE	Low	Date from the relay serial ports	Date only
NONV CLK	Low	Time/date from the nonvolatile memory clock	Date and Time
FRONT PANEL TIME	Low	Time from the front-panel TIME entry screen	Time only
FRONT PANEL DATE	Low	Time from the front-panel DATE entry screen	Date only

The IRIG 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 problems. If the IRIG Time Mark Period value changes significantly between successive **TIME Q** commands, there may be too much noise in the signal for the relay timekeeping function.

Adaptive Internal Clock Period Adjustment

The Internal Clock Period is the internal relay timekeeping period. The relay adjusts this master internal clock when you apply HIRIG mode timekeeping, adapting the internal relay clock for your installation temperature conditions. If you lose the HIRIG timing lock, the relay internal clock operates at this precisely adapted clock period until HIRIG mode is restored. Time tags for event reports during a loss of HIRIG mode timekeeping remain very accurate. Lower accuracy time sources do not adaptively adjust the internal relay clock period.

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. The TSOK Relay Word bit is at logical 1 when the relay is in HIRIG time mode. For this application example, use a PSV (Protection SELOGIC Variable) to monitor time keeping status.

PSV01 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 have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords: Terminal on page U.4.9* to change the default access level passwords). Also, you should be familiar with ACSELERATOR QuickSet (see *Section 3: PC Software*).

Step 1. Configure the communications port.

a. Start ACSELERATOR QuickSet.

b. On the top toolbar, open the **Communication** menu, and then click **Port Parameters**.

You will see the **Port Parameters** dialog box similar to *Figure 4.7*.

c. Select the **Data Speed**, **Data Bits**, **Stop Bits**, **Parity**, and **RTS/CTS** that match the relay settings.

The defaults are **9600**, **8**, **1**, **None**, and **Off**, respectively.

d. Click **OK** to update the ACSELERATOR QuickSet communications parameters.

e. Confirm that the **Communications Status** bar at the bottom of the ACSELERATOR QuickSet window says **Connected**.

Step 2. Confirm the correct ACSELERATOR QuickSet passwords.

a. Reopen the **Communication** menu and click **Port Parameters**.

b. Enter your Access Level 1 password in the **Level One Password** text box, and your Access Level 2 password in the **Level Two Password** text box.

c. Click **OK** to accept changes and close the dialog box.

Step 3. Read the present configuration in the SEL-421. Click **Settings > Read**.

The relay sends all configuration and settings data to ACSELERATOR QuickSet.

Step 4. Access the protection free-form SELOGIC settings.

a. Click the **+** mark next to **Group 1** in the **Settings** tree view.

b. Click the **Protection Logic 1** settings (see *Figure 4.68*).

Step 5. Enter the two lines of SELOGIC control equation programming in the **Protection Free-Form Logic Settings** shown in *Figure 4.68*.

Comments begin with the **#** character (see *Fixed SELOGIC Control Equations on page R.3.4*).

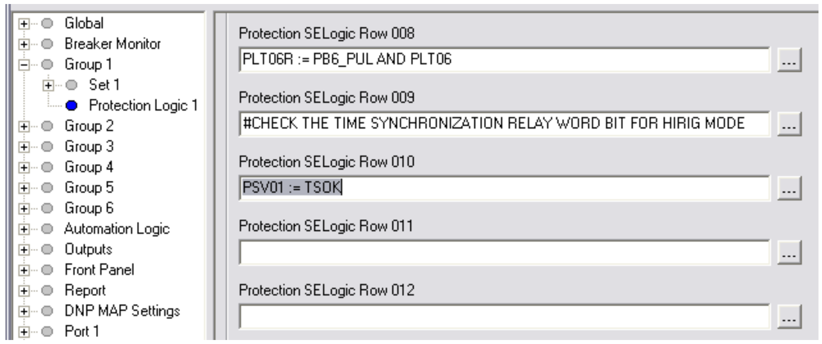


Figure 4.68 Programming a PSV in ACSELERATOR QuickSet

Step 6. Configure a control output to alarm a loss of HIRIG mode.

a. In the **Settings** tree view, double-click **Outputs** and then click **Main Board** (see *Figure 4.69*).

b. In the **OUT108 Main Board Outputs** text box, enter the OR NOT PSV01 condition to the preexisting OUT108 := NOT (SALARM OR HALARM) equation, as shown in *Figure 4.69*.

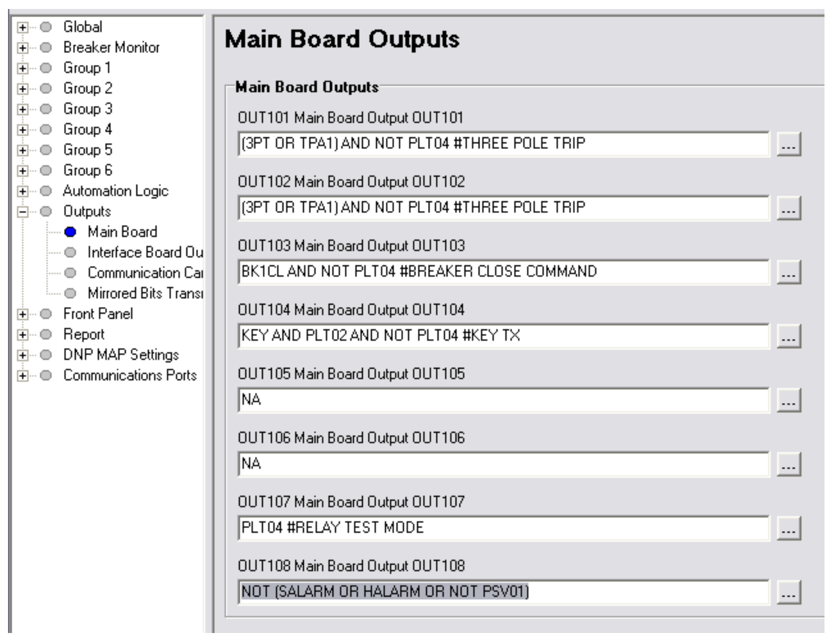


Figure 4.69 Setting OUT108 in ACSELERATOR QuickSet

Step 7. Click **File** > **Save** to save the new settings in ACSELERATOR QuickSet.

Step 8. Upload the new settings to the SEL-421.

a. Click **File** > **Send**.

ACSELERATOR QuickSet prompts you for the settings class or instance you want to send to the relay.

b. Click the check box for **Group 1** check box and the **Output** check box, as shown in the first dialog box of *Figure 4.56*.

c. Click **OK**.

ACSELERATOR QuickSet responds with a display similar to the second dialog box of *Figure 4.56*.

If you see no error message, the new settings are loaded in 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 SEL-421 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 SEL-421.

Step 2. Isolate the relay TRIP control output.

Step 3. Perform point-to-point continuity checks on the circuits associated with the SEL-421 to verify the accuracy and correctness of the ac and dc connections.

Step 4. Apply power to the relay (see *Connecting and Applying Power on page U.4.3*).

The green **ENABLED** LED on the front panel will illuminate.

Step 5. Use an SEL Cable C234A 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 on page U.4.6*).

Step 9. Change the default passwords (see *Changing the Default Passwords on page U.4.6*).

Step 10. Set the DATE and TIME (see *Making Simple Settings Changes on page U.4.13*).

Step 11. Use test sources to verify relay ac connections (see *Examining Metering Quantities on page U.4.33*).

Step 12. Verify control input connections (see *Operating the Relay Inputs and Outputs on page U.4.56* and *Control Inputs on page U.2.5*).

Step 13. Verify control output connections (see *Operating the Relay Inputs and Outputs on page U.4.56* and *Control Outputs on page U.2.7*).

Step 14. Perform protection element tests (see *Checking Relay Operation on page U.6.24*).

Step 15. Set the relay (see *Making Simple Settings Changes on page U.4.13*, *Section 1: Protection Application Examples in the Applications Handbook*, and *Section 1: Protection Functions in the Reference Manual*).

Step 16. Connect the relay for tripping/closing duty (see *AC/DC Connection Diagrams on page U.2.50*).

Step 17. From Access Level 2, use a communications terminal to issue the commands to clear the relay data buffers (listed in *Table 4.11*).

Table 4.11 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 (see *User's Guide Section 2: Installation*).

Step 19. Use the **MET** command or the ACSELERATOR QuickSet HMI to view relay metering to confirm secondary connections (see *Examining Metering Quantities on page U.4.33*).

Section 5
Front-Panel Operations

The SEL-421 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 liquid crystal display (LCD). Front-panel targets and other LED indicators give a quick look at SEL-421 operation status. You can perform often-used control actions rapidly by using the large direct-action pushbuttons. All of these features help you operate the relay from the front panel and include:

➤ Reading metering
➤ Inspecting targets
➤ Accessing settings
➤ Controlling relay operations

This section includes the following:

Front-Panel Layout

The front panel for the horizontal 3U (3 rack unit) SEL-421 configuration is shown in *Figure 5.1* (other configurations are similar).

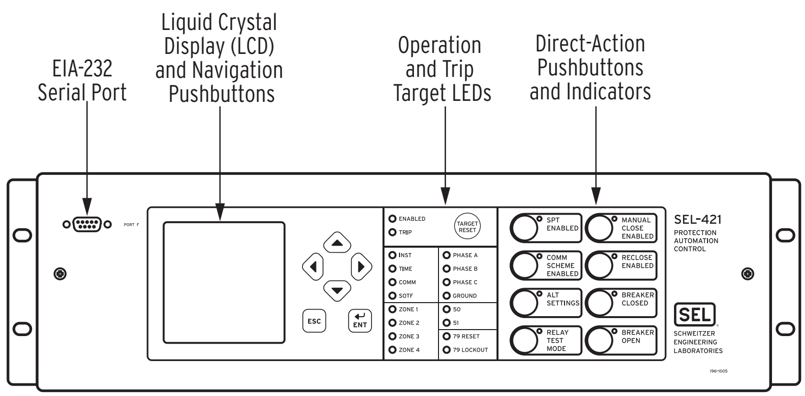


Figure 5.1 SEL-421 Front Panel (8 pushbutton model)

The front panel for the horizontal 5U (5-rack unit) SEL-421 configured with auxiliary **{TRIP}/{CLOSE}** pushbuttons is shown in *Figure 5.2*.

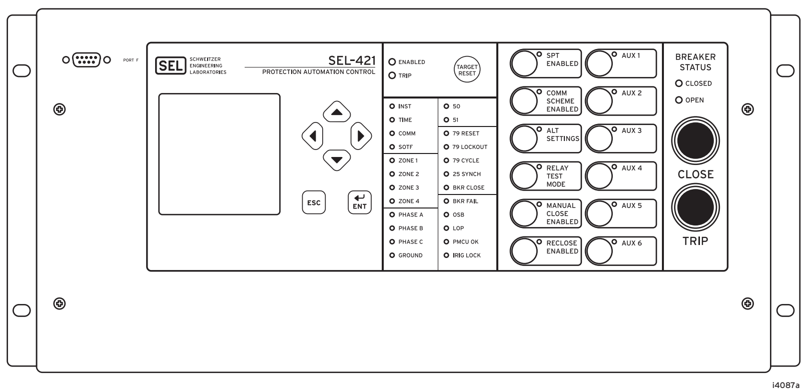


Figure 5.2 SEL-421 Front Panel (12 pushbutton model)

A 128 x 128 pixel LCD (liquid crystal display) 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 relate important power system metering parameters; you can easily change this ROTATING DISPLAY to suit your particular on-site monitoring needs. Use a simple and efficient menu structure to operate the relay from the front panel. With these menus you can quickly access SEL-421 metering, control, and settings.

Front-panel LEDs (light emitting diodes) indicate the relay operating status. You can confirm that the SEL-421 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 SEL-421 models feature auxiliary {TRIP}/{CLOSE} pushbuttons. These pushbuttons are electrically isolated from the rest of the relay. See *Auxiliary {TRIP}/{CLOSE} Pushbutton and Breaker Status LED Jumpers (select models only) on page U.2.29* for more information about this feature.

The SEL-421 front panel features large operator control pushbutton switches 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.

The SEL-421 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 *Communications Ports Connections on page U.2.47* and *Serial Communication on page R.4.2*.

Front-Panel LCD

The LCD is the prominent feature of the SEL-421 front panel. *Figure 5.3* shows the 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.

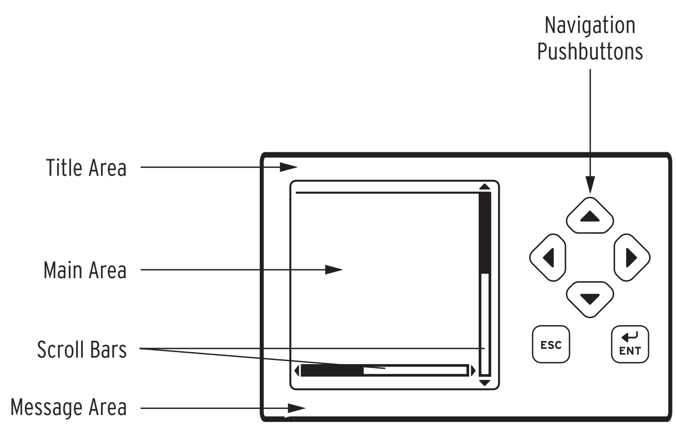


Figure 5.3 LCD Display and Navigation Pushbuttons

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. You can control the duration of the time out with relay setting FP_TO, listed in *Table 5.1*.

To set FP_TO, use the **SET F** (set front panel) settings from any communications port or use the Front Panel branch of the ACSELERATOR QuickSet **Settings** tree view. The maximum backlight time is one hour. Obtain this 60-minute maximum backlight time by setting FP_TO to 60 or to OFF. When the front-panel times out, the relay displays an automatic ROTATING DISPLAY, described later in this section under *Screen Scrolling on page U.5.5*.

Table 5.1 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 SEL-421 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 5.3*) to navigate these front-panel menus.

The navigation pushbuttons 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 5.4 shows an example of the highlighted item RELAY ELEMENTS in the MAIN MENU. When you highlight a menu item, pressing the {ENT} pushbutton selects the highlighted item.

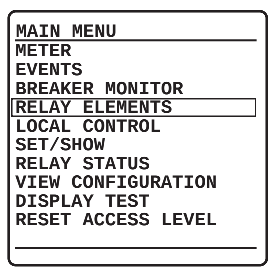


Figure 5.4 RELAY ELEMENTS Highlighted in MAIN MENU

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 {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 {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 display 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

The SEL-421 has 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:

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

The relay displays enabled metering screens in the order listed in *Table 5.2*. (see *Figure 5.19* for samples of the metering screens.) This sequence comprises the ROTATING DISPLAY.

NOTE: The initial display can present only the RMS_I line current screen. This can occur when you have not enabled any of the metering screens, alarm points, and display points.

Table 5.2 Metering Screens Enable Settings

Name	Description	Range	Default
RMS_V	RMS Line Voltage Screen	Y, N	N
RMS_I	RMS Line Current Screen[a]	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[a]	Y, N	Y
FUNDSEQ	Fundamental Sequence Quantities Screen	Y, N	N
FUND_BK	Fundamental Breaker Currents Screen	Y, N	N

[a] The default displays are RMS_I and FUND_VI.

Use the front-panel settings (the **SET F** command from a communications port or the Front Panel settings in ACSELERATOR QuickSet) to access the metering screen enables. Entering a **Y** (Yes) for a metering screen enable setting causes the corresponding metering screen to appear in the ROTATING DISPLAY. Entering an **N** (No) hides the metering screen from presentation in the ROTATING DISPLAY. *Figure 5.5* shows a sample ROTATING DISPLAY consisting of an example alarm points screen, an example display points screen, and the two factory-default metering screens, RMS_I and FUND_VI (the screen values in *Figure 5.5* are representative values).

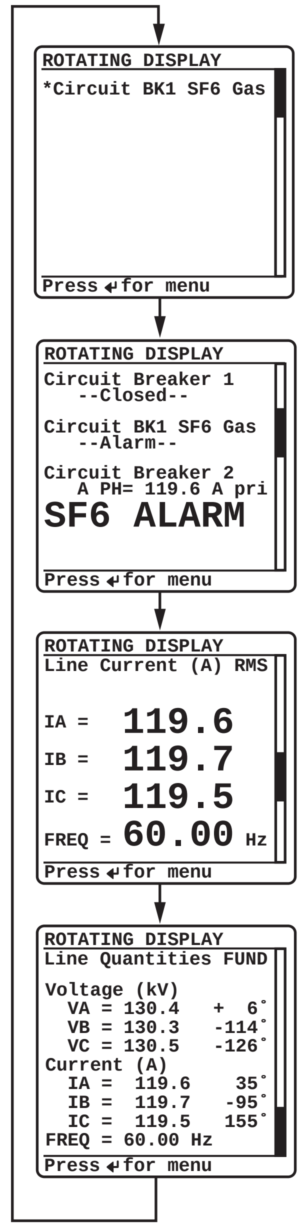


Figure 5.5 Sample ROTATING DISPLAY

The active alarm points are the first set of screens displayed in the ROTATING DISPLAY (see *Alarm Points on page U.5.7*). Each alarm points screen shows as many as 11 alarm conditions. The SEL-421 can present a maximum of 6 alarm points screens.

The active display points are the second set of screens in the ROTATING DISPLAY (see *Display Points on page U.5.10*). Each display points screen shows as many as 11 enabled display points. (With 96 display points, the SEL-421 can present a maximum of 9 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-settable period of time. Front-panel setting SCROLD defines the period of time 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 U.5.3*). 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 the 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 SEL-421 front-panel LCD that indicate alarm conditions in the power system. The relay uses alarm points to place these messages on the LCD.

Figure 5.6 shows a sample alarm points screen. The relay is capable of displaying up to 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.

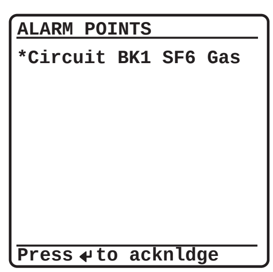


Figure 5.6 Sample Alarm Points Screen

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 5.3*. 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 double quotation marks. See *Example 5.1* for particular information on the format for entering SER point data.

Table 5.3 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
Clear 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. Up to 19 characters of the given alias are displayed, with a character reserved for the "*." The asterisk denotes if the element is asserted. Initially, an alarm point must be asserted in order 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 acknowledgement, as shown in *Example 5.1*.

EXAMPLE 5.1 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 5.6. 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" in order to enable alarm points screen display of this element.

While in the scrolling mode, the assertion of IN101 will cause Figure 5.6 to automatically display. Upon the deassertion of IN101, the asterisk will disappear, as in Figure 5.7.

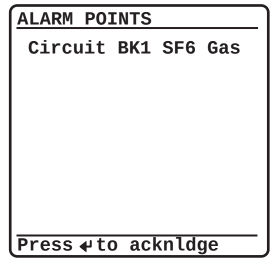


Figure 5.7 Deasserted Alarm Point

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 5.8.

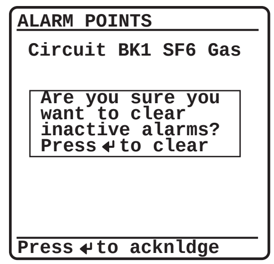


Figure 5.8 Clear Alarm Point Confirmation Screen

In the case that all alarms are deasserted, pressing the **{ENT}** pushbutton will allow the user to acknowledge and clear all alarms. After clearing, you will see a screen showing the results of the action, as depicted in Figure 5.9.

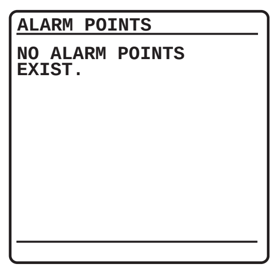


Figure 5.9 No Alarm Points Screen

Alarm points are not updated for a particular element if it has been deleted from the SER due to chatter criteria (see Automatic Deletion and Reinsertion on page A.3.36). 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 5.10 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.

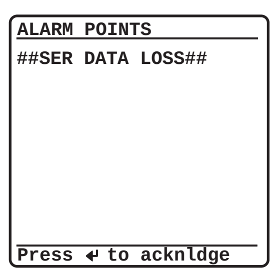


Figure 5.10 Alarm Points Data Loss Screen

Display Points

You can display messages on the SEL-421 front-panel LCD that indicate conditions in the power system. The relay uses display points to place these messages on the LCD.

Figure 5.11 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 96 possible display points; *Table 5.4* and *Table 5.5* 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.

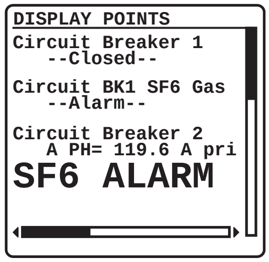


Figure 5.11 Sample Display Points Screen

To enable a display point, enter the display point settings listed in *Table 5.4* or *Table 5.5*. 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 5.4 Display Point Settings—Boolean

Description	Range
Relay Word Bit Name	Reference Manual, *Appendix A: Relay Word Bits*
Alias	ASCII string
Set String	ASCII string
Clear String	ASCII string
Text Size	S, D

Table 5.5 Display Point Settings—Analog

Description	Range
Analog Quantity Name	Reference Manual, *Appendix B: Analog Quantities*
User Text and Formatting	ASCII string
Text Size	S, D

Table 5.6 Display Point Settings—Boolean and Analog Examples

Example Display Point Setting Value	Example Display 12345678901234567890
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*
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 U.4.18* 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 5.2 Creating a Display Point

Display points screens provide operator feedback about the readiness of equipment connected to the SEL-421. A display points screen contains 11 display points; this example demonstrates a method to set the display point messages that are shown in Figure 5.11. The SEL-421 in this example has an additional I/O interface board.

This example is based on a three-pole circuit breaker, with breaker input settings entered as shown in Setting a Control Input for Circuit Breaker Auxiliary Contacts (52A): ACSELERATOR QuickSet on page U.4.67. The 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--"**

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 5.3 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 on-site 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 5.12 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.

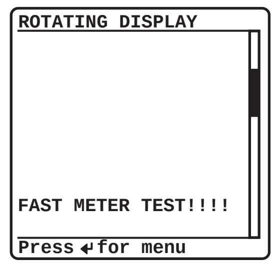


Figure 5.12 Fast Meter Display Points Sample Screen

Front-Panel Menus and Screens

Operate the SEL-421 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 5.4*). These additional menus allow you on-site access to metering, control, and settings for configuring the SEL-421 to your specific application needs. Use the following menus and screens to set the relay, perform local control actions, and read metering:

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

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 contrast adjustment 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 5.13 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.

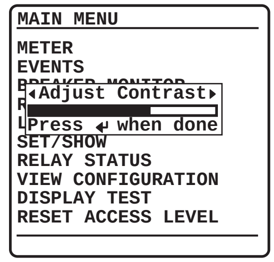


Figure 5.13 Contrast Adjustment

Password

⚠WARNING
This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.

The SEL-421 uses passwords to control access to settings and control menus. The relay has six access-level passwords. See *Changing the Default Passwords on page U.4.6* for more information on access levels and setting passwords. The SEL-421 front panel is at Access Level 1 upon initial power-up and after front-panel time out.

Password validation occurs only when you request a menu function that is at a higher access level than the presently authorized level. At this point, the relay displays a password entry screen, shown in *Figure 5.14*. This screen has a blank password field and an area containing alphabetic, numeric, and special password characters with a movable highlight box.

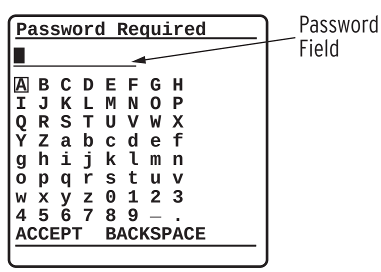


Figure 5.14 Enter Password Screen

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 5.15*. 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.

```
Password Invalid


The Password Entered
Is Not Sufficient for
The Required Access
Level.
```

Figure 5.15 Invalid Password Screen

Main Menu

The MAIN MENU is the starting point for all other front-panel menus. The relay MAIN MENU is shown in *Figure 5.16*. When the front-panel LCD is in the ROTATING DISPLAY, press the **{ENT}** pushbutton to show the MAIN MENU.

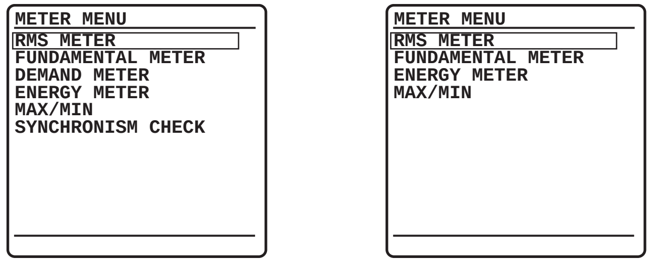
```
MAIN MENU
METER
EVENTS
BREAKER MONITOR
RELAY ELEMENTS
LOCAL CONTROL
SET/SHOW
RELAY STATUS
VIEW CONFIGURATION
DISPLAY TEST
RESET ACCESS LEVEL
```

Figure 5.16 MAIN MENU

Meter

The SEL-421 displays metering screens on the LCD. Highlight METER on the MAIN MENU screen to select these screens. The METER MENU, shown in *Figure 5.17*, allows you to choose the following metering screens corresponding to the relay metering modes:

- RMS METER
- FUNDAMENTAL METER
- DEMAND METER (if enabled)
- ENERGY METER
- MAX/MIN
- SYNCHRONISM CHECK (if enabled)



Demand Meter Enabled
(EDEM := ROL or
EDEM := THM)
Synchronism Check Enabled
(E25BK1 := Y or
E25BK2 := Y)

No Synchronism Check
No Demand Metering
(E25BK1 := N)
(E25BK2 := N)
(EDEM := OFF)

Figure 5.17 METER MENU Screens

NOTE: Global settings ESS (Enable Source Selection) and NUMBK (Number of Circuit Breakers) affect how the SEL-421 determines the line current and the voltage source for protection functions (directional elements, load encroachment, out-of-step logic, distance element, and loss-of-potential).

Combinations of relay Global settings ESS and NUMBK give you metering data for Line, Circuit Breaker 1, and Circuit Breaker 2 when you view RMS METER, FUNDAMENTAL METER, and MAX/MIN metering screens. The relay shows the METER SUBMENU of *Figure 5.18* so you can choose the line or circuit breaker data that you want to display.

For example, if you have two sources feeding a transmission line through two circuit breakers and you set ESS := 3, NUMBK := 2, then the SEL-421 measures BREAKER 1 currents, BREAKER 2 currents, and combined (Circuit Breakers 1 and 2) currents for LINE. The relay displays the METER SUBMENU screen when you make this settings configuration.

Other combinations of settings ESS and NUMBK do not require separate circuit breaker metering screens; for these configurations, the relay does not present the METER SUBMENU screen. See *Current and Voltage Source Selection on page R.1.2* and *Global Settings on page R.10.4* for information on configuring global settings ESS, NUMBK, LINEI, BK1I, and BK2I.

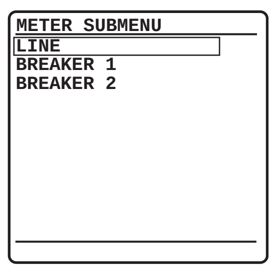


Figure 5.18 METER SUBMENU

The relay presents the meter screens in the order shown in each column of *Figure 5.19* and *Figure 5.20*. Once you have selected the type of metering data to display (RMS METER, FUNDAMENTAL METER, DEMAND METER, ENERGY METER, MAX/MIN, or SYNCHRONISM CHECK), you can scroll through the particular display column by pressing the **{Down Arrow}** pushbutton. Return to a previously viewed screen in each column by pressing the **{Up Arrow}** pushbutton. Press **{ESC}** to revert the LCD screen to the METER SUBMENU and METER MENU screens.

The metering screens show reset options for the MAX/MIN, ENERGY METER, PEAK DEMAND METER, and DEMAND METER metering quantities at the end of each screen column. Use the **{Left Arrow}** and **{Right Arrow}** pushbuttons to select a NO or YES response to the reset prompt, and then press **{ENT}** to reset the metering quantity.

LINE METERING

```
RMS LINE METER
VOLTAGE (kV)
  VA = x xxx.x
  VB = x xxx.x
  VC = x xxx.x
CURRENT (A)
  IA = x xxx.x
  IB = x xxx.x
  IC = x xxx.x
FREQ = 60.00 Hz
VDC1 = xxx.x V
VDC2 = xxx.x V
```

```
RMS LINE METER
VOLTAGE (kV)
 VAB = x xxx.x
 VBC = x xxx.x
 VCA = x xxx.x
```

```
RMS LINE METER
ACTIVE POWER (MW)
   A = -xx xxx.x
   B = -xx xxx.x
   C = -xx xxx.x
  3P = -xx xxx.x
REACTIVE (MVAR)
   A = -xx xxx.x
   B = -xx xxx.x
   C = -xx xxx.x
  3P = -xx xxx.x
```

```
RMS LINE METER
APPARENT POWER (MVA)
   A =  xx xxx.x
   B =  xx xxx.x
   C =  xx xxx.x
  3P =  xx xxx.x
POWER FACTOR
   A =  x.xx LAG
   B =  x.xx LAG
   C =  x.xx LAG
  3P =  x.xx LAG
```

```
FUND LINE METER
VOLTAGE (kV)
  VA = x xxx.x +xxx°
  VB = x xxx.x +xxx°
  VC = x xxx.x +xxx°
CURRENT (A)
  IA = x xxx.x +xxx°
  IB = x xxx.x +xxx°
  IC = x xxx.x +xxx°
FREQ = 60.00 Hz
VDC1 = xxx.x V
VDC2 = xxx.x V
```

```
FUND LINE METER
VOLTAGE (kV)
 VAB = x xxx.x +xxx°
 VBC = x xxx.x +xxx°
 VCA = x xxx.x +xxx°
```

```
FUND LINE METER
SEQUENCE I (A)
  I1 = x xxx.x +xxx°
 3I2 = x xxx.x +xxx°
 3I0 = x xxx.x +xxx°

SEQUENCE V (kV)
  V1 = x xxx.x +xxx°
 3V2 = x xxx.x +xxx°
 3V0 = x xxx.x +xxx°
```

```
FUND LINE METER
ACTIVE POWER (MW)
   A = -xx xxx.x
   B = -xx xxx.x
   C = -xx xxx.x
  3P = -xx xxx.x
REACTIVE (MVAR)
   A = -xx xxx.x
   B = -xx xxx.x
   C = -xx xxx.x
  3P = -xx xxx.x
```

```
FUND LINE METER
APPARENT POWER (MVA)
  A =  xx xxx.xx
  B =  xx xxx.xx
  C =  xx xxx.xx
 3P =  xx xxx.xx
POWER FACTOR
  A =  x.xx LEAD
  B =  x.xx LEAD
  C =  x.xx LEAD
 3P =  x.xx LEAD
```

```
DEMAND METER
CURRENTS (A)
 IA PEAK = xxx xxx.x
     DEM = xxx xxx.x
 IB PEAK = xxx xxx.x
     DEM = xxx xxx.x
 IC PEAK = xxx xxx.x
     DEM = xxx xxx.x
3I2 PEAK = xxx xxx.x
     DEM = xxx xxx.x
3I0 PEAK = xxx xxx.x
     DEM = xxx xxx.x
```

```
DEMAND METER
POWER (MW)
 A PEAK = xxx xxx.x
    DEM = xxx xxx.x
 B PEAK = xxx xxx.x
    DEM = xxx xxx.x
 C PEAK = xxx xxx.x
    DEM = xxx xxx.x
3P PEAK = xxx xxx.x
    DEM = xxx xxx.x
```

```
DEMAND METER
POWER(MVA)
  A PEAK = xxx xxx.x
     DEM = xxx xxx.x
  B PEAK = xxx xxx.x
     DEM = xxx xxx.x
  C PEAK = xxx xxx.x
     DEM = xxx xxx.x
 3P PEAK = xxx xxx.x
     DEM = xxx xxx.x
```

```
DEMAND METER

LAST PEAK DEMAND
RESET:
MM/DD/YYYY HH:MM:SS
 RESET PEAK NOW?
     NO   YES
```

```
DEMAND METER

LAST DEMAND RESET:
MM/DD/YYYY HH:MM:SS
 RESET DEMAND NOW?
     NO   YES
```

BREAKER METERING

```
RMS BREAKER n METER
CURRENTS (A)
  IA = x xxx.x
  IB = x xxx.x
  IC = x xxx.x
```

```
FUND BREAKER n METER
CURRENTS (A)
  IA = x xxx.xx +xxx°
  IB = x xxx.xx +xxx°
  IC = x xxx.xx +xxx°
```

n = 1 or 2, representing Circuit Breaker 1 or Circuit Breaker 2, respectively.

Figure 5.19 RMS, FUND, and DEMAND Metering Screens

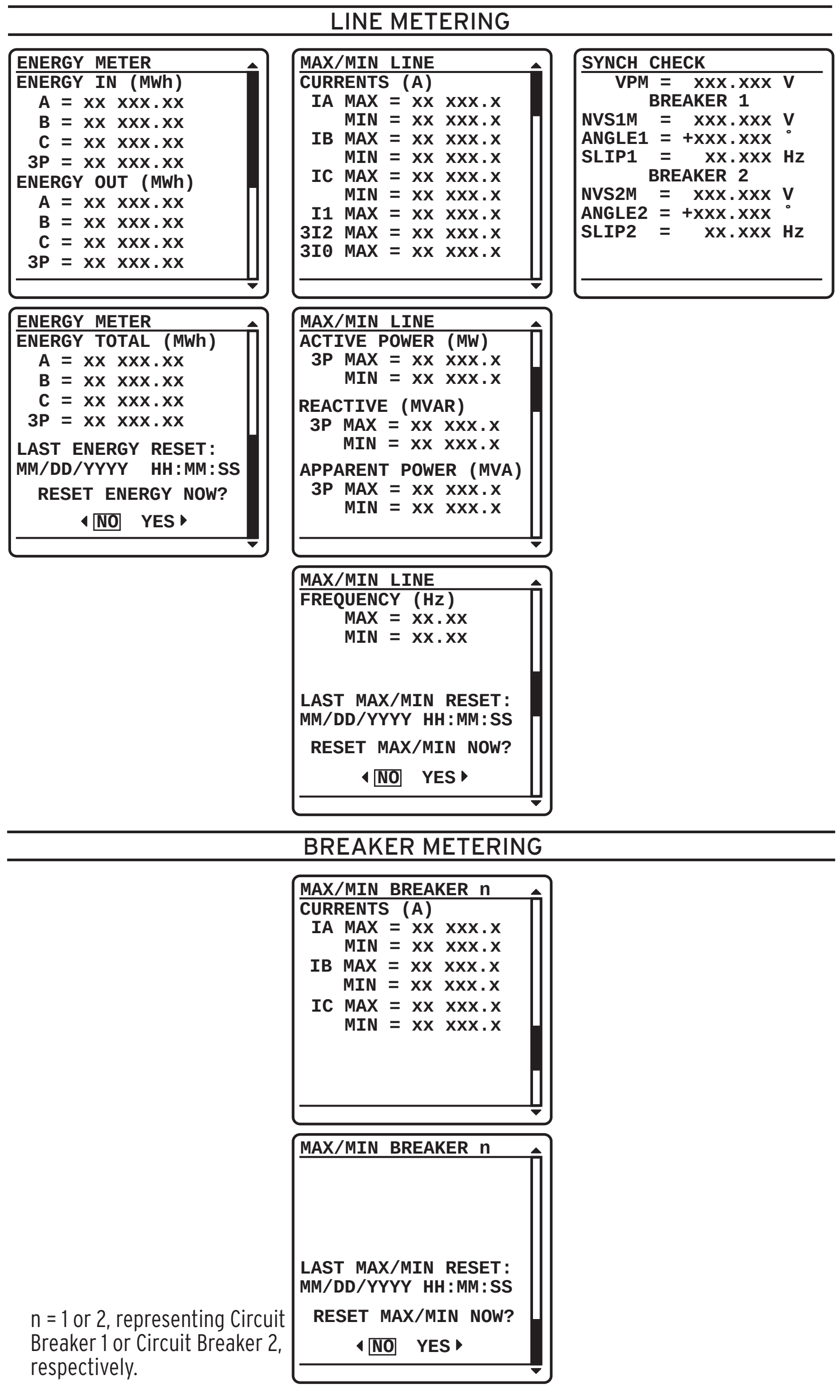


Figure 5.20 ENERGY, MAX/MIN, and SYNCH CHECK Metering Screens

Events

The SEL-421 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 A.3.12* 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. *Figure 5.21* 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 (*Front-Panel Automatic Messages on page U.5.34*) or programmable front-panel operator control pushbutton (*Front-Panel Operator Control Pushbuttons on page U.5.40*).

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 MAIN MENU.

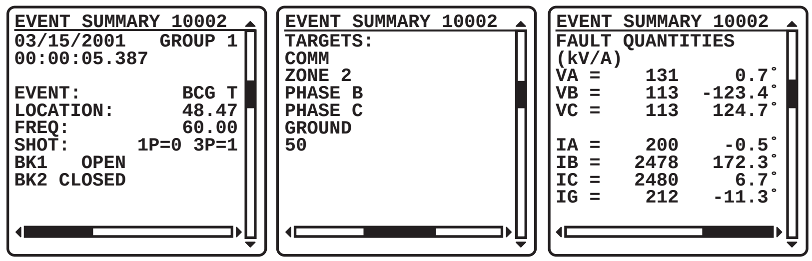


Figure 5.21 EVENT SUMMARY Screens

SER

The Sequential Events Recorder records state changes of user-programmable Relay Word bits. State changes are time-tagged for future analysis of relay operations during an event. See *SER (Sequential Events Recorder) on page A.3.34* 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 5.22*. SER events are also viewable using programmable front-panel operator-control pushbuttons; see *Front-Panel Operations on page U.5.1*.

Figure 5.22 illustrates the SER Events display screen. Data reported in this screen for each event are the SER number, 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. Using the navigation pushbuttons, the most recent 200 SER events are viewable on the front-panel display. The topmost event is the most recent event and the bottommost event is the oldest. The upper right of the screen displays the number 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.

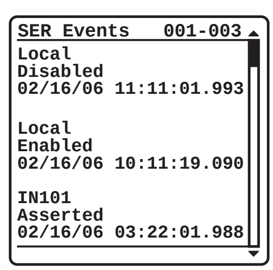


Figure 5.22 SER Events Screen

If no SER events are available, *Figure 5.23* is displayed.

Figure 5.23 No SER Events Screen

While viewing the SER events, front-panel pushbuttons provide navigation and control functions as indicated in *Table 5.7*.

Table 5.7 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.

Breaker Monitor

The SEL-421 features an advanced circuit breaker monitor. Select `BREAKER MONITOR` screens from the `MAIN MENU` to view circuit breaker monitor alarm data on the front-panel display.

Figure 5.24 shows sample breaker monitor display screens. The `BKR n ALARM COUNTER` screen displays the number of times the circuit breaker exceeded certain alarm thresholds (see *Circuit Breaker Monitor on page A.2.1*).

If you have two circuit breakers and have set NUMBK := 2, the alarm submenu in *Figure 5.24* appears first. Use the navigation pushbuttons to choose either `Circuit Breaker 1` or `Circuit Breaker 2`. Press **{ENT}** to view the selected circuit breaker monitor information. An example of the `Circuit Breaker 1 ALARM COUNTER` screen for a single-pole tripping circuit breaker is shown on the right side of *Figure 5.24*.

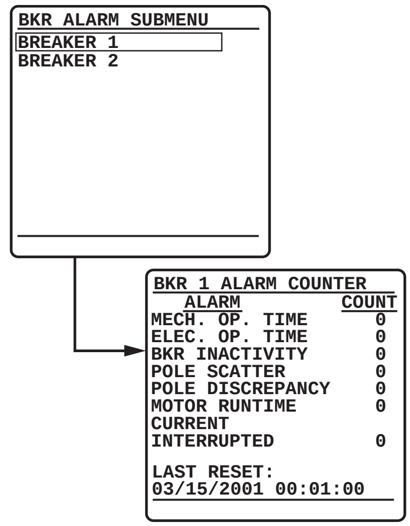


Figure 5.24 BREAKER MONITOR Report Screens

Relay Elements (Relay Word Bits)

You can view the RELAY ELEMENTS screen to check the state of the Relay Word bits in the SEL-421. 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 5.25* 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. The asterisk (*) in *Figure 5.25* indicates that this Relay Word bit position is reserved for future use.

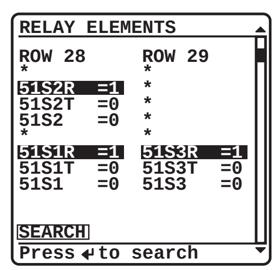


Figure 5.25 RELAY ELEMENTS Screen

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 2 rows every second for the first 10 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.

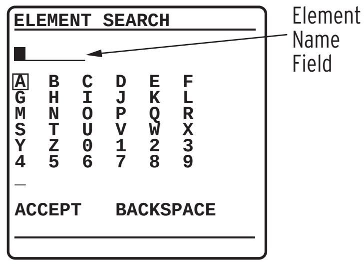


Figure 5.26 ELEMENT SEARCH Screen

Search mode allows you to find a specific relay target element quickly. *Figure 5.26* 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 SEL-421 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 5.27*, 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 (see *Operating the Relay Inputs and Outputs on page U.4.56* and *Password and Circuit Breaker Jumpers on page U.2.18*). 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 5.4*) appear in the local control bit names field between `--BREAKER CONTROL--` and `--OUTPUT TESTING--`, as shown in *Figure 5.27*. 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 5.27 LOCAL CONTROL Initial Menu

BREAKER CONTROL

The `BREAKER CONTROL` option presents a circuit breaker selection submenu if NUMBK := 2. Use the navigation pushbuttons and **{ENT}** to select the circuit breaker you want to control.

Figure 5.28 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. 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. The `BREAKER 1 STATUS` changes to `CLOSED`.

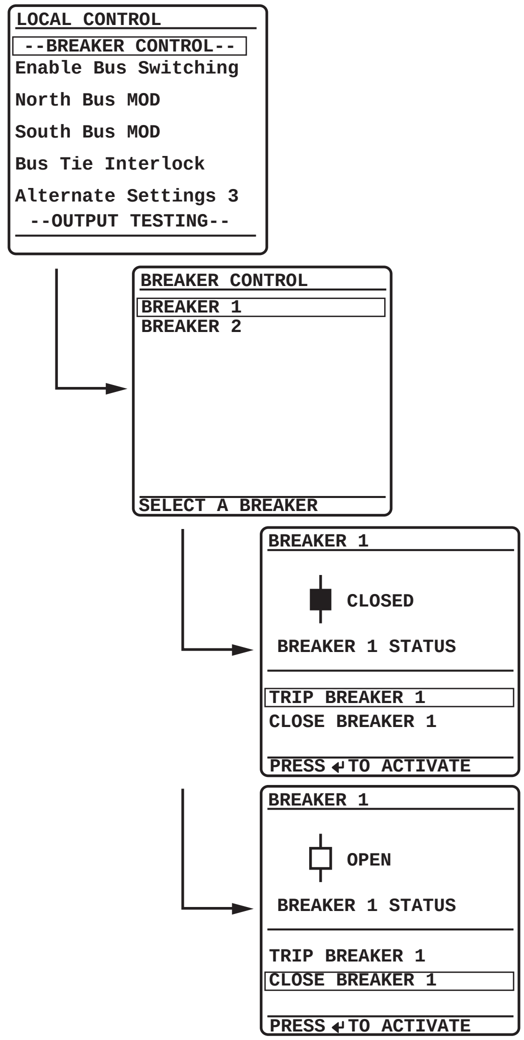


Figure 5.28 BREAKER CONTROL Screens

LOCAL CONTROL BITS

The relay provides 32 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 SEL-421 saves the states of the local bits in nonvolatile memory and restores the local bit states at relay power-up.

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.

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 5.9* defines the local bit SELOGIC settings available in the Front Panel settings class. *Figure 5.30* illustrates the logic that supervises all local bit operations (Set, Clear, Pulse).

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 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 5.29*, the 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 5.29* 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 5.29*. 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 5.29* 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.

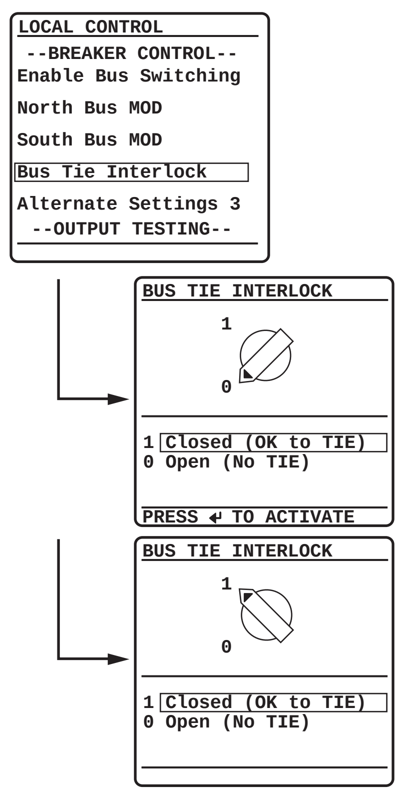


Figure 5.29 LOCAL CONTROL Example Menus

To enable a local bit, enter the local bit settings in *Table 5.8* (*n* = 1–32). 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 5.4* for particular information on enabling a local control bit.

Table 5.8 Local Bit Control Settings[a]

Description	Range	Default
Local Bit *n*	1–32	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 = 1–32

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 `Too many characters`.

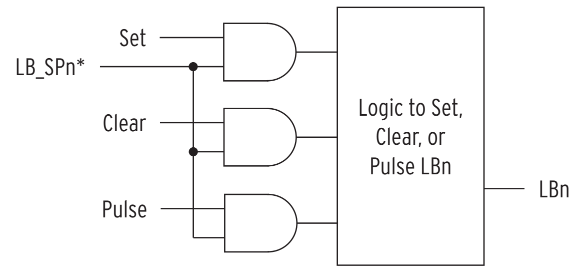
Table 5.9 Local Bit SELogic[a]

Description	Range	Default
Local Bit Supervision *n*	SELogic Equation, NA	1
Local Bit Status Display *n*	SELogic Equation, NA	LB*n*

[a] n = 1–32, only available if the corresponding local bit is defined.

Local Bit Supervision SELogic control equation provides supervision of Local Bit Set, Clear, and Pulse operations

Local Bit Status Display SELogic control equation returns the status of the local bit switch state.



*SELOGIC Control Equation

Figure 5.30 Local Bit Supervision Logic

EXAMPLE 5.4 Enabling Local Bit Control

This application example demonstrates a method to create one of the control points in the LOCAL CONTROL screens of Figure 5.29 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 U.4.18 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 J18C must be installed to perform output testing (see Main Board Jumpers on page U.2.18).

You can check for proper operation of the SEL-421 control outputs by using the OUTPUT TESTING submenu of the LOCAL CONTROL menu. A menu screen similar to *Figure 5.31* displays a list of the control outputs available in your relay configuration. For more information on output testing, see *Control Output on page U.4.56*.

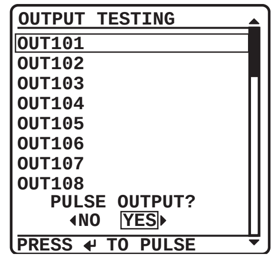


Figure 5.31 OUTPUT TESTING Screen

Set/Show

NOTE: You cannot use the front-panel SET/SHOW menus to change front-panel settings. To change front-panel settings, use a communications port interface and the **SET F** command or use the ACSELERATOR QuickSet Front Panel settings.

You can use the SET/SHOW menus to examine or modify SEL-421 port settings, global settings, active group settings, and date/time. From the front panel you can change only the settings classes and settings listed in *Table 5.10*.

Table 5.10 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 5.32 shows how to enter the 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 of *Figure 5.32*. Use the navigation pushbuttons to select the relay settings class (PORT, GROUP, and GLOBAL) or to change the ACTIVE GROUP or the DATE/TIME. 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 5.32*). 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 5.32* 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 5.32* 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 5.32*). 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 using a method similar to the method described in *Relay Elements (Relay Word Bits) on page U.5.21*. Place characters in the element name field (with the block cursor) using the navigation pushbuttons.

If the data you entered is 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 5.32). 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 5.32*).

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).

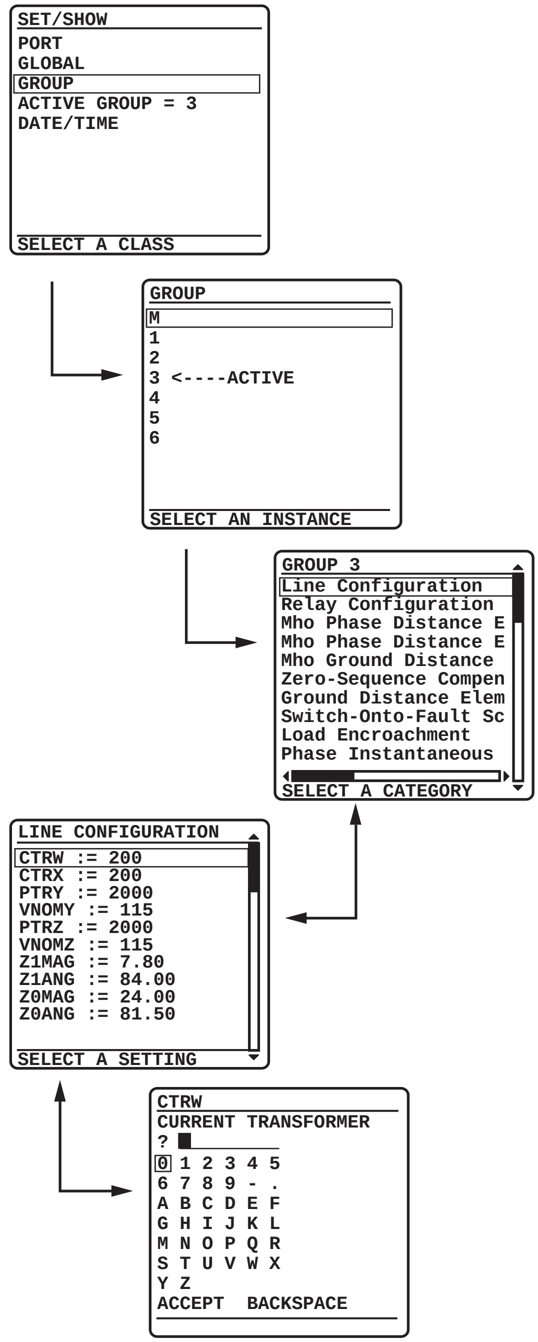
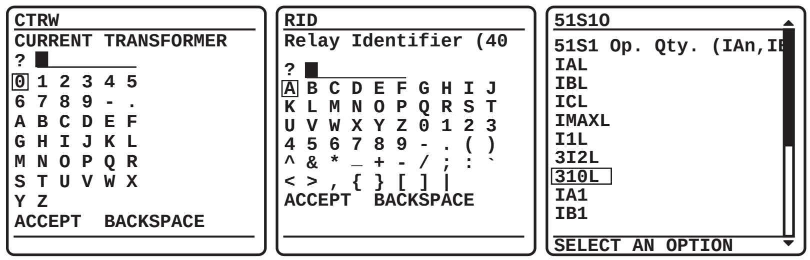


Figure 5.32 SET/SHOW Screens

The SEL-421 displays different settings entry screens depending on the settings type. For the CTRW setting in *Figure 5.32*, 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 5.33* shows examples of the settings input screens.



Basic Alphanumeric | Character or String or SELOGIC control equations | Setting Options

Figure 5.33 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 5.32*) 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 5.34*.

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.

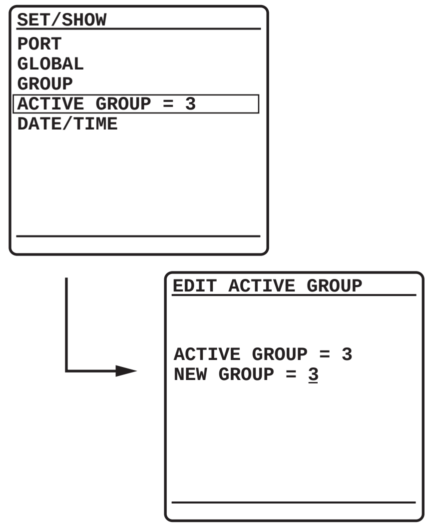


Figure 5.34 Changing the ACTIVE GROUP

DATE/TIME

Another submenu item of the SET/SHOW first screen (*Figure 5.32*) is the DATE/TIME screen shown in *Figure 5.35*. The SEL-421 generates date and time information internally, or you can use external high-accuracy time modes with time sources such as a GPS receiver.

Figure 5.35 is the relay date/time screen when a high accuracy source is in use. Possible time sources, qqqqq, are listed in *Table 4.10*. 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.

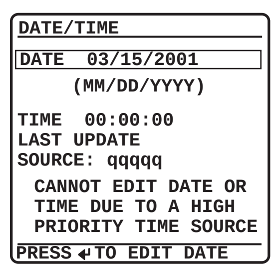


Figure 5.35 DATE/TIME Screen

When operating from a non-high-accuracy time source, you can use the front-panel DATE and TIME entry screens to set the date and time.

Figure 5.36 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 High-Accuracy Timekeeping on page U.4.71*.

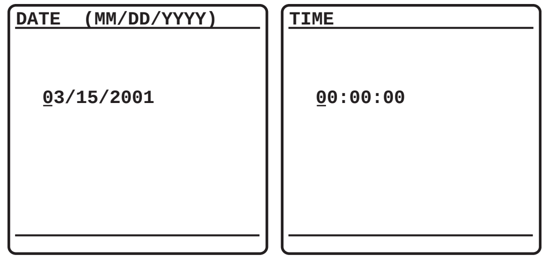


Figure 5.36 Edit DATE and Edit TIME Screens

To enable a high-accuracy external time source, connect an IRIG-B clock to the relay. For a discussion of the IRIG timing modes in the SEL-421 see *Configuring High-Accuracy Timekeeping on page U.4.71*. See *TIME Input Connections on page U.2.45* for more information on connecting time source inputs.

Relay Status

The SEL-421 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 5.37 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 U.6.38*.

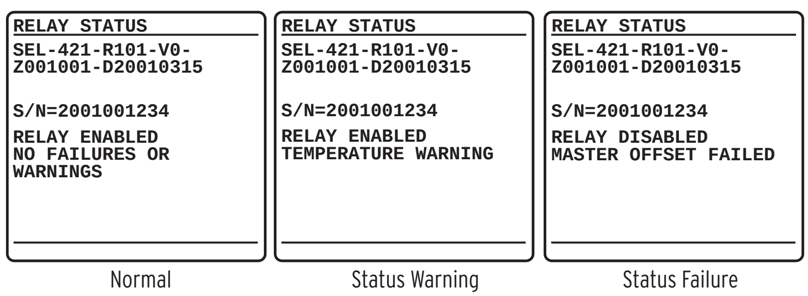


Figure 5.37 Relay STATUS Screens

View Configuration

You can use the front panel to view detailed information about the configuration of the firmware and hardware components in the SEL-421 Relay. 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 5.38*. 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-421-R101-V0-
  Z001001-D20010315

PART NUMBER:
  04210615X22XXHX
S/N=200101234
SELBOOT:
  BFID=SLBT-421-
  R101-V0-Z001001-
  D20010315
  CHECKSUM: D97F
```

```
CONFIGURATION INFO
MAINBOARD:
  CODE FLASH:   4 MB
  DATA FLASH:   8 MB
  RAM:          3 MB
  EEPROM:      32 KB

ANALOG INPUTS:
  W: CURRENTS:   5 A
  X: CURRENTS:   5 A
  Y: VOLTAGE:   67 V
  Z: VOLTAGE:   67 V
```

```
CONFIGURATION INFO
FIBER PORT:
  NOT INSTALLED

INTERFACE BOARDS:
  BOARD 1: 8 INPUTS
          15 OUTPUTS
  BOARD 2:NOT
          INSTALLED

EXTENDED FEATURES:
  DNP ACTIVE
```

```
CONFIGURATION INFO
COMMUNICATIONS CARD:
  MODEL: SEL-2701
  DESCR: Ethernet
  FID=SEL-2701-R101
  V0-Z000000-
  D20010307
  BFID=SLBT-2701-
  R100-V0-Z000000-
  D20010307
```

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

Figure 5.38 VIEW CONFIGURATION Sample Screens

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 5.39* 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.

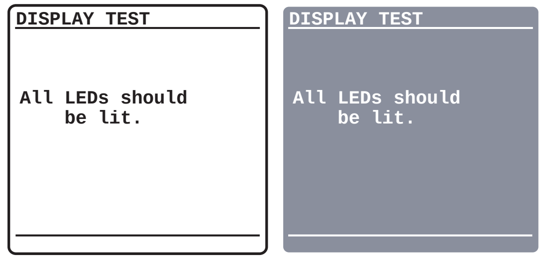


Figure 5.39 DISPLAY TEST Screens

Reset Access Level

The SEL-421 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 U.5.14* in this section). 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 5.40* and places the front panel at Access Level 1.

The relay automatically resets the access level to Access Level 1 upon front-panel timeout (setting FP_TO is not set to OFF). Use this feature to reduce the front-panel access level before the timeout occurs.

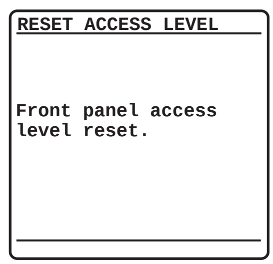


Figure 5.40 RESET ACCESS LEVEL Screen

Front-Panel Automatic Messages

The SEL-421 automatically displays alert messages. Any message generated due to an alert condition takes precedence over the normal ROTATING DISPLAY and the MAIN MENU. Alert conditions include these significant events:

- Alarm Point assertions
- Event reports and trips (user defined)
- Status warnings
- Status failures

In order 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 described in *Table 3.6 on page A.3.29* 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 5.41*.

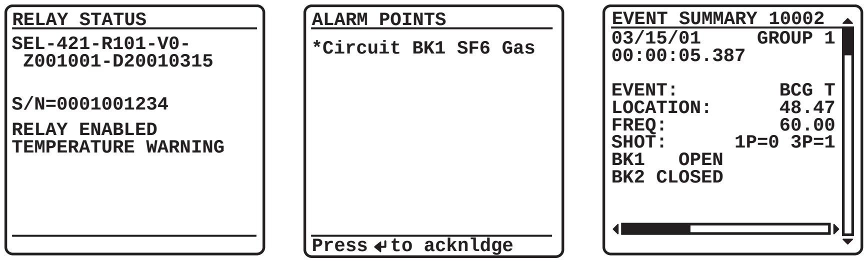


Figure 5.41 Sample Status Warning, Alarm Point Assertion, and Trip EVENT SUMMARY Screens

If you are on site using the SEL-421 front panel in menus and screens other than the MAIN MENU and a status warning occurs, 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 5.42* 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.

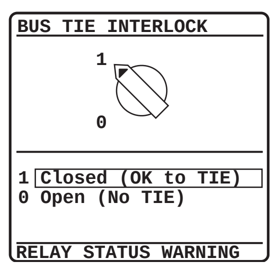


Figure 5.42 Sample Status Warning in the LCD Message Area

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 U.6.45*).

Operation and Target LEDs

The SEL-421 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-421 provides 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 subsection. Settings T*n*_LED are SELOGIC control equations that, when asserted during a relay trip event, light the corresponding LED. Parameter *n* is a number from 1 through 24 that indicates each LED. LED positions are described in parenthesis next to each LED in *Figure 5.43*.

Program settings 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 (up to eight characters) with settings T*n*LEDA. The asserted and deasserted colors for the LED are determined with settings T*n*LEDC. Options include red, green, amber, or off.

After setting the target LEDs, issue the **TAR R** command to reset the target LEDs. For a concise listing of the default programming on the front-panel LEDs, see *Front-Panel Settings on page R.10.37*.

Use the slide-in labels to mark the LEDs with custom names. Included on the SEL-421 Product Literature CD are Customer Label Templates to print labels for the slide-in label carrier.

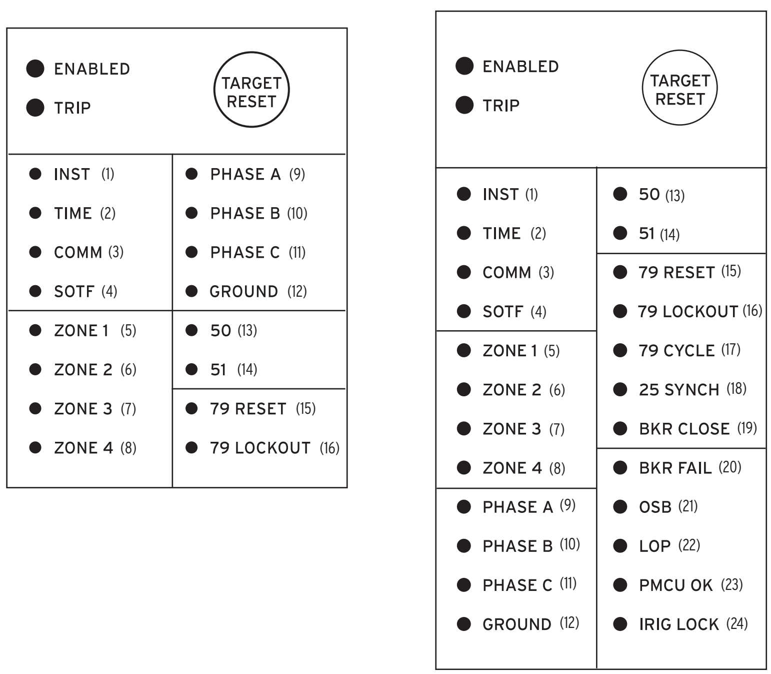


Figure 5.43 Factory Default Front-Panel Target Areas (16 or 24 LEDs)

Figure 5.43 shows the arrangement of the operation and target LEDs region into several areas as described in *Table 5.11*.

Table 5.11 Front-Panel Target LEDs

Label	Function
ENABLED, TRIP	Operational
INST, TIME, COMM, SOTF	Trip Type
ZONE 1, ZONE 2, ZONE 3, ZONE 4	Zone Activated
PHASE A, PHASE B, PHASE C, GROUND	Phase(s) or Ground
50, 51	Instantaneous and Time-Delayed Overcurrent
79 RESET, 79 LOCKOUT, 79 CYCLE[a]	Recloser Status
25 SYNCH[a], BKR CLOSE[a], BKR FAIL[a], OSB[a], LOP[a]	Miscellaneous Status
PMCU OK[a], IRIG LOCKED[a]	Synchrophasor Status

[a] Only available in 24 LED models..

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 (except for the **ENABLED** LED and the Recloser Status area 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.

Lamp Test Function With LCD DISPLAY TEST Menu

The LCD menus provide a front-panel `DISPLAY TEST` mode. This menu-activated lamp test, from the `DISPLAY TEST` menu, does not reset the target LEDs (see *Display Test on page U.5.33*).

Other Target Reset Options

You can reset the target LEDs with the ASCII command **TAR R**; see *TARGET on page R.9.50* 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, as shown in *Figure 1.81 on page R.1.127*. TRGTR is the factory default setting for the unlatch trip SELOGIC control equation, ULTR, in group settings. See *Table 1.75 on page R.1.110*.

You can reset the targets from the ACSELERATOR QuickSet **Control** branch of the HMI tree view. Programming specific conditions in the SELOGIC control equation RSTTRGT 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.

Trip Type

The SEL-421 indicates essential information about the most recent relay trip event with the LEDs of the Trip Type area. These trip types are **INST**, **TIME**, **COMM**, and **SOTF**. For information on setting the corresponding trip logic, see *Trip Logic on page R.1.107*.

The **INST** target LED illuminates, indicating operation of the SEL-421 instantaneous elements. This LED lights if elements M1P (the Zone 1 mho phase distance element) or Z1G (the Zone 1 mho ground distance element) pick up and the relay has not illuminated the **COMM** or **SOTF** targets.

The **TIME** target LED indicates that a timed relay element caused a relay trip. *Table 5.12* lists the elements that activate the **TIME** LED in the factory default settings.

Table 5.12 TIME Target LED Trigger Elements—Factory Defaults

Mho	Quadrilateral
M2PT	Z2GT
M3PT	Z3GT
M4PT	Z4GT
M5PT	Z5GT

The **COMM** LED illuminates, indicating that tripping resulted from a communications-assisted trip. The relay lights the **COMM** target when there is a relay tripping condition and the Relay Word bit COMPRM (communications-assisted trip permission) asserts.

The **SOTF** target LED indicates that the switch-onto-fault protection logic operated. The relay illuminates the **SOTF** target when there is a relay tripping condition and the Relay Word bit SOTFT (switch-onto-fault trip) asserts.

Zone Activated

The zone activated area target indicators are the **ZONE 1**, **ZONE 2**, **ZONE 3**, and **ZONE 4** LEDs. These targets illuminate when the corresponding zone distance elements pick up and there is a relay tripping condition.

In factory default programming, the lowest zone LED has priority; only the LED corresponding to the closest protection zone latches for distance element pickups.

The **ZONE 1** target illuminates if either the M1P or Z1G distance elements operated or if the high-speed Zone 1 elements operated.

The **ZONE 2** target illuminates if either the M2P or Z2G distance elements operated or if the high-speed Zone 2 elements operated and the similar elements in Zone 1 did not operate.

The **ZONE 3** target illuminates if either the M3P or Z3G distance elements operated or if the high-speed Zone 3 elements operated and the similar elements in Zone 1 and Zone 2 did not operate.

The **ZONE 4** target illuminates if either the M4P or Z4G distance elements operated and the similar elements in Zone 1, Zone 2, and Zone 3 did not operate.

Phase(s) or Ground

The phase(s) or ground targets illuminate according to the SEL-421 special targeting logic. This logic accurately classifies which phase, phases, and/or ground were involved in a trip event.

The PHASE A target LED lights for faults on the power system A-phase. Single-phase-to-ground faults from A-phase to ground illuminate both the **PHASE A** and **GROUND** targets. A phase-to-phase fault between A-phase and B-phase illuminates the **PHASE A** target and the **PHASE B** target.

The relay displays faults involving other phase combinations similarly. If the phase-to-phase fault includes ground, the relay also lights the **GROUND** target. The relay lights the **PHASE A**, **PHASE B**, and **PHASE C** target LEDS for a three-phase fault.

Instantaneous and Time-Delayed Overcurrent

The **50** target LED indicates that an instantaneous overcurrent element picked up. These elements are the nondirectional 50Pn phase overcurrent elements, 50Qn negative-sequence overcurrent elements, and the 50Gn ground overcurrent elements, where *n* is the overcurrent level; *n* = 1, 2, 3, and 4.

The **51** target LED illuminates if a time-overcurrent element has timed out. The relay lights this LED if any of the selectable operating quantity inverse-time overcurrent elements 51S1T, 51S2T, and 51S3T assert.

Recloser Status

The **79 RESET**, **79 LOCKOUT**, and **79 CYCLE** target LEDs show the operating status of the SEL-421 reclosing function.

The **79 RESET** LED indicates that the relay recloser is in the reset or ready-to-reclose state for Circuit Breaker 1 (Relay Word bit BK1RS is asserted).

The **79 LOCKOUT** target illuminates when the relay has completed the reclose attempts unsuccessfully (a drive-to-lockout condition), or when other programmed lockout conditions exist.

The **79 CYCLE** target illuminates when the relay the relay is in the auto-reclose cycle state for Circuit Breaker 1.

Miscellaneous Status

The **25 SYNCH**, **BKR CLOSE**, **BKR FAIL**, **OSB**, and **LOP** target LEDs illuminate in the SEL-421 for miscellaneous status conditions.

The **25 SYNCH** LED illuminates when the relay detects that the Circuit Breaker 1 voltages are within Synchronism Angle 1 (Relay Word bit 25A1BK1 is asserted). See *Synchronism Check on page R.2.50* for complete details.

The **BKR CLOSE** LED illuminates when the relay detects a breaker close command for Circuit Breaker 1 (Relay Word bit BK1CL is asserted).

The **BKR FAIL** LED illuminates when the relay detects a breaker failure trip for Circuit Breaker 1 (Relay Word bit BFTRIP1 is asserted). See *Circuit Breaker Failure Trip Logic on page R.1.123* for complete details.

The **OSB** LED illuminates when the relay detects an out-of-step condition (Relay Word bit OSB is asserted). See *Out-of-Step Logic on page R.1.44* for complete details.

The **LOP** LED illuminates when the relay detects a loss-of-potential condition (Relay Word bit LOP is asserted). See *Loss-of-Potential Logic on page R.1.24* for complete details.

Synchrophasor Status

The **PMCU OK** target LED illuminates when the relay is enabled for synchrophasor measurement (Relay Word bits TSOK and PMDOK are asserted). See *Synchrophasor Relay Word Bits on page R.7.18* for complete details.

The **IRIG LOCKED** target LED illuminates 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 on page U.4.71* for complete details.

Front-Panel Operator Control Pushbuttons

The SEL-421 front panel features large operator control pushbuttons coupled with amber annunciator LEDs for local control. *Figure 5.44* shows this region of the relay front panel with factory default configurable front-panel label text. The SEL-421 provides either 8 or 12 pushbuttons depending on ordering option.

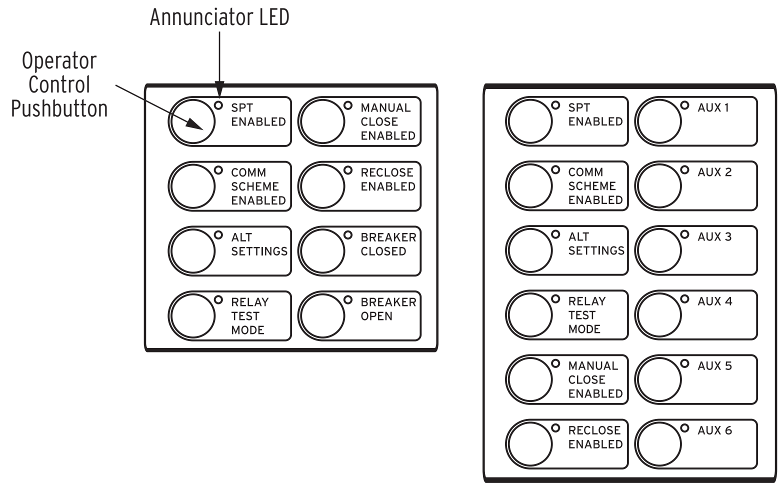


Figure 5.44 Operator Control Pushbuttons and LEDs (8 or 12 Pushbuttons)

Factory default programming associates specific relay functions with the eight pushbuttons and LEDs, as listed in *Table 5.13*. For a concise listing of the default programming for the front-panel pushbuttons and LEDs, see *Front-Panel Settings on page R.10.37*.

Table 5.13 Operator Control Pushbuttons and LEDs—Factory Defaults

Label	Function
SPT ENABLED	Enable single-pole tripping
COMM SCHEME ENABLED	Enable communications scheme
ALT SETTINGS	Switch between setting group 1 and setting group 2[a]. The LED is illuminated when group 1 is not the active setting group.
RELAY TEST MODE	Enter test mode
MANUAL CLOSE ENABLED	Enable manual closing
RECLOSE ENABLED	Enable automatic reclosing
AUX n[b]	Auxiliary
BREAKER CLOSED[c]	Close Circuit Breaker 1
BREAKER OPEN[c]	Open Circuit Breaker 1

[a] With factory settings, the {ALT SETTINGS} pushbutton must be pressed and held for three seconds before the SEL-421 will change setting groups.
[b] Available on 12-pushbutton models; n is the number of AUX buttons available depending on ordering option.
[c] Not available on model with auxiliary {TRIP/CLOSE} pushbuttons.

Press the operator control pushbuttons momentarily to toggle on and off the functions listed adjacent to each LED/pushbutton combination. The **CLOSE** and **TRIP** pushbuttons momentarily assert the close and trip relay outputs after a short delay.

The operator control pushbuttons and LEDs are programmable. *Figure 5.45* describes the factory defaults for the 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, and Event Summaries, and SER. 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 readily change the default LED functions. Use the slide-in labels to mark the pushbuttons and pushbutton LEDs with custom names to reflect any programming changes that you make. The labels are keyed; you can insert each Operator Control Label in only one position on the front of the relay. Included on the SEL-421 Relay Product Literature CD are word processor templates for printing slide-in labels. See the instructions included in the Configurable Label kit for more information on changing the slide-in labels.

The SEL-421 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 through PB12 are the “follow” outputs of operator control pushbuttons. Relay Word bits PB1_PUL through PB12PUL are the pulsed outputs.

Annunciator LEDs for each operator control pushbutton are PB1_LED through PB12LED. The factory defaults programmed for these LEDs are protection latches (PLT01, for example), settings groups, Relay Word bits (NOT SG1), and the status of the circuit breaker auxiliary contacts (52AA1). The asserted and deasserted colors for the LED are determined with settings PB*n*COL. Options include red, green, amber, or off.

You can change the LED indications to fit your specific control and operational requirements. This programmability allows great flexibility and provides operator confidence and safety, especially in indicating the status of functions that are controlled both locally and remotely.

SELogic Factory Setting	Operator Control Pushbutton / LED	Description
PBn_LED = NOT E3PT #SPT ENABLED	SPT ENABLED	Press this operator control pushbutton to enable/disable single-pole tripping. The corresponding LED illuminates to indicate the SPT ENABLED state.
PBn_LED = PLT02 #COMM SCHEME ENABLED	COMM SCHEME ENABLED	Press this operator control pushbutton to enable/disable communications-assisted tripping. The corresponding LED illuminates to indicate the COMM SCHEME ENABLED state.
PBn_LED = NOT SG1 #ALT SETTINGS	ALT SETTINGS	Press this operator control pushbutton for three seconds to switch the active setting group between the main setting group (Setting Group 1) and the alternate setting group (Setting Group 2). The corresponding LED illuminates to indicate the ALT SETTINGS state.
PBn_LED = PLT04 #RELAY TEST MODE	RELAY TEST MODE	Press this operator control pushbutton to enable/disable the relay test mode. The corresponding LED illuminates to indicate the RELAY TEST MODE state.
PBn_LED = PLT05 #MANUAL CLOSE ENABLED	MANUAL CLOSE ENABLED	Press this operator control pushbutton to enable/disable local front-panel circuit breaker closing using the CLOSE pushbutton. The corresponding LED illuminates to indicate the MANUAL CLOSE ENABLED state.
PBn_LED = PLT06 #RECLOSE ENABLED	RECLOSE ENABLED	Press this operator control pushbutton to enable/disable the automatic recloser. The corresponding LED illuminates to indicate the RECLOSE ENABLED state.
PBn_LED = 0 #AUX	AUX	Press this operator control pushbutton to enable/disable user-programmed auxiliary control. Program the corresponding LED to indicate the required state. NOTE: This operator control does not perform any function with the factory settings.
PBn_LED = 52ACL1 and 52BCL1 and 52CCL1 #BREAKER CLOSED	BREAKER CLOSED	Press this operator control pushbutton to close Circuit Breaker 1. The corresponding BREAKER CLOSED LED illuminates indicating that Circuit Breaker 1 is closed. The MANUAL CLOSE ENABLED function above enables and disables the CLOSE pushbutton.
PBn_LED = NOT 52ACL1 and 52BCL1 and 52CCL1 #BREAKER OPEN	BREAKER OPEN	Press this operator control pushbutton to trip Circuit Breaker 1. The corresponding BREAKER OPEN LED illuminates, indicating that Circuit Breaker 1 is open.

Figure 5.45 Factory Default Operator Control Pushbuttons

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Section 6
Testing and Troubleshooting

This section contains guidelines for determining and establishing test routines for the SEL-421 Relay. 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 these occur. The subsection *Relay Troubleshooting on page U.6.42* contains a quick-reference table for common relay operation problems.

Topics, tests, and troubleshooting procedures presented in this section include the following:

The SEL-421 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.

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 the SEL-421; 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 SEL-421 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 6.1*.

Table 6.1 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-421 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 U.4.33*).

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 FM**, **TEST DNP**, and **TEST DB** to check SCADA interfaces. (See *TEST DB on page R.9.52* for information on these relay commands.)

Table 6.2 lists guidelines for commissioning testing. For further discussion of these tests, see *Checking Relay Operation on page U.6.24*.

Table 6.2 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.

Maintenance Testing

The SEL-421 uses extensive self-testing routines and features 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 6.3*.

Table 6.3 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 SEL-421 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 A.2.1*.

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.

The SEL-421 is 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 6.3*. 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

The SEL-421 provides the following features to assist you during relay testing:

- Metering
- High-resolution oscillography
- Event reports
- Event summary reports
- SER (Sequential Events Recorder) reports

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 FM**
- **TEST DNP**

In addition, the SEL-421 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.

Test Features

Metering

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 *MET on page R.9.28*, *Meter on page U.5.15*, *HMI Meter and Control on page U.3.21*, and *Examining Metering Quantities on page U.4.33* for more information.

High-Resolution Oscillography

NOTE: Control Inputs are sampled 16 times per cycle, and the raw binary data (prior to debounce timer conditioning) is available in high-resolution oscillography—see Figure 3.1 on page A.3.3. The COMTRADE data labels for raw control input data are IN101–IN107, and optionally IN201–IN2nn, IN301–IN3nn, where nn = 01–08 or 01–24.

The SEL-421 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 the SEL-5601 Analytic Assistant 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 A.3.8* for more information.

Event Reports

NOTE: Control Inputs are sampled 16 times per cycle, and then conditioned by a debounce timer. The resulting Relay Word bits are updated 8 times per cycle and are available in standard event report files—see Figure 3.1 on page A.3.3.

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 ACSELERATOR QuickSet to view event reports. See *Event Reports, Event Summaries, and Event Histories on page A.3.11* 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 A.3.28* 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 *SER (Sequential Events Recorder) on page A.3.34*.

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 R.9.50* and *Operation and Target LEDs on page U.5.36*).

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 ACSELERATOR QuickSet HMI, and from the front-panel LCD (see *PULSE on page R.9.37*, *HMI Meter and Control on page U.3.21*, and *Operation and Target LEDs on page U.5.36*).

TEST DB Command

Use the **TEST DB** command for testing the communications card relay database. The **TEST DB** command can be used to override any value in the relay database. Since the relay database provides data to the Ethernet card interfaces, the **TEST DB** command can also be used to test the data read operations of the DNP3 LAN/ WAN or IEC 61850 protocols on an installed Ethernet card. Use the **MAP 1** command and the **VIEW1** command to inspect the relay database (see *MAP on page R.9.27*). You must be familiar with the relay database structure to use the **TEST DB** command effectively; see *Communications Card Database on page R.4.18* for more information.

TEST DNP Command

Use the **TEST DNP** command to test the serial DNP3 interface. Values you enter in the DNP3 map are override values. Use the **TEST DNP** command to write override values in the serial DNP3 map. The **TEST DNP** command does not affect data on the DNP3 LAN/WAN interface. For more information on serial DNP3 and the SEL-421, see *DNP3 Communications on page R.6.1*.

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, and so on). For more information on Fast Meter and the SEL-421, see *SEL Communications Protocols on page R.5.1*.

Low-Level Test Interface

The SEL-421 has a low-level test interface between the calibrated input module and the processing module. You can check the relay in two ways: by using secondary injection testing, or by applying low-magnitude ac voltage signals to the low-level test interface.

Connection

⚠CAUTION
Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can reuslt 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.

The top circuit board is the relay main board and the bottom circuit board is the input module board. At the right side of the relay main board (the top board) is the processing module. The input to the processing module is multipin connector J20, the analog or low-level test interface connection. Receptacle J20 is on the right side of the main board; for a locating diagram, see *Figure 2.19*.

Figure 6.1 shows the low-level interface connections. Note the nominal voltage levels, current levels, and scaling factors listed in *Figure 6.1* that you can apply to the relay. Never apply voltage signals greater than 6.6 Vp-p sinusoidal signal (2.33 Vrms) to the low-level test interface.

To use the low-level test interface, perform the following steps:

Step 1. Remove any cables connected to serial ports on the front panel.

Step 2. Loosen the four front-panel screws (they remain attached to the front panel), and remove the relay front panel.

Step 3. Remove the 34-pin ribbon cable from the front panel by pushing the extraction ears away from the connector.

Step 4. Remove the ribbon cable from the main board J20 receptacle.

Step 5. Substitute a test cable with the signals specified in *Figure 6.1*.

Step 6. Reconnect the cables removed in *Step 4* and replace the relay front-panel cover.

Step 7. Replace any cables previously connected to serial ports on the front panel.

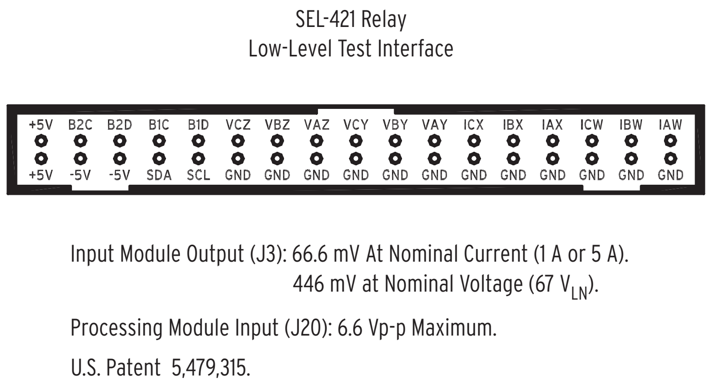


Figure 6.1 Low-Level Test Interface

Main Board Processing Module Tests

Use signals from the SEL-4000 Low-Level Relay Test System to test the relay processing module. Apply appropriate signals to the low-level test interface J20 from the SEL-4000 Relay Test System (see *Figure 6.1*). 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-421 in the SEL-5401 Relay Test System Software are shown in *Table 6.4* and *Table 6.5*.

Table 6.4 UUT Database Entries for SEL-5401 Relay Test System Software—5 A Relay

	Label	Scale Factor	Unit
1	IAW	75	A
2	IBW	75	A
3	ICW	75	A
4	IAX	75	A
5	IBX	75	A
6	ICX	75	A
7	VAY	150	V
8	VBY	150	V
9	VCY	150	V
10	VAZ	150	V
11	VBZ	150	V
12	VCZ	150	V

Table 6.5 UUT Database Entries for SEL-5401 Relay Test System Software—1 A Relay

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

Relay Test Connections

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.

The SEL-421 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.

Test Setup

Test Source Connections

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.

Connections for Three Voltage Sources and Three Current Sources

Figure 6.2 shows the connections to use when you have three voltage sources and three current sources available.

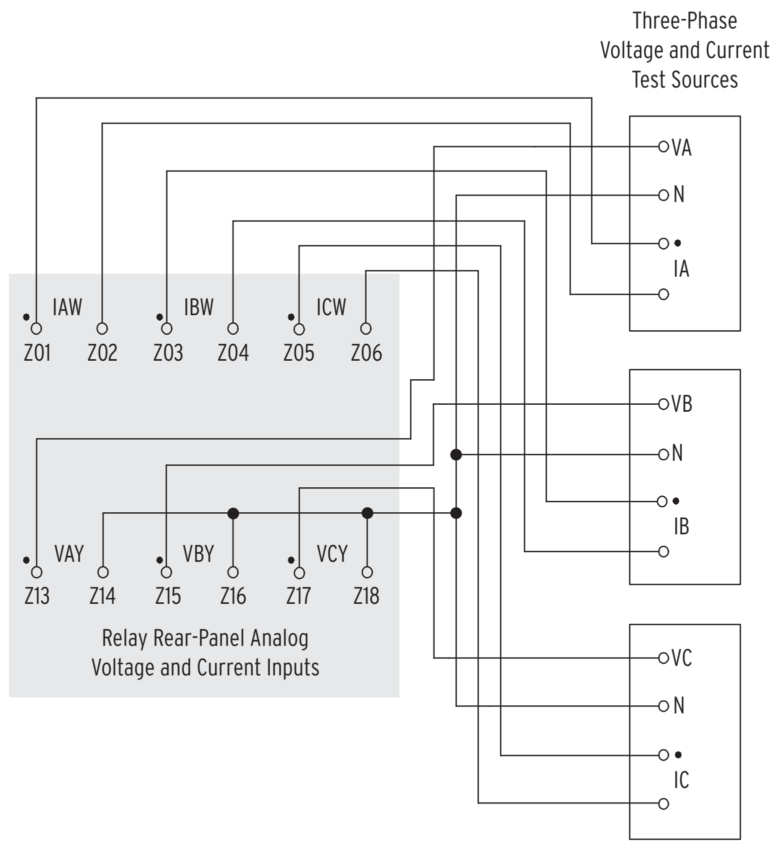


Figure 6.2 Test Connections Using Three Voltage and Three Current Sources

Connections for Three Voltage Sources and Two Current Sources

Figure 6.3 and *Figure 6.4* show connections to use when you have three voltage sources and two current sources. You can use the connections shown in *Figure 6.3* to simulate phase-to-phase, phase-to-ground, and two-phase-to-ground faults. Use the connections shown in *Figure 6.4* to simulate three-phase faults.

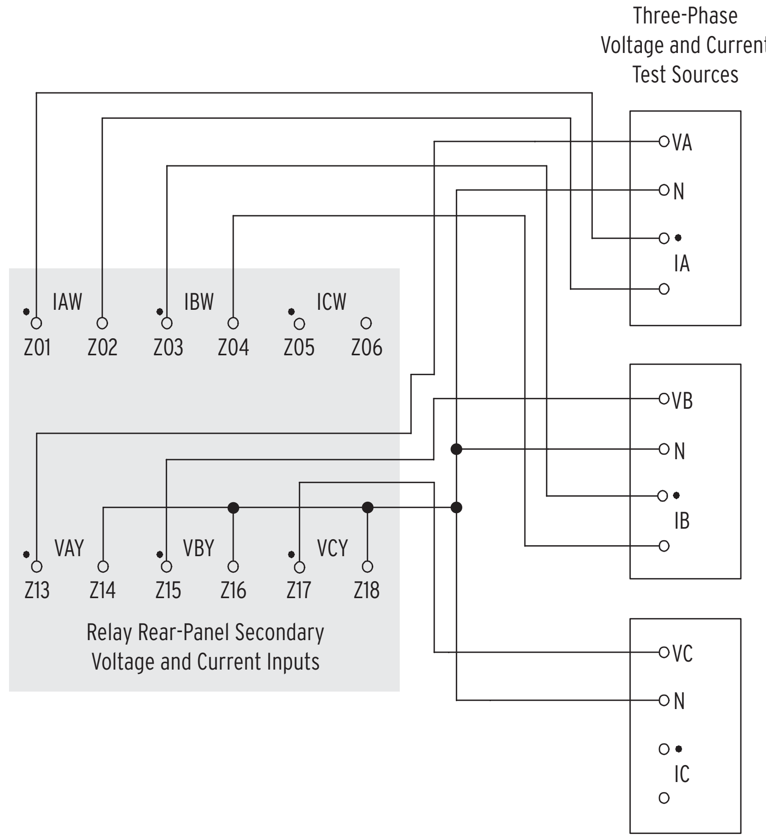


Figure 6.3 Test Connections Using Two Current Sources for Phase-to-Phase, Phase-to-Ground, and Two-Phase-to-Ground Faults

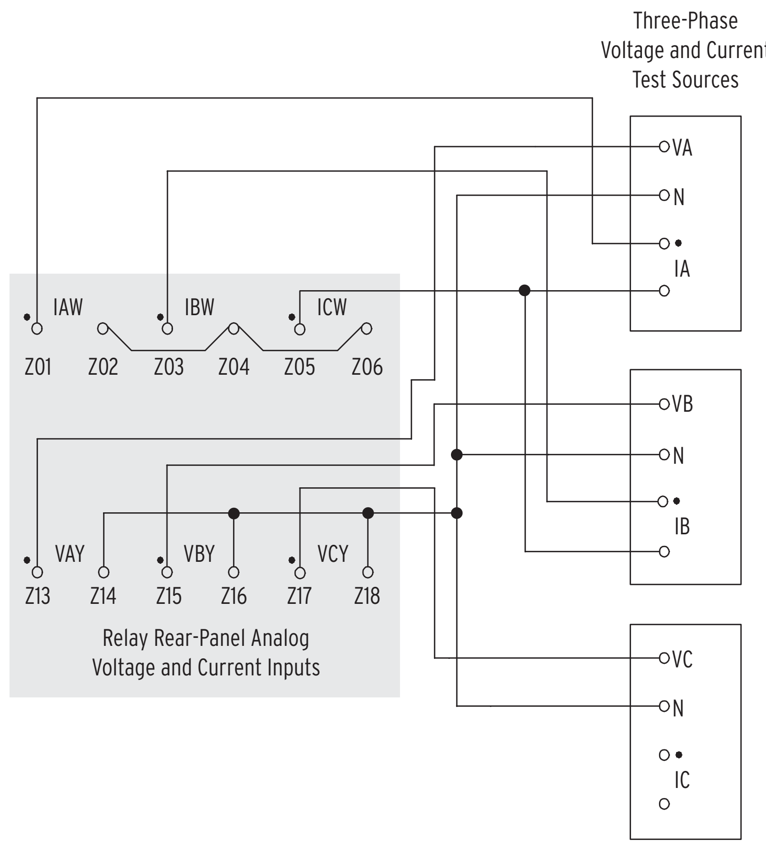


Figure 6.4 Test Connections Using Two Current Sources for Three-Phase Faults

Connections for Three Voltage Sources and One Current Source

Figure 6.5 and *Figure 6.6* show connections to use when you have three voltage sources and a single current source. You can use the connections shown in *Figure 6.5* to simulate phase-to-ground faults. Use the connections shown in *Figure 6.6* to simulate phase-to-phase faults.

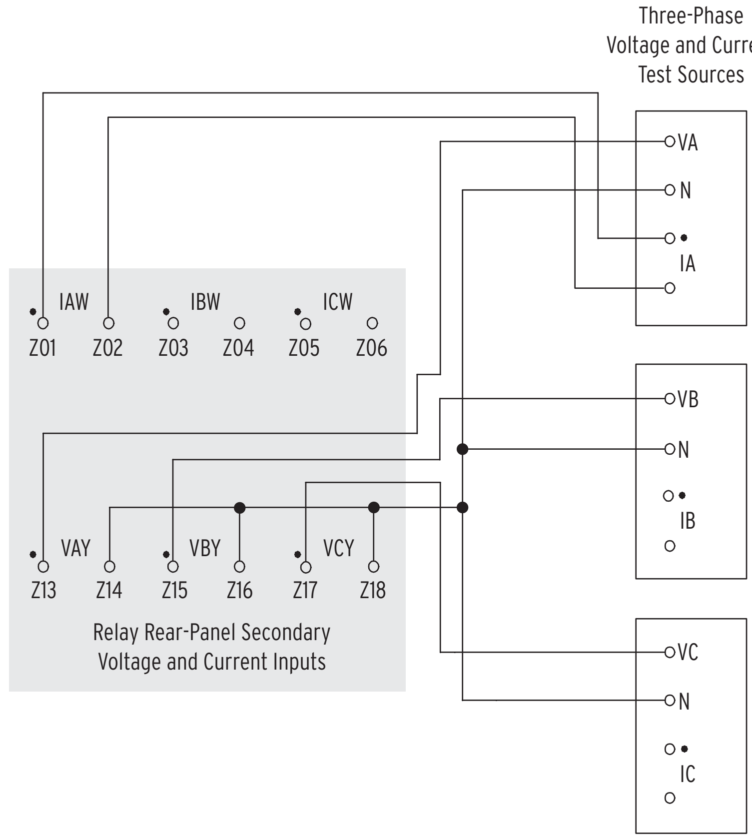


Figure 6.5 Test Connections Using a Single Current Source for a Phase-to-Ground Fault

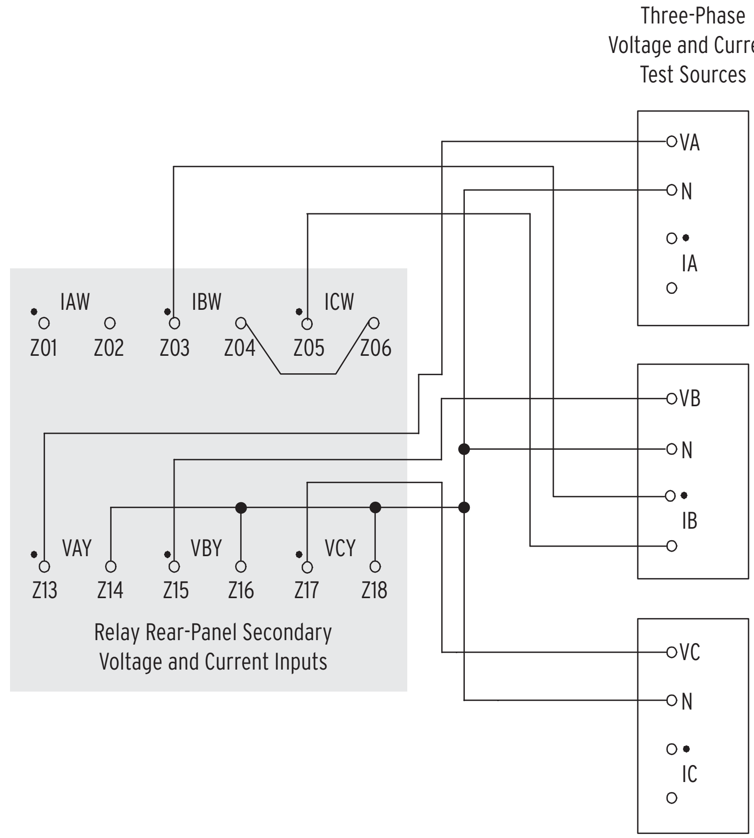


Figure 6.6 Test Connections Using a Single Current Source for a Phase-to-Phase Fault

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 subsections 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 Targets

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 With a Serial Terminal

The procedure in the following steps shows you how to view a change in state for the 50P1 Phase Instantaneous Overcurrent element from a communications port. Use the factory defaults for the pickup level (see *Table 6.6*). For more information on the 50P elements, see *Instantaneous Line Overcurrent Elements on page R.1.66*.

Table 6.6 Phase Instantaneous Overcurrent Pickup

Setting	Description	Default (5A)
50P1P	Level 1 Pickup (OFF, 0.25–100 amps secondary)	10.00

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 U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords on page U.4.6* 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 (see *Figure 6.5* and *Section 2: Installation*).

Step 4. Type **TAR 50P1 <Enter>** to view the initial element status.

The relay returns a target terminal screen similar to *Figure 6.7*.

```
=>TAR 50P1 <Enter>

50P1  50P2  50P3  50P4  67P1  67P2  67P3  67P4

0     0     0     0     0     0     0     0
=>
```

Figure 6.7 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).

b. Increase the current source to produce a current magnitude greater than 10.00 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 With the Front-Panel LCD

You can use the front-panel display and navigation pushbuttons to check Relay Word bit elements. See *Section 5: Front-Panel Operations* for more information on using the relay front panel.

This procedure uses the 50P1 Phase Instantaneous Overcurrent element. Use the factory defaults for the pickup level (*Table 6.6*). For more information on the 50P elements, see *Instantaneous Line Overcurrent Elements on page R.1.66*.

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 6.8*.

Step 3. Press the **{Down Arrow}** navigation pushbutton to highlight the RELAY ELEMENTS action item (see the first screen of *Figure 6.8*).

Step 4. Press the **{ENT}** pushbutton.

You will see a RELAY ELEMENTS screen (the second screen of *Figure 6.8*).

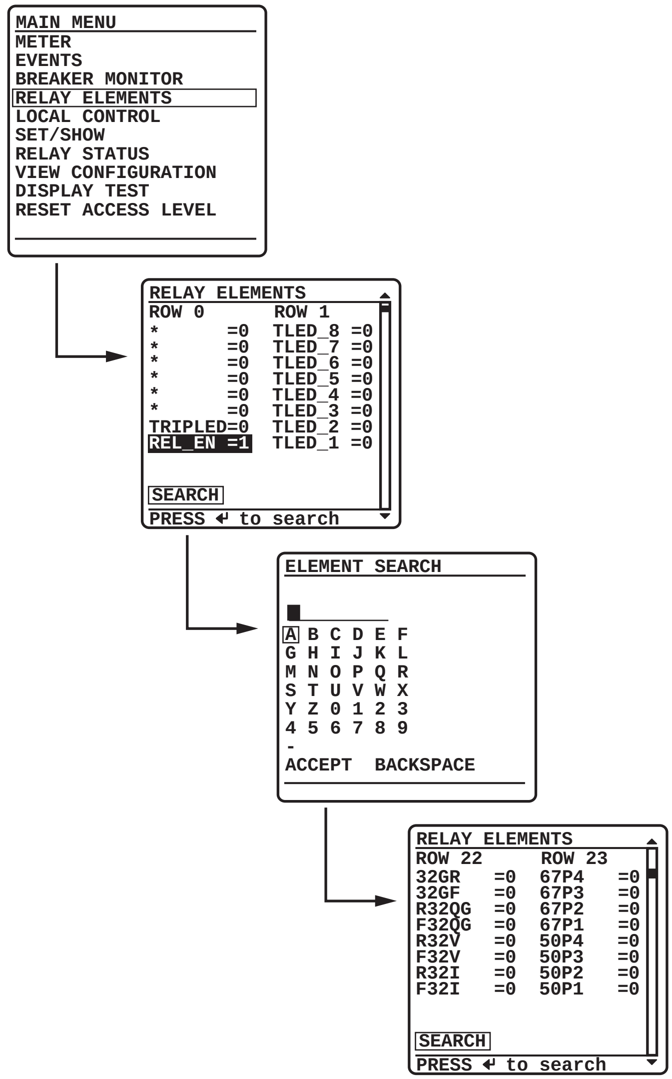


Figure 6.8 Viewing Relay Word Bits From the Front-Panel LCD

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 6.8*.

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 in the last screen of *Figure 6.8*.

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 (see *Figure 6.5* and *Secondary Circuits on page U.2.4*).

Step 7. View the target status change.

a. Increase the current source to produce a current magnitude greater than 10.00 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 With a 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 50P1 Phase Instantaneous Overcurrent element. Use the factory defaults for the pickup level (see *Table 6.6*). For more information on the 50P elements, see *Instantaneous Line Overcurrent Elements on page R.1.66*.

In this example, use ACSELERATOR QuickSet to configure the relay. You must have a computer that is communicating with the SEL-421 and running the ACSELERATOR QuickSet (see *Making Settings Changes: Initial Global Settings on page U.4.17*). In addition, you need a variable current source suitable for relay testing.

Step 1. Prepare to control the relay with ACSELERATOR QuickSet by establishing communication, checking passwords, and reading relay settings (see *Making Settings Changes: Initial Global Settings on page U.4.17*).

Step 2. Set a pushbutton LED SELOGIC control equation.

a. Expand the **Front Panel** branch of the **Settings** tree view and click **Pushbuttons** (see *Figure 6.9*).

ACSELERATOR QuickSet displays the **Pushbuttons** dialog box similar to *Figure 6.9*.

b. Click in the **PB4_LED** text box and type **50P1**.

c. Tab or click to any other text box.

ACSELERATOR QuickSet checks the validity of the setting.

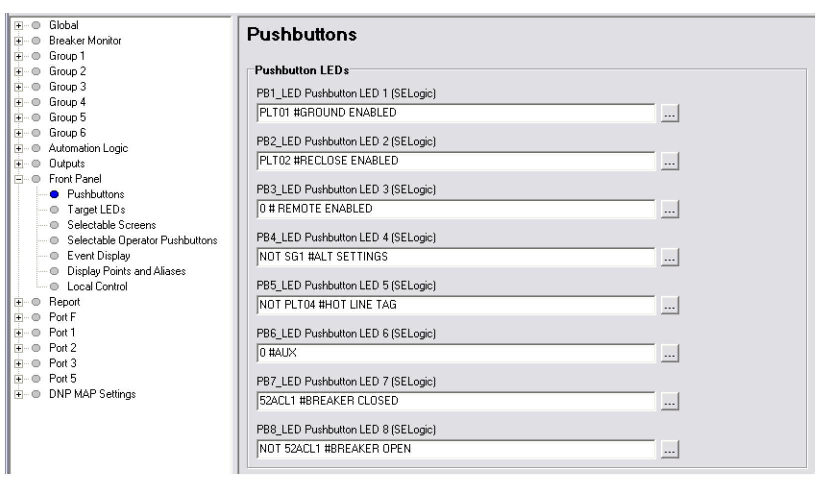


Figure 6.9 Setting Pushbutton LED Response: ACSELERATOR QuickSet

Step 3. Click **File** > **Save** to save the new settings in ACSELERATOR QuickSet.

Step 4. Upload the new settings to the SEL-421.

a. Click **File** > **Send**.

ACSELERATOR QuickSet prompts you for the settings class you want to send to the relay, as shown in the **Group Select** dialog box of *Figure 6.10*.

b. Click the check box for **Front Panel**.

c. Click **OK**.

The relay responds with the **Transfer Status** dialog box of *Figure 6.10*.

If you see no error message, the new settings are loaded in the relay.

NOTE: The **Relay Editor** dialog boxes shown in Figure 6.10 are for the SEL-421. The SEL-421-1 and SEL-421-2 dialog boxes do not contain Automation 2 through Automation 10 setting instances.

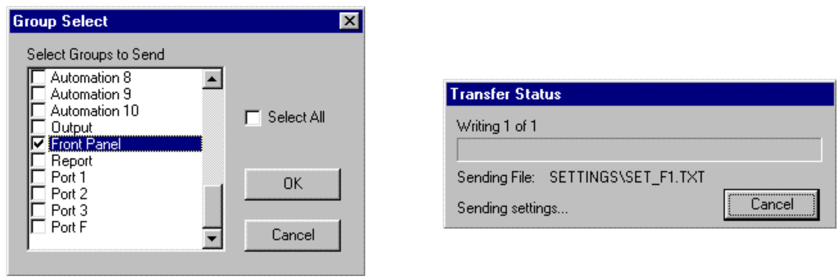


Figure 6.10 Uploading Front-Panel Settings to the SEL-421

Step 5. 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 (see *Figure 6.5* and *Secondary Circuits on page U.2.4*).

Step 6. View the target status change.

a. Increase the current source to produce a current magnitude greater than 10.00 A secondary in the relay.

b. Observe the LED next to the **RELAY TEST MODE** pushbutton (PB4) on the SEL-421 front panel.

You will see the LED light when the input current exceeds the 50P1P setting threshold.

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 through OUT108, for example) to respond to the Relay Word bit for the element under test. See *Operating the Relay Inputs and Outputs on page U.4.56* for configuring control inputs and control outputs. *Appendix A: Relay Word Bits in the Reference Manual* lists the names of the relay element logic outputs.

Testing the 50P1 Element With a Control Output

This procedure shows how to set control output OUT105 to test the 50P1 Phase Instantaneous Overcurrent element. Use the factory defaults for the pickup level (see *Table 6.6*). For more information on the 50P elements, see *Instantaneous Line Overcurrent Elements on page R.1.66*.

For this test, you must have a computer with ACSELERATOR QuickSet for the SEL-421, a variable current source for relay testing, and a control output closure indicating device such as a test set or a VOM (volt ohmmeter).

In this example, use ACSELERATOR QuickSet to configure the relay. You must have a computer that is communicating with the SEL-421 and running ACSELERATOR QuickSet (see *Making Settings Changes: Initial Global Settings on page U.4.17*).

Step 1. Prepare to control the relay with ACSELERATOR QuickSet by establishing communication, checking passwords, and reading relay settings (see *Making Settings Changes: Initial Global Settings on page U.4.17*).

Step 1. Click the **Outputs** > **Main Board** branch of the ACSELERATOR QuickSet **Settings** tree structure to view output settings (shown in *Figure 6.11*).

The **Main Board Outputs** dialog box appears.

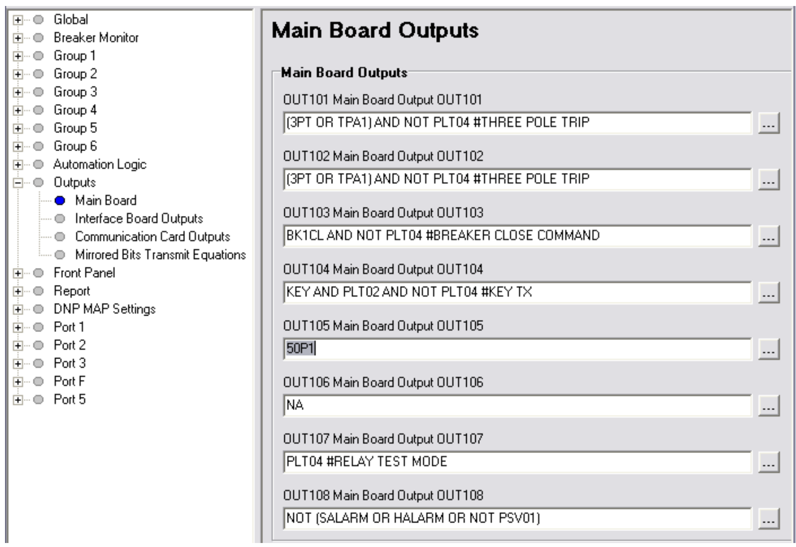


Figure 6.11 Setting Main Board Outputs: ACSELERATOR QuickSet

Step 2. Set OUT105 to respond to the 50P1 element pickup.

a. Move the cursor to the OUT105 Main Board Output105 (SELOGIC) text box and double-click the left (regular) mouse button.

b. Delete the NA default setting.

c. Type **50P1**.

d. Press <**Tab**> or click in any other text box.

e. The relay checks the validity of the setting you entered.

An invalid setting (you could have mistyped the element name) causes the OUT105 text box to turn red.

If the setting is valid, the text box displays the new setting on a white background.

Step 3. Click **File** > **Save** to save the new settings in ACSELERATOR QuickSet.

Step 4. Upload the new settings to the SEL-421.

a. Click **File** > **Send**.

ACSELERATOR QuickSet prompts you for the settings class you want to send to the relay, as shown in the **Group Select** dialog box in *Figure 6.12*.

b. Click the **Output** check box.

c. Click **OK**.

The relay responds with the **Transfer Status** dialog box in *Figure 6.12*.

If you see no error message, the new settings are loaded in the relay.

NOTE: The **Relay Editor** dialog boxes shown in Figure 6.12 are for the SEL-421. The SEL-421-1 and SEL-421-2 dialog boxes do not contain Automation 2 through Automation 10 setting instances.

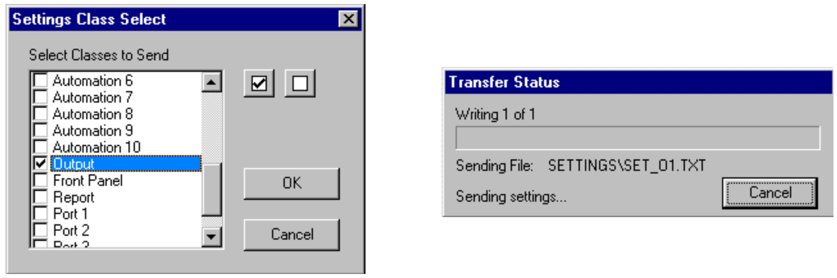


Figure 6.12 Uploading Output Settings to the SEL-421

Step 5. Connect an indicating device to OUT105 on the relay rear panel.

A VOM multi-tester on a low resistance scale can indicate an OUT105 control output closure.

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 (see *Figure 6.5* and *Secondary Circuits on page U.2.4*).

Step 7. Increase the current source to produce a current magnitude greater than 10.00 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 SEL-421 SER to simplify reading the SER report. See *SER (Sequential Events Recorder) on page A.3.34* for complete information on the SER.

Testing the 51S1 Element Using the SER

The SER gives exact time data for testing time-overcurrent element timeouts. 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, and electromechanical reset (*Table 6.7*).

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.

Table 6.7 Selectable Operating Quantity Time-Overcurrent Element (51S1) Default Settings

Setting	Description	Default 5A
51S1O	51S1 Operating Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0L, 3I01, 3I02)[a]	3I0L
51S1P	51S1 Overcurrent Pickup (0.25–16 amps, secondary)	0.75
51S1C	51S1 Inv-Time Overcurrent Curve (U1–U5, C1–C5)	U3
51S1TD	51S1 Inv-Time Overcurrent Time Dial (0.50–15.0)	1.00
51S1RS	51S1 Inv-Time Overcurrent EM Reset (Y, N)	N
51S1TC	51S1 Torque Control (SELOGIC control equation)	32GF

[a] n is L, 1, and 2 for Line, Circuit Breaker 1, and Circuit Breaker 2, respectively.

The relay uses *Equation 6.1* and *Equation 6.2* 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:

$$\begin{aligned} I_{TEST} &= M \bullet (51S1P) \\ &= 1.5 \bullet (0.75\ A) \\ &= 1.125\ A \end{aligned} \qquad \textbf{Equation 6.1}$$

where M is the pickup multiple and 51S1P is the element pickup value (see *Table 6.7*).

The operating time (t_p) for a time dial (TD) equal to 1 for the U3 (Very Inverse) Curve is:

$$\begin{aligned} t_p &= TD \bullet \left(0.0963 + \frac{3.88}{M^2 - 1}\right) \\ &= 1 \bullet 0.0963 + \frac{3.88}{1.5^2 - 1} \\ &= 3.2\ \text{seconds} \end{aligned} \qquad \textbf{Equation 6.2}$$

For more information on the 51S elements, see *Inverse-Time Overcurrent Elements on page R.1.72*.

In this example, use ACSELERATOR QuickSet to configure the relay. You must have a computer that is communicating with the SEL-421 and running the ACSELERATOR QuickSet (see *Making Settings Changes: Initial Global Settings on page U.4.17*). You also need a variable current source for relay testing.

Step 1. Prepare to control the relay with ACSELERATOR QuickSet by establishing communication, checking passwords, and reading relay settings (see *Making Settings Changes: Initial Global Settings on page U.4.17*).

Step 2. Set the selectable operating quantity time-overcurrent element for test operation.

a. Open the **Group 1 > Relay Configuration > Time Overcurrent** branch of the **Settings** tree view (see *Figure 6.13*).

b. In the **Time Overcurrent** dialog box, check that setting **51S1O Operating Quantity** is at **3I0L**.

c. Check the remaining element configurations against *Table 6.7*.

➢ Set torque control 51S1TC to **1** to constantly operate the 51S1 element

➢ Type **1** in the text box for 51S1TC.

➢ For more information on using ACSELERATOR QuickSet to change settings, see *Making Initial Global Settings: ACSELERATOR QuickSet on page U.4.25*.)

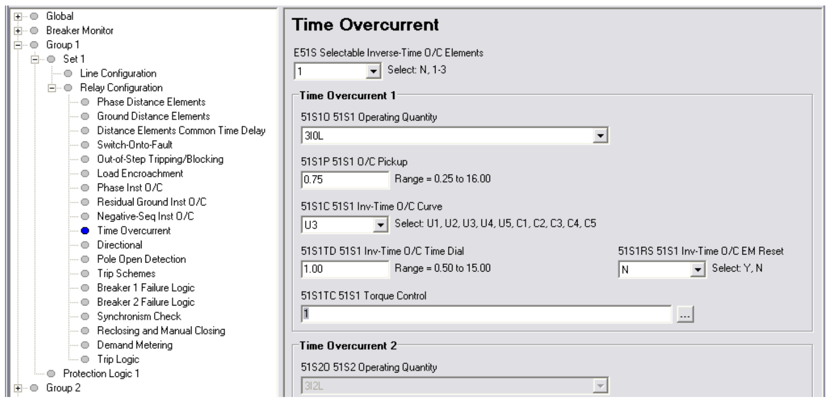


Figure 6.13 Checking the 51S1 Overcurrent Element: ACSELERATOR QuickSet

Step 3. View the SER settings.

a. Click the + mark next to the **Report** branch of the ACSELERATOR QuickSet **Settings** tree view structure shown in *Figure 6.14*.

b. Click on the **SER Points and Aliases** branch.

The **SER Points and Aliases** dialog box appears (see *Figure 6.14*).

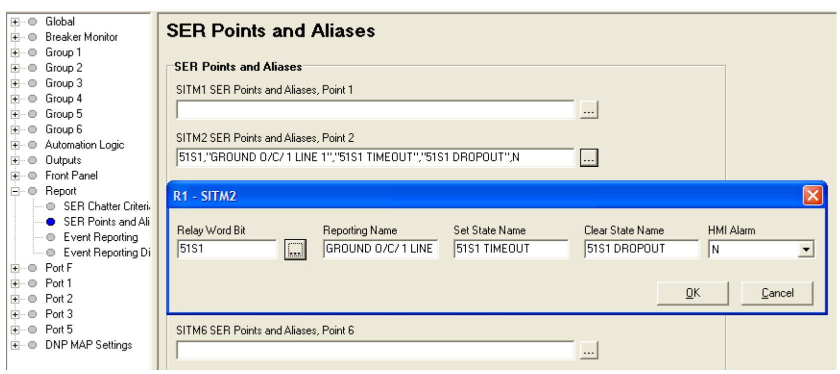


Figure 6.14 Setting SER Points and Aliases: ACSELERATOR QuickSet

Step 4. Enter SER element names and aliases.

a. Locate **SITM1 SER Points and Aliases, Point 1** entry field, and then click the [...] button beside the entry box.

b. Click the [...] button beside the **Relay Word bit** entry field.

c. Select Overcurrent Element Bits.

d. Double-click on 51S1T to copy the name into the Relay Word Bit field.

e. Type **GROUND O/C 1 LINE 1** in the **Alias Name** field.

f. Type **51S1 TIMEOUT** in the **Set Alias** field.

g. Type **51S1 DROPOUT** in the **Clear Alias** field.

h. Click on the OK button.

i. Repeat Steps *Step a–Step h* for **SITM2 SER Points and Aliases, Point 2**, with setting values **51S1, GROUND O/C 1 LINE 1, 51S1 PICKED UP, 51S1 RESET**. *Figure 6.14* shows the entry field for SITM2 just before pressing the OK button.

You can enter as many as 250 relay elements in the **SER Points and Aliases** list (see *SER (Sequential Events Recorder) on page A.3.34*).

Step 5. Click **File > Save** to save the new settings in ACSELERATOR QuickSet.

Step 6. Upload the new settings to the SEL-421.

a. Click **File** > **Send**.

b. ACSELERATOR QuickSet prompts you for the settings class you want to send to the relay, as shown in the **Group Select** dialog box of *Figure 6.15*.

c. Click the check box for **Group 1** and for **Report**.

d. Click **OK**.

ACSELERATOR QuickSet responds with a **Transfer Status** dialog box as in *Figure 6.15*.

If you see no error message, the new settings are loaded in the relay.

NOTE: The **Relay Editor** dialog boxes shown in Figure 6.15 are for the SEL-421. The SEL-421-1 SEL-421-2 dialog boxes do not contain Automation 2 through Automation 10 setting instances.

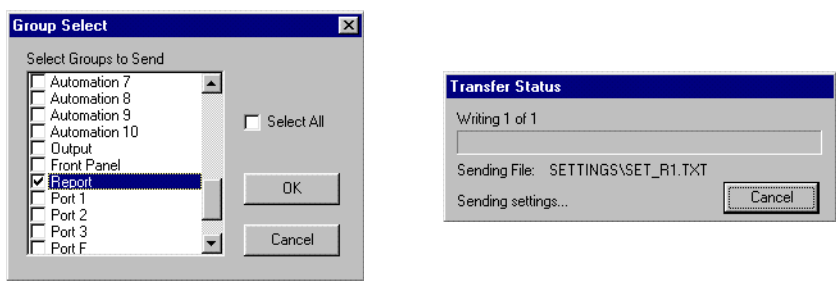


Figure 6.15 Uploading Group 1 and Report Settings to SEL-421

Step 7. 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 (see *Figure 6.5* and *Secondary Circuits on page U.2.4*).

Step 8. 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 timeout (longer than 3.2 seconds).

c. Return the current source to zero after the element time out.

Step 9. Select the HMI menu (top toolbar) and then click **Meter and Control** to start the ACSELERATOR QuickSet HMI interface.

Step 10. View the SER report.

Step 11. Click the **SER** button of the HMI tree view (see *Figure 6.16*).

ACSELERATOR QuickSet displays the **SER** report similar to *Figure 6.17*.

The time difference between SER entries **51S1 PICKED UP** and **51S1 TIMOUT** is approximately 3.2 seconds.

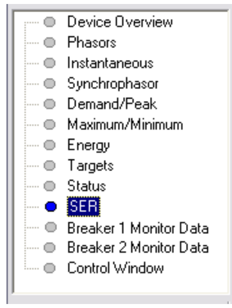


Figure 6.16 HMI Tree View: ACSELERATOR QuickSet

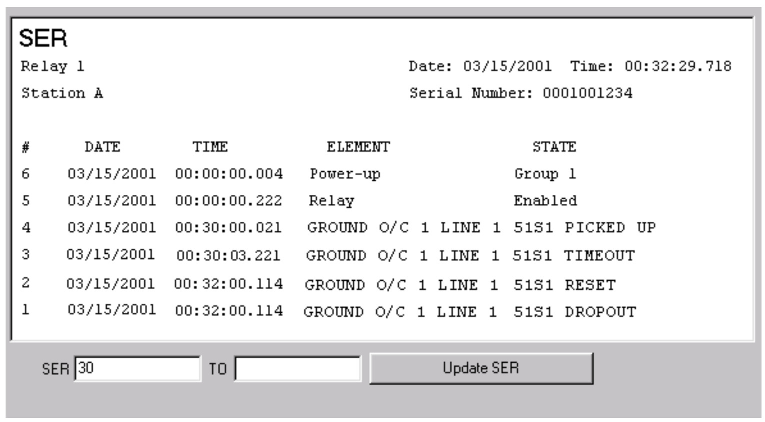


Figure 6.17 SER Report: ACSELERATOR QuickSet HMI

Checking Relay Operation

The SEL-421 comes to you with all functions fully checked and calibrated so that the relay operates correctly and accurately. You can perform tests on 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-421 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 are the proper magnitude and phase rotation (see *Examining Metering Quantities on page U.4.33*).

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 U.4.56*).

Brief functional tests and element verification confirm correct internal relay processing.

Selected Element Tests

This subsection discusses tests of the following relay elements:

- Overcurrent element: negative-sequence instantaneous, 50Q1
- Directional element: negative-sequence portion, F32Q/R32Q, of the phase directional element, F32P/R32P
- Distance element: phase-to-phase mho element, MBC2, of Zone 2 mho distance element M2P

Testing Overcurrent Elements

Overcurrent elements operate by detecting power system sequence quantities and asserting when these quantities exceed a preset threshold.

Apply current to the analog current inputs and compare relay operation to the element pickup settings to test the instantaneous and definite-time overcurrent elements. Be sure to apply the test current to the proper input set (IW or IX), according to the Global Current and Voltage Source Selection settings (ESS and ALINEI, for example) to accept the input. See *Current and Voltage Source Selection on page R.1.2* for more information.

Phase Overcurrent Elements

The SEL-421 phase overcurrent elements compare the phase current applied to the secondary current inputs with the phase overcurrent element pickup setting. The relay asserts the phase overcurrent elements when any of the three phase currents exceeds the corresponding element pickup setting.

Negative-Sequence Overcurrent Elements

The SEL-421 negative-sequence overcurrent elements compare a negative-sequence calculation of the three-phase secondary inputs with the corresponding negative-sequence overcurrent element pickup setting. The relay makes this negative-sequence calculation (assuming ABC rotation):

$3I_2$ = A-phase + B-phase (shifted by –120°) + C-phase (shifted by 120°)

The relay asserts negative-sequence overcurrent elements when the $3I_2$ calculation exceeds the corresponding negative-sequence current pickup setting. If balanced currents are applied to the relay, the relay reads $3I_2 \approx 0$ (load conditions) and does not pick up the negative-sequence overcurrent elements.

For testing, apply current to a single phase of the relay, causing the negative-sequence overcurrent elements to operate. For example, assume 1 A of current on A-phase and zero current input on the B-phase and C-phase:

$3I_2$ = 1 A + 0 (shifted –120°) + 0 (shifted 120°) = 1 A (a simulated ground fault condition)

Ground Overcurrent Elements

The SEL-421 ground overcurrent elements compare a residual ground calculation of the three-phase inputs with the residual overcurrent setting. The relay makes this residual current calculation:

$3I_0$ = A-phase + B-phase + C-phase

The relay asserts ground overcurrent elements when the $3I_0$ calculation exceeds the ground current element pickup setting. If balanced currents are applied to the relay, the relay reads $3I_0 = 0$ (load conditions) because the currents cancel in the calculation; the relay does not pick up the ground overcurrent elements.

For testing, apply current to a single phase of the relay, causing the residual overcurrent elements to operate. For example, assume 1 A of current on A-phase and zero current input on B-phase and C-phase:

$3I_0 = 1\text{ A} + 0 + 0 = 1\text{ A}$ (a simulated ground fault condition)

Checking the Negative-Sequence Instantaneous Overcurrent Element, 50Q1

NOTE: As you perform this test, other protection elements can assert. This causes the relay to assert other targets and possibly close control outputs. Be sure to isolate the relay from the power system to avoid unexpected system effects.

The procedure in the following steps tests the 50Q1 negative-sequence overcurrent element. Use a similar procedure to test other overcurrent elements.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords on page U.4.6* to change the default access level passwords and enter higher relay access levels). You should be familiar with ACSELERATOR QuickSet (see *Section 3: PC Software*).

Step 1. Configure the relay.

a. Start ACSELERATOR QuickSet and read the present configuration in the SEL-421.

b. Click **Settings > Read**.

The relay sends all settings and configuration data to ACSELERATOR QuickSet.

c. Expand the **Group 1** settings and click the **Negative-Seq Inst O/C** button of the **Settings** tree view as shown in *Figure 6.18*.

You will see the **Negative Sequence Instantaneous Overcurrent** dialog box similar to *Figure 6.18*.

d. Click the arrow in the **Instantaneous and Definite Time Overcurrent Element Levels E50Q** dialog box and select **1**.

e. For this test, set the **50Q1P** level to **1.00** and **67Q1TC** to **1**.

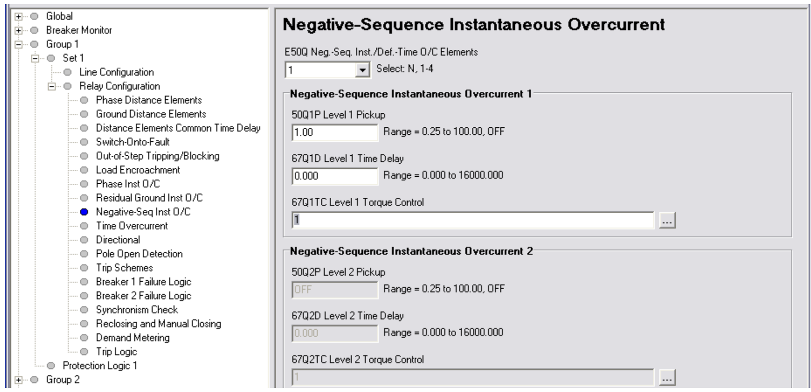


Figure 6.18 Negative-Sequence Instantaneous Overcurrent Element Settings: ACSELERATOR QuickSet

Step 2. Upload the new setting to the SEL-421.

a. Click **File > Send**.

ACSELERATOR QuickSet prompts you for the settings class you want to send to the relay, as shown in the **Group Select** dialog box in *Figure 6.19*.

b. Click the check box for **Group 1**.

c. Click **OK**.

The relay responds with the **Transfer Status** dialog box similar to *Figure 6.19*.

If you see no error message, the new settings are loaded in the relay.

NOTE: The **Relay Editor** dialog boxes shown in Figure 6.19 are for the SEL-421. The SEL-421-1 SEL-421-2 dialog boxes do not contain Automation 2 through Automation 10 setting instances.

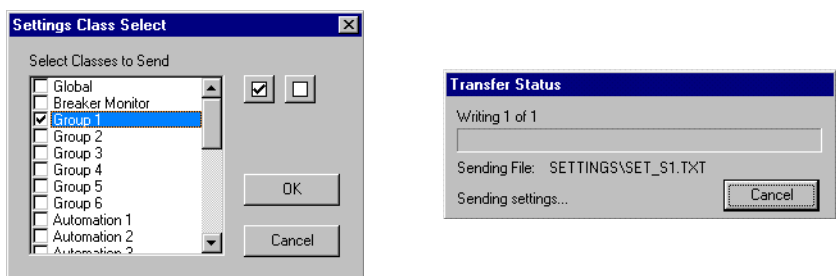


Figure 6.19 Uploading Group 1 Settings to the SEL-421

Step 3. Display the 50Q1 Relay Word bit on the front-panel LCD screen.

a. Access the front-panel LCD MAIN MENU.

b. Highlight RELAY ELEMENTS and press **{ENT}**.

c. Press **{ENT}** to go to the ELEMENT SEARCH submenu of *Figure 6.20*.

d. Use the navigation keys to highlight 5 and then press **{ENT}** to enter characters in the text input field.

e. Enter the **0**, **Q**, and **1** characters in turn.

f. Highlight ACCEPT and press **{ENT}**.

The relay displays the screen containing the 50Q1 element, as shown in *Figure 6.21*.

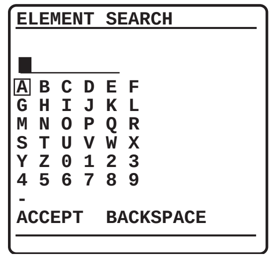


Figure 6.20 ELEMENT SEARCH Screen

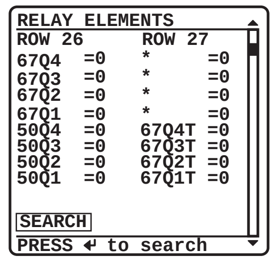


Figure 6.21 RELAY ELEMENTS Screen Containing Element 50Q1

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 (see *Figure 6.5* and *Secondary Circuits on page U.2.4*).

Step 5. Increase the current source to produce a current magnitude greater than 1.00 A secondary in the relay.

You will see that the 50Q1 element state changes on the LCD screen from 50Q1 = 0 to 50Q1 = 1.

Negative-Sequence Directional Element for Phase Faults

The SEL-421 features a phase directional element (represented by Relay Word bits F32P/R32P) to supervise the phase distance elements and to control phase directional elements. The negative-sequence directional element, F32Q/R32Q, is a part of the phase directional element, F32P/R32P. Whenever the negative-sequence directional element asserts, the phase directional element asserts.

The relay also contains a ground directional element, F32G/R32G, for directional control of the ground distance elements and ground overcurrent elements. For more information on directional elements, see *Ground Directional Element on page R.1.28*, and *Section 1: Protection Application Examples in the Applications Handbook*.

The SEL-421 calculates the negative-sequence impedance Z2 from the magnitudes and angles of the negative-sequence voltage and current. *Table 6.3* defines this function (the ‘c’ in Z2c indicates “calculated”).

$$
\begin{aligned}
Z2c &= \frac{\mathrm{Re}[V_2 \bullet (1\angle Z1ANG \bullet I_2)^*]}{|I_2|^2} \\
&= \frac{|V_2|}{|I_2|} \bullet \cos(\angle V_2 - \angle Z1ANG - \angle I_2)
\end{aligned}
\qquad \textbf{Equation 6.3}
$$

where:

V_2 = the negative-sequence voltage
I_2 = the negative-sequence current
Z1ANG = the positive-sequence line impedance angle
Re = the real part of the term in brackets, for example, (Re[A + jB] = A)
* = the complex conjugate of the expression in parentheses, (A + jB)* = (A – jB)

The result of *Equation 6.3* is an impedance magnitude that varies with the magnitude and angle of the applied current. Normally, a forward fault results in a negative Z2c relay calculation.

Test Current

Solve *Equation 6.3* to find the test current values that you need to apply to the relay to test the element. For the negative sequence current I_2, the result is

$$|I_2| = \frac{|V_2|}{Z2c}$$ **Equation 6.4**

when:

$$\angle I_2 = \angle V_2 - \angle Z1ANG$$ **Equation 6.5**

Multiply the quantities in *Equation 6.4* by three to obtain $3I_2$, the negative-sequence current that the relay processes. With a fixed applied negative-sequence voltage V_A, the relay negative sequence voltage is $3V_2$. Set Z2c = Z2F to find the test current magnitude at the point where the impedance calculation equals the forward fault impedance threshold. *Equation 6.4* becomes:

$$|I_{TEST}| = |3I_2| = \frac{|3V_2|}{Z2c} = \frac{|3V_2|}{Z2F}$$ **Equation 6.6**

when:

$$\angle I_{TEST} = \angle 3I_2 = \angle 3V_2 - \angle Z1ANG$$ **Equation 6.7**

For a reverse fault impedance threshold, where Z2c = Z2R, *Equation 6.4* becomes:

$$|I_{TEST}| = |3I_2| = \frac{|3V_2|}{Z2c} = \frac{|3V_2|}{Z2R}$$ **Equation 6.8**

when the angle calculation is the same as *Equation 6.7*.

For more information on the directional elements, see *Ground Directional Element on page R.1.28* and *Quadrilateral Ground Distance Elements on page R.1.56*. For settings and application information, see *Section 1: Protection Application Examples in the Applications Handbook*.

Checking the Negative-Sequence Directional Element (Phase Faults)

NOTE: As you perform this test, other protection elements can assert. This causes the relay to assert other targets and possibly close control outputs. Be sure to isolate the relay from the power system to avoid unexpected system effects.

This test confirms operation of the F32Q and the R32Q negative-sequence directional elements. This test procedure is for a 5 A relay; scale values appropriately for a 1 A relay.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords on page U.4.6* to change the default access level passwords and enter higher relay access levels). You should be familiar with ACSELERATOR QuickSet (see *Section 3: PC Software*).

Step 1. Configure the relay.

a. Open ACSELERATOR QuickSet and read the present configuration in the SEL-421.

b. Click **Settings > Read**.

The relay sends all settings and configuration data to ACSELERATOR QuickSet.

c. Expand the **Group 1** settings and click the **Relay Configuration** branch of the **Settings** tree view as shown in *Figure 6.22*.

d. Disable supervisory elements.

Confirm that **ELOP** is set to **N**.

e. In a similar sequence, click on the + button to expand the **Relay Configuration** tree view, click on **Load Encroachment**, and confirm that **ELOAD** is set to **N**.

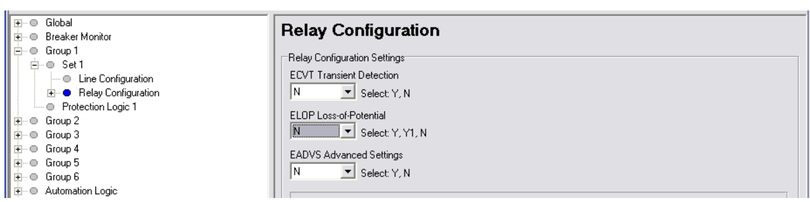


Figure 6.22 Group 1 Relay Configuration Settings: ACSELERATOR QuickSet

f. Defeat the pole-open logic.

g. Click the **+** button next to **Breaker Monitor** to expand the **Breaker Monitor** branch of the **Settings** tree view (see *Figure 6.23*).

h. Click **Breaker 1**.

You will see the **Breaker 1** dialog box similar to *Figure 6.23*.

i. Enter **1** in the text boxes for **52AA1 A-Phase N/O Contact Input -BK1**, **52AB1 B-Phase N/O Contact Input -BK1**, and **52AC1 C-Phase N/O Contact Input -BK1**.

The text boxes in *Figure 6.23* appear if Breaker Monitor setting BK1TYP := 1.

j. If BK1TYP := 3, enter **1** in the **52AA1 N/O Contact Input -BK1** text box (the other circuit breaker input boxes are dimmed.)

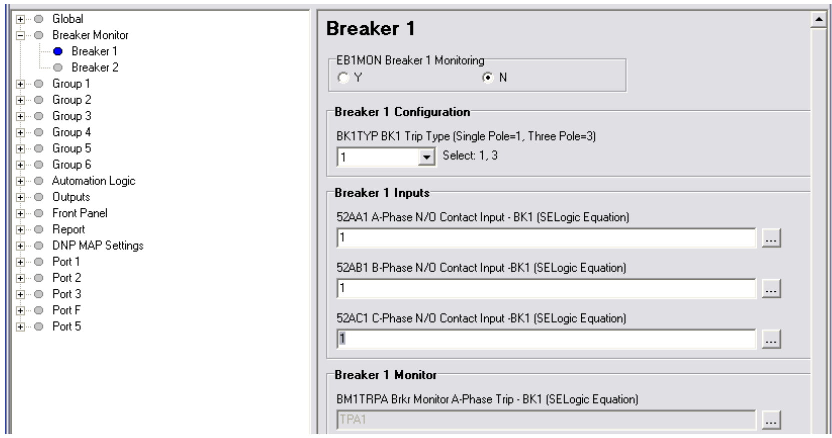


Figure 6.23 Breaker 1 Breaker Monitor Settings: ACSELERATOR QuickSet

Step 2. Set test values in the relay.

a. Expand the **Group 1** settings as shown in *Figure 6.24* and select the **Line Configuration** button.

You will see the **Line Configuration** dialog box of *Figure 6.24*.

b. Confirm the default settings of **Z1MAG** at **7.80** and **Z1ANG** at **84.00**.

c. Click the **+** mark next to the **Relay Configuration** branch to expand that **Settings** branch.

d. Select the **Directional** button.

You will see the **Directional** dialog box similar to *Figure 6.25*.

e. Confirm the following settings: **E32** is **AUTO**, **ORDER** is **Q**, **50FP** is **0.60**, **50RP** is **0.40**, **Z2F** is **3.90**, **Z2R** is **4.00**, **a2** is **0.10**, and **k2** is **0.2**.

The dialog box is dim since there are no settings to change.

The relay calculates these numeric settings automatically because **E32** is set to **AUTO**.

f. If you need to change these settings, set **E32** to **Y**.

Table 6.8 shows the calculations.

See *Ground Directional Element on page R.1.28* for details on these relay calculations.

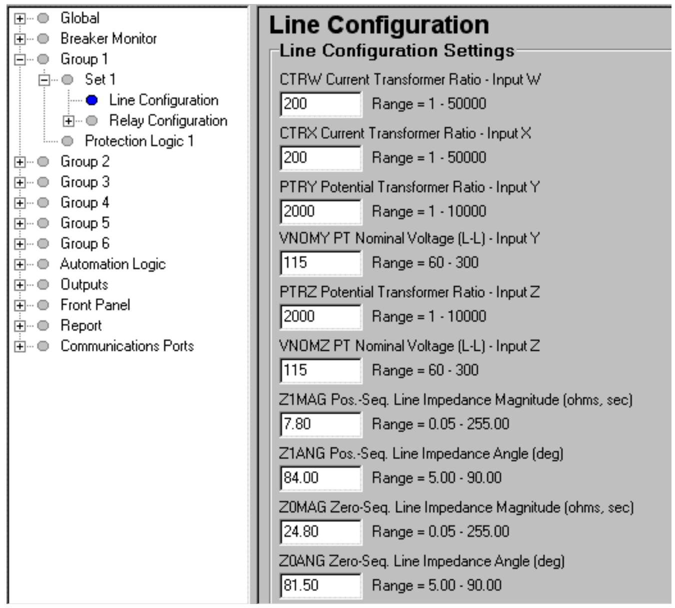


Figure 6.24 Group 1 Line Configuration Settings: ACSELERATOR QuickSet

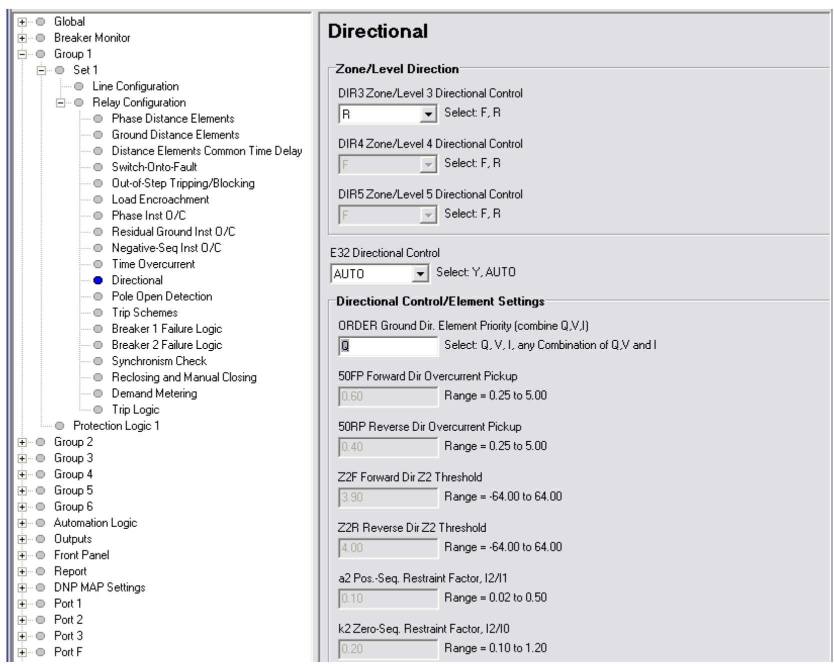


Figure 6.25 Directional Settings: ACSELERATOR QuickSet

Table 6.8 Negative-Sequence Directional Element Settings AUTO Calculations

Setting	Calculation
50FP	$0.12 \cdot I_{nom}$
50RP	$0.08 \cdot I_{nom}$
Z2F	0.5 • Z1MAG
Z2R	$Z2F + 1 / (2 \cdot I_{nom})$
a2	0.1
k2	0.2

Step 3. Upload the new settings to the SEL-421.

a. Click **File** > **Send**.

ACSELERATOR QuickSet prompts you for the settings class you want to send to the relay, as shown in the **Group Select** dialog box in *Figure 6.26*.

b. Click the check box for **Group 1** and for **Breaker Monitor**.

c. Click **OK**.

d. ACSELERATOR QuickSet responds with a **Transfer Status** dialog box as in *Figure 6.26*.

If you see no error message, the new settings are loaded in the relay.

NOTE: The **Relay Editor** dialog boxes shown in Figure 6.26 are for the SEL-421. The SEL-421-1 SEL-421-2 dialog boxes do not contain Automation 2 through Automation 10 setting instances.

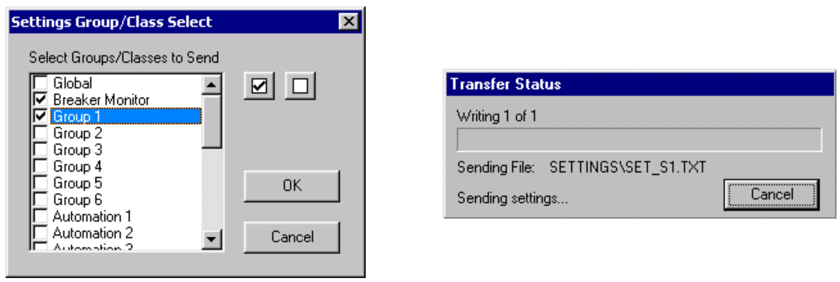


Figure 6.26 Uploading Group 1 and Breaker Monitor Settings to the SEL-421

Step 4. Display the F32Q and R32Q Relay Word bits on the front-panel LCD screen.

a. Access the front-panel LCD `MAIN MENU`.

b. Highlight `RELAY ELEMENTS` and press **{ENT}**.

You will see a `RELAY ELEMENTS` screen with `SEARCH` highlighted at the bottom of the screen.

c. Press **{ENT}** to go to the `ELEMENT SEARCH` submenu of *Figure 6.20*.

d. Enter characters in the text input field using the navigation keys.

e. Highlight `F` and press **{ENT}** to enter the `F` character.

f. Enter the `3`, `2`, and `Q` characters in like manner.

g. Highlight `ACCEPT` and press **{ENT}**.

The relay displays the screen containing the F32Q and R32Q elements, as shown in *Figure 6.27*.

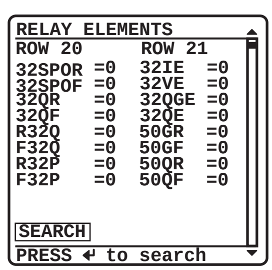


Figure 6.27 RELAY ELEMENTS LCD Screen Containing Elements F32Q and R32Q

Step 5. Calculate impedance thresholds.

a. For this test, apply an A-phase voltage of $V_A = 3V_2 = 18.0 \angle 180°$ V secondary.

b. Use *Equation 6.8* to find the current that is equal to the reverse impedance threshold Z2R:

$$|I_{TEST}| = |3I_2| = \frac{|3V_2|}{Z2R} = \frac{|18.0\angle 180°V|}{4.00} = 4.50\ A$$

Step 6. Use *Equation 6.6* to find the current that is equal to the forward impedance threshold Z2F:

$$|I_{TEST}| = |3I_2| = \frac{|3V_2|}{Z2RF} = \frac{|18.0\angle 180°V|}{3.90} = 4.62\ A$$

Step 7. Use *Equation 6.7* to determine the applied current angle ($\angle I_{TEST}$):

$$\angle I_{TEST} = \angle 3I_2 = \angle 3V_2 - \angle Z1ANG = 180° - 84° = 96°$$

Step 8. Apply a test current to confirm operation of R32Q and F32Q.

a. Connect a single current test source as shown in *Figure 6.5*.

b. Apply an A-phase voltage of $V_A = 18.0 \angle 180°$ V secondary.

c. Set the current source for $I_A = 0.0 \angle 96°$ A.

d. Slowly increase the magnitude of I_A to apply the source test current.

e. Observe the RELAY ELEMENT LCD screen.

Relay Word bit R32Q asserts when $|I_A| = 0.4$ A, indicating that the relay negative-sequence current is greater than the 50RP pickup threshold.

R32Q deasserts when $|I_A| = 4.5$ A, indicating that the relay negative-sequence calculation Z2c is now less than the Z2 reverse threshold Z2R (see *Reverse Threshold on page R.1.38* and *Forward Threshold on page R.1.37*.)

f. Continue to increase the current source while you observe the RELAY ELEMENT LCD screen.

Relay Word bit F32Q asserts when $|I_A| = 4.62$ A, indicating that the relay negative-sequence calculation Z2c is less than the Z2 forward threshold Z2F.

Distance Elements

Apply voltages and currents to the relay analog inputs that simulate fault and load conditions to test distance elements. The relay supervises distance elements so that these elements operate under the appropriate conditions. Be sure to satisfy all the element supervisory conditions before testing a relay element. For supervisory conditions for a particular element, see *Mho Ground Distance Elements on page R.1.51*.

Phase-to-Phase Distance Element MBC2

The SEL-421 contains mho phase distance elements among the many protection elements in the relay. The relay has phase distance elements to detect phase-to-phase faults, phase-to-phase-to-ground faults, and three-phase faults. The SEL-421 has five independent zones of mho phase distance protection; each zone consists of phase-to-phase elements that the relay combines to produce a particular zone output.

For example, the OR combination of MAB2, MBC2, and MCA2 produces the M2P Zone 2 mho phase element. For more information on the mho phase elements and other distance elements, see *Section 1: Protection Functions in the Reference Manual* and *Section 1: Protection Application Examples in the Applications Handbook*.

Test Current and Voltage for a Phase-to-Phase Fault

To find the test current for a phase-to-phase fault, consider *Equation 6.9* for a B-phase to C-phase fault:

$$I_{TEST} = I_B = -I_C \qquad \textbf{Equation 6.9}$$

The B-phase to C-phase current vector, I_{BC}, is:

$$I_{BC} = I_B - I_C = I_B + (I_B) = 2 \bullet I_B = 2 \bullet I_{TEST} \qquad \textbf{Equation 6.10}$$

Choose a convenient test source current magnitude, $|I_{TEST}| = 2.5$ A; then $|I_{BC}| = 2 \bullet |I_{TEST}| = 5$ A.

Find the magnitude of the test source voltage $|V_{TEST}|$:

$$\begin{aligned}|V_{TEST}| &= |V_{BC}| = |I_{BC}| \bullet |Z_{BC}| = |I_{BC}| \bullet Z2P \\ &= 2 \bullet |I_{TEST}| \bullet Z2P\end{aligned} \qquad \textbf{Equation 6.11}$$

where relay setting Z2P (Zone 2 Reach) substitutes for the B-phase to C-phase impedance Z_{BC}. For setting Z2P of 9.36 Ω, the test voltage magnitude $|V_{BC}|$ is:

$$\begin{aligned}|V_{TEST}| &= 2 \bullet |I_{TEST}| \bullet Z2P \\ &= 2 \bullet 2.5 \bullet 9.36 = 46.8 \text{ V}\end{aligned} \qquad \textbf{Equation 6.12}$$

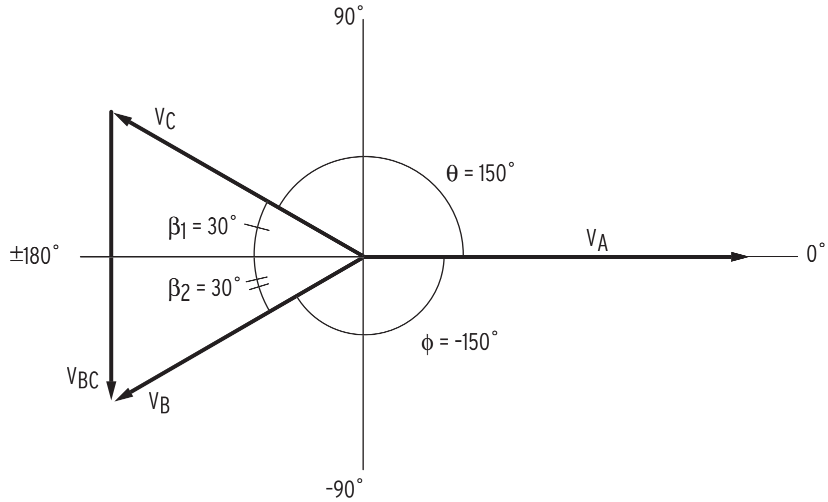


Figure 6.28 Finding Phase-to-Phase Test Quantities

One way to create a V_{BC} phasor is to equate $|V_B|$ and $|V_C|$ and determine the appropriate angles to make an equilateral triangle as shown in *Figure 6.28*.

Subtract 30 degrees (angle β_1) from 180 degrees to obtain the angle for test source V_C phasor; $V_C = 46.8 \angle 150°$ V.

Similarly, add 30 degrees (angle β_2) to –180 degrees to obtain test source V_B phasor; $V_B = 46.8 \angle –150°$ V.

Test voltage V_A can be the nominal value, $V_A = 67 \angle 0°$ V.

Thus, the resulting phase-to-phase voltage is $V_{BC} = 46.8 \angle –90°$ V, referenced to the V_A phasor at 0 degrees.

The relay measures phase distance element maximum reach when the faulted phase-to-phase current lags the faulted phase-to-phase voltage by the distance element maximum torque angle. In the SEL-421, the phase distance element maximum torque angle is setting Z1ANG. Current I_{BC} should lag voltage V_{BC} by Z1ANG.

In this example, Z1ANG is 84.0 degrees. From *Equation 6.9*, the angle of I_B is the angle of I_{TEST}, and the angle of I_C is 180 degrees from the angle of I_{TEST}. The test source current for I_B is the following:

$$\begin{aligned} I_B &= 2.5\angle(-90° - \text{Z1ANG})\text{A} \\ &= 2.5\angle(-90° - 84°)\text{A} \\ &= 2.5\angle -174°\text{A} \end{aligned}$$ **Equation 6.13**

And the test source current for I_C is the following:

$$I_C = -I_B = -(2.5\angle -174°\text{A}) = 2.5\angle 6°\text{A}$$ **Equation 6.14**

Checking the MBC2 Portion of the M2P Phase Distance Element

NOTE: As you perform this test, other protection elements can assert. This causes the relay to assert other targets and possibly close control outputs. Be sure to isolate the relay from the power system to avoid unexpected system effects.

The following procedure describes how to test the B-phase to C-phase distance element MBC2. Although this test refers directly to the Zone 2 phase distance element, you can apply this procedure to any other forward-reaching phase-to-phase distance element zone.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page U.4.5*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords on page U.4.6* to change the default access level passwords and enter higher relay access levels). You should be familiar with ACSELERATOR QuickSet (see *Section 3: PC Software*).

Step 1. Configure the relay.

Perform the procedure listed under *Step 1* in *Checking the Negative-Sequence Directional Element (Phase Faults) on page U.6.30*.

Step 2. Set test values in the relay.

Perform the procedure listed under *Step 2* in *Checking the Negative-Sequence Directional Element (Phase Faults) on page U.6.30*.

Step 3. Set the phase distance element reach.

a. Select the **Phase Distance** button of the ACSELERATOR QuickSet **Settings** tree view.

You will see the Phase Distance Elements dialog box similar to *Figure 6.29*.

b. Confirm the settings of **E2IP** at **2**, **Z1P** at **6.24** and **Z2P** at **9.36**.

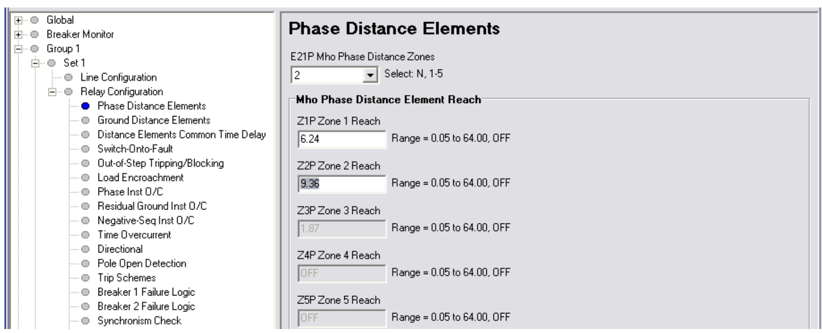


Figure 6.29 Phase Distance Elements Settings: ACSELERATOR QuickSet

Step 4. Upload the new settings to the SEL-421.

a. Click **File** > **Send**.

b. ACSELERATOR QuickSet prompts you for the settings class you want to send to the relay, as shown in the **Group Select** dialog box of *Figure 6.26*.

c. Click the check box for **Group 1**.

d. Click **OK**.

ACSELERATOR QuickSet responds with a dialog box similar to the second dialog box of *Figure 6.26*.

If you see no error message, the new settings are loaded in the relay.

Step 5. Display the MBC2 Relay Word bit on the front-panel LCD screen.

a. Access the front-panel LCD `MAIN MENU`.

b. Highlight `RELAY ELEMENTS` and press **{ENT}**.

c. You will see a RELAY ELEMENTS screen with SEARCH highlighted at the bottom of the screen.

d. Press **{ENT}** to go to the ELEMENT SEARCH submenu of *Figure 6.20*.

e. Use the navigation keys to highlight M and press **{ENT}** to enter character in the text input field.

f. Enter the B, C, and 2 characters in like manner.

g. Highlight ACCEPT and press **{ENT}**.

The relay displays the LCD screen containing the MBC2 element, as shown in *Figure 6.30*.

```
RELAY ELEMENTS
ROW 8          ROW 9
*        =0    *        =0
MCA2     =0    MCA4     =0
MBC2     =0    MBC4     =0
MAB2     =0    MAB4     =0
*        =0    *        =0
MCA1     =0    MCA3     =0
MBC1     =0    MBC3     =0
MAB1     =0    MAB3     =0

SEARCH
PRESS ↵ to search
```

Figure 6.30 RELAY ELEMENTS LCD Screen Containing Element MBC2

Step 6. Set the magnitudes and angles of the test signals for a B-phase-to-C-phase fault.

a. Connect the test sources (with power off) to the relay, as in *Figure 6.6*.

This connection is a B-phase-to-C-phase fault where $I_A \approx 0$ and $I_B = -I_C$.

b. Adjust the voltage sources to provide the following test voltages: $V_A = 67$ V $\angle 0°$, $V_B = 46.8$ V $\angle -150°$, and $V_C = 46.8$ V $\angle 150°$.

c. Set the current source for $I_B = 0.0$ A $\angle -174°$.

Step 7. Apply the sources to confirm operation of MBC2.

a. Apply the source test current by slowly increasing the magnitude of I_B.

b. Observe the RELAY ELEMENT LCD screen.

Relay Word bit MBC2 asserts when $|I_B| \geq 2.5$ A, indicating that the relay impedance calculation is less than the Z2P reach setting.

Relay Self-Tests

The SEL-421 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 SEL-421 performance.

Status Warning and Status Failure

The relay reports out-of-tolerance conditions as a status warning or a 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/close logic processing and deenergizes all control outputs. When disabled, the **ENABLED** front-panel LED is not illuminated.

The relay signals a status warning by pulsing the HALARM Relay Word bit (hardware alarm) to logical 1 for five seconds. For a Status Failure, the relay latches the HALARM Relay Word bit at logical 1. SEL-421 relays will restart on certain diagnostic failures. When this occurs, the relay will log a `Diagnostic Restart` in the SER, and the HALARM Relay Word bit will assert for five seconds. See *Appendix A: Firmware and Manual Versions* for affected firmware revisions. 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). See *Alarm Output on page U.2.43* on connecting this alarm output for the SEL-421.

If you repeatedly receive status warnings, check the 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 U.6.45*).

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 (see *Status*), except that the power supply information from the **STA A** response is included after the SELOGIC control equation error messages.

The relay also displays status warning and status failure automatic messages on the front-panel LCD. Use the serial port **STATUS** and **CSTATUS** commands, the ACSELERATOR QuickSet HMI **Status** button, and the front-panel `RELAY STATUS` menu to display status warnings and status failures. See *STATUS on page R.9.48*, *Checking Relay Status on page U.4.10*, and *Relay Status on page U.5.32* for more information on automatic status notifications and on viewing relay status.

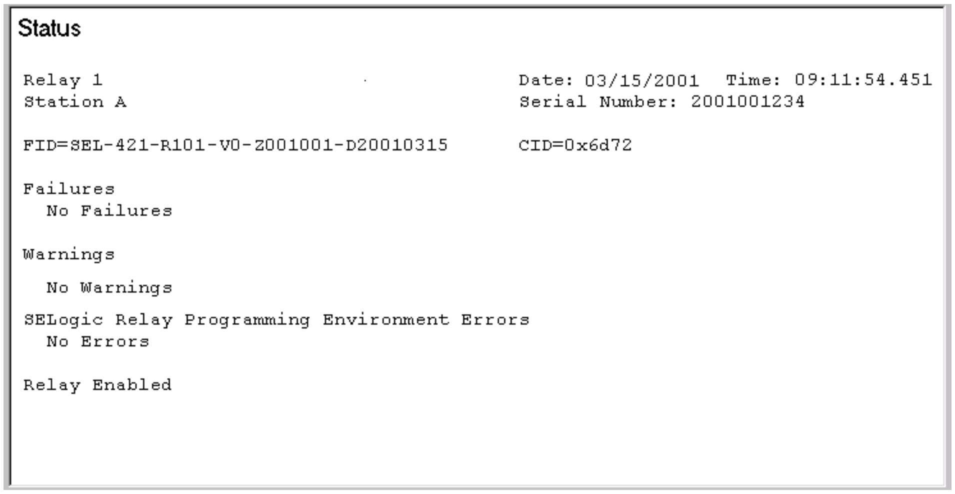
Status

Figure 6.31 is a sample **STATUS** screen from the Status option of the ACSELERATOR QuickSet **HMI > Meter and Control** tree view (the terminal **STATUS** report is similar). *Figure 6.32* is the **STATUS A** report showing all status information on a terminal.

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 string). The first character in the four-place firmware version number is R (representing Release).

For example, in *Figure 6.31* and *Figure 6.32*, the firmware version number is R101. SEL numbers subsequent firmware releases sequentially; the next revision following R101 is R102. See *Appendix A: Firmware and Manual Versions* for firmware version information.



Status

```
Relay 1                                   Date: 03/15/2001  Time: 09:11:54.451
Station A                                 Serial Number: 2001001234

FID=SEL-421-R101-V0-Z001001-D20010315     CID=0x6d72

Failures
  No Failures

Warnings

  No Warnings

SELogic Relay Programming Environment Errors
  No Errors

Relay Enabled
```

Figure 6.31 Relay Status: ACSELERATOR QuickSet HMI

```
=>>STA A <Enter>

Relay 1                                     Date: 03/15/2001  Time: 04:48:49.938
Station A                                   Serial Number: 2001001234

FID=SEL-421-R101-V0-Z001001-D20010315      CID=0x4572

Failures
  No Failures

Warnings
  No Warnings

Channel Offsets (mV)   W=Warn    F=Fail
  CH1  CH2  CH3  CH4  CH5  CH6  CH7  CH8  CH9 CH10 CH11 CH12  MOF
    0    0    0    0    0    0    0    0    0    0    0    0    0

Power Supply Voltages (V)   W=Warn    F=Fail
  3.3V_PS  5V_PS  N5V_PS  15V_PS   N15V_PS
     3.28   4.91   -4.93   14.70    -14.79

Temperature
   23.7 degrees Celsius

Communication Interfaces

Active High Accuracy Time Synchronization Source: IRIG-B
  IRIG-B Source PRESENT

SELogic Relay Programming Environment Errors
  No Errors

Relay Enabled
=>>
```

Figure 6.32 Relay Status From a STATUS A Command on a Terminal

CSTATUS

The relay also reports status information in the Compressed ASCII format when you issue the **CST** command. The Compressed ASCII status message is shown in *Figure 6.33*:

```
"RID","SID","FID","yyyy",

"relay_name","station_name","FID=SEL-xxx-x-Rxxx-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_Settings","DSP_RAM","DSP","DSP_Chksum","DSP_TIME
    OUT","CPU_CARD_RAM","CPU_DSP_RAM","FRONT_PANEL","CAL_BOARDA","CAL_BOARDB","Comm_
    Card_Change","Comm_Card","Comm_Card_Code","QUART","Analog_Conv","IO_1","IO_2","I
    O_3","IO_4","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 W or F),(Ok or W or F),(Ok or W or F),(Ok or W),(Ok or
    W),(ccrdh),(Ok or F),(Ok or F),(Ok or F),(Ok or F),(Ok or F),(Ok or F),"yyyy"

"AtoD_Offset","Master_Offset","3.3V_PS","5V_PS","N5V_PS","15V_PS","N15V_PS","Temp_St
    atus","Temp","FPGA","ADC_FPGA","yyyy"

(Ok or W),(Ok or W or F),(Ok or W or F),(Ok or W or F),(Ok or W or F),(Ok or W or
    F),(Ok or W or F),(Ok or W or F),(Temp value),(Ok or Fail),(Ok or Fail),"yyyy"

"Fast_Fiber_Port","MBA","MBB","Active_Time_Source","SELogic_Math","FM_Test","CCrd_Te
    st","DNP_Test","Event_Playback_Mode","Relay_Status","Port_F_Transp","Port_1_Tran
    sp","Port_2_Transp","Port_3_Transp","Port_4_Transp","Port_5_Transp","yyyy"
(Ok_or_F),(Inac or Ok or F),(Inac or Ok or F),(HIRIG or IRIG or " "), (Ok or F),
    (Enabled or Disabled),(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),(F, 0 - 5),"yyyy"
```

Figure 6.33 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
- ccrd is the communications card hex code
- (description) is text that the relay supplies
- (Ok or W or F) is normal, warning, or failure, respectively

Figure 6.34 is a sample Compressed ASCII status message.

```
=>CST <Enter>

"RID","SID","FID","03e2"
"Relay 1","Station A","SEL-421-R101-V0-Z001001-D20010315","0e06"
"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","0ACA"
3,15,2001,13,2,26,938,"0437"
"CPU_RAM","CPU_Prog","SELBOOT","CPU_Settings","DSP_RAM","DSP","DSP_Chksum","DSP_
TIMEOUT","CPU_CARD_RAM","CPU_DSP_RAM","FRONT_PANEL","CAL_BOARD","Comm_Card","Com
m_Card_Code","QUART","Analog_Conv","IO_1","IO_2","3B86"
"Ok","Ok","Ok","Ok","Ok","Ok","Ok","Ok","Ok","Ok","Ok","Ok",,,"Ok","Ok","Ok","Ok
","12F8"
"AtoD_Offset","Master_Offset","3.3V_PS","5V_PS","N5V_PS","15V_PS","N15V_PS","Tem
p_Status","Temp","FPGA","ADC_FPGA","20C0"
"Ok","Ok","Ok","Ok","Ok","Ok","Ok","Ok",24.8,"Ok","Ok","0C9C"
"Fast_Fiber_Port","MBA","MBB","Active_Time_Source","SELogic_Math","FM_Test","CCr
d_Test","DNP_Test","Relay_Status","Port_F_Transp","Port_1_Transp","Port_2_Transp
","Port_3_Transp","Port_5_Transp","4029"
"Not_Installed","Inac","Inac"," ","Ok","Disabled","Disabled","Disabled","Enabled"
,"0","0","0","0","0","yyyy"
=>
```

Figure 6.34 Compressed ASCII CST Command on a Terminal

Relay Troubleshooting

Inspection Procedure

Complete the following inspection procedure before disturbing the system. After you finish the inspection, proceed to *Troubleshooting Procedures*.

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 6.9*. The table lists each symptom, possible causes, and corresponding diagnoses/solutions. Related SEL-421 commands are listed in bold capitals. See *Section 9: ASCII Command Reference in the Reference Manual* for details on SEL-421 commands and *Section 10: Settings in the Reference Manual* for details on relay settings.

Table 6.9 Troubleshooting Procedures (Sheet 1 of 3)

Possible 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 U.2.40*).
Poor contrast adjustment.	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.	Contact the SEL factory or your Technical Service Center. The OUT108 relay control output b contacts will be closed if you programmed NOT HALARM to OUT108 (see *Alarm Output on page U.2.43*).
Alarm Output Asserts	
Power is off.	Restore power.
Blown power supply fuse.	Replace the fuse (see *Power Supply Fuse Replacement on page U.2.40*).
Power supply failure.	LCD displays `STATUS FAILURE` screen. Contact the SEL factory or your Technical Service Center.
Main board or interface board failure.	LCD displays `STATUS FAILURE` screen. Contact the SEL factory or your Technical Service Center.

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.

Table 6.9 Troubleshooting Procedures (Sheet 2 of 3)

Possible Cause	Diagnosis/Solution
Other self-test failure.	LCD displays STATUS FAILURE screen. Contact the SEL factory or your Technical Service Center.
System Does Not Respond to Commands	
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 U.5.28*).
Incorrect communications cables.	Use SEL communications cables, or cables you build according to SEL specifications (see *Communications Ports Connections on page U.2.47*).
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 *Communications Ports Connections on page U.2.47*).
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 *Communications Ports Connections on page U.2.47*).
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 (see *Section 1: Protection Application Examples in the Applications Handbook*).
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 U.4.33*).
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 U.2.15*).
Check the relay self-test status.	Take preventive action as directed by relay Status Warning and Status Failure information (see *Relay Self-Tests on page U.6.38* and *Checking Relay Status on page U.4.10*).

Table 6.9 Troubleshooting Procedures (Sheet 3 of 3)

Possible Cause	Diagnosis/Solution
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; a contacts will be open and b contacts will 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.
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.
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 converter failure.	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.
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
1k PPS cable still connected.	Remove 1k PPS cable (see *Configuring High-Accuracy Timekeeping on page U.4.71*)
IRIG-B connected to incorrect BNC input.	Ensure that the correct BNC connector is being used. See *Figure 4.63 on page U.4.74*.
A low-priority time source error.	Check last update source (**TIME Q** command or `HMI SET/SHOW | Date/Time` screen). See *Table 4.9 on page U.4.71*.
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 *Battery-Backed Clock on page U.2.11*.

Technical Support

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

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Appendix A
Firmware and Manual Versions

Firmware

Determining the Firmware Version in Your Relay

To find the firmware revision number in your relay, view the status report using the serial port **STATUS** command. The status report displays the Firmware Identification (FID) label:

FID=SEL-421-Rxxx-Vx-Zxxxxxx-Dxxxxxxxx, or

FID=SEL-421-x-Rxxx-Vx-Zxxxxxx-Dxxxxxxxx

You can also view the FID label from the front panel. From the ROTATING DISPLAY front-panel screen, press the **{ENT}** pushbutton to advance to the MAIN MENU screen. Use the **{Down Arrow}** pushbutton to highlight the RELAY STATUS option, and press the **{ENT}** pushbutton. The FID label displays on the screen:

SEL-421-Rxxx-Vx-Zxxxxxx-Dxxxxxxxx, or

SEL-421-x-Rxxx-Vx-Zxxxxxx-Dxxxxxxxx

In the FID label, the firmware revision number follows the R and the release date follows the D.

For example,

FID=SEL-421-R115-V0-Z006005-D20051107

is firmware revision number 115, release date November 7, 2005.

Table A.1 lists the firmware versions, a description of modifications, and the instruction manual date code that corresponds to firmware versions. The most recent firmware version is listed first.

Table A.1 Firmware Revision History (Sheet 1 of 8)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-421-2-R131-V0-Z100011-D20130627 SEL-421-3-R131-V0-Z100011-D20130627	➤ Added setting 3PRIH to three-pole recloser initiate logic instead of hard-coded 15 cycles. ➤ Added option Y2 to setting EOOS to use the positive-sequence current restraint factor a2 as part of the OOS override logic. ➤ Added a VMEMC setting which selects between short- or medium-length memory voltage as the polarizing quantity in distance calculations. The relay uses the medium-length memory when ESERCMP = Y to ensure proper operation during voltage inversions.	20130627
SEL-421-2-R130-V0-Z015011-D20111004 SEL-421-3-R130-V0-Z015011-D20111004	➤ Ethernet card firmware (see *Table A.2*) and manual update only (see *Table A.5*).	20111215

Table A.1 Firmware Revision History (Sheet 2 of 8)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-421-2-R130-V0-Z015011-D20111004 SEL-421-3-R130-V0-Z015011-D20111004	➤ Improved reclosing function so recloser goes to lockout if circuit breaker does not open after a reclose initiate. ➤ Added CCOK bit to indicate Ethernet card is alive. ➤ Added real-time watchdog to quickly detect Ethernet card failures.	20111004
SEL-421-2-R129-V0-Z012011-D20100803 SEL-421-3-R129-V0-Z012011-D20100803	➤ Ethernet card update only (see *Table A.2*).	20101109
SEL-421-2-R129-V0-Z012011-D20100803 SEL-421-3-R129-V0-Z012011-D20100803	➤ Corrected DNP SER point initialization issue when using the Extended DNP Map. ➤ Corrected issue with the DNP3 Cold Restart operation.	20100803
SEL-421-2-R128-V0-Z012011-D20090428 SEL-421-3-R128-V0-Z012011-D20090428	➤ Manual update only (see *Table A.5*).	20090715
SEL-421-2-R128-V0-Z012011-D20090428 SEL-421-3-R128-V0-Z012011-D20090428	➤ Manual update only (see *Table A.5*).	20090529
SEL-421-2-R128-V0-Z012011-D20090428 SEL-421-3-R128-V0-Z012011-D20090428	➤ Improved accuracy of fault locator when used with a fast breaker by using only full-cycle data. ➤ Improved loss-of-potential handling during the transition of a breaker from opened to closed. ➤ Corrected handling of DNP fault summary records when EVELOCK = 0.	20090428
SEL-421-2-R127-V0-Z012011-D20090218 SEL-421-3-R127-V0-Z012011-D20090218	➤ Added EPORT port setting so user can disable ports. ➤ Added MAXACC port setting so user can restrict maximum privileges on a port. ➤ Extended password length from 6 to 12 characters. ➤ Ethernet card firmware (see *Table A.2*) and manual update (see *Table A.5*).	20090218
SEL-421-2-R125-V0-Z011011-D20090105 SEL-421-3-R125-V0-Z011011-D20090105 SEL-421-R204-V0-Z007007-D20090105 SEL-421-1-R204-V0-Z007007-D20090105	**Applies to firmware version R125 only.** ➤ Modified LOP logic to include negative-sequence check when breaker is closed. ➤ Added ability to act as client for up to two remote synchrophasor units. Time align collected data with local data to permit control operations using this data. **Applies to firmware version R125 and R204.** ➤ Security correction (see www.selinc.com/privacy.htm for details). ➤ Corrected possible bad timestamps in synchrophasor messages after relay enable. ➤ Corrected issue that could cause Fast SER to stop.	20090105
SEL-421-2-R123-V0-Z010010-D20070223 SEL-421-3-R123-V0-Z010010-D20070223 SEL-421-R201-V0-Z007007-D20070220 SEL-421-1-R201-V0-Z007007-D20070220	➤ Ethernet card firmware (see *Table A.2*) and manual update only (see *Table A.5*).	20081022
SEL-421-2-R123-V0-Z010010-D20070223 SEL-421-3-R123-V0-Z010010-D20070223 SEL-421-R201-V0-Z007007-D20070220 SEL-421-1-R201-V0-Z007007-D20070220	➤ Ethernet card firmware (see *Table A.2*) and manual update only (see *Table A.5*).	20080917

Table A.1 Firmware Revision History (Sheet 3 of 8)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-421-2-R123-V0-Z010010-D20070223 SEL-421-3-R123-V0-Z010010-D20070223 SEL-421-R201-V0-Z007007-D20070220 SEL-421-1-R201-V0-Z007007-D20070220	➤ Ethernet card firmware (see *Table A.2*) and manual update only (see *Table A.5*).	20080110
SEL-421-2-R123-V0-Z010010-D20070223 SEL-421-3-R123-V0-Z010010-D20070223	➤ Ethernet card firmware (see *Table A.2*) and manual update only (see *Table A.5*).	20070914
SEL-421-2-R123-V0-Z010010-D20070223 SEL-421-3-R123-V0-Z010010-D20070223 SEL-421-R201-V0-Z007007-D20070220 SEL-421-1-R201-V0-Z007007-D20070220	➤ Manual update only (see *Table A.5*).	20070717
SEL-421-2-R123-V0-Z010010-D20070223 SEL-421-3-R123-V0-Z010010-D20070223	➤ Added support for synchrophasors over Ethernet. ➤ Added TLED_17 through TLED_24 and PB9_LED through PB12_LED to the Fast Message response. ➤ Corrected intermittent pickup of RTDCOMF bit when connected to an SEL-2600. ➤ Expanded diagnostics coverage to include additional failure modes that will result in a relay restart. ➤ Modified frequency and rate-of-change of frequency (DFDT) measurements in the synchrophasor data packet. These quantities are now calculated using synchrophasor data. ➤ Added a new global setting (IRIGC) that selects if the IRIG signal uses the C37.118 control bits. ➤ Added Ethernet card information in the **ID** command.	20070223
SEL-421-R201-V0-Z007007-D20070220 SEL-421-1-R201-V0-Z007007-D20070220	➤ Made enhancements to diagnostics. Expanded coverage to include additional failure modes that will result in a relay restart.	20070223
SEL-421-2-R122-V0-Z009009-D20061215 SEL-421-3-R122-V0-Z009009-D20061215	Note: This firmware version was not production released. See R123 above. ➤ Added support for expanded HMI features: auxiliary **{TRIP}**/ **{CLOSE}** pushbuttons, 12 operator control pushbuttons, 24 target LEDs, double-height display points, and tri-colored LEDs. ➤ Added Alias Settings class. ➤ Added new DNP setting MAPSEL and implemented extended binary input map. ➤ Implemented DNP single-event mode. ➤ Increased number of SELOGIC conditional timers from 16 to 32. ➤ Decreased LOP latching delay from 60 cycles to 15 cycles. ➤ Added Fast Message commands to read database regions. ➤ Added 3I01 and 3I02 to Selectable Operating Quantity Inverse-Time Overcurrent Elements (51S). ➤ Restrained DNP power factor binary inputs from updating if voltage falls below 10 percent of nominal or Open Phase Detection Logic asserts. ➤ Modified HMI password entry so that characters are not echoed to the screen.	20061215
SEL-421-2-R121-V0-Z008008-D20060814 SEL-421-3-R121-V0-Z008008-D20060814 SEL-421-R200-V0-Z007007-D20060814 SEL-421-1-R200-V0-Z007007-D20060814	➤ Modified diagnostic failure mode management. Certain diagnostic test errors will result in a relay restart. Relay will log `Diagnostic Restart` in the SER if this event occurs.	20060814

Table A.1 Firmware Revision History (Sheet 4 of 8)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-421-2-R120-V0-Z008008-D20060808 SEL-421-3-R120-V0-Z008008-D20060808 Note: This version was not released from the factory.	➤ Fixed incorrect metering condition following a pulse of the Alternate Voltage Source (ALTV) or Alternate Current Source (ALTI) SELOGIC equations. ➤ Enhanced rms metering to properly measure analog quantities with greater than 50% harmonic content.	20060808
SEL-421-2-R119-V0-Z008008-D20060710 SEL-421-3-R119-V0-Z008008-D20060710	➤ Improvement to automatic removal of chattering SER points where the status of the chattering element is reported after it is reinserted in the SER record. ➤ Improvement to dropout time of breaker failure overcurrent fault detector under extreme subsidence current conditions.	20060710
SEL-421-2-R118-V0-Z008008-D20060630 SEL-421-3-R118-V0-Z008008-D20060630	Note: Firmware version R118 and newer are not applicable to the SEL-421 and SEL-421-1. ➤ Corrected IG magnitude and angle calculations in the CEV summary report. ➤ Added IEC 61850 support for the optional Ethernet card.	20060703
SEL-421-R117-V0-Z007007-D20060413 SEL-421-1-R117-V0-Z007007-D20060413 SEL-421-2-R117-V0-Z007007-D20060413 SEL-421-3-R117-V0-Z007007-D20060413	Note: This firmware version requires the use of R109 or later firmware on any installed SEL-2701 Ethernet Card. ➤ Improved accuracy of time-tagged DNP LAN/WAN binary inputs.	20060413
SEL-421-R116-V0-Z007007-D20060126 SEL-421-1-R116-V0-Z007007-D20060126 SEL-421-2-R116-V0-Z007007-D20060126 SEL-421-3-R116-V0-Z007007-D20060126	➤ Manual update only (see *Table A.5*).	20060302
SEL-421-R116-V0-Z007007-D20060126 SEL-421-1-R116-V0-Z007007-D20060126 SEL-421-2-R116-V0-Z007007-D20060126 SEL-421-3-R116-V0-Z007007-D20060126	➤ Added support for Main Board B and interface boards INT2, INT7, and INT8 which are optoisolated versions of Main Board A and interface boards INT1, INT5, and INT6. ➤ Updated to the released (non-draft) version of C37.118 IEEE Synchrophasor Standard. ➤ Added support for SEL-421-2 and SEL-421-3. ➤ Updated to the released (non-draft) version of C37.118 IEEE Synchrophasor Standard. ➤ Added alarm points and SER settings parameter HMI Alarm in order to enable automatic HMI display of alarm points. ➤ Added analog display points. ➤ Expanded to 96 display points and changed format to display on a single line. ➤ Changed Global setting class for contact inputs to support Main Board A and Main Board B and interface boards INT1, INT2, INT4, INT5, INT6, INT7, and INT8. ➤ Added setting SCROLD for changing the ROTATING DISPLAY update rate. ➤ Added settings PB1_HMI through PB8_HMI for assigning alarm point, display point, or event summary screens to the selectable operator pushbuttons. ➤ Added settings DISP_ER and TYPE_ER for enabling and configuring automatic HMI display of event summary screens. ➤ Added setting NUM_ER to specify the number of event summary screens viewed through the operator pushbutton. ➤ Added 15 messages per second option for Global setting MRATE.	20060126

Table A.1 Firmware Revision History (Sheet 5 of 8)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Corrected the voltage check element logic which is using incorrect input voltages. ➤ Improved performance of phase directional element logic. ➤ Corrected transition from ROTATING DISPLAY to manual mode when using navigational arrows.	
SEL-421-R115-V0-Z006006-D20051107 SEL-421-1-R115-V0-Z006006-D20051107	Note: This firmware version requires the use of R108 or later firmware on any installed SEL-2701 Ethernet card. ➤ Added DNP3 LAN/WAN support when using the SEL-2701 Ethernet Card. ➤ The **STATUS A** command will now include information on how many Telnet sessions are active. ➤ Added second file transfer session to allow access to SEL-2701 settings files (SET_DNP*n*.TXT) via FTP. ➤ Fixed the Trip Unlatch logic to ignore 52AA2 logic when NUMBK =1. ➤ SET_DNP*n*.TXT files from the SEL-2701 are now available in the relay file system and can be accessed via FTP or the ASCII **FILE** command. ➤ Added time-stamped SER data from the relay into TARGET region of the SEL-2701 DNP3 database. ➤ Fixed IRIG/HIRIG time synchronization problem to properly lock onto the incoming time signal after a year rollover. ➤ Enhanced the LOP logic to accommodate a corner case scenario. If SPO bit is set to three-pole tripping and 52AA*n* status shows breaker is open, even though it is closed (due to removing dc or settings mistake) and phase current is below the open pole detection then LOP will assert. ➤ Enhanced the **PORT 5** command to allow transparent access to the SEL-2701 user interface from the host relay.	20051107
SEL-421-R114-V0-Z005005-D20050805 SEL-421-1-R114-V0-Z005005-D20050805	➤ Adjusted processing to make synchrophasor analog quantities contemporaneous with streamed synchrophasor data. ➤ Improved POTT logic to speed up tripping in WIF applications (ELOP := Y1). ➤ Added independent two-breaker reclosing (E79 := Y1). ➤ Added single- and three-pole open interval supervision condition logic (SPOISC, SPOISD, 3POISC, 3POISD). ➤ Corrected issue where momentary setting of LOP can slow down tripping in WIF applications (ELOP = Y1). ➤ Expanded front-panel target rows from 255 to 323. ➤ Removed scaling from floating point phasor magnitudes per IEEE C37.118. ➤ Adjusted Second-of-Century (SOC) to Universal-Time-Coordination (UTC) rather than local time. ➤ Corrected issue where incoming IRIG/HIRIG data are ignored for two minutes after a year rollover. ➤ Provided autoscaling of voltage magnitudes on front-panel HMI. ➤ Corrected issue where daylight savings time (DST) or UTC offset (TUTC) assertion could corrupt SOC value.	20050805
SEL-421-R113-V0-Z004005-D20050119 SEL-421-1-R113-V0-Z004005-D20050119	➤ Improvements for manufacturability. This firmware includes all of the enhancements listed under R112, below.	20050119

Table A.1 Firmware Revision History (Sheet 6 of 8)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-421-R112-V0-Z004005-D20041217 SEL-421-1-R112-V0-Z004005-D20041217	Note: This firmware version was not production released. See R113, above. ➤ Added support for IEEE C37.118, Standard for Synchrophasors for Power Systems. ➤ Added Synchrophasor support to the SEL-421-1. ➤ Added PMU (Phasor Measurement Unit) to the serial port settings protocol (PROTO) options for dedicated synchrophasor communications. ➤ Removed port settings PMADDR and PMDATA. Similar functionality is now provided through Global settings, Synchrophasor category. ➤ Changed the TIME input processing to provide high-accuracy timekeeping with a GPS-synchronized IRIG-B signal applied to the IRIG-B BNC connector. ➤ Removed 1k PPS BNC input. ➤ Renamed high-accuracy timekeeping mode HIRIG (previously called PPS mode). ➤ Added timekeeping-related analog quantities for time quality (TQUAL) and UTC Offset (TUTC). ➤ Added Synchrophasor data to the analog quantities available for use in SELOGIC®. ➤ Added a rate-of-change-of-frequency calculation analog quantity, DFDT. ➤ Added time-error calculation logic, and analog quantities TE and TECORR. ➤ Added **TEC** (Time-Error Calculation) command for viewing the time-error, or pre-loading a correction value. ➤ Added support for INT4 I/O Interface Board with 24 optoisolated control inputs and 8 control outputs. ➤ Added Relay Word bits for Synchrophasor (PMU) Triggers, Time and Synchronization Control, Time-Error Calculation, and INT4 I/O Interface board support. ➤ Changed Global settings class to support new Synchrophasor settings, Time-Error Calculation settings, and settings for INT4 I/O Interface Board support. ➤ Removed Time and Date Management settings from Global settings class. ➤ Added **SER CV** and **SER RV** commands for clearing viewed SER data. ➤ Added analog quantities CTRW, CTRX, PTRY, PTRZ, based on the active group settings of the same name. ➤ Reduced minimum allowable pickup settings for the inverse-time overcurrent elements to 0.05 • I_{NOM}. ➤ Modified auto-reclose logic for two circuit breaker, three-pole cycle state to include a check for enable conditions E3PR1 and E3PR2 to properly handle reclose supervision after multi-phase faults. ➤ Corrected error in logic for breaker monitor mechanical operating time alarm that may have caused incorrect B1MSOAL operation. Error introduced in firmware revision R110. ➤ Improved faulted phase identification logic performance for isolated zero-sequence source conditions. ➤ Corrected port settings class handling of leading spaces in MIRRORED BITS® analog settings MBANA*n*. ➤ Reduced healthy voltage qualifying time from 15 to 6 cycles in 25ENBK1 and 25ENBK2 synchronism check enable logic. ➤ Corrected uncompensated synch check element logic for 25A1BK1, which may have caused incorrect assertion under test conditions.	20041217

Table A.1 Firmware Revision History (Sheet 7 of 8)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Corrected issue where a conflict in DNP processing and communications could suspend all relay communications. ➤ Corrected issue where incorrect scaling of stored values could cause an erroneous drift in metered quantities. ➤ Corrected issue where incorrect scaling of stored values could cause an erroneous drift in the metered slip frequency for synchronism check. ➤ Added Security Enhancements when used with the SEL-2701 Ethernet Processor.	
SEL-421-R111-V0-Z003004-D20040602 SEL-421-1-R111-V0-Z003004-D20040602	➤ Corrected issue where turning off power may cause a low-set (less than 50% of I_{NOM}) 50G or 67G element to inadvertently operate. ➤ Corrected issue where the dc battery monitor may report incorrect values for Vdc.	20040602
SEL-421-R110-V0-Z003004-D20030918 SEL-421-1-R110-V0-Z003004-D20030918	➤ Added fast message protocol compatibility with the SEL-2600 RTD Module. ➤ Improved distance elements. ➤ Improved out-of-step logic. ➤ Increased free-form protection SELOGIC capacity from 100 lines to 250 lines. ➤ Improved cross-country fault detection. ➤ Added high-speed distance elements to the Relay Word. ➤ Improved relay security features, including the addition of the BADPASS Relay Word bit. ➤ Increased number of SELOGIC math variables displayed from 16 to all. ➤ Addressed condition in which if IRIG-B time source is used and the date rolls over from December 31st to January 1st, the year may not increment. ➤ Corrected file command error message. ➤ Fixed condition where the SEL-421 does not send the fast message power-up bit in the status byte of the first message. ➤ Fixed condition in R109 where a file read of events or compressed history using the no modem option may cause the relay to become non-responsive. ➤ Fixed condition where significant communications traffic, i.e., MIRRORED BITS at 38400 baud with an SEL-2701 Ethernet card installed, may cause delays in servicing of low-priority background tasks.	20030918
SEL-421-R109-V0-Z002003-D20030409 SEL-421-1-R109-V0-Z002003-D20030409	➤ Fixed condition where inverse-time overcurrent protection does not operate for multiples of pickup setting greater than 50 when U1, U2, U3, U5, C1, or C5 characteristic is selected.	20030409
SEL-421-R108-V0-Z002003-D20021216 SEL-421-1-R108-V0-Z002003-D20021216	➤ Fixed condition where protection and automation latch elements may not restore to previous set state after loss of power.	20021216
SEL-421-R107-V0-Z002003-D20020918 SEL-421-1-R107-V0-Z002003-D20020918	➤ Modified handling of RTS signal with DNP protocol to properly act as a transmit enable with a non-zero PREDLY setting. ➤ Enabled MIRRORED BITS communications loopback function. ➤ Added enable condition to pole open logic so that single-pole open (SPO) indication does not operate for three-pole trip applications.	20020918

Table A.1 Firmware Revision History (Sheet 8 of 8)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-421-R106-V0-Z002003-D20020819 SEL-421-1-R106-V0-Z002003-D20020819	➤ Corrected issue that causes front-panel display and serial port to simultaneously lock up during settings save/rotating display change. ➤ Corrected OFF value for phase-to-phase, phase-to-ground, and ground quadrilateral distance zones. ➤ Corrected KEY1 and KEY3 pulse during relay warm start. ➤ Paused unsolicited Sequence of Events message during a file transfer. ➤ Corrected the default value for the Ground Detection Factor for DC Monitor 1.	20020819
SEL-421-R105-V0-Z002003-D20020621 SEL-421-1-R105-V0-Z002003-D20020621	➤ Updated values stored in the meter region of the communications card database to be stored in volts rather than kilovolts. ➤ Updated values stored in the meter region of the communications card database to be stored in volts rather than kilovolts.	20020621
SEL-421-R104-V0-Z002002-D20020528 SEL-421-1-R104-V0-Z002002-D20020528	➤ Corrected issue with update of Object 1 status for Object 2 default map indices over 800. ➤ Increased DNP event buffer for Object Type 2 to 1024 from 512.	20020528
SEL-421-R103-V0-Z002002-D20020417 SEL-421-1-R103-V0-Z002002-D20020417	➤ Manual update only (see *Table A.5*).	20020501
SEL-421-R103-V0-Z002002-D20020417 SEL-421-1-R103-V0-Z002002-D20020417	➤ Using a serial port for interleaved data may cause the relay to disable. This condition occurs when a communications processor is automatically retrieving data from the relay simultaneously with a serial port terminal session.	20020417
SEL-421-R102-V0-Z002001-D20020403 SEL-421-1-R102-V0-Z002001-D20020403	➤ Added new analog quantities for use in the following SELOGIC control equations: Terminal W and X current magnitudes Terminal Y and Z voltage magnitudes Instantaneous sequence quantities Contact inputs ➤ Initial Release with Synchrophasor Measurement capability to the SEL-421 (not in the SEL-421-1). ➤ Added VAZ, VBZ, VCZ settings options to SYNCP. ➤ Added VAY, VBY, VCY settings options to SYNCS1, SYNCS2, and ASYNCS2. ➤ Added ACOS, ASIN, CEIL, FLOOR, and LOG math functions to SELOGIC® control equations. ➤ Modified CHI output for SEL-2030 compatibility.	20020403
SEL-421-R101-V0-Z001001-D20020104 SEL-421-1-R101-V0-Z001001-D20020104	➤ Added 8-cycle lockout for subsequent ALTI or ALTV switches. ➤ Initial SEL-421-1 version.	20020108
SEL-421-R100-V0-Z001001-D20010703	➤ Initial SEL-421 version.	20010703

Table A.2 lists the Ethernet card firmware versions, a description of modifications, and the instruction manual date code that corresponds to firmware versions. The most recent firmware version is listed first.

Table A.2 Ethernet Card Firmware Revision History (Sheet 1 of 2)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-2702-R115-V0-Z002002-D20190325 SLBT-2701-R103-V0-Z000000-D20080820	➤ Resolved an issue where certain Ethernet traffic could cause the relay to safely restart.	20190325
SEL-2702-R114-V0-Z002002-D20190308 SLBT-2701-R103-V0-Z000000-D20080820	**Note:** This firmware did not production release.	---

Table A.2 Ethernet Card Firmware Revision History (Sheet 2 of 2)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-2702-R113-V0-Z002002-D20111215 SLBT-2701-R103-V0-Z000000-D20080820	➤ Added support for database references in IEC 61850 configuration files.	20111215
SEL-2702-R112-V0-Z002002-D20110715 SLBT-2701-R103-V0-Z000000-D20080820	➤ Improved port failover performance.	20111004
SEL-2702-R111-V0-Z002002-D20101109 SLBT-2701-R103-V0-Z000000-D20080820	➤ Added support for multicast synchrophasors.	20101109
SEL-2702-R110-V0-Z001001-D20090205 SLBT-2701-R103-V0-Z000000-D20080820	➤ Improved security (see www.selinc.com/privacy.htm for details).	20090205
SEL-2702-R109-V0-Z001001-D20081022 SLBT-2701-R103-V0-Z000000-D20080820	➤ Updated IEC 61850 firmware to streamline MMS processing and improve TCP/IP connections. ➤ Security correction (see www.selinc.com/privacy.htm for details). ➤ Corrected issue that could cause the Ethernet card to fail under heavy DNP traffic.	20081022
SEL-2702-R108-V0-Z001001-D20080729 SLBT-2701-R103-V0-Z000000-D20080820	➤ Corrected issue that could cause the Ethernet card to fail under heavy DNP traffic.	20080917
SEL-2702-R107-V0-Z001001-D20080107 SLBT-2701-R102-V0-Z000000-D20051107	➤ Enhanced IEC 61850 with KEMA certification updates. ➤ Added indication of ICD/CID file parse failure to the SEL-2702 user interface (**ID**, **STA**, **GOO** commands).	20080110
SEL-2702-R106-V0-Z001001-D20070914 SLBT-2701-R102-V0-Z000000-D20051107	➤ Added additional improvements to IEC 61850 control operation priorities when using IEC 61850 GOOSE messaging. ➤ Corrected issue where communications card MAC address is deleted when upgrading from SEL-2701 firmware version R105 to an SEL-2702.	20070914
SEL-2702-R104-V0-Z001001-D20070717 SLBT-2701-R102-V0-Z000000-D20051107	➤ Made improvements to IEC61850 control operation priorities when using IEC61850 GOOSE messaging. ➤ Allocated additional memory for read/write of large IEC 61850 messages. ➤ Fixed ability to pulse Breaker and Latch control bits using DNP LAN/WAN when DNPMAP = AUTO.	20070717
SEL-2702-R103-V0-Z001001-D20070223 SLBT-2701-R102-V0-Z000000-D20051107	➤ Added support for synchrophasors over Ethernet.	20070223
SEL-2702-R101-V0-Z000000-D20060808 SLBT-2701-R102-V0-Z000000-D20051107	➤ Added support for pulse operations on DNP LAN/WAN control points, both paired and unpaired. ➤ Added ability to sense local operations and update IEC 61850 origination category.	20060808
SEL-2702-R100-V0-Z000000-D20060630 SLBT-2701-R102-V0-Z000000-D20051107	➤ Initial version.	20060703

The optional Ethernet card (SEL-2701 or SEL-2702) must be paired with a compatible SEL-421 or SEL-421 version. You may need to upgrade your SEL-421 firmware to access features in new versions of the Ethernet cards. *Table A.1* includes notes on SEL-421 modifications that support new features of the Ethernet cards.

To find the firmware revision number in your Ethernet card, first connect to the SEL-421 with the **ACC** command. View the FIDs with the **VERSION** command. Look for the Ethernet card Firmware Identification (FID) label in the response under Communications Card:

FID=SEL-270x-Rxxx-Vx-Zxxxxxx-Dxxxxxxxx

In the FID label, the 4 digits after "SEL" indicate which Ethernet card is installed. The firmware revision number follows the R and the release date follows the D.

For example,

SEL-2701-R108-V0-Z002001-D20051205

is for an SEL-2701 Ethernet card, firmware revision number 108, release date December 5, 2005.

Table A.3 lists current Ethernet card firmware versions with compatible SEL-421 versions.

Table A.3 Compatible SEL-421 and Ethernet Card Firmware Versions

SEL-421 Firmware	Ethernet Card	Ethernet Card Firmware
R123 or higher	SEL-2702	R103 or higher
R118–R122	SEL-2702	R100–R101
R115–R116; R200 or higher	SEL-2701	R106 or higher
R114 or lower	SEL-2701	R105 or lower

Newer SEL-2702 card firmware (R106 and higher) uses a different software library from lower versions and is unable to process version 001 CID files. ACSELERATOR Architect generates CID files from ICD files so the ICD file version number and CID file version number are the same. If downloaded to the Ethernet card, an incompatible CID file will generate file parse errors during processing and disable the IEC 61850 protocol.

If you perform an Ethernet card firmware upgrade that spans different file version compatibilities, the relay may not be able to process the stored CID file. See the *Ethernet Port Firmware Upgrade Instructions* in the *SEL-400 Series Firmware Upgrade Instructions* for CID file conversion procedures.

See *Table A.4* for compatibilities between ACSELERATOR Architect, ICD/CID file, and Ethernet card firmware versions.

Table A.4 ACSELERATOR Architect CID File Compatibility

ACSELERATOR Architect Software Version	ACSELERATOR Architect ICD/CID File Version	SEL-2702 Card Firmware
All versions	Ver 001	R100–R106
R.1.1.69.0 or higher	Ver 002 (all)	R107 or higher

Instruction Manual

The date code at the bottom of each page of this manual reflects the creation or revision date.

Table A.5 lists the instruction manual release dates and a description of modifications. The most recent instruction manual revisions are listed at the top.

Table A.5 Instruction Manual Revision History (Sheet 1 of 16)

Revision Date	Summary of Revisions
20190325	**User's Guide** Appendix A ➤ Updated for Ethernet firmware version R115-V0.
20130627	**User's Guide** Appendix A ➤ Updated for firmware version R131. **Applications Handbook** Section 1 ➤ Added *EOOS = Y* and *EOOS = Y2*. **Reference Manual** Section 1 ➤ Updated *Out-of-Step Logic*. ➤ Updated *Figure 1.35: Zone 1 Mho Ground Distance Element Logic Protection*, *Figure 1.38: Zone 1 Quadrilateral Ground Distance Element Logic Diagram*, and *Figure 1.41: Zone 1 Mho Phase Distance Element Logic Diagram*. ➤ Added *Polarizing Quantity Distance Element Calculations*. Section 2 ➤ Added 3PR1H setting to *Table 2.24: Auto-Reclose Logic Settings*. Section 10 ➤ Added 3PR1H setting to *Table 10.67: Three-Pole Reclose Logic Settings*.
20111215	**User's Guide** Section 2 ➤ Updated *Specifications*. Appendix A ➤ Updated for Ethernet card firmware version R113. **Reference Manual** Section 3 ➤ Updated *Table 3.27 Math Error Examples*. Section 6 ➤ Updated *Table 6.24 SEL-421 DNP3 Object List*. Section 10 ➤ Updated *Table 10.10 Settings Group Selection*.
20111004	**User's Guide** Appendix A ➤ Updated for firmware version R130. ➤ Updated for Ethernet card firmware version R112. **Reference Manual** Section 2 ➤ Added information about reclose cycle operations in under *Single-Pole Mode* and *Three-Pole Mode* in *One Circuit Breaker Auto-Reclose Modes*. Section 4 ➤ Added description of Relay bit CCOK actions in *Ethernet Card*. Appendix A ➤ Updated *Table A.1: Relay Word Bits: Relay Alarms*. ➤ Updated *Table A.35: Relay Word Bits: Relay Alarms*.

Table A.5 Instruction Manual Revision History (Sheet 2 of 16)

Revision Date	Summary of Revisions
20101109	**User's Guide** Appendix A ➤ Updated for Ethernet card firmware version R111.
20100803	**User's Guide** Appendix A ➤ Updated for firmware version R129.
20090715	**Reference Manual** Section 2 ➤ Added information about reclose cycle operations.
20090529	**User's Guide** Section 1 ➤ Removed reference to 10BASE-FL communications card option. Section 2 ➤ Removed reference to 10BASE-FL communications card option. ➤ Removed *Figure 2.44: Two 10BASE-FL Port Configuration*, *Figure 2.45: 100BASE-FX and 10BASE-FL Port Configuration*, and *Figure 2.46: 10BASE-FL and 10/100BASE-T Port Configuration*. **Applications Handbook** Section 7 ➤ Removed reference to 10BASE-FL communications card option from *Table 7.2: Ethernet Connection Options*.
20090428	**User's Guide** Appendix A ➤ Updated for firmware version R128.
20090218	**User's Guide** Section 4 ➤ Updated *Changing the Default Passwords* to add Access Level C information. ➤ Updated *Figure 4.5: Access Level Structure*. ➤ Updated *Table 4.3: SEL-421 Access Levels* and *Table 4.4: SEL-421 Access Level Commands and Passwords*. ➤ Updated *Communications Ports Access Levels* to reflect new Access Level C port settings. ➤ Updated steps under *Passwords.* Appendix A ➤ Updated for Ethernet card firmware version R110. ➤ Updated for firmware version R127. **Reference Manual** Section 9 ➤ Modified *Password* to reflect the extended password length from 6 to 12 characters. Section 10 ➤ Updated *Table 10.93: Protocol Selection*.
20090105	**User's Guide** Section 1 ➤ Updated *Table 1.1: Application Highlights*. Section 4 ➤ Added description of **CAL** access level. Appendix A ➤ Updated for firmware version R125 (SEL-421-2, -3) and R204 (SEL-421-0, -1). **Reference Manual** Section 7 ➤ Added synchrophasor settings MRTCDLY, RTCRATE, PMUMODE, RTCID. ➤ Updated *Table 7.1: PMU Settings in the* SEL-421 *for C37.118 Protocol in Global Settings* and *Table 7.3:* SEL-421 *Serial Port Settings for Synchrophasors.* ➤ Added *Table 7.11: Synchrophasor Client Status Bits*, *Table 7.12: Remote Synchrophasor Data Bits*, and *Table 7.14: Synchrophasor Aligned Analog Quantities*.

Table A.5 Instruction Manual Revision History (Sheet 3 of 16)

Revision Date	Summary of Revisions
	Section 9 ➤ Added **CAL**, **COM RTC**, **COM RTC *c* C** and **COM RTC *c* R**, **MET RTC**, and **RTC** commands and descriptions. Modified the **PAS** command description. Section 10 ➤ Updated *Table 10.15: Synchronized Phasor Measurement*. ➤ Added *Table 10.99: PMU Protocol Settings*. Appendix A ➤ Updated *Table A.1: Alphabetic List of Relay Word Bits* and *Table A.50: Time and Synchronization Control Bits*. ➤ Added *Table A.55: RTC Remote Digital Status* and *Table A.56: Fast Operate Transmit Bits*. Appendix B Updated *Table B.1: Analog Quantities Sorted Alphabetically* and *Table B.2: Analog Quantities Sorted by Function*.
20081022	**User's Guide** Appendix A ➤ Updated for Ethernet card firmware version R109 and SELBOOT firmware version R103.
20080917	**User's Guide** Appendix A ➤ Updated for Ethernet card firmware version R108 and SELBOOT firmware version R103.
20080110	**User's Guide** Appendix A ➤ Updated for Ethernet card firmware version R107. ➤ Added *Table A.4: ACSELERATOR Architect CID File Compatibility*. **Reference Manual** Section 4 Added descriptions of **ID**, **STA**, and **GOO** commands ICD/CID file parse failure indication. Section 8 ➤ Added and edited tables to document new ICD file versions supported by ACSELERATOR Architect version R.1.1.69.0. ➢ Added *Table 8.7: ICD Logical Nodes Summary*. ➢ Updated *Table 8.8: Logical Device: PRO (Protection)* through *Table 8.11: Logical Device: ANN (Annunciation)*.
20070914	**User's Guide** Appendix A ➤ Updated for Ethernet card firmware version R106. **Reference Manual** Added details and examples to indicate how to get SOE-quality timestamped data over a DNP LAN/WAN connection in the following sections. Section 4 ➤ Updated titles in *Table 4.19–Table 4.27*. Section 6 ➤ Updated *Table 6.21*, *Table 6.26*, and *Table 6.28*. ➤ Added *Figure 6.4*.
20070717	**User's Guide** Section 5 ➤ Added SER section to *Front-Panel Menus and Screens*. ➤ Revised Local Control Bits in *Front-Panel Menus and Screens*. Appendix A ➤ Updated for Ethernet card firmware version R104. **Reference Manual** Section 2 ➤ Updated *Figure 2.10*, *Figure 2.11*, *Figure 2.12*, *Figure 2.14*, and *Figure 2.15*. Section 10 ➤ Added Local Bit SELOGIC table.

Table A.5 Instruction Manual Revision History (Sheet 4 of 16)

Revision Date	Summary of Revisions
	Appendix A ➤ Added LB_DP01 through LB_DP32 to *Table A.1*. ➤ Added LB_SP01 through LB_SP32 to *Table A.1*. ➤ Added Relay Word bits: Local Bit Supervision and Status table for rows 284–291 to *Table A.53*.
20070223	**User's Guide** Appendix A ➤ Updated for firmware version R123 (SEL-421-2, -3) and R201 (SEL-421-0, -1). **Applications Handbook** Section 6 ➤ Added LED and pushbutton statuses from expanded HMI to *Table 6.7*. Section 7 ➤ Added synchrophasor to list of available protocols. **Reference Manual** Section 1 ➤ Added *Frequency Estimation Provided* by *Synchrophasor*. Section 4 ➤ Added the Ethernet card as one of the available communications interfaces for the Phasor Measurement Protocol. Section 7 ➤ Added *Table 7.2* for the Time and Date Management setting IRIGC. ➤ Added *Table 7.4 Ethernet Port Settings for Synchrophasors*. ➤ Changed FREQ to FREQ_PM (frequency measurement using phasor measurement quantities) in *Table 7.9*. ➤ Added synchrophasor protocol availability when EPMIP := Y. ➤ Revised example logic settings in *Table 7.15*. Section 10 ➤ Added *Table 10.16* for the Time and Date Management setting IRIGC.
20061215	Note: This version was not released from the factory. The 20070223 version contains the following changes. **User's Guide** Section 1 ➤ Added *Alias Settings* and *Auxiliary* {TRIP}/{CLOSE} *Pushbuttons* to *Features*. ➤ Added INT3 to *Models and Options*. ➤ Added INT3 to *SEL-421 Versions and Supported Features*. ➤ Added INT3 and Auxiliary {TRIP}/{CLOSE} Pushbuttons to *Specifications*. Section 2 ➤ Added INT3 to *Control Inputs*. ➤ Added *Figure 2.12*. ➤ Added INT3 to *Table 2.3* and *Table 2.4*. ➤ Added INT3 to *I/O Interface Board Jumpers*. ➤ Added *Figure 2.22*. ➤ Added *Auxiliary {TRIP}/{CLOSE} Pushbutton and Breaker Status LED Jumpers (select models only)* with *Table 2.8*, *Table 2.9*, and *Table 2.10*. ➤ Updated *Figure 2.26* to include optional pushbuttons. ➤ Added *Figure 2.32*. ➤ Add INT3 to *Control Inputs*. ➤ Added *Auxiliary {TRIP}/{CLOSE} Pushbuttons and OPEN/CLOSED LEDs (select models only)* to *Connection*. ➤ Added *Figure 2.51*. Section 4 ➤ Added Alias Settings to *Table 4.5*. ➤ Edited *Figure 4.13* and *Figure 4.14* for Display Points Text Size parameter. ➤ Added *Alias Settings*. ➤ Added *Figure 4.15*, *Figure 4.16*, and *Figure 4.17*.

Table A.5 Instruction Manual Revision History (Sheet 5 of 16)

Revision Date	Summary of Revisions
	Section 5 ➤ Added *Figure 5.2*. ➤ Updated *Front-Panel Layout* for HMI changes: expanded pushbuttons, expanded target LEDs, tri-color LEDs, and auxiliary {TRIP}/{CLOSE} pushbuttons. ➤ Updated *Figure 5.5*, *Figure 5.11*, and *Example 5.2* to include double-height Display Points. ➤ Updated *Display Points* and *Table 5.4* and *Table 5.5* to include Text Size parameter. ➤ Updated *Relay Elements (Relay Word Bits)* for Alias impact. ➤ Updated *Operation and Target LEDs* for HMI changes: expanded target LEDs and tri-color LEDs. ➤ Updated *Figure 5.43* for expanded target LEDs. ➤ Added *Table 5.11*. ➤ Updated *Recloser Status* for expanded target LEDs. ➤ Added *Miscellaneous Status* and *Synchrophasor Status* for expanded target LEDs. ➤ Updated *Figure 5.44*, *Table 5.13*, and *Figure 5.45* for expanded pushbuttons. Section 6 ➤ Updated *Figure 6.8* for Alias impact. Appendix A ➤ Updated for firmware version R122. **Applications Handbook** Section 1 ➤ Updated 3I0*n* 51S quantity in the following: ➢ *230 kV Overhead Transmission Line Example* and *Table 1.6*. ➢ *500 kV Parallel Transmission Lines With Mutual Coupling Example* and *Table 1.13*. ➢ *345 kV Tapped Overhead Transmission Line Example* and *Table 1.21*. ➢ *EHV Parallel 230 kV Underground Cables Example* and *Table 1.31*. Section 3 ➤ Added INT3 to *Data Processing*. ➤ Added *Alias Names* to *Event Reports, Event Summaries, and Event Histories*. ➤ Updated *Digital Section of the Event Report* and *Settings Section of the Event Report* for Alias impact. ➤ Updated *Figure 3.12* and *Figure 3.13* to include Alias settings. Section 6 ➤ Updated *Table 6.3* to include new database region 20 messages. **Reference Manual** Section 1 ➤ Updated *Figure 1.17* to decrease LOP latching delay from 60 cycles to 15 cycles. ➤ Updated *Table 1.56*, *Table 1.57*, and *Table 1.58* for 3I0*n* 51S quantity. ➤ Updated *Figure 1.70* to include NUMBK = 2 logic input. Section 3 ➤ Added Aliases to *Table 3.1*. ➤ Updated *Table 3.2* and *Table 3.13* to include 32 conditioning timers. ➤ Added *Aliases*. ➤ Added *Example 3.10*. ➤ Updated *Table 3.28* to include 32 conditioning timers. Section 5 ➤ Updated *Table 5.10* to include Alias settings.

Table A.5 Instruction Manual Revision History (Sheet 6 of 16)

Revision Date	Summary of Revisions
	Section 6 ➤ Updated *Table 6.6* for new settings EVELOCK, MINDIST, and MAXDIST. ➤ Updated *Table 6.7* new setting for MAPSEL. ➤ Updated *Default Data Map* to explain new reference maps. ➤ Updated *Table 6.10* to include two reference maps and new index 182. ➤ Added *Reading Relay Event Data* section. ➤ Corrected Bit values in *Table 6.14*. ➤ Updated *Figure 6.2* for new setting MAPSEL. ➤ Updated *Table 6.18* for new settings EVELOCK, MINDIST, and MAXDIST. Section 9 ➤ Added ***SET T*** and ***SHO T*** commands. ➤ Updated ***TAR*** command to include aliases. Section 10 ➤ Added Alias Settings and *Table 10.1* and *Figure 10.1*. ➤ Updated *Table 10.11* for new setting RSTDNPE. ➤ Updated *Table 10.52*, *Table 10.53*, and *Table 10.54* for 3I0*n* 51S quantity. ➤ Updated *Table 10.65* for new BK1MCL default settings. ➤ Updated *Table 10.70* for new BK1MTR default settings. ➤ Updated *Table 10.79* for HMI changes: tri-color LEDs, expanded pushbuttons, and expanded target LEDs. ➤ Updated Table 10.81 for expanded pushbuttons. ➤ Updated *Table 10.83* and *Table 10.84* for Text Size parameter. ➤ Updated *Table 10.96* for new settings EVELOCK, MINDIST, and MAXDIST. ➤ Added *Table 10.101*. Appendix A ➤ Updated *Table A.1* to increment certain Relay Word bit rows and added Relay Word bits EVELOCK, PB9_PUL-PB12PUL, PCT17Q–PCT32Q, PB_CLSE, PB_TRIP, RSTDNPE, and TLED_17–TLED_24. ➤ Added PCT17Q–PCT32Q to *Table A.27*. ➤ Added RSTDNPE to *Table A.39*. ➤ Added *Table A.50*. ➤ Added *Table A.52*. Appendix B ➤ Added PCT17DO–PCT32DO and PCT17PU–PCT32PU to *Table B.1* and *Table B.2*.
20060814	**User's Guide** Section 6 ➤ In *Status Warning and Status Failure* added information about the relay restarting on certain diagnostic failures. Appendix A ➤ Updated for firmware version R121 (SEL-421-2, -3) and R200 (SEL-421-0, -1). **Applications Handbook** Section 3 ➤ Added diagnostic restart to the list of conditions captured by the SER.
20060808	Note: This version was not released from the factory. The 20060814 version contains the following changes. **User's Guide** Section 2 ➤ Updated Ethernet card rear-panel layouts. Appendix A ➤ Updated for firmware revision R120. ➤ Updated for SEL-2702 firmware version R101.

Table A.5 Instruction Manual Revision History (Sheet 7 of 16)

Revision Date	Summary of Revisions
	Reference Manual Section 6 ➤ Documented additional support for paired control outputs (BO). Section 8 ➤ Clarified multiple client access for Unbuffered Reports. ➤ Added Protocol Implementation Conformance Statement (PICS).
20060710	**User's Guide** Appendix A ➤ Updated for firmware revision R119.
20060703	**User's Guide** Section 2 ➤ Included network port configurations and safety warnings in *Network Connection*. Appendix A ➤ Updated for firmware revision R118. **Applications Handbook** Section 7 ➤ Revised FTP File Structure description in *FTP*. ➤ Specified CID file location in *FTP*. **Reference Manual** Section 4 ➤ Added Ethernet card commands to *Ethernet Card Commands*. ➤ Added "keep alive" settings ETCPKA, KAIDLE, KAINTV, and KACNT to *Ethernet Network Operation Settings*. ➤ Revised FTP File Structure description in *File Structure*. Section 6 ➤ Increased CCINs from 32 to 128 (DNP LAN/WAN map) and adjusted indices as necessary. Section 8 ➤ Added new IEC 61850 section (replaced the UCA2 section). Section 9 ➤ Added information about new **ID** command response for an Ethernet card with IEC 61850 support. Appendix A ➤ Increased CCINs from 32 to 128 (Relay Word bits) and adjusted row numbers for those and all subsequent rows. Glossary ➤ Added IEC 61850 entries. Miscellaneous ➤ Removed GOMSFE appendix. ➤ Removed references to UCA2 and GOMSFE. ➤ Modified GOOSE references to describe IEC 61850 GOOSE.
20060413	**User's Guide** Appendix A ➤ Updated for firmware version R117.
20060302	**User's Guide** Appendix A ➤ Corrected Z-numbers in *Table A.1* for firmware versions R115 and R116. ➤ Corrected Z-number in *Table A.1* for firmware version R116.
20060126	Preface ➤ Moved cautions, warnings, and dangers in English and French from reverse of front cover to the *Preface*.

Table A.5 Instruction Manual Revision History (Sheet 8 of 16)

Revision Date	Summary of Revisions
	User's Guide Section 1 ➤ Added a table distinguishing the versions of the SEL-421. ➤ Added information about Main Board A and Main Board B and interface boards INT2, INT7, and INT8. Section 2 ➤ Corrected *Figure 2.5* to remove positive polarity mark. ➤ Corrected number of Form C outputs for INT6 shown in *Table 2.4*. ➤ Adjusted *Table 2.5* to add more description on the control enable jumper. ➤ Added more description of the J18C jumper. ➤ Added information that BADPASS Relay Word bit pulses after three unsuccessful password entry attempts in the Alarm Output subsection. ➤ Added Main Board B and interface boards INT2, INT7, and INT8. ➤ Added rear-panel drawings: 4U Rear Panel, Main Board B, INT8 I/O Interface Board; 5U Rear Panel, Main Board A, INT6 and INT4 I/O Interface Board; 5U Rear Panel, Main Board B, INT2 and INT7 I/O Interface Board. Section 3 ➤ Corrected reference to the Settings Editor Selection dialog box. ➤ Updated *Figure 3.16: Setting the Relay Part Number in ACSELERATOR*. Section 4 ➤ Corrected *Figure 4.1*. ➤ Made typographical corrections. ➤ Added footnote to *Table 4.2*. ➤ Corrected the IRIG-B jitter tolerance level. ➤ Modified *Figure 4.41* to reflect new SER setting parameter HMI Alarm. ➤ Modified *Figure 4.42* to reflect Report Settings upload. ➤ Modified *Figure 4.45* to reflect new SER setting parameter HMI Alarm. ➤ Updated *Table 4.8* with the information for Main Board A and Main Board B and interface board INT2, INT7, and INT8. ➤ Updated *Figure 4.57* to reflect changes to Control Inputs settings and added *Figure 4.58* to reflect changes to Main Board Control Inputs settings. Section 5 ➤ Made typographical corrections. ➤ Updated figures throughout to correct **Enter** pushbutton graphic. ➤ Updated figures throughout to correct footer capitalization errors. ➤ Added alarm points screen to *Figure 5.4*. ➤ Added *Alarm Points*. ➤ Modified *Display Points* to allow for analog quantity display points. ➤ Added note clarifying the line current and voltage source for protection functions. ➤ Modified *Events* to explain event summary access options. ➤ Modified *Front-Panel Automatic Messages* to include alarm points. ➤ Added alarm points screen to *Figure 5.32*. ➤ Added application references for TRGTR Relay Word bit and group setting ULTR. ➤ Modified *Front-Panel Operator Control Pushbuttons* to include alarm points, display points, and event summary viewing options. Section 6 ➤ Made typographical corrections. ➤ Modified *Figure 6.9* to update for new front-panel settings categories. ➤ Modified *Figure 6.14* to reflect new SER setting parameter HMI Alarm. Command Summary ➤ Added footnote explaining that the SEL-421-1 and SEL-421-2 have only one instance of automation logic settings.

Table A.5 Instruction Manual Revision History (Sheet 9 of 16)

Revision Date	Summary of Revisions
	Applications Handbook Section 1 ➤ Corrected *Equation 1.74*. ➤ Clarified when BK1CLST will assert. Section 2 ➤ Revised *Example 2.3* and *Example 2.4*. ➤ Corrected name of Relay Word bit B1ITAL to B1BITAL. ➤ Corrected typographical errors. ➤ Corrected range for EDEM in *Table 2.20*. Section 3 ➤ Corrected typographical errors. ➤ Modified Setting SER Points and Aliases section to reflect new SER setting parameter HMI Alarm. ➤ Updated *Figure 3.1* to include Main Board A and Main Board B and Interface Boards INT1, INT2, INT4, INT5, INT6, INT7, and INT8. ➤ Added IN101 through IN107 analog channels in *Figure 3.5*. Section 4 ➤ Corrected *Figure 4.5* and *Figure 4.6*. Section 6 ➤ Added note about IRIG-B time signal and high-accuracy IRIG timekeeping. **Reference Manual** Section 1 ➤ Corrected Relay Word bit names DSTART to DSTRT and NSTART to NSTRT. ➤ Corrected a cross reference in *Table 1.13*. ➤ Corrected *Figure 1.25*. ➤ Corrected *Figure 1.26*. ➤ Corrected *Figure 1.68*. ➤ Added the heading Trip Logic Settings and Relay Word Bits, text, and footnotes to *Table 1.72*. ➤ Corrected Relay Word bit names BTPA to ATPB and CTPA to ATPC in *Table 1.73*. Section 2 ➤ Changed title of section to *Auto-Reclosing and Synchronism Check*. ➤ Deleted duplicative *Figure 2.10: Voltage Check Elements*. ➤ Added note about voltage check elements and synchronism check feature. ➤ Corrected *Figure 2.21* and *Figure 2.22*. Section 3 ➤ Corrected typographical errors. Section 4 ➤ Corrected cross references on first page. Section 5 ➤ Corrected typographical error. ➤ Updated *Table 4.4*. Section 6 ➤ Corrected typographical errors. ➤ Added information about setting TIMERQ. Section 7 ➤ Added footnote to *Table 7.9*. ➤ Added a row (15 option to the range of MRATE in the Global setting class) to *Table 7.11*. ➤ Corrected typographical errors. ➤ Corrected footnote to *Table 7.16*.

Table A.5 Instruction Manual Revision History (Sheet 10 of 16)

Revision Date	Summary of Revisions
	Section 9 ➤ Corrected typographical errors. ➤ Corrected *Table 9.113*. Section 10 ➤ Corrected typographical errors. ➤ Updated *Table 10.5, Table 10.6, Table 10.7*, and *Table 10.8* for the changes in the Control Inputs, Main Board Control Inputs, Interface Board #1 Control Inputs, and Interface Board #2 Control Inputs settings. ➤ Added 15 option to the range of MRATE setting in *Table 10.19*. ➤ Added new front-panel settings categories to *Table 10.78*. ➤ Added new setting SCROLD to *Table 10.80*. ➤ Added new front-panel settings *Table 10.81* and *Table 10.82*. ➤ Split Display Points and Aliases table into two separate tables, *Table 10.81* and *Table 10.82*, for Boolean and Analog Display Points. ➤ Added new setting parameter HMI Alarm to *Table 10.86*. Appendix A ➤ Corrected typographical errors. Appendix B ➤ Corrected typographical errors.
20051107	Revised entire manual to include new DNP3 LAN/WAN functionality.
20050805	**General** ➤ Added independent two-breaker reclosing functionality (E79 := Y1). **User's Guide** Section 4 ➤ Added note describing internal clock year value behavior in *TIME Q Descriptions*. Appendix A ➤ Updated *Table A.1* with firmware version R114. **Applications Handbook** Section 1 ➤ Added text explaining auto-reclose sequence for both dependent (E79 := Y) and independent (E79 := Y1) two-breaker reclosing applications. ➤ Updated E79 entries in *Table 1.6*, *Table 1.13*, *Table 1.21*, *Table 1.31*, and *Table 1.39*. ➤ Added E79 row to *Table 1.40*. **Reference Manual** Section 1 ➤ Updated *Figure 1 26*. ➤ Updated *Figure 1 63* to match firmware change. ➤ Updated *Figure 1 65*. Section 2 ➤ Added text explaining two auto-reclose modes available for two-breaker reclosing applications. ➤ Added text explaining single-pole open interval supervision condition (SPOISC) and corresponding timer (SPOISD) for single-pole two-circuit-breaker auto-reclosing applications. ➤ Added text detailing both dependent (E79 := Y) and independent (E79 := Y1) three-pole two-circuit-breaker auto-reclosing applications. ➤ Added text explaining three-pole open interval supervision condition (3POISC) and corresponding timer (3POISD) for three-pole two-circuit-breaker auto-reclosing applications. ➤ Modified *Figure 2 6* title (added "E79 := Y"). ➤ Added *Figure 2 7* ("Line-Open Logic Diagram When E79 := Y1"). ➤ Modified *Figure 2 13* title (added "E79 := Y"). ➤ Modified *Figure 2 15* title (added "E79 := Y"). ➤ Updated E79 entries in *Table 2 19* and *Table 2 20*.

Table A.5 Instruction Manual Revision History (Sheet 11 of 16)

Revision Date	Summary of Revisions
	Section 10 ➤ Updated E79 entry in *Table 10 29*. ➤ Updated *Table 10 64* to include new settings SPOISC and SPOISD. ➤ Updated *Table 10 65* to include new settings 3POISC and 3POISD. Appendix A ➤ Updated *Table A.1* to include new Relay Word Bits SPOISC and 3POISC. ➤ Updated *Table A.2* footnote describing internal clock year value behavior. ➤ Updated *Table A.9* to include new Relay Word Bits SPOISC and 3POISC. ➤ Updated *Table A.50* footnote describing internal clock year value behavior.
20050119	**User's Guide** Appendix A ➤ Updated *Table A.1* and *Table A.5* with firmware version R113.
20041217	**General** ➤ Changed DNP 3.0 to DNP3 throughout manual. ➤ Added contents list to the start of each section. ➤ Added Glossary entries for C37.118, Fast Message, IEEE, RTD, Time Error, Time Quality, and TVE. ➤ Updated Glossary entry for PPS. **User's Guide** Section 1 ➤ Updated *Specifications*. Section 2 ➤ Added INT4 I/O Interface Board information, including instructions for using the optoisolated control inputs to detect ac control signals. ➤ Updated rear-panel figures and related text to show new TIME input configuration. ➤ Removed *Front-Panel Labels*—the configurable label instructions are now in a separate package included with the relay. Section 3 ➤ Updated ACSELERATOR SEL-5030 screen captures and related text. Section 4 ➤ Updated ACSELERATOR SEL-5030 screen captures and related text. ➤ Updated serial number label in *Figure 4 1* and related text. ➤ Added Access Level information to *Table 4 5*. ➤ Added INT4 I/O Interface Board control inputs information and *Figure 4 8*. ➤ Updated Configuring High-Accuracy Timekeeping subsection. Section 6 ➤ Updated ACSELERATOR SEL-5030 screen captures and related text. Appendix A ➤ Updated *Table A.1* and *Table A.5* with firmware version R112 and literature changes. **Applications Handbook** Section 2 ➤ Updated *Time-Synchronized Metering*. Section 3 ➤ Updated *Figure 3.1*. Section 4 ➤ Updated *Relay Configuration for High-Accuracy Timekeeping*. ➤ Updated *State Estimation Verification*. Section 6 ➤ Updated *Table 6.7*.

Table A.5 Instruction Manual Revision History (Sheet 12 of 16)

Revision Date	Summary of Revisions
	Reference Manual Section 1 ➤ Updated *Current and Voltage Source Selection*, including new *Figure 1.1* through *Figure 1.4*, and new *Table 1.1* through *Table 1.3*. ➤ Updated *Frequency Estimation*, and added rate-of-change-of-frequency, DFDT, to *Table 1.13* and *Figure 1.12*. ➤ Added *Time-Error Calculation*. ➤ Updated pickup setting range for Inverse-Time Overcurrent Elements in *Table 1.57*. ➤ Renamed and clarified *Trip During Open-Pole Time Delay*. Section 2 ➤ Reorganized subsections. ➤ Clarifications made to *Figure 2.10* and *Figure 2.11*. Updated *Figure 2.15* to reflect changes made to the two circuit breaker, three-pole auto-reclose logic. ➤ Added *Voltage Checks for Auto-Reclosing and Manual Closing* (in place of previous *Voltage Checks* subsection). ➤ Reduced healthy voltage qualifying time from 15 to 6 cycles in *Figure 2.28*. Section 3 ➤ Added Multiple Setting Groups subsection to describe this feature already in the SEL-421. Section 4 ➤ Updated *Table 4.1* and *Figure 4.2*. Section 5 ➤ Updated *Table 5.2*. ➤ Added Automatic Messages and Timeout subsections to describe these features already in the SEL-421. ➤ Removed Fast Message Synchrophasor information—now covered in *Section 7*. Section 6 ➤ Updated *Table 6.10* to include analog quantity information, and the new TECORR value (Object 40, 41; Index 1). ➤ Updated Application Example to show DNP Map settings entry, including custom scaling. Section 7 ➤ Added new *Section 7: Synchrophasors*. Includes information on both IEEE C37.118 and SEL Fast Message synchrophasor protocols. Section 9 ➤ Updated **MET PM** command description. ➤ Added **SER CV**, **SER RV**, and **TEC** commands. Section 10 ➤ Removed Global settings for Time and Date Management. ➤ Added Global settings for INT4 I/O Interface Board (*Table 10.5*, *Table 10.8*, and *Table 10.10*), Time-Error Calculation (*Table 10.12*), and Synchrophasors (*Table 10.3* and *Table 10.14*). ➤ Updated Group settings 51S1P, 51S2P, 51S3P (*Table 10.50* through *Table 10.52*). ➤ Added PMU protocol option to Port settings (*Table 10.90*). ➤ Removed Port settings PMADDR and PMDATA. Appendix A ➤ Updated tables with new Relay Word bits, and new row numbers for Relay Word bits above row 96. Appendix B ➤ Reordered tables to match Appendix A (alphabetic list first). ➤ Added function subheadings to *Table B.2*. ➤ Added new analog quantities DFDT, TUTC, TQUAL, TECORR, TE, CTRW, CTRX, PTRY, PTRZ, and 66 synchrophasor measurement quantities.
20040602	**User's Guide** Appendix A ➤ Included information on new firmware R111.

Table A.5 Instruction Manual Revision History (Sheet 13 of 16)

Revision Date	Summary of Revisions
20030918	Introduced new typographic and step instruction conventions in the Preface and applied them throughout the manual. **User's Guide** Section 1 ➤ Added EA Certification statement to *Specifications*. Appendix A ➤ Included information on new firmware R110 and instruction manual changes. ➤ Added EA Certification statement to *Specifications*. **Applications Handbook** Section 1 ➤ Modified the application examples to include new information on communications-assisted protection schemes and out-of-step logic. **Reference Manual** Section 1 ➤ Added information (including new logic diagram figures) about communications-assisted protection schemes, out-of-step logic, and trip logic. ➤ Updated *Figure 1.65*, *Figure 1.66*, and *Figure 1.68*. Section 3 ➤ Changed quantity of free-form protection SELOGIC. ➤ Updated *Table 3.6*, *Table 3.7*, and *Table 3.8*. Section 5 ➤ Added new section on using the SEL-2600A RTD module. Section 9 ➤ Added OFF to the XC setting range. Appendix A ➤ Added new Relay Word bits to support communications-assisted protection schemes, security, and the SEL-2600 RTD module. Appendix B ➤ Added analog quantities to support the SEL-2600A RTD module.
20030409	**User's Guide** Section 2 ➤ Modified all of the installation instructions that include removing and reattaching the front panel to reflect changes in the front-panel hardware. ➤ Replaced *Figure 2.26* with latest rear-panel diagram. Appendix A ➤ Included information on new firmware R109.
20021216	**User's Guide** Section 1 ➤ Added Terminal Connection information. ➤ Corrected typographic error. ➤ Corrected pickup accuracy for *Station DC Battery System Monitor*. Appendix A ➤ Included information on new firmware R108. **Applications Handbook** Section 1 ➤ Corrected *Equation 1.74*. Section 2 ➤ Clarified synchrophasor measurement statement.

Table A.5 Instruction Manual Revision History (Sheet 14 of 16)

Revision Date	Summary of Revisions
	Reference Manual Section 1 ➤ Added NAND gates (SPOA, SPOB, and SPOC) at the DTA, DTB, and DTC SELOGIC Settings inputs in *Figure 1.60, Trip During Pole Open to TPA*. Section 3 ➤ Corrected *Example 3.6*. ➤ Change “conditioning” to “sequence” in the sentence before *Figure 3.8* and in the caption for *Figure 3.8*. ➤ Corrected typographical error.
20020918	**User’s Guide** Appendix A ➤ Included information on new firmware R107. **Reference Manual** Section 1 ➤ Modified *Figure 1.9* and *Figure 1.63*.
20020819	**User’s Guide** Appendix A ➤ Included information on new firmware R106. ➤ Removed “Instruction” from appendix title.
20020621	Removed Manual Change Information section and integrated it into User’s Guide *Appendix A: Firmware and Instruction Manual Versions*. **User’s Guide** Section 2 ➤ Updated *Figure 2.2*, *Figure 2.3*, *Figure 2.10*, *Figure 2.13*, *Figure 2.21*, *Figure 2.25*, *Figure 2.27*, and *Figure 2.28*. Appendix A ➤ Firmware updated. **Reference Manual** Section 6 ➤ Updated *Table 6.9*. ➤ Updated *Table 6.10*.
20020528	**User’s Guide** Appendix A ➤ Firmware updated. **Reference Manual** Section 6 ➤ Updated *Table 6.5*.
20020501	**Reference Manual** Section 6 ➤ Updated *Table 6.17*. Appendix C ➤ All UCA2 control points were made readable. Default data were set for the UCA2 FAULT model.
20020417	**User’s Guide** Appendix A ➤ Firmware updated. Spurious Quart interrupts caused by varying character spacing will cause the relay to disable. This condition occurs when a communications processor is automatically retrieving data from the relay simultaneously with a serial port terminal session.

Table A.5 Instruction Manual Revision History (Sheet 15 of 16)

Revision Date	Summary of Revisions
20020403	➤ Initial Release with Synchrophasor Measurement capability to SEL-421. ➤ Added VAZ, VBZ, VCZ settings options to SYNCP. ➤ Added VAY, VBY, VCY settings options to SYNCS1, SYNCS2 and ASYNCS2. ➤ Added ACOS, ASIN, CEIL, FLOOR and LOG math functions to SELOGIC control equations. ➤ Added new analog quantities for use in SELOGIC control equations: ➢ Terminal W and X current magnitudes ➢ Terminal Y and Z voltage magnitudes ➢ Instantaneous sequence quantities ➢ Contact inputs ➤ Modified CHI output for SEL-2030 compatibility.
20020108	➤ SEL-421-1 Relay introduction. ➤ Configurable front-panel labels. ➤ I and V Source Selection settings clarifications. Preface ➤ Added Notes explanation. **User's Guide** Section 1 ➤ Added description of SEL-421-1 Relay. ➤ Added Notes to flag the differences in the SEL-421-1 Relay. ➤ Added Humidity to *Specifications*. ➤ Added SEL-421-1 Relay Maximum Operating Time to *Specifications*. ➤ Revised Power and Energy in *Specifications*. Section 2 ➤ Added *Front-Panel Labels* to describe configurable front-panel labels. Section 3 ➤ Added description of ACSELERATOR® SEL-5030 software Analysis function keys F2, F3, and F4. ➤ Revised Relay Editor settings tree view operation. Section 4 ➤ Included front-panel label kit in shipped items list. ➤ Added Notes to flag the differences in the SEL-421-1 Relay. ➤ Fixed *Figure 4.45* and setting SER example procedure. ➤ Fixed *Figure 4.55* and setting control input/52A example procedure. Section 5 ➤ Added descriptions of configurable front-panel labels. Section 6 ➤ Updated ACSELERATOR software screen captures. **Applications Handbook** Section 1 ➤ Added Notes to flag the differences in the SEL-421-1 Relay. ➤ Corrected control inputs in *Auto-Reclose Examples*. ➤ Added explanation for missing setting 3PMRCD (Manual Close Reclaim Time Delay) in *Recloser Closing*. Section 2 ➤ Corrected communications equipment battery voltage to 48 Vdc in *Figure 2.12*. ➤ Revised text and *Table 2.16* for power and energy specifications. Section 3 ➤ Corrected Compressed ASCII command example in Event File Download procedure. **Reference Manual** Section 1 ➤ Added Notes to flag the differences in the SEL-421-1 Relay. ➤ Included more explanation for settings ALTI and ALTV in *Current and Voltage Source Selection*. ➤ Corrected setting ORDER text in *ORDER*. ➤ Supplemented *Series-Compensation Line Logic* material.

Table A.5 Instruction Manual Revision History (Sheet 16 of 16)

Revision Date	Summary of Revisions
	Section 3 ➤ Added Notes to flag the differences in the SEL-421-1 Relay. Section 6 ➤ Updated setting TIMERQ to reflect correct prompt and default (no change in the relay). Section 9 ➤ Added Notes to flag the differences in the SEL-421-1 Relay. Appendix A ➤ Added Notes to flag the differences in the SEL-421-1 Relay. Index ➤ Added index entries for configurable front-panel labels, SEL-421-1 Relay, and series-compensated line.
20010703	Initial version.

SEL-421 Relay

Protection and Automation System

Instruction Manual

Applications Handbook

20190325

SCHWEITZER ENGINEERING LABORATORIES, INC.

PM421-02

Section 1
Protection Application Examples

Overview

This section provides detailed instructions for setting the SEL-421 Relay protection functions. Use these application examples to help familiarize yourself with the relay, and to assist you with your own protection settings calculations. The settings that are not mentioned in these examples do not apply.

Introduction

Detailed setting calculation guidelines are provided for the following applications:

➤ *230 kV Overhead Transmission Line Example on page A.1.2*

➤ *500 kV Parallel Transmission Lines With Mutual Coupling Example on page A.1.18*

➤ *345 kV Tapped Overhead Transmission Line Example on page A.1.51*

➤ *EHV Parallel 230 kV Underground Cables Example on page A.1.84*

Separate protection application examples are provided for the following functions:

➤ *Out-of-Step Logic Application Examples on page A.1.115*

➤ *Auto-Reclose Example on page A.1.133*

➤ *Auto-Reclose and Synchronism Check Example on page A.1.137*

➤ *Circuit Breaker Failure Application Examples on page A.1.147*

Relay Settings

Enter settings in the following order for the first four examples listed above:

➤ *Global Settings*

➤ *Breaker Monitor*

➤ *Group Settings*

➤ *Control Outputs*

All the settings are listed in a single table at the end of each application example.

230 kV Overhead Transmission Line Example

Figure 1.1 shows a double-ended 230 kV line with SEL-421 protection at each end. This example explains how to calculate settings for the SEL-421 at Station S that protects the line between Stations S and R.

NOTE: The SEL-421-1 and the SEL-421-2 provide fast and secure tripping for the line segment but does not have the high-speed distance elements of the SEL-421.

This application example uses step-distance protection to provide high-speed tripping for faults in the first 80 percent of the line and time-delayed tripping for the last 20 percent.

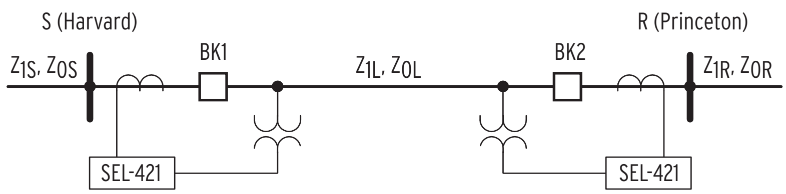


Figure 1.1 230 kV Overhead Transmission Line

Power System Data

Table 1.1 lists the power system data for this application example. Substitute the values and parameters that correspond to your system when you set the relay, using this example as a guide.

Table 1.1 System Data—230 kV Overhead Transmission Line

Parameter	Value
Nominal system line-to-line voltage	230 kV
Nominal relay current	5 A secondary
Nominal frequency	60 Hz
Line length	50 miles
Line impedances: Z_{1L}, Z_{0L}	39 Ω ∠84° primary, 124 Ω ∠81.5° primary
Source S impedances: $Z_{1S} = Z_{0S}$	50 Ω ∠86° primary
Source R impedances: $Z_{1R} = Z_{0R}$	50 Ω ∠86° primary
PTR (potential transformer ratio)	230 kV:115 V = 2000
CTR (current transformer ratio)	500:5 = 100
Phase rotation	ABC

Convert the power system impedances from primary to secondary, so you can later calculate protection settings. *Table 1.2* lists the corresponding secondary impedances. Convert the impedances to secondary ohms as follows:

$$k = \frac{CTR}{PTR} = \frac{100}{2000} = 0.05$$ **Equation 1.1**

$$\begin{aligned} Z_{1L(secondary)} &= k \bullet Z_{1L(primary)} \\ &= 0.05 \bullet (39\ \Omega\angle 84°) \\ &= 1.95\ \Omega\angle 84° \end{aligned}$$ **Equation 1.2**

Table 1.2 Secondary Impedances

Parameter	Value
Line impedances: Z_{1L}, Z_{0L}	1.95 Ω ∠84° secondary, 6.2 Ω ∠81.5° secondary
Source S impedances: $Z_{1S} = Z_{0S}$	2.5 Ω ∠86° secondary
Source R impedances: $Z_{1R} = Z_{0R}$	2.5 Ω ∠86° secondary

The maximum load current is 495 A primary.

Application Summary

This particular example is for a single circuit breaker, three-pole tripping application with the following functions:

- Two zones of mho distance protection
  - Zone 1, forward-looking, instantaneous underreaching protection
  - Zone 2, forward-looking, time-delayed tripping
- Inverse-time directional zero-sequence overcurrent backup protection
- SOTF protection, fast tripping when the circuit breaker closes

Relay settings that are not mentioned in these examples do not apply to this application example.

Global Settings

General Global Settings

The SEL-421 has settings for identification. These settings allow you to identify the following:

- Station (SID)
- Relay (RID)
- Circuit Breaker 1 (BID1)

You can enter as many as 40 characters per identification setting.

SID := **HARVARD — 230 kV** Station Identifier (40 characters)

RID := SEL-421 **Relay** Relay Identifier (40 characters)

Configure the SEL-421 for one circuit breaker.

NUMBK := **1** Number of Breakers in Scheme (1, 2)

BID1 := **Circuit Breaker 1** Breaker 1 Identifier (40 characters)

You can select both nominal frequency and phase rotation for the relay.

NFREQ := **60** Nominal System Frequency (50, 60 Hz)

PHROT := **ABC** System Phase Rotation (ABC, ACB)

Current and Voltage Source Selection

The voltage and current source selection is for one circuit breaker. The relay derives the line current source from current input IW when you set ESS to N.

ESS := **N** Current and Voltage Source Selection (Y, N, 1, 2, 3, 4)

Figure 1.2 illustrates the current and voltage sources for this particular application. The relay uses potential input VY and current input IW for line relaying; potential input VAZ is for synchronism check. *Section 2: Auto-Reclosing and Synchronism Check in the Reference Manual* describes how to apply the synchronism-check function.

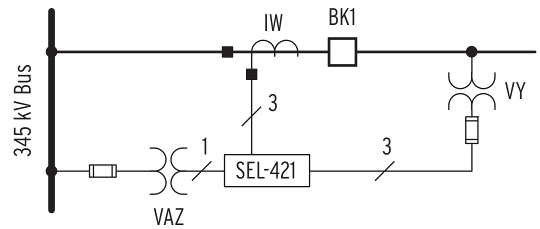


Figure 1.2 Circuit Breaker Arrangement at Station S

Breaker Monitor

Circuit Breaker Configuration

Set the relay to indicate that Circuit Breaker 1 is a three-pole trip circuit breaker.

BK1TYP := **3** Breaker 1 Trip Type (Single-Pole = 1, Three-Pole = 3)

Circuit Breaker 1 Inputs

The SEL-421 uses a normally open auxiliary contact from the circuit breaker to determine whether the circuit breaker is open or closed.

52AA1 := **IN101** A-Phase N/O Contact Input -BK1 (SELOGIC Equation)

Group Settings

Line Configuration

The SEL-421 has four transformer turns ratio settings that convert the secondary potentials and currents that the relay measures to the corresponding primary values. These settings are the potential transformer and current transformer ratios PTRY, PTRZ, CTRW, and CTRX.

Use the Y potential input for line relaying and the Z potential input for synchronism check. Use the W current input for line relaying. The settings VNOMY and VNOMZ specify the nominal secondary line-to-line voltage of the potential transformers (see *Figure 1.2*).

CTRW := **100** Current Transformer Ratio—Input W (1–50000)

PTRY := **2000** Potential Transformer Ratio—Input Y (1–10000)

VNOMY := **115** PT Nominal Voltage (L-L)—Input Y (60–300 V secondary)

PTRZ := **2000** Potential Transformer Ratio—Input Z (1–10000)

VNOMZ := **115** PT Nominal Voltage (L-L)—Input Z (60–300 V secondary)

Enter the secondary value of the positive-sequence impedance of the protected line. See *Table 1.2* for the secondary line impedances.

Z1MAG := **1.95** Positive-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)

Z1ANG := **84.00** Positive-Sequence Line Impedance Angle (5.00–90 degrees)

Enter the secondary value of the zero-sequence impedance of the protected line.

Z0MAG := **6.20** Zero-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)

Z0ANG := **81.50** Zero-Sequence Line Impedance Angle (5.00–90 degrees)

Enable the fault locator.

EFLOC := **Y** Fault Location (Y, N)

The LL setting is the line length. This value has no defined unit; you can set the line length in miles, kilometers, ohms, etc. For this example, set the length in miles.

LL := **50** Line Length (0.10–999)

The fault locator uses the values you enter for Z1MAG, Z1ANG, Z0MAG, Z0ANG, and LL.

Relay Configuration

You can select from zero to five phase zones of mho phase (E21P), mho ground (E21MG), and quadrilateral ground (E21XG) distance protection. You can independently select the number of zones per type of distance protection. Select only the number of zones needed. For this application example, use two zones of mho phase and ground distance protection.

E21P := **2** Mho Phase Distance Zones (N, 1–5)

E21MG := **2** Mho Ground Distance Zones (N, 1–5)

E21XG := **N** Quadrilateral Ground Distance Zones (N, 1–5)

Now enable the other logic you will need for this application example.

You do not need CVT transient detection if the SIR (Source Impedance Ratio) is less than five. SIR is equal to the ratio of the local source impedance to the relay reach. Calculate the ratio based on the Zone 1 reach because you do not want Zone 1 distance protection to overreach during an external fault.

$$\begin{aligned} \text{SIR} &= \frac{|Z_{1S}|}{0.8 \bullet |Z_{1L}|} \\ &= \frac{2.5\ \Omega}{0.8 \bullet 1.95\ \Omega} \\ &= 1.603,\ \text{SIR} < 5 \end{aligned}$$

Equation 1.3

ECVT := **N** CVT Transient Detection (Y, N)

NOTE: The SEL-421-1 and the SEL-421-2 do not provide series-compensated line protection logic.

The transmission line is not series compensated.

ESERCMP := **N** Series-Compensated Line Logic (Y, N)

You can select a common time delay or an independent time delay per zone for phase and ground distance protection. If you choose independent timing, evolving faults (such as those changing from single phase to multi-phase) cause the timer to reset and result in additional delay. Select common time delay for this application.

ECDTD := **Y** Distance Element Common Time Delay (Y, N)

The SOTF logic permits tripping by specified protection elements for a settable time after the circuit breaker closes.

ESOTF := **Y** Switch-Onto-Fault (Y, N)

Do not enable the Out-of-Step logic for this application example.

EOOS : = **N** Out-of-Step (Y, N)

Do not enable the load-encroachment logic, as the minimum apparent load impedance is outside the mho phase distance characteristics.

ELOAD := **N** Load Encroachment (Y, N)

Use Level 1 high-set instantaneous phase overcurrent element for SOTF protection.

E50P := **1** Phase Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

This application does not require residual ground overcurrent protection.

E50G := **N** Residual Ground Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

This application does not require negative-sequence overcurrent protection.

E50Q := **N** Negative-Sequence Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

Use inverse-time overcurrent protection to provide backup protection for high-resistance ground faults. The 51S1 element provides backup protection for unbalanced faults if the step distance protection fails to operate.

E51S := **1** Selectable Inverse-Time Overcurrent Element (N, 1–3)

Set E32 to AUTO and the relay automatically calculates the settings corresponding to the ground directional element (32G).

E32 := **AUTO** Directional Control (Y, AUTO)

Communications-assisted tripping is not required.

ECOMM := **N** Communications-Assisted Tripping (N, DCB, POTT, POTT2, POTT3, DCUB1, DCUB2)

Fuses or molded case circuit breakers often protect potential transformers. Operation of one or more fuses, or molded case circuit breakers, results in a loss of polarizing potential inputs to the relay. Loss of one or more phase voltages prevents the relay from properly determining fault distance or direction.

Occasional LOP (loss-of-potential) to the distance relay, while unavoidable, is detectable. When the relay detects the loss-of-potential, the relay can block distance element operation, block or enable forward directional overcurrent elements, and issue an alarm for any true LOP condition.

NOTE: If line-side PTs are used, the circuit breaker(s) must be closed for the LOP logic to detect an LOP condition. Therefore, if three-phase potential to the relay is lost while the circuit breaker(s) is open (e.g., the PT fuses are removed while the line is de-energized), the relay cannot detect an LOP when the circuit breaker(s) closes again.

Table 1.3 LOP Enable Options

Option	Description
N	The LOP logic operates but does not disable voltage-polarized directional elements, distance elements, and forward directional overcurrent elements. Use LOP in this case for alarm only.
Y	The relay disables all voltage-polarized directional elements and distance elements, but enables forward directional overcurrent elements. These forward directional overcurrent elements effectively become nondirectional and provide overcurrent protection during an LOP condition.
Y1	The relay disables all voltage-polarized directional elements and distance elements. The relay also disables the overcurrent elements controlled by the voltage-polarized directional elements.

Set ELOP to Y1 for this application example. This choice reduces the chances of false tripping because of a loss-of-potential condition.

ELOP := **Y1** Loss-of-Potential (Y, Y1, N)

You do not need Advanced Settings for this application example.

EADVS := **N** Advanced Settings (Y, N)

Phase Distance Elements (21P)

Mho Phase Distance Element Reach

Employ each zone of mho phase distance protection as follows:

- Zone 1—Instantaneous underreaching tripping
- Zone 2—Time-delayed overreaching backup tripping

Zone 1 Phase Distance Element Reach. Zone 1 phase distance protection provides instantaneous protection for phase-to-phase, phase-to-phase-to-ground, and three-phase faults in the first 80 percent of the transmission line. Errors in the current transformers and potential transformers, modeled transmission line data, and fault study data do not permit setting Zone 1 for 100 percent of the transmission line. If you set Zone 1 for 100 percent of the transmission line, unwanted tripping could occur for faults just beyond the remote end of the line.

Set Zone 1 phase distance protection equal to 80 percent of the transmission line positive-sequence impedance.

$Z1P = 0.8 \cdot Z1L = 1.56\ \Omega$

Z1P := **1.56** Zone 1 Reach (OFF, 0.05-64 Ω secondary)

Zone 2 Phase Distance Element Reach. Zone 2 phase distance protection must have adequate reach to detect all phase-to-phase, phase-to-phase-to-ground, and three-phase faults along the protected line to make certain delayed tripping occurs for faults located in the last 20 percent of the line. Set Zone 2 phase distance reach equal to 120 percent of the positive-sequence impedance of the transmission line.

$Z2P = 1.2 \cdot Z1L = 2.34\ \Omega$

Z2P := **2.34** Zone 2 Reach (OFF, 0.05–64 Ω secondary)

Ground Distance Elements (21MG)

Mho Ground Distance Element Reach

Employ each zone of mho ground distance protection as follows:

- Zone 1—Instantaneous underreaching tripping
- Zone 2—Time-delayed overreaching backup tripping

Zone 1 Mho Ground Distance Element Reach. Zone 1 mho ground distance reach must meet the same requirement as that for Zone 1 mho phase distance protection; i.e., the reach setting can be no greater than 80 percent of the line.

$Z1MG = 0.8 \cdot Z1L = 1.56\ \Omega$

Z1MG := **1.56** Zone 1 (OFF, 0.05–64 Ω secondary)

Zone 2 Mho Ground Distance Element Reach. Zone 2 mho ground distance reach must meet the same requirement as that for Zone 2 mho phase distance protection; i.e., set the reach equal to 120 percent of the line.

$$Z2MG = 1.2Z1L = 2.34\ \Omega$$

Z2MG : = **2.34** Zone 2 (OFF, 0.05–64 Ω secondary)

Zero-Sequence Current Compensation Factors

Zero-sequence current compensation helps to keep the phase and ground distance elements at the same reach if you set the reach equal per zone (for example, Z1P = Z1MG). Ground distance elements should measure fault impedance in terms of positive-sequence impedance only. The relay automatically calculates the setting for the Zone 1 zero-sequence current compensation factor when you set k0M1 to AUTO.

k0M1 := **AUTO** Zone 1 ZSC Factor Magnitude (AUTO, 0.000–10)

When you enter AUTO as the setting for k0M1, the relay calculates the zero-sequence current compensation as follows:

$$k01 = \frac{Z0MAG\angle Z0ANG - \angle Z1MAG\angle Z1ANG}{3 \bullet Z1MAG\angle Z1ANG}$$ **Equation 1.4**

Zone 2 uses the same zero-sequence current compensation factor as that for Zone 1 because the Advanced Settings are disabled.

The relay displays the following values for k0M1 and k0A1:

k0M1 := **0.727** Zone 1 ZSC Factor Magnitude (AUTO, 0.000–10)

k0A1 := **–3.65** Zone 1 ZCS Factor Angle

Distance Element Common Time Delay

Set the appropriate timers Z1D and Z2D for both phase and ground distance elements.

You do not need to delay Zone 1 distance protection; it trips instantaneously.

Z1D := **0.000** Zone 1 Time Delay (OFF, 0.000–16000 cycles)

Zone 2 distance protection must coordinate with downstream Zone 1 distance protection, plus downstream circuit breaker operating time and a safety margin. A typical Zone 2 phase and ground distance time delay setting is 20 cycles.

Z2D := **20.000** Zone 2 Time Delay (OFF, 0.000–16000 cycles)

SOTF Scheme

SOTF (Switch-Onto-Fault) logic is enabled when the circuit breaker closes. This logic provides protection for a short duration (setting SOTFD) until other protection (such as tripping from SELOGIC control equations TR and TRCOMM) is available. The TRSOTF SELOGIC control equation defines which protection elements cause the relay to trip when the SOTF scheme is active. Assertion of the protection elements assigned to TRSOTF during the SOTFD time causes the relay to trip instantaneously.

Apply SOTF when using line-side potentials for relaying. Use nondirectional overcurrent protection to clear close-in faults. Also use instantaneous overreaching distance protection to clear faults along the line. Assign instantaneous Zone 2 mho phase and ground distance protection plus Level 1 phase overcurrent element to TRSOTF.

TRSOTF := **M2P OR Z2G OR 50P1** Switch-Onto-Fault Trip (SELOGIC Equation)

Single-Pole SOTF

This is a three-pole tripping application example; confirm that the SOTF protection is for three-pole tripping.

ESPSTF := **N** Single-Pole Switch-Onto-Fault (Y, N)

Voltage Reset

You can configure the logic such that the SOTF enable duration resets within at least 5 cycles after it first asserted, but before the SOTFD timer expires. To quickly reset the SOTF period, the relay must sense that the positive-sequence voltage is greater than 85 percent of the nominal voltage.

Use setting EVRST (Switch-Onto-Fault Voltage Reset) to enable fast reset. The advantage of resetting SOTF protection quickly is that unwanted tripping does not occur for subsequent faults external to the remote terminals during the SOTF period; these trips can occur if you set instantaneous Zone 2 distance protection elements in the TRSOTF SELOGIC control equation. Enable the voltage reset option.

EVRST := **Y** Switch-Onto-Fault Voltage Reset (Y, N)

SOTF Initiation

The SOTF logic asserts via one or both of the following methods:

- A change in the normally open auxiliary contact 52A status showing that the circuit breaker has just opened
- Assertion of the relay control input assigned to the circuit breaker close bus

The 52A method works well for both single and multiple circuit breaker applications and does not require an input from the close bus. However, the close bus method only enables SOTF protection immediately following the close command to the circuit breaker. For more information see *Switch-Onto-Fault Logic on page R.1.86*.

Turn off 52AEND, 52A Pole Open Time Delay.

52AEND := **OFF** 52A Pole Open Time Delay (OFF, 0.000–16000 cycles)

Select the close bus option for this application and set the close enable delay (CLOEND) shorter than the shortest reclose open interval.

CLOEND := **10.000** CLSMON or Single-Pole Open Delay (OFF, 0.000–16000 cycles)

SOTF Duration

Setting SOTFD determines the longest period the SOTF logic can assert after the circuit breaker closes.

SOTFD := **10.000** Switch-Onto-Fault Enable Duration (0.500–16000 cycles)

Close Signal Monitor

Assign the Relay Word bit CLSMON to a control input, so the relay can detect execution of the close command. Connect IN102 in parallel with the circuit breaker close coil.

CLSMON := **IN102** Close Signal Monitor (SELOGIC Equation)

Phase Instantaneous/Definite-Time Overcurrent Elements

Use 50P1, Level 1 phase instantaneous overcurrent element, as a nondirectional high-set phase overcurrent element for SOTF protection. If the local circuit breaker closes into a close-in three-phase bolted fault with line-side potential transformers, the polarizing voltage for the phase distance elements is zero. Therefore, the distance protection does not operate. In this case, the 50P1 element quickly trips the circuit breaker because this overcurrent element does not rely on the polarizing voltage.

To rapidly clear faults, set 50P1P equal to 50 percent of the fault current measured at the local terminal for a close-in three-phase fault; use weak source conditions so that the relay operates for low-level fault current.

50P1P := **13.29** Level 1 Pickup (OFF, 0.25–100 A secondary)

This application uses 50P1 as an instantaneous overcurrent element; you do not need time delay.

67P1D := **0.000** Level 1 Time Delay (0.000–16000 cycles)

This application uses 50P1 as a nondirectional overcurrent element; you do not need torque control.

67P1TC := **1** Level 1 Torque Control (SELOGIC Equation)

Selectable Operating Quantity Time Overcurrent Element 1

Use inverse-time overcurrent protection to provide backup protection for high-resistance ground faults. The 51S1 element provides backup protection for unbalanced faults if the step distance protection fails to operate.

Select zero-sequence line current as the operating quantity.

NOTE: Use your company practices and philosophy when determining these settings.

51S1O := **3I0L** 51S1 Operate Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0*n*)

The *n* in the 51S1O setting is L for line, 1 for BK1, and 2 for BK2.

The relay measures 8.61 A secondary of $3I_0$ for a bolted single phase-to-ground fault at the remote terminal. Set the pickup to 20 percent of $3I_0$.

51S1P := **1.72** 51S1 Overcurrent Pickup (0.25–16 A secondary)

Use the following formula to determine approximately how much primary fault resistance coverage (R_F) is provided by 51S1P on a radial basis:

$$
\begin{aligned}
R_F &= \frac{PTR}{CTR} \bullet \frac{VNOMY/\sqrt{3}}{51S1P} \\
&= \frac{2000}{100} \bullet \frac{115V/\sqrt{3}}{1.72A} \\
&= 722\ \Omega
\end{aligned}
$$

Equation 1.5

Use the following as a guide to set the curve and time dial; for secure backup protection, perform a coordination study. Set the local overcurrent element to coordinate with the downstream overcurrent element such that there is an 18-cycle (60 Hz nominal) safety margin for ground faults in front of the first downstream overcurrent element. Assume the operating time of the downstream overcurrent element is 12 cycles for a close-in ground fault. Therefore, set the local time-overcurrent element to operate approximately 30-cycles for ground faults in front of the first downstream overcurrent element.

51S1C := **U3** 51S1 Inverse-Time Overcurrent Curve (U1–U5)

51S1TD := **1.96** 51S1 Inverse-Time Overcurrent Time Dial (0.50–15)

Set the overcurrent element to emulate electromechanical reset, so the overcurrent element coordinates properly with electromechanical relays.

51S1RS := **Y** 51S1 Inverse-Time Overcurrent Electromechanical Reset (Y, N)

Torque control the overcurrent element with the forward decision from the ground directional element.

51S1TC := **32GF** 51S1 Torque Control (SELOGIC Equation)

Directional Control

The SEL-421 uses an array of directional elements to supervise the ground distance elements and residual ground directional overcurrent elements during ground fault conditions. Internal logic automatically selects the best choice for the ground directional element (32G) from among the negative-sequence voltage-polarized directional element (32QG), zero-sequence voltage-polarized directional element (32V), and the zero-sequence current-polarized directional element (32I).

The relay setting ORDER determines the order in which the relay selects directional elements to provide ground directional decisions. You can set ORDER with any combination of Q, V, and I. The listed order of these directional elements determines the priority in which these elements operate to provide the ground directional element. Only one specific directional element operates at any one time. Directional element classification is as follows:

- Q—Negative-sequence voltage-polarized directional element
- V—Zero-sequence voltage-polarized directional element
- I—Zero-sequence current-polarized directional element

Set ORDER equal to QV. The first listed directional element choice, Q, is the first priority directional element to provide directional control for the ground distance elements and residual ground directional overcurrent elements. If Q is not operable, the second listed directional element choice, V, provides directional control for the ground distance elements and residual ground directional overcurrent elements. A polarizing quantity was not available for choice I, so I is not selected for this particular application example.

ORDER := **QV** Ground Directional Element Priority (combine Q, V, I)

SELOGIC control equation E32IV must assert to logical 1 to enable V or I for directional control of the ground distance elements and residual ground directional overcurrent elements. Set E32IV equal to logical 1.

E32IV := **1** Zero-Sequence Voltage and Current Enable (SELOGIC Equation)

Pole Open Detection

The setting EPO, Enable Pole-Open logic, offers two options for deciding what conditions signify an open pole, as listed in *Table 1.4*.

Table 1.4 Options for Enabling Pole-Open Logic

Option	Description
EPO := V	The logic declares a single-pole open if the corresponding phase undervoltage element asserts and the open phase detection logic declares the pole is open. *Select this option only if you use line-side potential transformers for relaying purposes.* A typical setting for the 27PO, pole-open undervoltage threshold, is 60 percent of the nominal line-to-neutral voltage. Do not select this option when shunt reactors are applied because the voltage slowly decays after the circuit breaker opens. With this option selected, the relay cannot declare an open pole during assertion of LOP.
EPO := 52	The logic declares a single-pole open if the corresponding 52A contact (e.g., 52AA1) from the circuit breaker deasserts and the open phase detection logic declares that the pole is open.

Select the second option because a 52A contact is available. The relay uses both open phase detection and status information from the circuit breaker to make the most secure decision.

EPO := **52** Pole-Open Detection (52, V)

Pole-Open Time Delay on Dropout

The setting 3POD establishes the time delay on dropout after the Relay Word bit 3PO deasserts. This delay is important when you use line-side potential transformers for relaying. Use the 3POD setting to stabilize the ground distance elements in case of pole scatter during closing of the circuit breaker.

3POD := **0.500** Three-Pole Open Time Dropout Delay (0.000–60 cycles)

Trip Logic

This logic configures the relay for tripping. These settings consist of four categories:

- Trip equations
- Trip unlatch options
- Trip timers
- Three-pole tripping enable

Trip Equations

Set these two SELogic control equations for tripping:

- TR (unconditional)
- TRSOTF (SOTF)

TR. The TR SELogic control equation determines which protection elements cause the relay to trip unconditionally. You typically set all direct tripping and time-delayed protection elements in the SELogic control equation TR. Direct tripping and time-delayed protection elements include step distance protection elements, plus instantaneous and time-overcurrent protection elements.

Set TR equal to Zone 1 instantaneous protection (Z1T), time-delayed Zone 2 distance protection, and the inverse-time overcurrent element (51S1T). For information on setting 51S1T, see *Selectable Operating Quantity Time Overcurrent Element 1 on page A.1.10*.

TR := **Z1T OR Z2T OR 51S1T** Trip (SELOGIC Equation)

TRSOFT. The TRSOTF SELOGIC control equation defines which protection elements cause the relay to trip when the SOTF scheme is active. Assertion of these protection elements during the SOTFD time causes the relay to trip instantaneously (see *SOTF Scheme on page A.1.8*). Set instantaneous Zone 2 distance protection (M2P and Z2G) and Level 1 phase instantaneous overcurrent element (50P1) in the TRSOTF SELOGIC control equation.

TRSOTF := **M2P OR Z2G OR 50P1** Switch-Onto-Fault Trip (SELOGIC Equation)

Trip Unlatch Options

Unlatch the control output you programmed for tripping (OUT101) after the circuit breaker 52A contacts break the dc current. The SEL-421 provides two methods for unlatching control outputs following a protection trip:

- ULTR—all three poles
- TULO—phase selective

ULTR. Use ULTR, the Unlatch Trip SELOGIC control equation, to unlatch all three poles. Use the default setting, which asserts ULTR when you push the front-panel **{TARGET RESET}** pushbutton.

ULTR := **TRGTR** Unlatch Trip (SELOGIC Equation)

TULO. Use TULO (Trip Unlatch Option) to select the conditions that cause the SEL-421 to unlatch the control outputs that you programmed for tripping. *Table 1.5* shows the four trip unlatch options for setting TULO.

Table 1.5 Setting TULO Unlatch Trip Options

Option	Description
1	Unlatch the trip when the relay detects that one or more poles of the line terminal are open, and Relay Word bit 3PT has deasserted.
2	Unlatch the trip when the relay detects that the corresponding 52A contact(s) from both circuit breakers (e.g., 52AA1 and 52AA2) are deasserted.
3	Unlatch the trip when the relay detects that the conditions for Options 1 and 2 are satisfied.
4	Do not run this logic.

Select Option 3 because a 52A contact is available; the relay uses both open phase detection and status information from the circuit breaker to make the most secure decision. For information on the pole-open logic, see *Pole Open Logic on page R.1.21*.

TULO := **3** Trip Unlatch Option (1, 2, 3, 4)

Trip Timers

The SEL-421 provides dedicated timers for minimum trip duration.

Minimum Trip Duration. The minimum trip duration timer setting, TDUR3D, determines the minimum time that Relay Word bit 3PT asserts. For this application example, Relay Word bit 3PT is assigned to OUT101. The corresponding control output closes for TDUR3D time or the duration of the trip condition, whichever is longer.

A typical setting for this timer is 9 cycles.

TDUR3D := **9.000** Three-Pole Trip Minimum Trip Duration Time Delay (2.000–8000 cycles)

Three-Pole Tripping Enable

The relay contains both three-pole and single-pole tripping logic. Set E3PT (Three-Pole Trip Enable) equal to logical 1 to enable the SEL-421 for three-pole tripping only.

E3PT := **1** Three-Pole Trip Enable (SELOGIC Equation)

Also set the appropriate three-pole tripping SELOGIC control equation for Circuit Breaker 1.

E3PT1 := **1** Breaker 1 3PT (SELOGIC Equation)

Control Outputs

Main Board

OUT101 trips Circuit Breaker 1.

OUT101 := **3PT**

Example Completed

This completes the application example describing configuration of the SEL-421 for step-distance protection of a 230 kV overhead transmission line. You can use this example as a guide when setting the relay for similar applications. Analyze your particular power system so you can properly determine your corresponding settings.

Relay Settings

Table 1.6 lists the protection relay settings for this example. Settings used in this example appear in boldface type.

Table 1.6 Settings for 230 kV Overhead TX Example (Sheet 1 of 5)

Setting	Description	Entry
General Global (Global)		
SID	Station Identifier (40 characters)	HARVARD - 230 kV
RID	Relay Identifier (40 characters)	SEL-421 Relay
NUMBK	Number of Breakers in Scheme (1, 2)	1
BID1	Breaker 1 Identifier (40 characters)	Circuit Breaker 1
NFREQ	Nominal System Frequency (Hz)	60
PHROT	System Phase Rotation (ABC, ACB)	ABC
DATE_F	Date Format (MDY, YMD, DMY)	MDY
FAULT	Fault Condition Equation (SELOGIC Equation)	50P1 OR 51S1 OR M2P OR Z2G OR M3P OR Z3G

Table 1.6 Settings for 230 kV Overhead TX Example (Sheet 2 of 5)

Setting	Description	Entry
Current and Voltage Source Selection (Global)		
ESS	Current and Voltage Source Selection (Y, N, 1, 2, 3, 4)	N
Breaker Configuration (Breaker Monitoring)		
EB1MON	Breaker 1 Monitoring (Y, N)	N
BK1TYP	Breaker 1 Trip Type (Single Pole = 1, Three Pole = 3)	3
Breaker 1 Inputs (Breaker Monitoring)		
52AA1	A-Phase N/O Contact Input—BK1 (SELOGIC Equation)	IN101
Line Configuration Settings (Group)		
CTRW	Current Transformer Ratio—Input W (1–50000)	100
CTRX	Current Transformer Ratio—Input X (1–50000)	200
PTRY	Potential Transformer Ratio—Input Y (1–10000)	2000
VNOMY	PT Nominal Voltage (L-L)—Input Y (60–300 V secondary)	115
PTRZ	Potential Transformer Ratio—Input Z (1–10000)	2000
VNOMZ	PT Nominal Voltage (L-L)—Input Z (60–300 V secondary)	115
Z1MAG	Positive-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)	1.95
Z1ANG	Positive-Sequence Line Impedance Angle (5.00–90 degrees)	84.00
Z0MAG	Zero-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)	6.20
Z0ANG	Zero-Sequence Line Impedance Angle (5.00–90 degrees)	81.50
EFLOC	Fault Location (Y, N)	Y
LL	Line Length (0.10–999)	50
Relay Configuration (Group)		
E21P	Mho Phase Distance Zones (N, 1–5)	2
E21MG	Mho Ground Distance Zones (N, 1–5)	2
E21XG	Quadrilateral Ground Distance Zones (N, 1–5)	N
ECVT	CVT Transient Detection (Y, N)	N
ESERCMP	Series-Compensated Line Logic (Y, N)	N
ECDTD	Distance Element Common Time Delay (Y, N)	Y
ESOTF	Switch-Onto-Fault (Y, N)	Y
EOOS	Out-of-Step (Y, Y2, N)	N
ELOAD	Load Encroachment (Y, N)	N
E50P	Phase Inst./Def.-Time O/C Elements (N, 1–4)	1
E50G	Residual Ground Inst./Def.-Time O/C Elements (N, 1–4)	N
E50Q	Negative-Sequence Inst./Def.-Time O/C Elements (N, 1–4)	N
E51S	Selectable Inverse-Time O/C Elements (N, 1–3)	1
E32	Directional Control (Y, AUTO)	AUTO

Table 1.6 Settings for 230 kV Overhead TX Example (Sheet 3 of 5)

Setting	Description	Entry
ECOMM	Communications-Assisted Tripping (N, DCB, POTT, POTT2, POTT3, DCUB1, DCUB2)	N
EBFL1	Breaker 1 Failure Logic (N, 1, 2)	N
E25BK1	Synchronism Check for Breaker 1 (Y, N)	N
E79	Reclosing (Y, Y1, N)	N
EMANCL	Manual Closing (Y, N)	N
ELOP	Loss-of-Potential (Y, Y1, N)	Y1
EDEM	Demand Metering (N, THM, ROL)	N
EADVS	Advanced Settings (Y, N)	N
Mho Phase Distance Element Reach (Group)		
Z1P	Zone 1 Reach (OFF, 0.05–64 Ω secondary)	1.56
Z2P	Zone 2 Reach (OFF, 0.05–64 Ω secondary)	2.34
Mho Phase Distance Element Time Delay (Group)		
Z1PD	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z2PD	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	OFF
Mho Ground Distance Element Reach (Group)		
Z1MG	Zone 1 (OFF, 0.05–64 Ω secondary)	1.56
Z2MG	Zone 2 (OFF, 0.05–64 Ω secondary)	2.34
Zero-Sequence Current Compensation Settings (Group)		
k0M1	Zone 1 ZSC Factor Magnitude (AUTO, 0.000–10)	AUTO
k0A1	Zone 1 ZSC Factor Angle (–180.0 to +180.0 degrees)	–3.65
Ground Phase Distance Element Time Delay (Group)		
Z1GD	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z2GD	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	OFF
Distance Element Common Time Delay (Group)		
Z1D	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	0.000
Z2D	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	20.000
SOTF Scheme Settings (Group)		
ESPSTF	Single Pole Switch-Onto-Fault (Y, N)	N
EVRST	Switch-Onto-Fault Voltage Reset (Y, N)	Y
52AEND	52A Pole Open Delay (OFF, 0.000–16000 cycles)	OFF
CLOEND	CLSMON or Single Pole Delay (OFF, 0.000–16000 cycles)	10.000
SOTFD	Switch-Onto-Fault Enable Duration (0.500–16000 cycles)	10.000
CLSMON	Close Signal Monitor (SELOGIC Equation)	IN102
Phase Instantaneous Overcurrent Pickup Settings (Group)		
50P1P	Level 1 Pickup (OFF, 0.25–100 A secondary)	13.29
Phase Overcurrent Definite-Time Delay (Group)		
67P1D	Level 1 Time Delay (0.000–16000 cycles)	0.000
Phase Overcurrent Torque Control (Group)		
67P1TC	Level 1 Torque Control (SELOGIC Equation)	1

Table 1.6 Settings for 230 kV Overhead TX Example (Sheet 4 of 5)

Setting	Description	Entry
Selectable Operating Quantity Time Overcurrent Element Settings (Group)		
51S1O	51S1 Operating Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0*n*)[a]	3I0L
51S1P	51S1 Overcurrent Pickup (0.25–16 A secondary)	1.72
51S1C	51S1 Inverse-Time Overcurrent Curve (U1–U5)	U3
51S1TD	51S1 Inverse-Time Overcurrent Time Dial (0.50–15.00)	1.96
51S1RS	51S1 Inverse-Time Overcurrent Electromechanical Reset (Y, N)	Y
51S1TC	51S1 Torque Control (SELOGIC Equation)	32GF
Directional Control (Group)		
ORDER	Ground Directional Element Priority (combine Q, V, I)	QV
E32IV	Zero-Sequence Voltage and Current Enable (SELOGIC Equation)	1
Pole Open Detection Settings (Group)		
EPO	Pole-Open Detection (52, V)	52
SPOD	Single-Pole Open Dropout Delay (0.000–60 cycles)	0.500
3POD	Three-Pole Open Dropout Delay (0.000–60 cycles)	0.500
Trip Logic Settings (Group)		
TR	Trip (SELOGIC Equation)	Z1T OR Z2T OR 51S1T
TRSOTF	Switch-Onto-Fault Trip (SELOGIC Equation)	M2P OR Z2G OR 50P1
DTA	Direct Transfer Trip A-Phase (SELOGIC Equation)	NA
DTB	Direct Transfer Trip B-Phase (SELOGIC Equation)	NA
DTC	Direct Transfer Trip C-Phase (SELOGIC Equation)	NA
BK1MTR	Manual Trip – Breaker 1 (SELOGIC Equation)	OC1 OR PB8_PUL
ULTR	Unlatch Trip (SELOGIC Equation)	TRGTR
ULMTR1	Unlatch Manual Trip – Breaker 1 (SELOGIC Equation)	NOT (52AA1 AND 52AB1 AND 52AC1)
TOPD	Trip During Open Pole Time Delay (2.000–8000 cycles)	2.000
TULO	Trip Unlatch Option (1, 2, 3, 4)	3
Z2GTSP	Zone 2 Ground Distance Time Delay SPT (Y, N)	N
67QGSP	Zone 2 Dir. Neg.-Seq./Residual O/C Single Pole Trip (Y, N)	N
TDUR1D	SPT Minimum Trip Duration Time Delay (2.000–8000 cycles)	6.000
TDUR3D	3PT Minimum Trip Duration Time Delay (2.000–8000 cycles)	9.000
E3PT	Three-Pole Trip Enable (SELOGIC Equation)	1
E3PT1	Breaker 1 3PT (SELOGIC Equation)	1

Table 1.6 Settings for 230 kV Overhead TX Example (Sheet 5 of 5)

Setting	Description	Entry
ER	Event Report Trigger (SELOGIC Equation)	R_TRIG M2P OR R_TRIG Z2G OR R_TRIG 51S1 OR R_TRIG M3P OR R_TRIG Z3G
Main Board (Outputs)		
OUT101	(SELOGIC Equation)	3PT

[a] Parameter n is 1 for BK1, 2 for BK2, and L for Line.

500 kV Parallel Transmission Lines With Mutual Coupling Example

Figure 1.3 shows double-ended overhead 500 kV parallel lines with SEL-421 protection at each end of the first circuit. These transmission lines have zero-sequence mutual coupling. This example explains how to calculate settings for the SEL-421 at Station S that protects Line 1 in *Figure 1.3* between Stations S and R.

This application example uses communications-assisted tripping with a digital communications channel to provide high-speed protection for faults along the 500 kV circuit. Distance protection is enabled.

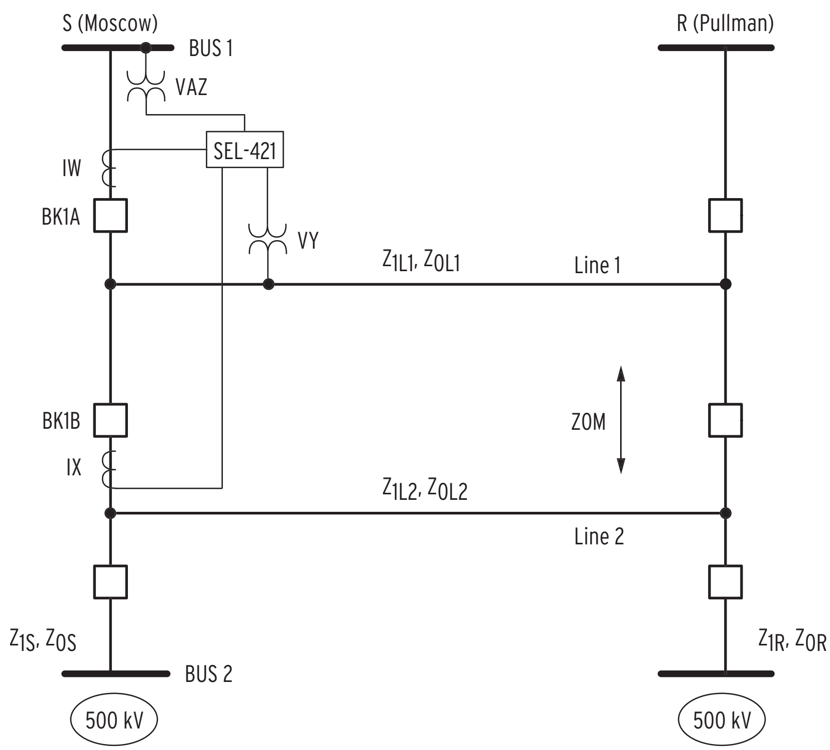


Figure 1.3 500 kV Parallel Overhead Transmission Lines

Power System Data

Table 1.7 lists the power system data for this application example. Substitute the values and parameters that correspond to your system when you set the relay using this example as a guide.

Table 1.7 System Data—500 kV Parallel Overhead Transmission Lines

Parameter	Value
Nominal system line-to-line voltage	500 kV
Nominal relay current	5 A secondary
Nominal frequency	60 Hz
Line length	75 miles
Line impedances:	
$Z_{1L1} = Z_{1L2}$	44.78 Ω ∠87.6° primary
$Z_{0L1} = Z_{0L2}$	162.9 Ω ∠82.1° primary
Zero-sequence mutual coupling:	
Z_{0M}	88.35 Ω ∠76.6° primary
Source S impedances:	
$Z_{1S} = Z_{0S}$	50 Ω ∠88° primary
Source R impedances:	
$Z_{1R} = Z_{0R}$	20 Ω ∠88° primary
PTR (Potential transformer ratio)	500 kV:111.11 V = 4500
CTR (Current transformer ratio)	2000:5 = 400
Phase rotation	ABC

Convert the power system impedances from primary to secondary so you can later calculate protection settings. *Table 1.8* lists the corresponding secondary impedances. Convert the impedances to secondary ohms as follows:

$$k = \frac{CTR}{PTR} = \frac{400}{4500} = 0.089 \quad \textbf{Equation 1.6}$$

$$\begin{aligned} Z_{1L1(secondary)} &= k \cdot Z_{1L1(primary)} \\ &= 0.089 \cdot (44.78\ \Omega\ \angle 87.6°) \\ &= 3.98\ \Omega\ \angle 87.6° \end{aligned} \quad \textbf{Equation 1.7}$$

Table 1.8 Secondary Impedances

Parameter	Value
Line impedances:	
$Z_{1L1} = Z_{1L2}$	3.98 Ω ∠87.6° secondary
$Z_{0L1} = Z_{0L2}$	14.48 Ω ∠82.1° secondary
Zero-sequence mutual coupling:	
Z_{0M}	7.86 Ω ∠76.6° secondary
Source S impedances:	
$Z_{1S} = Z_{0S}$	4.45 Ω ∠88° secondary
Source R impedances:	
$Z_{1R} = Z_{0R}$	1.78 Ω ∠88° secondary

The maximum load current is 1302 A primary and occurs when the parallel line is out of service.

Application Summary

This application is for two circuit breakers, single-pole tripping application with the following functions:

- POTT (permissive overreaching transfer tripping) scheme
- Three zones of phase (mho) and ground (mho and quadrilateral) distance protection
  - Zone 1, forward-looking, instantaneous underreaching protection
  - Zone 2, forward-looking, communications-assisted and time-delayed tripping
  - Zone 3, reverse-looking, prevents unwanted tripping during current reversals
- Inverse-time directional zero-sequence overcurrent backup protection
- SOTF protection, fast tripping when the circuit breaker closes

Relay settings that are not mentioned in this example do not apply to this application example.

Global Settings

General Global Settings

The SEL-421 has settings for identification. These settings allow you to identify the following:

- Station (SID)
- Relay (RID)
- Circuit Breaker 1 (BID1)
- Circuit Breaker 2 (BID2)

You can enter as many as 40 characters per identification setting.

SID := **MOSCOW — 500 kV** Station Identifier (40 characters)

RID := SEL-421 **Relay** Relay Identifier (40 characters)

Configure the SEL-421 for two circuit breakers. This particular application uses two circuit breakers because the terminal is a circuit breaker-and-a-half configuration.

NUMBK := **2** Number of Breakers in Scheme (1, 2)

BID1 := **Circuit Breaker 1** Breaker 1 Identifier (40 characters)

BID2 := **Circuit Breaker 2** Breaker 2 Identifier (40 characters)

You can select both the nominal frequency and phase rotation.

NFREQ := **60** Nominal System Frequency (50, 60 Hz)

PHROT := **ABC** System Phase Rotation (ABC, ACB)

Current and Voltage Source Selection

The voltage and current source selection is for two circuit breakers in a circuit breaker-and-a-half configuration. Set ESS to 3.

ESS := **3** Current and Voltage Source Selection (Y, N, 1, 2, 3, 4)

After you select 3 for setting ESS, the relay automatically sets LINEI, BK1I, and BK2I as follows:

LINEI :=**COMB** Line Current Source (IW, COMB)

BK1I := **IW** Breaker 1 Current Source (IW, IX, NA)

BK2I := **IX** Breaker 2 Current Source (IW, IX, NA)

In this application example Circuit Breaker BK1A is Breaker 1 in the relay settings and BK1B is Breaker 2 in the relay settings.

Figure 1.4 illustrates the current and voltage sources for this particular application. The relay uses potential input VY and the combination of current inputs IW and IX for line relaying; potential input VAZ is for synchronism check. *Auto-Reclose and Synchronism Check Example on page A.1.137* describes how to apply the synchronism-check function.

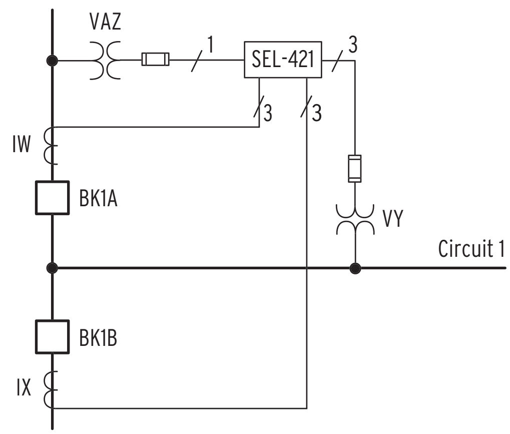


Figure 1.4 Circuit Breaker-and-a-Half Arrangement: Station S, Line 1

Breaker Monitor

Circuit Breaker Configuration

Set the relay to indicate that both circuit breakers are single-pole trip type.

BK1TYP := **1** Breaker 1 Trip Type (Single-Pole = 1, Three-Pole = 3)

BK2TYP := **1** Breaker 2 Trip Type (Single-Pole = 1, Three-Pole = 3)

Circuit Breaker 1 Inputs

The SEL-421 uses normally open auxiliary contacts from the circuit breakers to determine whether each pole is opened or closed.

52AA1 := **IN101** A-Phase N/O Contact Input—BK1 (SELOGIC Equation)

52AB1 := **IN102** B-Phase N/O Contact Input—BK1 (SELOGIC Equation)

52AC1 := **IN103** C-Phase N/O Contact Input—BK1 (SELOGIC Equation)

Circuit Breaker 2 Inputs

52AA2 := **IN104** A-Phase N/O Contact Input—BK2 (SELOGIC Equation)

52AB2 := **IN105** B-Phase N/O Contact Input—BK2 (SELOGIC Equation)

52AC2 := **IN106** C-Phase N/O Contact Input—BK2 (SELOGIC Equation)

Group Settings

Line Configuration

The SEL-421 has four transformer turns ratio settings that convert the secondary potentials and currents that the relay measures to the corresponding primary values. These settings are the potential transformer and current transformer ratios PTRY, PTRZ, CTRW, and CTRX. Use the Y potential input for line relaying and the Z potential input for synchronism checks. Enable the voltage and current source selection so you can combine W and X current inputs for the line current. VNOMY and VNOMZ specify the nominal secondary line-to-line voltage of the potential transformers (see *Figure 1.4*).

CTRW := **400** Current Transformer Ratio—Input W (1–50000)

CTRX := **400** Current Transformer Ratio—Input X (1–50000)

PTRY := **4500** Potential Transformer Ratio—Input Y (1–10000)

VNOMY := **111** PT Nominal Voltage (L–L)—Input Y (60–300 V secondary)

PTRZ := **4500** Potential Transformer Ratio—Input Z (1–10000)

VNOMZ := **111** PT Nominal Voltage (L–L)—Input Z (60–300 V secondary)

Enter the secondary value of the positive-sequence impedance of the protected line. See *Table 1.8* for the secondary line impedances.

Z1MAG := **3.98** Positive-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)

Z1ANG := **87.6** Positive-Sequence Line Impedance Angle (5.00–90 degrees)

Enter the secondary value of the zero-sequence impedance of the protected line.

Z0MAG := **14.48** Zero-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)

Z0ANG := **82.1** Zero-Sequence Line Impedance Angle (5.00–90 degrees)

Enable the fault locator.

EFLOC := **Y** Fault Location (Y, N)

The LL setting is the line length. This value has no defined unit; you can set the line length in miles, kilometers, ohms, etc. Set the length in miles.

LL := **75.00** Line Length (0.10–999)

The relay fault locator uses the values you enter for Z1MAG, Z1ANG, Z0MAG, Z0ANG, and LL.

Relay Configuration

You can select from zero to five phase mho (E21P), ground mho (E21MG), and ground quadrilateral (E21XG) distance zones. You can independently select the number of zones per type of distance protection. Select only the number of zones needed. For this application example, use three zones of phase and ground distance protection.

E21P := **3** Mho Phase Distance Zones (N, 1–5)

E21MG := **3** Mho Ground Distance Zones (N, 1–5)

E21XG := **3** Quadrilateral Ground Distance Zones (N, 1–5)

Now enable the other logic you will need for this application example.

You do not need CVT transient detection if the SIR (Source Impedance Ratio) is less than five. SIR is equal to the ratio of the local source impedance to the relay reach. Calculate the ratio based on the Zone 1 reach because you do not want Zone 1 distance protection to overreach during an external fault. Double the source impedance magnitude because the relay measures half the total fault current when the parallel line is in service and the fault is located at the remote bus.

$$\begin{aligned} \text{SIR} &= \frac{2 \bullet |Z_{1S}|}{0.8 \bullet |Z_{1L}|} \\ &= \frac{2 \bullet 4.45\ \Omega}{0.8 \bullet 3.98\ \Omega} \\ &= 2.76,\ \text{SIR} < 5 \end{aligned}$$

Equation 1.8

ECVT := **N** CVT Transient Detection (Y, N)

NOTE: The SEL-421-1 and the SEL-421-2 do not provide series-compensated line protection logic.

The transmission line is not series compensated.

ESERCMP := **N** Series-Compensated Line Logic (Y, N)

You can select a common time delay or an independent time delay per zone for phase and ground distance protection. If you choose independent timing, evolving faults (such as those changing from single phase to multiphase) cause the timer to reset and result in additional delay. Select common time delay for this application.

ECDTD := **Y** Distance Element Common Time Delay (Y, N)

The SOTF logic permits tripping by specified protection elements for a settable time after the circuit breaker closes.

ESOTF := **Y** Switch-Onto-Fault (Y, N)

Do not enable the Out-of-Step logic for this application example.

EOOS : = **N** Out-of-Step (Y, N)

Do not enable the load-encroachment logic, as the minimum apparent load impedance is outside the mho phase distance characteristics.

ELOAD := **N** Load Encroachment (Y, N)

Use Level 1 high-set instantaneous phase overcurrent element for SOTF protection.

E50P := **1** Phase Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

This application does not require residual ground overcurrent protection.

E50G := **N** Residual Ground Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

This application does not require negative-sequence overcurrent protection.

E50Q := **N** Negative-Sequence Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

Use inverse-time overcurrent protection to provide backup protection for high-resistance ground faults. The 51S1 element provides backup protection for unbalanced faults if both the communications-assisted and step distance protection fail to operate.

E51S := **1** Selectable Inverse-Time Overcurrent Element (N, 1–3)

Set E32 to AUTO and the relay automatically calculates the settings corresponding to the ground directional element (32G).

E32 := **AUTO** Directional Control (Y, AUTO)

Use the two-channel POTT trip scheme (POTT2) to quickly clear faults internal to the protected line.

ECOMM := **POTT2** Communications-Assisted Tripping (N, DCB, POTT, POTT2, POTT3, DCUB1, DCUB2)

Fuses or molded case circuit breakers often protect potential transformers. Operation of one or more fuses, or molded case circuit breakers, results in a loss of polarizing potential inputs to the relay. Loss of one or more phase voltages prevents the relay from properly determining fault distance or direction.

Occasional loss-of-potential to the distance relay, while unavoidable, is detectable. When the relay detects a loss-of-potential condition, the relay can block distance element operation, block or enable forward-looking directional overcurrent elements, and issue an alarm for any true loss-of-potential condition.

If line-side PTs are used, the circuit breaker(s) must be closed for the LOP logic to detect an LOP condition. Therefore, if three-phase potential to the relay is lost while the circuit breaker(s) is open (e.g., the PT fuses are removed while the line is de-energized), the relay cannot detect a loss-of-potential condition when the circuit breaker(s) closes again. At circuit breaker closing, the relay can detect one or two missing potentials that occurred while the circuit breaker was open. See *Loss-of-Potential Logic on page R.1.24* for more information.

Table 1.9 lists the three choices for enabling LOP.

Table 1.9 LOP Enable Options

Option	Description
N	The LOP logic operates but does not disable voltage-polarized directional elements, distance elements, and forward-looking directional overcurrent elements. Use LOP in this case for alarm only.
Y	The relay disables all voltage-polarized directional elements and distance elements, but enables forward-looking directional overcurrent elements. These forward-looking directional overcurrent elements effectively become nondirectional and provide overcurrent protection during an LOP condition.
Y1	The relay disables all voltage-polarized directional elements and distance elements. The relay also disables the overcurrent elements controlled by the voltage-polarized directional elements.

Set ELOP to Y1 for this application example. This choice reduces the chances of false tripping because of a loss-of-potential condition.

ELOP := **Y1** Loss-of-Potential (Y, Y1, N)

Enable the Advanced Settings so you can properly set the zero-sequence compensation factors for the zero-sequence mutual coupling between the parallel transmission lines.

EADVS := **Y** Advanced Settings (Y, N)

Phase Distance Elements (21P)

Mho Phase Distance Element Reach

Employ each zone of distance protection as follows:

- Zone 1—Instantaneous underreaching direct tripping
- Zone 2—Forward-looking tripping elements for the POTT scheme and backup tripping
- Zone 3—Current reversal guard for the POTT scheme, echo tripping, and weak infeed logic

Zone 1 Phase Distance Element Reach. Zone 1 phase distance protection provides instantaneous protection for phase-to-phase, phase-to-phase-to-ground, and three-phase faults in the first 80 percent of the transmission line. Errors in the current transformers, potential transformers, modeled transmission line data, and fault study data do not permit setting of Zone 1 for 100 percent of the transmission line. Unwanted tripping could occur for faults just beyond the remote end of the line if you set Zone 1 for 100 percent of the transmission line.

Set Zone 1 phase distance protection equal to 80 percent of the transmission line positive-sequence impedance.

$$Z1P = 0.8 \bullet Z_{1L1} = 3.18\ \Omega$$

Z1P := **3.18** Zone 1 Reach (OFF, 0.05–64 Ω secondary)

Zone 2 Phase Distance Element Reach. Zone 2 phase distance protection must have adequate reach to detect all phase-to-phase, phase-to-phase-to-ground, and three-phase faults along the protected line. Set Zone 2 phase distance reach to 120 percent of the positive-sequence impedance of the transmission line. This setting provides high-speed tripping via the communications channel for faults located in the last 20 percent of the line.

$$Z2P = 1.2 \bullet Z_{1L1} = 4.78\ \Omega$$

Z2P := **4.78** Zone 2 Reach (OFF, 0.05–64 Ω secondary)

Zone 3 Phase Distance Element Reach. Zone 3 phase distance protection must have adequate reach to prevent unwanted tripping during current reversals (this application example uses a permissive overreaching transfer tripping (POTT) scheme). Set the Zone 3 reach equal to Zone 2 and rely on the length of the protected transmission line for the safety margin. This setting makes the Zone 3 fault coverage greater than the Zone 2 fault coverage at the remote terminal.

$$Z3P = Z2P = 4.78\ \Omega$$

Z3P := **4.78** Zone 3 Reach (OFF, 0.05–64 Ω secondary)

Ground Distance Elements (21MG and 21XG)

Mho Ground Distance Element Reach

Employ each zone of distance protection as follows:

- Zone 1—Instantaneous underreaching direct tripping
- Zone 2—Forward-looking tripping elements for the POTT scheme and backup tripping
- Zone 3—Current reversal guard for the POTT scheme, echo tripping, and weak infeed logic

Zone 1 Mho Ground Distance Element Reach. Zone 1 mho ground distance reach must meet the same requirement as that for Zone 1 mho phase distance protection; the reach setting should be no greater than 80 percent of the line.

$$Z1MG = 0.8 \cdot Z_{1L1} = 3.18\ \Omega$$

Z1MG := **3.18** Zone 1 (OFF, 0.05–64 Ω secondary)

Zone 2 Mho Ground Distance Element Reach. Zone 2 mho and ground distance reach must meet the same requirement as that for Zone 2 mho phase distance protection; the reach setting is 120 percent of the line.

$$Z2MG = 1.2 \cdot Z_{1L1} = 4.78\ \Omega$$

Z2MG := **4.78** Zone 2 (OFF, 0.05–64 Ω secondary)

Zone 3 Mho Ground Distance Element Reach. Zone 3 mho ground distance reach must meet the same requirement as that for Zone 3 mho phase distance protection; it equals the Zone 2 reach.

$$Z3MG = Z2MG = 4.78\ \Omega$$

Z3MG := **4.78** Zone 3 (OFF, 0.05–64 Ω secondary)

Quadrilateral Ground Distance Element Reach

The reactive reach for each zone of quadrilateral ground distance protection lies on the relay characteristic angle (Z1ANG), rather than on the ordinate (reactance) of the impedance plane (see *Figure 1.5*).

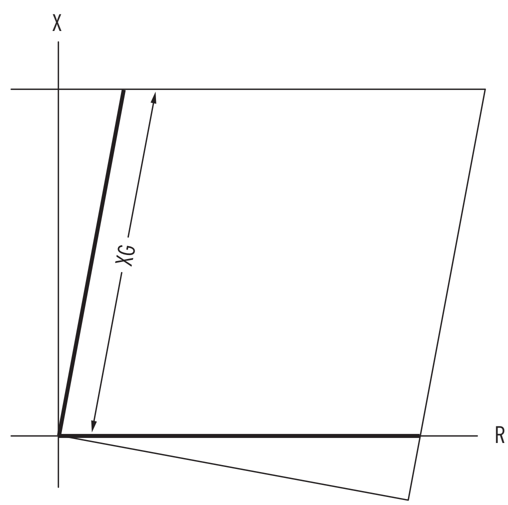


Figure 1.5 Quadrilateral Ground Distance Element Reactive Reach Setting

Zone 1 Reactance. Zone 1 quadrilateral ground distance reactance reach must meet the same requirement as that for Zone 1 mho phase distance protection; the reach setting should be no greater than 80 percent of the line.

$$XG1 = 0.8 \cdot Z_{1L1} = 3.18\ \Omega$$

XG1 := **3.18** Zone 1 Reactance (OFF, 0.05–64 Ω secondary)

Zone 1 Resistance. Find RG1 (Zone1 resistance) from the per-unit reach *m* of the Zone 1 reactance. Use *Equation 1.9* which is Equation (3) in *Appendix A—Quadrilateral Reactive Reach Versus Resistive Reach Setting*

Guideline from the paper *Digital Communications for Power System Protection: Security, Availability, and Speed*. You can find a copy of this paper on the SEL website at www.selinc.com.

$$m = 1 - \frac{R}{X_{1L1} \cdot 20} \qquad \textbf{Equation 1.9}$$

where:

m = per-unit reach of XG1
R = RG1, the Zone 1 resistance
X_{1L1} = positive-sequence transmission line reactance

XG1 is set at 80 percent of the transmission line (i.e., m = 0.8 per-unit); the positive-sequence reactance of the overhead transmission line X_{1L1} is 3.977 Ω secondary (from the rectangular form of Z_{1L1} in *Table 1.8*).

$$\begin{aligned} Z_{1L1} &= 3.98\Omega\angle 87.6° \\ &= R_{1L1} + jX_{1L1} \\ &= 0.167 + j3.977 \end{aligned} \qquad \textbf{Equation 1.10}$$

Rearrange *Equation 1.9* as follows to calculate RG1:

$$\begin{aligned} RG1 &= (1 - m) \cdot 20 \cdot X_{1L1} \\ &= (1 - 0.8) \cdot 20 \cdot 3.977\ \Omega \\ &= 15.9\ \Omega \end{aligned} \qquad \textbf{Equation 1.11}$$

SEL recommends that you apply a safety margin of 50 percent because single pole tripping is enabled for this particular application.

RG1 = 0.5 • 15.9 Ω = 7.96 Ω

RG1 := **7.96** Zone 1 Resistance (0.05–50 Ω secondary)

Zone 2 Reactance. Zone 2 quadrilateral ground distance reach must meet the same requirement as that for Zone 2 mho phase distance protection; the reach setting is 120 percent of the line.

XG2 = 1.2 • Z_{1L1} = 1.2 • 3.98 = 4.78 Ω

XG2 := **4.78** Zone 2 Reactance (OFF, 0.05–64 Ω secondary)

Zone 2 Resistance. Set Zone 2 quadrilateral resistive reach as follows:

$$\begin{aligned} RG2 &= XG2 \cdot \frac{RG1}{XG1} \\ &= 4.78\ \Omega \cdot \frac{7.96\ \Omega}{3.18\ \Omega} \\ &= 11.97\ \Omega \end{aligned} \qquad \textbf{Equation 1.12}$$

RG2 := **12.00** Zone 2 Resistance (0.05–50 Ω secondary)

Zone 3 Reactance. Zone 3 quadrilateral ground distance reach must meet the same requirement as that for Zone 3 mho phase distance protection; it equals Zone 2 reach.

XG3 = XG2 = 4.78 Ω

XG3 := **4.78** Zone 3 Reactance (OFF, 0.05–64 Ω secondary)

Zone 3 Resistance. The Zone 3 quadrilateral resistive reach is also scaled by an additional factor of 125 percent to ensure that it has greater coverage than the remote Zone 2 during external resistive ground faults behind the local terminal.

$$RG3 = 1.25 \cdot RG2 = 1.25 \cdot 12.00 = 15\ \Omega$$

RG3 := **15.00** Zone 3 Resistance (0.05–50 Ω secondary)

Quadrilateral Ground Polarizing Quantity

You must enter two final settings for quadrilateral ground distance protection because Advanced Settings are enabled. These settings are XGPOL and TANG.

XGPOL allows you to choose the polarizing quantity for the quadrilateral ground distance protection. You can choose either negative- or zero-sequence current. Choose appropriately to reduce overreach and underreach of the reactance line. The reactance line can underreach or overreach during high-resistance single phase-to-ground faults. Nonhomogeneous negative- or zero-sequence networks can cause this underreach or overreach.

Figure 1.6 defines whether the negative- or zero-sequence network is homogeneous.

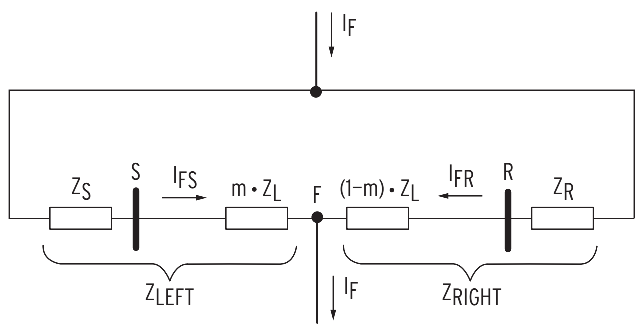


Figure 1.6 Definition of Homogeneous Network

Z_{LEFT} is the total impedance up to the fault (F) on the left-hand side, while Z_{RIGHT} is the total impedance up to the fault on the right-hand side. A network is homogeneous with respect to the particular fault location if equation 1.12 is satisfied:

$$\frac{X_{LEFT}}{R_{LEFT}} = \frac{X_{RIGHT}}{R_{RIGHT}} \qquad \textbf{Equation 1.13}$$

Use *Equation 1.14* and *Equation 1.15* to determine the zero-sequence and negative-sequence homogeneity:

$$T_0 = \arg\left(\frac{Z_{0S} + Z_{0L} + Z_{0R}}{(1 - m) \cdot Z_{0L} + Z_{0R}}\right) \qquad \textbf{Equation 1.14}$$

$$T_2 = \arg\left(\frac{Z_{1S} + Z_{1L} + Z_{1R}}{(1 - m) \cdot Z_{1L} + Z_{1R}}\right) \qquad \textbf{Equation 1.15}$$

The values T_0 and T_2 represent how much the apparent fault impedance (Z_F) measured by relay tilts up or down (electrical degrees) because of the nonhomogeneity of the corresponding network for a fault at location *m* (see *Figure 1.7*).

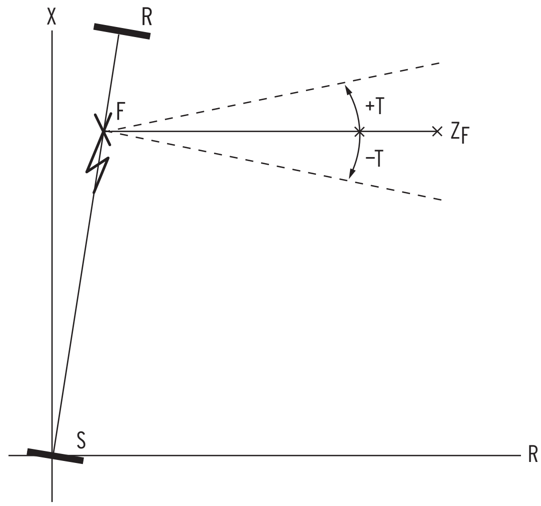


Figure 1.7 Tilt in Apparent Fault Impedance Resulting From Nonhomogeneity

Calculate T_0 and T_2 for a ground fault at the remote bus (i.e., *m* equals one per unit). The magnitude of whichever angle is greater indicates that the corresponding network is less homogeneous for a ground fault at the remote bus. The remote bus is selected for the fault location to prevent Zone 1 ground distance overreach.

Table 1.15 provides the results of *Equation 1.14* and *Equation 1.15* for both the negative-sequence and zero-sequence networks. The negative-sequence network is more homogeneous than the zero-sequence network because the magnitude of T_2 is less than the magnitude of T_0.

Table 1.10 Tilt Resulting From Nonhomogeneity

Calculation	Angle
T_2	–0.2°
T_0	–4.1°

Select negative-sequence current flowing in the line as the polarizing quantity for the ground distance quadrilateral reactance measurement.

XGPOL := **I2** Quadrilateral Ground Polarizing Quantity (I2, IG)

Nonhomogeneous Correction Angle

TANG is the nonhomogeneous angle setting that also helps prevent overreach or underreach by compensating the angle of the reactance line.

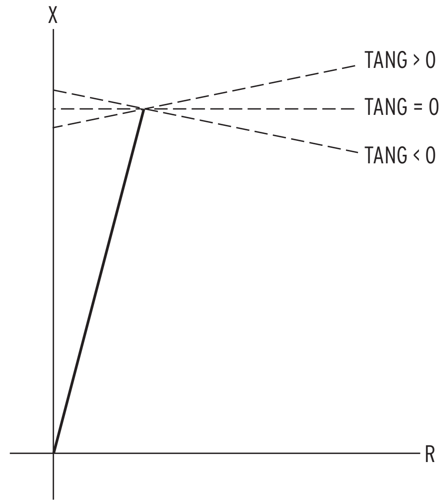


Figure 1.8 Nonhomogeneous Angle Setting

Set TANG to prevent the Zone 1 quadrilateral ground distance reactance measurement from overreaching for ground faults located at the remote bus. *Equation 1.15* (T_2) from Quadrilateral Ground Polarizing Quantity was approximately zero. Therefore, set TANG equal to zero.

TANG := **0** Nonhomogeneous Correction Angle (–40.0 to +40.0 degrees)

Zero-Sequence Current Compensation Factors

Zero-sequence current compensation helps to keep the phase and ground distance elements at the same reach if you set the reach equal per zone (for example, Z1P = Z1MG). Ground distance elements should measure fault impedance in terms of positive-sequence impedance only.

The relay has three zero-sequence current compensation factors (k01, k0, and k0R). The Zone 1 ground distance element has a dedicated zero-sequence current compensation factor (k01). Advanced Settings are enabled for this particular example; set two independent zero-sequence current compensation factors, one for forward-looking (k0) zones and one for reverse-looking (k0R) zones.

The SEL-421 ground distance elements do not employ zero-sequence mutual coupling compensation. Zero-sequence mutual coupling can cause under/overreaching problems on both the faulted line and the nonfaulted line relaying terminals for parallel line applications employing ground distance elements. Set the residual current compensation factors k0 and k0R appropriately to compensate for the effect of mutual coupling on parallel lines.

Apply the following expression for the Zone 1 zero-sequence current compensation factor.

$$\begin{aligned} k01 &= \frac{Z_{0L1} - Z_{1L1}}{3 \bullet Z_{1L1}} \\ &= \frac{14.48\ \Omega\ \angle 82.1° - 3.98\ \Omega\ \angle 87.6°}{3 \bullet 3.98\ \Omega\ \angle 87.6°} \\ &= 0.88\ \angle -7.6° \end{aligned}$$

Equation 1.16

k0M1 := **0.880** Zone 1 ZSC Factor Magnitude (AUTO, 0.000–10)

k0A1 := **-7.60** Zone 1 ZSC Factor Angle (–180.0 to +180.0 degrees)

Zone 2 ground distance elements tend to underreach for faults at the remote bus because residual current flows in the same direction for both parallel lines. Apply the following expression for the forward compensation factor so that Zone 2 ground distance elements see ground faults at the remote bus when zero-sequence mutual coupling is a concern.

$$\begin{aligned} k0 &= \frac{Z_{0L1} - Z_{1L1} + Z_{0M}}{3 \bullet Z_{1L1}} \\ &= \frac{14.48\ \Omega\ \angle 82.1° - 3.98\ \Omega\ \angle 87.6° + 7.86\ \Omega\ \angle 76.6°}{3 \bullet 3.98\ \Omega\ \angle 87.6°} \\ &= 1.54\ \angle{-9°} \end{aligned}$$

Equation 1.17

k0M := **1.540** Forward Zones ZSC Factor Magnitude (0.000–10)

k0A := **–9.0** Forward Zones ZSC Factor Angle (–180.0 to +180.0 degrees)

Set the reverse compensation factor equal to the forward compensation factor so that Zone 3 ground distance protection has the same reach for external faults as the remote Zone 2 ground distance protection.

K0MR := **1.540** Reverse Zones ZSC Factor Magnitude (0.000–10)

k0AR := **–9.0** Reverse Zones ZSC Factor Angle (–180.0 to +180.0 degrees)

Parallel Line Out-of-Service. When the parallel line is out-of-service, Zone 2 and 3 ground distance elements overreach; these elements still coordinate properly during external faults because the elements overreach by the same amount. Consider using an alternate settings group if Zone 2 ground distance protection provides time-delayed backup protection; Zone 2 ground distance protection and downstream Zone 1 ground distance protection could coordinate poorly.

Distance Element Common Time Delay

Set the appropriate timers Z1D, Z2, and Z3D for both phase and ground distance elements.

There is no need to delay Zone 1 distance protection since it trips instantaneously.

Z1D = **0.000** Zone 1 Time Delay (OFF, 0.000–16000 cycles)

Zone 2 distance protection must coordinate with downstream Zone 1 distance protection, downstream circuit breaker operating time, and a safety margin. A typical Zone 2 phase and ground distance time delay setting is 20 cycles.

Z2D := **20.000** Zone 2 Time Delay (OFF, 0.000–16000 cycles)

Set Zone 3 for zero time delay.

Z3D := **0.000** Zone 3 Time Delay (OFF, 0.000–16000 cycles)

SOTF Scheme

SOTF (Switch-Onto-Fault) logic is enabled when the circuit breaker closes. This logic provides protection for a short duration (setting SOTFD) until other protection (such as tripping from SELOGIC control equations TR and TRCOMM) is available. The TRSOTF SELOGIC control equation defines which protection elements cause the relay to trip when the SOTF scheme is active. Assertion of the protection elements assigned to TRSOTF during the SOTFD time causes the relay to trip instantaneously.

Apply SOTF when using line-side potentials for relaying. Use nondirectional overcurrent protection to clear close-in faults. Also use instantaneous overreaching distance protection to clear faults along the line. Assign instantaneous Zone 2 mho phase and ground distance protection plus Level 1 phase overcurrent element to TRSOTF.

TRSOTF := **M2P OR Z2G OR 50P1** Switch-Onto-Fault Trip (SELOGIC Equation)

Single-Pole SOTF

Single-pole tripping is applied for this particular example. The ability to single-pole trip when SOTF is enabled helps improve transient power system stability. The setting ESPSTF enables single-pole switch-onto-fault protection; the SOTF is armed following a single-pole reclose attempt. Enable this option.

ESPSTF := **Y** Single-Pole Switch-Onto-Fault (Y, N)

Voltage Reset

You can configure the logic so the SOTF enable duration resets within at least 5 cycles after it first asserted, but before the SOTFD timer expires. To quickly reset the SOTF period, the relay must sense that the positive-sequence voltage is greater than 85 percent of the nominal voltage.

Use setting EVRST (Switch-Onto-Fault Voltage Reset) to enable fast reset. The advantage of resetting SOTF protection quickly is that unwanted tripping does not occur for subsequent faults external to the remote terminals during the SOTF period; these trips can occur if you set instantaneous Zone 2 distance protection elements in the TRSOTF SELOGIC control equation. Enable the voltage reset option.

EVRST := **Y** Switch-Onto-Fault Voltage Reset (Y, N)

SOTF Initiation

The SOTF logic asserts via one or both of the following methods:

- A change in the normally open auxiliary contact 52A status showing that the circuit breaker has just opened
- Assertion of the relay control input assigned to the circuit breaker close bus

The 52A method works well for both single and multiple circuit breaker applications and does not require an input from the close bus. However, the close bus method only enables SOTF protection immediately following the close command to the circuit breaker. For more information, see *Switch-Onto-Fault Logic on page R.1.86*.

Select the 52A option for this application and set the delay (52AEND) shorter than the shortest reclose open interval.

52AEND := **10.000** 52A Pole Open Time Delay (OFF, 0.000–16000 cycles)

Turn off CLOEND (CLSMON Delay) since this method is not used.

CLOEND := **OFF** CLSMON or Single Pole Open Delay
(OFF, 0.000–16000 cycles)

SOTF Duration

Setting SOTFD determines the longest period the SOTF logic can assert after the circuit breaker closes.

SOTFD := **10.000** Switch-Onto-Fault Enable Duration (0.500–16000 cycles)

Phase Instantaneous/Definite-Time Overcurrent Elements

Use 50P1, Level 1 phase instantaneous overcurrent element, as a nondirectional high-set phase overcurrent element for SOTF protection. If the local circuit breaker closes into a close-in three-phase bolted fault with line-side potential transformers, the polarizing voltage for the phase distance elements is zero. Therefore, the distance protection does not operate. In this case, the 50P1 element quickly trips the circuit breaker because this overcurrent element does not rely on the polarizing voltage.

To rapidly clear faults, set 50P1P equal to 50 percent of the fault current measured at the local terminal for a close-in three-phase fault; use weak source conditions so that the relay operates for low-level fault current.

50P1P := **7.21** Level 1 Pickup (OFF, 0.25–100 A secondary)

This application uses 50P1 as an instantaneous overcurrent element; you do not need time delay.

67P1D := **0.000** Level 1 Time Delay (0.000–16000 cycles)

This application uses 50P1 as a nondirectional overcurrent element; place no conditions on torque control.

67P1TC := **1** Level 1 Torque Control (SELOGIC Equation)

Selectable Operating Quantity Time Overcurrent Element 1

Use inverse-time overcurrent protection to provide backup protection for high-resistance ground faults. The 51S1 element provides backup protection for unbalanced faults if both the communications-assisted and step distance protection fail to operate.

NOTE: Use your company practices and philosophy when determining these settings.

Select zero-sequence line current as the operating quantity.

51S1O := **3I0L** 51S1 Operate Quantity (Ia*n*, Ib*n*, Ic*n*, IMAX*n*, I1L, 3I2L, 3I0*n*)

The *n* in the 51S1O setting is L for line, 1 for BK1, and 2 for BK2.

The fault current ($3I_0$) measured by the relay for a bolted single phase-to-ground fault at the remote station with both lines in-service is 2.25 A secondary. (A remote end fault for the downstream relay gives a fault current of 1.22 A secondary.) Set the pickup to 30 to 50 percent of $3I_0$.

51S1P = **0.50** 51S1 Overcurrent Pickup (0.25–16 A secondary)

Use the following formula to determine approximately how much primary fault resistance coverage (R_F) is provided by 51S1P on a radial basis:

$$\begin{aligned} R_F &= \frac{PTR}{CTR} \cdot \frac{VNOMY / \sqrt{3}}{51S1P} \\ &= \frac{4500}{400} \cdot \frac{111.11\ V / \sqrt{3}}{0.50\ A} \\ &= 1443\ \Omega \text{ primary} \end{aligned}$$

Equation 1.18

Use the following as a guide to set the curve and time dial; for secure backup protection, perform a coordination study.

Set the local overcurrent element to coordinate with the downstream overcurrent element such that there is an 18-cycle (60 Hz nominal) safety margin for ground faults in front of the first downstream overcurrent element. Assume the operating time of the downstream overcurrent element is 12 cycles for a close-in ground fault. Therefore, set the local time-overcurrent element to operate approximately 30 cycles for ground faults in front of the first downstream overcurrent element.

51S1C = **U3** 51S1 Inverse-Time Overcurrent Curve (U1–U5)

51S1TD = **1.68** 51S1 Inverse-Time Overcurrent Time Dial (0.50–15.0)

Set the overcurrent element to emulate electromechanical reset.

51S1RS = **Y** 51S1 Inverse-Time Overcurrent Electromechanical Reset (Y, N)

Torque control the overcurrent element with the forward decision from the ground directional element.

51S1TC = **32GF** 51S1 Torque Control (SELOGIC Equation)

Zone/Level Direction

Zone 1 and Zone 2 distance element directions are fixed in the forward direction. You can select the other zones independently as forward-looking (F), or reverse-looking (R). Set Zone 3 distance elements reverse-looking, because these are blocking elements for the POTT trip scheme.

DIR3 := **R** Zone/Level 3 Directional Control (F, R)

Directional Control

The SEL-421 uses an array of directional elements to supervise the ground distance elements and residual directional overcurrent elements during ground fault conditions. Internal logic automatically selects the best choice for the ground directional element (32G) from among the negative-sequence voltage-polarized directional element (32QG), zero-sequence voltage-polarized directional element (32V), and the zero-sequence current-polarized directional element (32I).

The relay setting ORDER determines the order in which the relay selects directional elements to provide ground directional decisions. You can set ORDER with any combination of Q, V, and I. The listed order of these directional elements determines the priority in which these elements operate to provide the ground directional element. Only one specific directional element operates at any one time. Directional element classification is as follows:

- Q—Negative-sequence voltage-polarized directional element
- V—Zero-sequence voltage-polarized directional element
- I—Zero-sequence current-polarized directional element

Set ORDER to QV. The first listed directional element choice, Q, is the first priority directional element to provide directional control for the ground distance elements and residual ground directional overcurrent elements. If Q is not operable, the second listed directional element choice, V, provides directional control for the ground distance elements and residual ground directional overcurrent elements. A polarizing quantity was not available for choice I, so I is not selected for this particular application example.

ORDER := **QV** Ground Directional Element Priority (combine Q, V, I)

SELOGIC control equation E32IV must assert to logical 1 to enable V or I for directional control of the ground distance elements and residual ground directional overcurrent elements. Set E32IV to logical 1.

E32IV := **1** Zero-Sequence Voltage and Current Enable (SELOGIC Equation)

Pole-Open Detection

The setting EPO, Enable Pole-Open logic, offers two options for deciding what conditions signify an open pole, as listed in *Table 1.11*.

Table 1.11 Options for Enabling Pole-Open Logic

Option	Description
EPO := V	The logic declares a single-pole open if the corresponding phase undervoltage element asserts and the open phase detection logic declares the pole is open. *Select this option only if you use line-side potential transformers for relaying purposes.* A typical setting for the 27PO, pole-open undervoltage threshold, is 60 percent of the nominal line-to-neutral voltage. Do not select this option when shunt reactors are applied, because the voltage slowly decays after the circuit breaker opens. With this option selected, the relay cannot declare an open pole during assertion of LOP.
EPO := 52	The logic declares a single-pole open if the corresponding 52A contact (52AA1, for example) from the circuit breaker deasserts and the open phase detection logic declares that the pole is open.

Select the second option because a 52A contact is available. The relay uses both open phase detection and status information from the circuit breaker to make the most secure decision.

EPO= **52** Pole-Open Detection (52, V)

Pole-Open Time Delay on Dropout

SPOD is the time delay on dropout after the Relay Word bit SPO deasserts. This time delay allows power system transients to settle after the open-pole recloses, thereby stabilizing the ground distance elements corresponding to that phase. If a three-pole open condition (3PO) asserts, SPOD resets immediately.

SPOD := **0.500** Single Pole Open Dropout Delay (0.000–60 cycles)

The setting 3POD establishes the time delay on dropout after the Relay Word bit 3PO deasserts. This delay is important when you use line-side potential transformers for relaying. Use the 3POD setting to stabilize the ground distance elements in case of pole scatter during closing of the circuit breaker(s).

3POD := **0.500** Three-Pole Open Dropout Delay (0.000–60 cycles)

POTT Trip Scheme

The permissive overreaching transfer trip (POTT) scheme is selected to provide high-speed tripping for faults along the protected line.

The POTT scheme logic consists of four sections:

- Current reversal guard logic
- Echo
- Weak infeed logic
- Permission to Trip Received

Current Reversal Guard Logic

You need current reversal guard for this parallel line application. When a reverse-looking element detects an external fault, the relay does not key the transmitter and ignores reception of a permissive signal from the remote terminal. The Zone 3 Reverse Block Delay (Z3RBD) timer extends these two conditions after a current reversal occurs and the reverse-looking elements drop out.

Set Z3RBD timer to accommodate for the following:

- Remote terminal R circuit breaker maximum opening time
- Maximum communications channel reset time
- Remote terminal R Zone 2 relay maximum reset time

Assume a circuit breaker opening time of 3 cycles, a communications channel reset time of 1 cycle, and remote Zone 2 relay reset time of 1 cycle. The sum of these times gives a conservative setting of 5 cycles for a three-cycle circuit breaker.

Z3RBD := **5.000** Zone 3 Reverse Block Time Delay (0.000–16000 cycles)

Echo

If the local circuit breaker is open, or a weak infeed condition exists at the local terminal, the received permissive signal can echo back to the remote relay and cause it to issue a high-speed trip for faults beyond the remote relay Zone 1 reach. The SEL-421 includes logic that echoes the received permissive signal back to the remote terminal after specific conditions are satisfied. The echo logic includes timers for qualifying the permissive signal as well as timers for blocking the echo logic during specific conditions.

Use EBLKD (Echo Block Time Delay) to block the echo logic after dropout of local permissive elements. The recommended setting for the EBLKD timer is the sum of the following:

- Remote terminal R circuit breaker opening time
- Communications channel round trip time
- Safety margin

Assume a circuit breaker opening time of 3 cycles, a communications channel round trip time of 2 cycles, and a safety margin of 5 cycles. The sum of these three times gives a conservative setting of 10 cycles for a 3-cycle circuit breaker.

EBLKD := **10.000** Echo Block Time Delay (OFF, 0.000–16000 cycles)

The echo time delay, setting ETDPU, makes certain that the reverse-looking elements at the receiving end have sufficient time to operate and block the received echo signal for external faults behind the remote terminal. The delay also guards the echo and weak infeed logic against noise bursts that can occur on the communications channel during close-in external faults.

Because of the brief duration of noise bursts and the pickup time for the reverse-looking elements, a received signal must be present for a short time to allow the POTT scheme to echo the permissive signal back to the remote terminal. The ETDPU (Echo Time Delay Pickup) timer specifies the time a permissive trip signal must be present. The ETDPU setting depends upon your communications equipment, but a conservative setting for this timer is 2 cycles.

ETDPU := **2.000** Echo Time Delay Pickup (OFF, 0.000–16000 cycles)

The setting EDURD (Echo Duration Time Delay) limits the duration of the echoed permissive signal. Once an echo signal initiates, it should remain for a minimum period of time and then stop, even if a terminal receives a continuous permissive signal. This termination of the echo signal prevents the permissive trip signal from latching between the two terminals. Assume a 3-cycle circuit breaker at the remote terminal and a 1-cycle channel delay. The sum of these two is a setting of 4 cycles.

EDURD := **4.000** Echo Duration Time Delay (0.000–16000 cycles)

Weak Infeed

The SEL-421 provides weak infeed logic to high-speed trip both line terminals for internal faults near the weak terminal. The weak terminal echoes the permissive signal back to the strong terminal and causes the strong terminal to trip. The weak terminal trips by converting the echoed permissive signal to a trip signal after satisfaction of specific conditions.

This application does not require use of the weak-infeed feature.

EWFC := **N** Weak Infeed Trip (Y, N, SP)

Permission to Trip Received

Two Relay Word bits identify receipt of permission to trip:

- **PT1**—General permission to trip received
- **PT3**—Three-pole permission to trip received

Refer to *Cross-Country Fault Identification on page A.1.41* for a detailed explanation of this particular communications-assisted tripping scheme logic.

If PT1 is asserted, the relay can high-speed single-pole trip via the communications channel. However, if PT3 is asserted, the relay high-speed three-pole trips via the communications channel. This logic prevents the SEL-421 at Station S from three-pole tripping for cross-country faults (for example, A-phase-to-ground fault on Line 1 and B-phase-to-ground fault simultaneously on Line 2) beyond the reach of local Zone 1 ground distance protection.

Direct tripping is also implemented for reliability and to decrease the overall tripping time of the SEL-421 at Station S for cross-country faults beyond the reach of local Zone 1 ground distance protection. The logic PT1 and PT3 requires that the circuit breakers at Station R single-pole trip the external fault on line 2 first before the SEL-421 at Station S can single-pole trip for the case of cross-country faults beyond the reach of Zone 1 ground distance protection at Station S. Direct tripping for cross-country faults is faster since the SEL-421 at Station S do not have to wait for the remote circuit breakers to single-pole trip.

PT1 := **RMB1A** General Permissive Trip Received (SELOGIC Equation)

PT3 := **RMB2A** Three-Pole Permissive Trip Received (SELOGIC Equation)

Trip Logic

Trip logic configures the relay for tripping. These settings consists of the following:

- Trip equations
- Trip unlatch options
- Single-pole trip options
- Trip timers
- Enable single-pole tripping

Trip Equations

Set these six SELOGIC control equations for tripping:

- TR (unconditional)
- TRCOMM (communications-assisted)
- TRSOTF (SOTF)
- DTA, DTB, and DTC (direct tripping)

The TR SELOGIC control equation determines which protection elements trip unconditionally. Set TR to Zone 1 instantaneous distance protection, Zone 2 time-delayed distance protection, and inverse time overcurrent protection for backup.

TR := **Z1T OR Z2T OR 51S1T** Trip (SELOGIC Equation)

The TRCOMM SELOGIC control equation determines which elements trip via the communication-based scheme logic. Set instantaneous Zone 2 distance protection in the TRCOMM logic equation.

TRCOMM := **M2P OR Z2G** Communications-Assisted Trip (SELOGIC Equation)

The TRSOTF SELOGIC control equation defines which elements trip when SOTF protection is active. Set instantaneous overcurrent element 50P1 and Zone 2 distance protection in the TRSOTF SELOGIC control equation.

TRSOTF := **M2P OR Z2G OR 50P1** Switch-Onto-Fault Trip (SELOGIC Equation)

The DTA, DTB, and DTC SELOGIC control equations receive single-pole direct transfer trips from the remote terminal whenever the remote SEL-421 single-pole trips. Use this tripping logic for reliability and to decrease SEL-421 operating time during cross-country faults beyond the reach of local Zone 1 ground distance protection.

DTA := **RMB3A** Direct Transfer Trip A-Phase (SELOGIC Equation)

DTB := **RMB4A** Direct Transfer Trip B-Phase (SELOGIC Equation)

DTC := **RMB5A** Direct Transfer Trip C-Phase (SELOGIC Equation)

Trip Unlatch Options

Unlatch the control output programmed for tripping after the circuit breaker auxiliary a contacts break the dc current. The SEL-421 provides three methods for unlatching control outputs programmed for tripping after occurrence of a protection trip:

- ULTR—following a protection trip, all three poles
- TOPD—Unlatch single-pole trip if another protection trip occurs during single-pole dead time
- TULO—following a protection trip, phase selective

ULTR. Use ULTR, the unlatch trip SELOGIC control equation, to unlatch all three poles. Use the default setting, to assert ULTR when you push the front-panel **{TARGET RESET}** pushbutton.

ULTR := **TRGTR** Unlatch Trip (SELOGIC Equation)

TOPD. It is common practice to trip the two remaining phases after the single-pole open dead time, or if the single-pole auto-reclose cycle does not reset, following the original single-pole trip. If the SEL-421 internal reclosing relay is being used, the E3PT, E3PT1, and E3PT2 settings in the trip logic should be set as shown in *Internal Recloser on page R.2.26*. See *Auto-Reclose Example on page A.1.133* for information on using the SEL-421 reclosing relay.

To illustrate another way of using an external reclosing relay, this example will not use the SEL-421 Relay's auto-reclose logic, rather, it uses the TOP (Trip During Open Pole) Relay Word bit to control the trip logic.

The timer setting TOPD determines the length of time for converting any subsequent single-pole trips to a three-pole trip following the original single-pole trip. Set this timer to the single-pole open dead time (30 cycles) and the reset time (three seconds) for the recloser plus a 5-cycle safety margin. See *Trip During Open-Pole Time Delay on page R.1.109* and *External Recloser on page R.2.27* for additional information.

TOPD := **215.00** Trip During Open Pole Time Delay (2.000–8000 cycles)

TULO. Use TULO (Trip Unlatch Option) to select the conditions that cause the SEL-421 to unlatch the control outputs that you programmed for tripping. You can select from among the four trip unlatch options in *Table 1.12*.

Table 1.12 Trip Unlatch Options

Option	Description
1	Unlatch the trip when the relay has detected that one or more poles of the line terminal are open, and Relay Word bit 3PT has deasserted.
2	Unlatch the trip when the relay has detected that the corresponding 52A contact(s) from both circuit breakers (e.g., 52AA1 and 52AA2) are deasserted.
3	Unlatch the trip when the relay has detected that the conditions for the first two options are satisfied.
4	Do not run this logic.

Select the third option if a 52A contact is available because the relay uses both open phase detection and status information from the circuit breaker(s). For information on the pole-open logic, see *Switch-Onto-Fault Logic on page R.1.86*.

TULO := **3** Trip Unlatch Option (1, 2, 3, 4)

Single-Pole Trip Options

You can program the SEL-421 to single-pole trip for Zone 2 ground distance operations. Employ this method if you want single-pole tripping during ground faults within the last 20 percent of the protected line when the communications channel is not available. Do not enable this option.

Z2GTSP := **N** Zone 2 Ground Distance Time Delay SPT (Y, N)

The SEL-421 can assert a single-pole trip during high resistance ground faults such that the fault impedance lies outside of the ground distance protection characteristics; the FIDS logic selects the faulted phase when residual directional overcurrent elements provide communications-assisted tripping. Do not enable this option.

67QGSP := **N** Zone 2 Dir. Negative-Sequence/Residual Ground Overcurrent SPT (Y, N)

Trip Timers

The SEL-421 provides dedicated timers for minimum trip durations and open-pole time delays.

Minimum Trip Duration. The minimum trip duration timer settings, TDUR1D and TDUR3D, determine the minimum length of time that Relay Word bits TPA1, TPA2, TPB1, TPB2, TPC1, TPC2, and 3PT assert. Use these timers to control the designated trip control outputs. The control outputs programmed for tripping close for the greater of the TDUR*n*D time, or the duration of the trip condition.

TDUR1D is the minimum trip duration following a single-pole trip. TDUR3D is the minimum trip duration following a three-pole trip. If another trip occurs during the single-pole open dead time following a single-pole trip, TDUR3D replaces TDUR1D.

A typical setting for both of these timers is 9 cycles.

TDUR1D := **9.000** SPT Min Trip Duration Time Delay (2.000–8000 cycles)

TDUR3D := **9.000** 3PT Min Trip Duration Time Delay (2.000–8000 cycles)

Enable Single-Pole Tripping

The relay contains both three-pole and single-pole tripping logic. The relay uses single-pole tripping logic if the setting for E3PT, Three-Pole Trip Enable SELOGIC control equation, equals logical 0. For this example, an external reclosing relay is present. Use the TOP (Trip During Open Pole) Relay Word bit and the IN107 control input, to enable single-pole tripping. If E3PT equals logical 0 (assigned control input is deasserted), single-pole tripping is enabled.

E3PT := **IN107 OR TOP** Three-Pole Trip Enable (SELOGIC Equation)

Also set the appropriate three-pole tripping SELOGIC control equation for Circuit Breaker BK1 and Circuit Breaker BK2. In this example, the same three-phase trip selection input is used for both breakers. See *Trip Logic and Reclose Sources on page R.2.9* for details on the three-pole trip enable settings.

E3PT1 := **IN107** Breaker 1 3PT (SELOGIC Equation)

E3PT2 := **IN107** Breaker 2 3PT (SELOGIC Equation)

Control Outputs

Main Board

Use SELOGIC control equations to assign the control outputs for tripping.

Use the Main Board control outputs for tripping. The first three control outputs trip Circuit Breaker BK1A and the next three trip circuit breaker BK1B.

OUT101 := **TPA1**

OUT102 := **TPB1**

OUT103 := **TPC1**

OUT104 := **TPA2**

OUT105 := **TPB2**

OUT106 := **TPC2**

Cross-Country Fault Identification

Fault Identification

The SEL-421 provides two means of implementing simultaneous ground fault tripping logic for single-pole tripping applications in double-circuit tower applications. This particular example is based upon the POTT2 scheme, a 2-channel POTT scheme. The implementation of this logic uses the simplicity and flexibility of SELOGIC control equations and MIRRORED BITS® communications.

For this particular example, when a cross-country fault occurs close in to Station R, the local line protection correctly identifies the faults as single phase-to-ground; Line 1 protection identifies a Zone 1 A Phase-to-ground fault, while Line 2 protection identifies a Zone 1 B Phase-to-ground fault. Tripping for both lines at Station R is instantaneous and independent from the communications channel. *Figure 1.9* illustrates a cross-country fault close in to Station R (that is, beyond Zone 1 reach with respect to Station S).

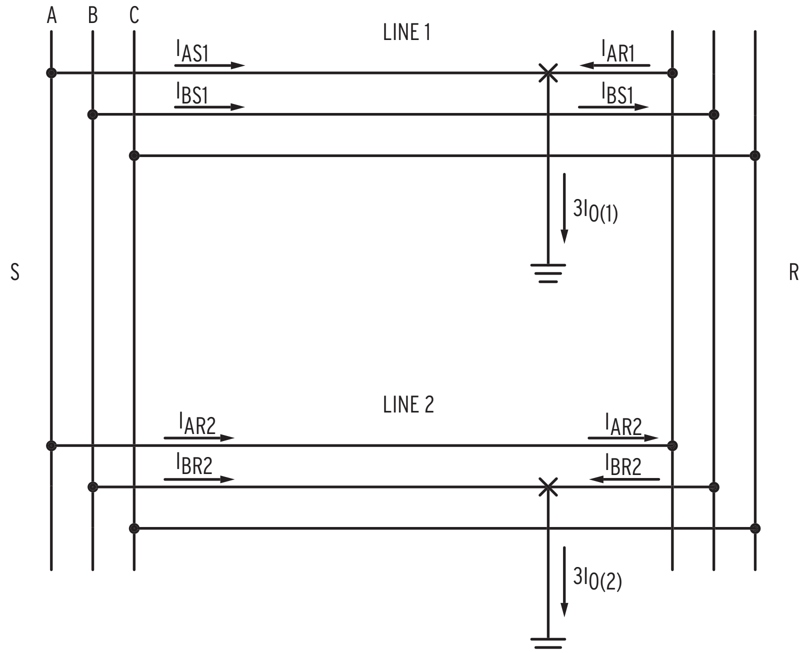


Figure 1.9 Current Distribution During Cross-Country Fault

The difficulty arises with the line protection at Station S prior to a circuit breaker opening at Station R (after the circuit breakers open at Station R, the line protection at Station S identifies each fault as single phase-to-ground). This difficulty diminishes as the fault location moves closer to Station S. At Station S, the relays for Lines 1 and 2 misidentify the fault as ABG. If the permissive trip signal from Station R arrives while an overreaching Zone 2 phase-phase distance element at Station S is picked up, an undesirable three-pole trip results for both lines at Station S. (An ABG fault involves more than one phase, so protection for this fault must use three-pole tripping.)

To avoid this, you must make provisions for identifying the mismatch in fault type identification between the line protection at both ends of the line. In doing so, you avoid three-pole tripping both lines at Station S while single-pole tripping both lines at Station R.

Transmit Equations

Overcoming this mismatch requires at least two communications channels, one for transmitting three-pole trip permission (KEY3) and another for transmitting all permissive trips (KEY1). The relay at Station S must receive both permissive signals before three-pole tripping via the communications scheme. Thus, the POTT2 scheme determines if there is agreement at both line ends on fault type declaration. The relay checks fault type agreement by comparing the local fault identification with the type of received permissive trip signal.

The Zone 2 phase distance (M2P) element asserts KEY1 and KEY3. The Zone 2 ground distance (Z2G) element asserts KEY1 only. Use two separate signals, rather than one, to send permission:

- KEY1—Transmit General Permissive Trip
- KEY3—Transmit Three-Phase Permissive Trip

Assign these two permissive signals to the first two Transmit MIRRORED BITS signals.

TMB1A := **KEY1 OR EKEY AND RMB1A** Transmit MIRRORED BIT 1A (SELOGIC Equation)

TMB2A := **KEY3 OR EKEY AND RMB2A** Transmit MIRRORED BIT 2A (SELOGIC Equation)

Receive Equations

Any type of fault detected within Zone 2 at Station R transmit KEY1, which is converted to PT1 at Station S through the MIRRORED BITS pair, TMB1A and RMB1A. The SEL-421 at Station S can high-speed single-pole trip via the communications channel if the fault type is identified as single-phase and single-pole tripping is enabled, regardless of fault selection at the remote terminal.

Figure 1.10 is a simplified logic diagram for the communications-assisted tripping logic.

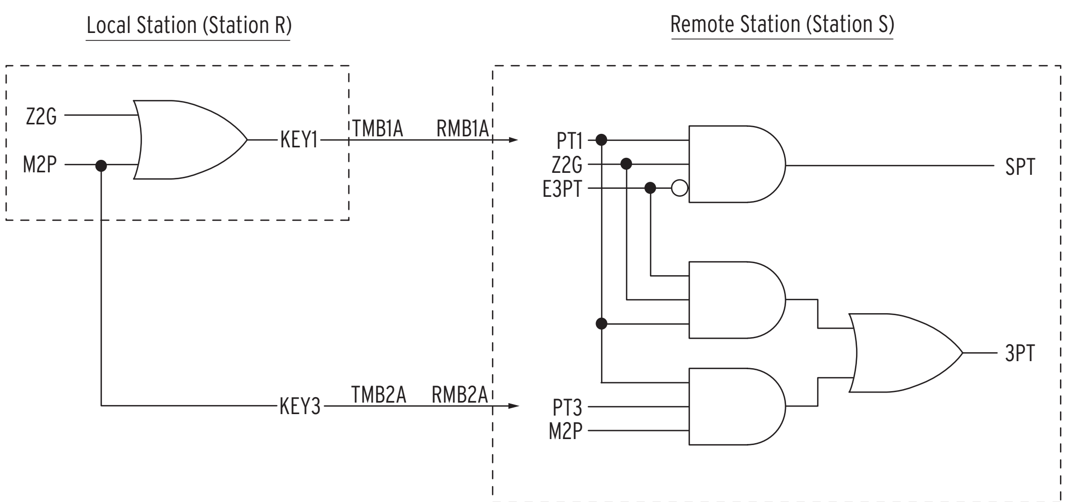


Figure 1.10 Simplified POTT Scheme KEY1/KEY3 Logic

If the SEL-421 at Station S detects a multiphase fault in Zone 2, it can high-speed three-pole trip only if both PT1 and PT3 assert. PT3 confirms that the remote terminal (Station R) has also identified the fault type as multiphase. If the SEL-421 detects a multiphase fault in Zone 2 and receives only PT1, like in the cross-country fault situation on a parallel-line system, the relay delays a trip until the permissive signal received agrees with the fault type detected locally. The fault type detected by the SEL-421 at Station S changes from a multiphase to a single-phase ground fault after Station R clears the external fault on line 2. The relay can then single-pole trip via the received PT1. Note that a desired single-pole trip at Station S occurs only after Station R clears the external fault on line 2. To avoid a delayed trip in a cross-country fault situation, you may choose the three-channel POTT scheme (POTT3), as described below.

Two Relay Word bits identify receipt of trip permission:

- PT1—General permission to trip received
- PT3—Three-pole permission to trip received

Assign PT1 to the corresponding Received MIRRORED BITS signals.

PT1 := **RMB1A** General Permissive Trip Received (SELOGIC Equation)

PT3 := **RMB2A** Three-Pole Permissive Trip Received (SELOGIC Equation)

Three-Channel POTT Scheme, POTT3

In a cross-country fault situation of a mutually coupled parallel-line system, a relay using the one-channel POTT scheme will trip all three poles at the remote-to-fault terminal. This is because the relay at the remote terminal sees a multiphase fault and receives the only permissive trip signal. Both transmission lines will be out of service if even a single-phase ground fault occurs on each circuit.

The two-channel POTT scheme retains the much-desired single-pole tripping in the event of cross-country faults. However, the relay at the remote terminal has to delay a single-pole trip until the external fault is cleared at the close-in terminal. This application example uses direct transfer trips described below to compliment the two-channel POTT scheme and reduce the single-pole trip delay to a minimum.

As an alternative to the two-channel POTT scheme with direct transfer trips, you may use the phase-segregate three-channel POTT scheme (POTT3) to correctly single-pole trip without a delay in the event of cross-country faults. In the previous cross-country fault example, the SEL-421 on line 1 at Station R will transmit KEYA to the relay at Station S, which converts it to PTA, a permissive A-phase trip signal. The relay then combines a locally detected Zone 2 phase distance element with the received PTA and trips A-phase only without a time delay. Because the direct transfer trips are not necessary in the three-channel POTT scheme, the total communications channels used would be three.

For three-channel POTT applications, the following equations apply:

ECOMM := **POTT3** Communications-Assisted Tripping (N, DCB, POTT, POTT2, POTT3, DCUB1, DCUB2)

TMB1A := **KEYA** Transmit MIRRORED BIT 1A (SELOGIC Equation)

TMB2A := **KEYB** Transmit MIRRORED BIT 2A (SELOGIC Equation)

TMB3A := **KEYC** Transmit MIRRORED BIT 3A (SELOGIC Equation)

PTA := **RMB1A** A-phase Permissive Trip Received (SELOGIC Equation)

PTB := **RMB2A** B-phase Permissive Trip Received (SELOGIC Equation)

PTC := **RMB3A** C-phase Permissive Trip Received (SELOGIC Equation)

Relay Word bit KEY is general permission to trip.

Single Line Applications

For single line applications, the following equations apply:

ECOMM := **POTT** Communications-Assisted Tripping (N, DCB, POTT, POTT2, POTT3, DCUB1, DCUB2)

TMB1A := **KEY** Transmit MIRRORED BIT 1A (SELOGIC Equation)

PT1 := **RMB1A** General Permissive Trip Received (SELOGIC Equation)

Relay Word bit KEY is general permission to trip.

Direct Tripping

Direct tripping is faster because the SEL-421 relays at Station S do not have to wait for the circuit breakers at Station R to single-pole trip first; that is, the SEL-421 relays at Station R single-pole direct transfer trip the SEL-421 relays at Station S during crossing country faults beyond the reach of Zone 1 ground distance protection at Station S.

Transmit Equations

TMB3A := **TPA AND NOT 3PT** Transmit MIRRORED BIT 3A (SELOGIC Equation)

TMB4A := **TPB AND NOT 3PT** Transmit MIRRORED BIT 4A (SELOGIC Equation)

TMB5A := **TPC AND NOT 3PT** Transmit MIRRORED BIT 5A (SELOGIC Equation)

Receive Equations

DTA := **RMB3A** Direct Transfer Trip A-Phase (SELOGIC Equation)

DTB := **RMB4A** Direct Transfer Trip B-Phase (SELOGIC Equation)

DTC := **RMB5A** Direct Transfer Trip C-Phase (SELOGIC Equation)

Example Completed

This completes the application example that describes how to set the SEL-421 for communications-assisted protection of 500 kV parallel overhead transmission lines with zero-sequence mutual coupling. Analyze your particular power system to determine the appropriate settings for your application.

Relay Settings

Table 1.13 lists all protection relay settings for this example. Settings used in this example appear in boldface type.

Table 1.13 Settings for 500 kV Parallel TX Example (Sheet 1 of 7)

Setting	Description	Entry
General Global (Global)		
SID	Station Identifier (40 characters)	MOSCOW - 500 kV
RID	Relay Identifier (40 characters)	SEL-421 Relay
NUMBK	Number of Breakers in Scheme (1, 2)	2
BID1	Breaker 1 Identifier (40 characters)	Circuit Breaker 1
BID2	Breaker 2 Identifier (40 characters)	Circuit Breaker 2
NFREQ	Nominal System Frequency (50, 60 Hz)	60
PHROT	System Phase Rotation (ABC, ACB)	ABC
DATE_F	Date Format (MDY, YMD, DMY)	MDY
FAULT	Fault Condition (SELOGIC Equation)	50P1 OR 51S1 OR M2P OR Z2G OR M3P OR Z3G
Current and Voltage Source Selection (Global)		
ESS	Current and Voltage Source Selection (Y, N, 1, 2, 3, 4)	3
LINEI	Line Current Source (IW, COMB)	COMB
BK1I	Breaker 1 Current Source (IW, IX, NA)	IW
BK2I	Breaker 2 Current Source (IX, COMB, NA)	IX

Table 1.13 Settings for 500 kV Parallel TX Example (Sheet 2 of 7)

Setting	Description	Entry
Breaker Configuration (Breaker Monitoring)		
EB1MON	Breaker 1 Monitoring (Y, N)	N
EB2MON	Breaker 2 Monitoring (Y, N)	N
BK1TYP	Breaker 1 Trip Type (Single Pole = 1, Three Pole = 3)	1
BK2TYP	Breaker 2 Trip Type (Single Pole = 1, Three Pole = 3)	1
Breaker 1 Inputs (Breaker Monitoring)		
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 Monitoring)		
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
Line Configuration (Group)		
CTRW	Current Transformer Ratio—Input W (1–50000)	400
CTRX	Current Transformer Ratio—Input X (1–50000)	400
PTRY	Potential Transformer Ratio—Input Y (1–10000)	4500
VNOMY	PT Nominal Voltage (L-L)—Input Y (60–300 V secondary)	111
PTRZ	Potential Transformer Ratio—Input Z (1–10000)	4500
VNOMZ	PT Nominal Voltage (L-L)—Input Z (60–300 V secondary)	111
Z1MAG	Positive-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)	3.98
Z1ANG	Positive-Sequence Line Impedance Angle (5.00–90 degrees)	87.6
Z0MAG	Zero-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)	14.48
Z0ANG	Zero-Sequence Line Impedance Angle (5.00–90 degrees)	82.1
EFLOC	Fault Location (Y, N)	Y
LL	Line Length (0.10–999)	75

Table 1.13 Settings for 500 kV Parallel TX Example (Sheet 3 of 7)

Setting	Description	Entry
Relay Configuration (Group)		
E21P	Mho Phase Distance Zones (N, 1–5)	3
E21MG	Mho Ground Distance Zones (N, 1–5)	3
E21XG	Quadrilateral Ground Distance Zones (N, 1–5)	3
ECVT	CVT Transient Detection (Y, N)	N
ESERCMP	Series-Compensated Line Logic (Y, N)	N
ECDTD	Distance Element Common Time Delay (Y, N)	Y
ESOTF	Switch-Onto-Fault (Y, N)	Y
EOOS	Out-of-Step (Y, Y2, N)	N
ELOAD	Load Encroachment (Y, N)	N
E50P	Phase Inst./Def.-Time O/C Elements (N, 1–4)	1
E50G	Residual Ground Inst./Def.-Time O/C Elements (N, 1–4)	N
E50Q	Negative-Sequence Inst./Def.-Time O/C Elements (N, 1–4)	N
E51S	Selectable Inverse-Time O/C Elements (N, 1–3)	1
E32	Directional Control (Y, AUTO)	AUTO
ECOMM	Communications-Assisted Tripping (N, DCB, POTT, POTT2, POTT3, DCUB2, DCUB2)	POTT2
EBFL1	Breaker 1 Failure Logic (N, 1, 2)	N
EBFL2	Breaker 2 Failure Logic (N, 1, 2)	N
E25BK1	Synchronism Check for Breaker 1 (Y, N)	N
E25BK2	Synchronism Check for Breaker 2 (Y, N)	N
E79	Reclosing (Y, Y1, N)	N
EMANCL	Manual Closing (Y, N)	N
ELOP	Loss-of-Potential (Y, Y1, N)	Y1
EDEM	Demand Metering (N, THM, ROL)	N
EADVS	Advanced Settings (Y, N)	Y
Mho Phase Distance Element Reach (Group)		
Z1P	Zone 1 Reach (OFF, 0.05–64 Ω secondary)	3.18
Z2P	Zone 2 Reach (OFF, 0.05–64 Ω secondary)	4.78
Z3P	Zone 3 Reach (OFF, 0.05–64 Ω secondary)	4.78
Mho Phase Distance Element Time Delay (Group)		
Z1PD	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z2PD	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z3PD	Zone 3 Time Delay (OFF, 0.000–16000 cycles)	OFF
Mho Ground Distance Element Reach (Group)		
Z1MG	Zone 1 (OFF, 0.05–64 Ω secondary)	3.18
Z2MG	Zone 2 (OFF, 0.05–64 Ω secondary)	4.78
Z3MG	Zone 3 (OFF, 0.05–64 Ω secondary)	4.78

Table 1.13 Settings for 500 kV Parallel TX Example (Sheet 4 of 7)

Setting	Description	Entry
Quadrilateral Ground Distance Element Reach (Group)		
XG1	Zone 1 Reactance (OFF, 0.05–64 Ω secondary)	3.18
RG1	Zone 1 Resistance (0.05–50 Ω secondary)	7.96
XG2	Zone 2 Reactance (OFF, 0.05–64 Ω secondary)	4.78
RG2	Zone 2 Resistance (0.05–50 Ω secondary)	12.00
XG3	Zone 3 Reactance (OFF, 0.05–64 Ω secondary)	4.78
RG3	Zone 3 Resistance (0.05–50 Ω secondary)	15.00
XGPOL	Quadrilateral Ground Polarizing Quantity (I2, IG)	I2
TANG	Nonhomogeneous Correction Angle (–40.0 to +40.0 degrees)	0.0
Zero-Sequence Current Compensation Factor (Group)		
k0M1	Zone 1 ZSC Factor Magnitude (AUTO, 0.000–10)	0.880
k0A1	Zone 1 ZSC Factor Angle (–180.0 to +180.0 degrees)	–7.6
k0M	Forward Zones ZSC Factor Magnitude (0.000–10)	1.540
k0A	Forward Zones ZSC Factor Angle (–180.0 to +180.0 degrees)	–9.0
k0MR	Reverse Zones ZSC Factor Magnitude (0.000–10)	1.540
k0AR	Reverse Zones ZSC Factor Angle (–180.0 to +180.0 degrees)	–9.0
Ground Distance Element Time Delay (Group)		
Z1GD	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z2GD	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z3GD	Zone 3 Time Delay (OFF, 0.000–16000 cycles)	OFF
Distance Element Common Time Delay (Group)		
Z1D	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	0.000
Z2D	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	20.000
Z3D	Zone 3 Time Delay (OFF, 0.000–16000 cycles)	0.000
SOTF Scheme Settings		
ESPSTF	Single-Pole Switch-Onto-Fault (Y, N)	Y
EVRST	Switch-Onto-Fault Voltage Reset (Y, N)	Y
52AEND	52A Pole Open Time Delay (OFF, 0.000–16000 cycles)	10.000
CLOEND	CLSMON or Single Pole Open Delay (OFF, 0.000–16000 cycles)	OFF
SOTFD	Switch-Onto-Fault Enable Duration (0.500–16000 cycles)	10.000
CLSMON	Close Signal Monitor (SELOGIC Equation)	NA
Phase Instantaneous Overcurrent Pickup (Group)		
50P1P	Level 1 Pickup (OFF, 0.25–100 A secondary)	7.21
Phase Overcurrent Definite-Time Delay (Group)		
67P1D	Level 1 Time Delay (0.000–16000 cycles)	0.000

Table 1.13 Settings for 500 kV Parallel TX Example (Sheet 5 of 7)

Setting	Description	Entry
Phase Overcurrent Torque Control (Group)		
67P1TC	Level 1 Torque Control (SELOGIC Equation)	1
Selectable Operating Quantity Inverse-Time Overcurrent Element 1 (Group)		
51S1O	51S1 Operating Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0*n*)[a]	3I0L
51S1P	51S1 Overcurrent Pickup (0.25–16 A secondary)	0.50
51S1C	51S1 Inverse-Time Overcurrent Curve (U1–U5)	U3
51S1TD	51S1 Inverse-Time Overcurrent Time Dial (0.50–15)	1.68
51S1RS	51S1 Inverse-Time Overcurrent Electromechanical Reset (Y, N)	Y
51S1TC	51S1 Torque Control (SELOGIC Equation)	32GF
Zone/Level Direction (Group)		
DIR3	Zone/Level 3 Direction Control (F, R)	R
Directional Control (Group)		
ORDER	Ground Directional Element Priority (combine Q, V, I)	QV
E32IV	Zero-Sequence Voltage and Current Enable (SELOGIC Equation)	1
Pole Open Detection (Group)		
EPO	Pole-Open Detection (52, V)	52
SPOD	Single-Pole Open Dropout Delay (cycles)	0.500
3POD	Three-Pole Open Dropout Delay (cycles)	0.500
POTT Trip Scheme (Group)		
Z3RBD	Zone 3 Reverse Block Time Delay (0.000–16000 cycles)	5.000
EBLKD	Echo Block Time Delay (OFF, 0.000–16000 cycles)	10.000
ETDPU	Echo Time Delay Pickup (OFF, 0.000–16000 cycles)	2.000
EDURD	Echo Duration Time Delay (0.000–16000 cycles)	4.000
EWFC	Weak Infeed Trip (Y, N, SP)	N
27PWI	Weak Infeed Phase Undervoltage Pickup (1.0–200 V secondary)	47.0
27PPW	Weak Infeed Phase-Phase Undervoltage Pickup (1.0–300 V secondary)	80.0
59NW	Weak Infeed Zero-Sequence Overvoltage Pickup (1.0–200 V secondary)	5.0
PT1	General Permissive Trip Received (SELOGIC Equation)	RMB1A
PT3	Three-Pole Permissive Trip Received (SELOGIC Equation)	RMB2A

Table 1.13 Settings for 500 kV Parallel TX Example (Sheet 6 of 7)

Setting	Description	Entry
Trip Logic (Group)		
TR	Trip (SELOGIC Equation)	Z1T OR Z2T OR 51S1T
TRCOMM	Communications-Assisted Trip (SELOGIC Equation)	Z2G OR M2P
TRSOTF	Switch-Onto-Fault Trip (SELOGIC Equation)	M2P OR Z2G OR 50P1
DTA	Direct Transfer Trip A-Phase (SELOGIC Equation)	RMB3A
DTB	Direct Transfer Trip B-Phase (SELOGIC control equation)	RMB4A
DTC	Direct Transfer Trip C-Phase (SELOGIC Equation)	RMB5A
BK1MTR	Manual Trip–Breaker 1 (SELOGIC Equation)	OC1 OR PB7_PUL
BK2MTR	Manual Trip–Breaker 2 (SELOGIC Equation)	OC2 OR PB8_PUL
ULTR	Unlatch Trip (SELOGIC Equation)	TRGTR
ULMTR1	Unlatch Manual Trip–Breaker 1 (SELOGIC Equation)	NOT (52AA1 AND 52AB1 AND 52AC1)
ULMTR2	Unlatch Manual Trip–Breaker 2 (SELOGIC Equation)	NOT (52AA2 AND 52AB2 AND 52AC2)
TOPD	Trip During Open Pole Time Delay (2.000–8000 cycles)	215.000
TULO	Trip Unlatch Option (1, 2, 3, 4)	3
Z2GTSP	Zone 2 Ground Distance Time Delay SPT (Y, N)	N
67QGSP	Zone 2 Directional Neg.-Seq./Residual Ground Overcurrent SPT (Y, N)	N
TDUR1D	SPT Minimum Trip Duration Time Delay (2.000–8000 cycles)	9.000
TDUR3D	3PT Minimum Trip Duration Time Delay (2.000–8000 cycles)	9.000
E3PT	Three-Pole Trip Enable (SELOGIC Equation)	IN107 OR TOP
E3PT1	Breaker 1 3PT (SELOGIC Equation)	IN107
E3PT2	Breaker 2 3PT (SELOGIC Equation)	IN107
ER	Event Report Trigger (SELOGIC Equation)	R_TRIG M2P OR R_TRIG Z2G OR R_TRIG 51S1 OR R_TRIG M3P OR R_TRIG Z3G
Main Board (Outputs)		
OUT101	(SELOGIC Equation)	TPA1
OUT102	(SELOGIC Equation)	TPB1
OUT103	(SELOGIC Equation)	TPC1
OUT104	(SELOGIC Equation)	TPA2
OUT105	(SELOGIC Equation)	TPB2
OUT106	(SELOGIC Equation)	TPC2

Table 1.13 Settings for 500 kV Parallel TX Example (Sheet 7 of 7)

Setting	Description	Entry
MIRRORED BITS Transmit Equations (Outputs)		
TMB1A	(SELOGIC Equation)	KEY1 OR EKEY AND RMB1A
TMB2A	(SELOGIC Equation)	KEY3 OR EKEY AND RMB2A
TMB3A	(SELOGIC Equation)	TPA AND NOT 3PT
TMB4A	(SELOGIC Equation)	TPB AND NOT 3PT
TMB5A	(SELOGIC Equation)	TPC AND NOT 3PT
TMB6A	(SELOGIC Equation)	NA
TMB7A	(SELOGIC Equation)	NA
TMB8A	(SELOGIC Equation)	NA
TMB1B	(SELOGIC Equation)	NA
TMB2B	(SELOGIC Equation)	NA
TMB3B	(SELOGIC Equation)	NA
TMB4B	(SELOGIC Equation)	NA
TMB5B	(SELOGIC Equation)	NA
TMB6B	(SELOGIC Equation)	NA
TMB7B	(SELOGIC Equation)	NA
TMB8B	(SELOGIC Equation)	NA

[a] Parameter n is 1 for BK1, 2 for BK2, and L for Line.

345 kV Tapped Overhead Transmission Line Example

Figure 1.11 shows a three-ended 345 kV transmission line with SEL-421 protection at Stations S and R. A tap midway between Stations S and R feeds an autotransformer. This example explains how to calculate settings for the SEL-421 at Station S that protects the 345 kV circuit between Substation S, Substation R, and the autotransformer. The 345 kV and 138 kV windings of the autotransformer are wye-connected and solidly grounded. The tertiary voltage windings are delta-connected and lag the other windings by 30 degrees.

This application example uses communications-assisted tripping with PLC (power line carrier) communication to provide high-speed protection for faults along the 345 kV circuit. The relay uses distance elements and residual ground directional overcurrent elements in this protection scheme.

Another SEL-421 located on the 138 kV side of the autotransformer blocks high-speed tripping at Stations S and R for faults on the 138 kV side of the autotransformer.

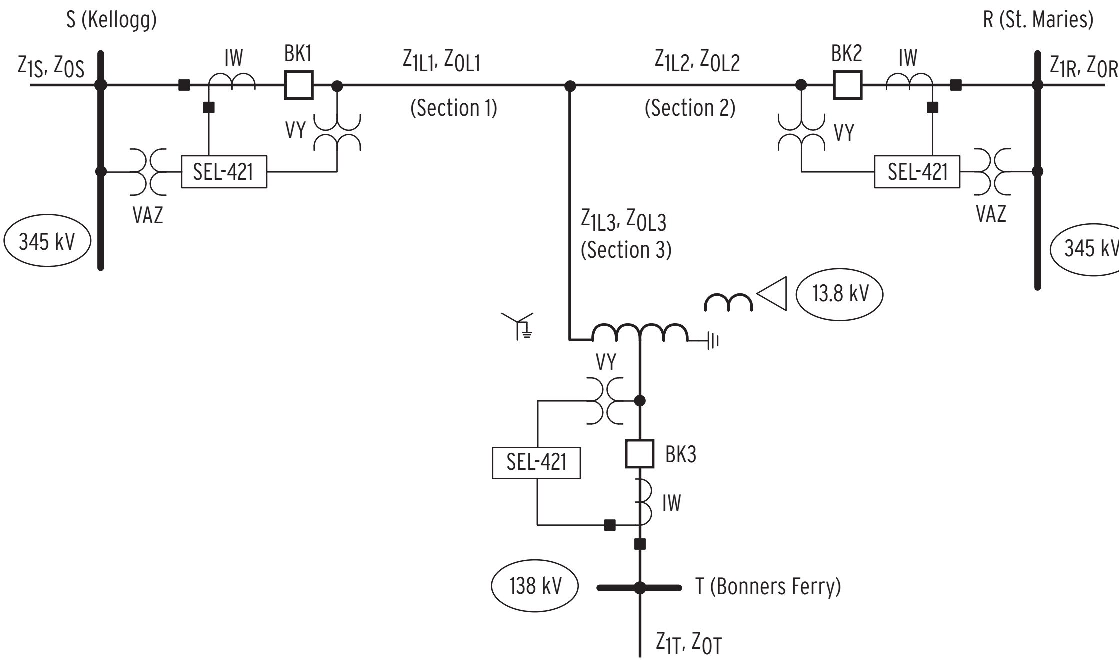


Figure 1.11 345 kV Tapped Overhead Transmission Line

Power System Data

Table 1.14 lists the power system data for this application example. Substitute the values and parameters that correspond to your system when you set the relay using this example as a guide.

Table 1.14 System Data—345 kV Tapped Overhead Transmission Line (Sheet 1 of 2)

Parameter	Value
EHV nominal system line-to-line voltage (transformer primary)	345 kV
HV line-to-line voltage (transformer secondary)	138 kV
MV line-to-line voltage (transformer tertiary)	13.8 kV
Nominal relay current	5 A secondary
Nominal frequency	60 Hz
Line lengths[a]	
S–t (Section 1)	50 miles
t–R (Section 2)	50 miles
t–T (Section 3)	75 miles
Line impedances:	
$Z_{1L1} = Z_{1L2}$	29.67 Ω ∠84.7° primary
$Z_{0L1} = Z_{0L2}$	96.65 Ω ∠73° primary
Z_{1L3}	44.5 Ω ∠84.7° primary
Z_{0L3}	144.98 Ω ∠73° primary
Transformer impedances:	
X_{HM}	8% on 500 MVA; 1.6% on 100 MVA
X_{ML}	10% on 25 MVA; 40% on 100 MVA
X_{HL}	15% on 25 MVA; 60% on 100 MVA

Table 1.14 System Data—345 kV Tapped Overhead Transmission Line (Sheet 2 of 2)

Parameter	Value
Source S impedances: $Z_{1S} = Z_{0S}$	10 Ω ∠87° primary
Source R impedances: $Z_{1R} = Z_{0R}$	35 Ω ∠87° primary
Source T impedances: $Z_{1T} = Z_{0T}$	0.656 Ω ∠87° per unit
PTR (potential transformer ratio)	345 kV:115 V = 3000
CTR (current transformer ratio)	1000:5 = 200
Phase rotation	ABC

[a] Parameter t is the tap point on the 345 kV line; S and R are terminals at the ends of the 345 kV line (see Figure 1.11).

Convert the power system impedances from primary to secondary so you can later calculate protection settings. *Table 1.15* lists the corresponding secondary impedances. Convert the impedances to secondary ohms as follows:

$$k = \frac{CTR}{PTR} = \frac{200}{3000} = 0.067$$ **Equation 1.19**

$$\begin{aligned} Z_{1L1(\text{secondary})} &= k \cdot Z_{1L1(\text{primary})} \\ &= 0.067 \cdot (29.67\Omega\angle 84.7°) \\ &= 2\Omega\angle 84.7° \end{aligned}$$ **Equation 1.20**

Table 1.15 Secondary Impedances

Parameter	Value
Line impedances:	
$Z_{1L1} = Z_{1L2}$	2 Ω ∠84.7° secondary
$Z_{0L1} = Z_{0L2}$	6.44 Ω ∠73° secondary
Z_{1L3}	3 Ω ∠84.7° secondary
Z_{0L3}	9.65 Ω ∠73° secondary
Transformer impedances:	
X_{HM}	8% @ 500 MVA; 1.6% on 100 MVA
X_{ML}	10% @ 25 MVA; 40% on 100 MVA
X_{HL}	15% @ 25 MVA; 60% on 100 MVA
Source S impedances:	
$Z_{1S} = Z_{0S}$	0.67 Ω ∠87° secondary
Source R impedances:	
$Z_{1R} = Z_{0R}$	2.33 Ω ∠87° secondary
Source T impedances:	
$Z_{1T} = Z_{0T}$	0.656 Ω ∠87° per unit

The tapped autotransformer is rated at 500 MVA; the corresponding maximum load current is 837 A primary at 354 kV.

Application Summary

This particular example is for a single circuit breaker, three-pole tripping application with the following functions:

- DCB (directional comparison blocking) trip scheme
- Three zones of mho phase and ground distance protection
  - Zone 1, forward-looking, instantaneous underreaching protection
  - Zone 2, forward-looking, communications-assisted high-speed tripping and time-delayed tripping
  - Zone 3, reverse-looking, starting element
- Two levels of zero-sequence directional overcurrent protection
  - Level 2, forward-looking, communications-assisted high-speed tripping
  - Level 3, reverse-looking, starting element
- Inverse-time directional zero-sequence overcurrent backup protection
- Load-encroachment logic: prevents unwanted tripping during heavy load conditions
- SOTF protection: fast tripping when the circuit breaker closes

Relay settings that are not mentioned in this example do not apply to this application example.

Global Settings

General Global Settings

The SEL-421 has settings for identification. These settings allow you to identify the following:

- Station (SID)
- Relay (RID)
- Circuit Breaker 1 (BID1)

You can enter as many as 40 characters per identification setting.

SID := **KELLOG - 345 kV** Station Identifier (40 characters)

RID := SEL-421 **Relay** Relay Identifier (40 characters)

Configure the SEL-421 for one circuit breaker.

NUMBK := **1** Number of Breakers in Scheme (1, 2)

BID1 := **Circuit Breaker 1** Breaker 1 Identifier (40 characters)

You can select both nominal frequency and phase rotation for the relay.

NFREQ := **60** Nominal System Frequency (50, 60 Hz)

PHROT := **ABC** System Phase Rotation (ABC, ACB)

Current and Voltage Source Selection

The voltage and current source selection is for one circuit breaker. The relay derives the line current source from current input IW when you set ESS to N.

ESS := **N** Current and Voltage Source Selection (Y, N, 1, 2, 3, 4)

Figure 1.12 illustrates the current and voltage sources for this particular application. The relay uses potential input VY and current input IW for line relaying; potential input VAZ is for synchronism check. *Section 2: Auto-Reclosing and Synchronism Check in the Reference Manual* describes how to apply the synchronism check function.

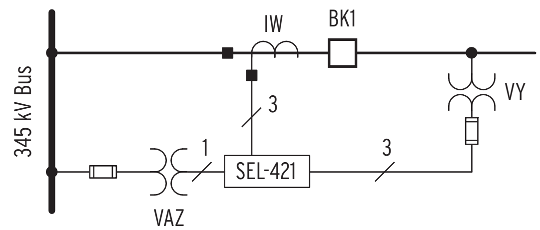


Figure 1.12 Circuit Breaker Arrangement at Station S

Breaker Monitor

Circuit Breaker Configuration

Set the relay to indicate that Circuit Breaker 1 is a three-pole trip circuit breaker.

BK1TYP := **3** Breaker 1 Trip Type (Single-Pole = 1, Three-Pole = 3)

Circuit Breaker 1 Inputs

The SEL-421 uses a normally open auxiliary contact from the circuit breaker to determine whether the circuit breaker is open or closed.

52AA1 := **IN101** A-Phase N/O Contact Input -BK1 (SELOGIC Equation)

Group Settings

Line Configuration

The SEL-421 has four transformer turns ratio settings that convert the secondary potentials and currents that the relay measures to the corresponding primary values. These settings are the potential transformer and current transformer ratios PTRY, PTRZ, CTRW, and CTRX. Use the Y potential input for line relaying and the Z potential input for synchronism checks. Use the W current input for line relaying. The settings VNOMY and VNOMZ specify the nominal secondary line-to-line voltage of the potential transformers (see *Figure 1.12*).

CTRW := **200** Current Transformer Ratio—Input W (1–50000)

PTRY := **3000** Potential Transformer Ratio—Input Y (1–10000)

VNOMY := **115** PT Nominal Voltage (L–L)—Input Y (60–300 V secondary)

PTRZ := **3000** Potential Transformer Ratio—Input Z (1–10000)

VNOMZ := **115** PT Nominal Voltage (L–L)—Input Z (60–300 V secondary)

Set Z1MAG equal to Z_{1L1} plus Z_{1L2} so the fault locator provides correct results for internal faults not located on the tap (i.e., source T is extremely weak and provides practically no infeed). See *Table 1.15* for the secondary line impedances.

Z1MAG := **4.00** Positive-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)

Z1ANG := **84.7** Positive-Sequence Line Impedance Angle (5.00–90 degrees)

Enter the secondary value of the zero-sequence impedance of the protected line from Station S to Station R, ignoring the tap.

Z0MAG := **12.88** Zero-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)

Z0ANG := **73.0** Zero-Sequence Line Impedance Angle (5.00–90 degrees)

Enable the fault locator.

EFLOC := **Y** Fault Location (Y, N)

The LL setting is the line length. This value has no defined unit; you can set the line length in miles, kilometers, ohms, etc. Set the length in miles.

LL := **100.00** Line Length (0.10–999)

The relay fault locator uses the values you enter for Z1MAG, Z1ANG, Z0MAG, Z0ANG, and LL.

Relay Configuration

You can select from zero to five phase zones of phase mho (E21P), ground mho (E21MG), and ground quadrilateral (E21XG) distance protection. You can independently select the number of zones per type of distance protection. Select only the number of zones needed. For this application example, use three zones of mho phase and ground distance protection.

E21P := **3** Mho Phase Distance Zones (N, 1–5)

E21MG := **3** Mho Ground Distance Zones (N, 1–5)

E21XG := **N** Quadrilateral Ground Distance Zones (N, 1–5)

Now enable the other logic you will need for this application example.

You do not need CVT transient detection if the SIR (Source Impedance Ratio) is less than five. SIR is equal to the ratio of the local source impedance to the relay reach. Calculate the ratio based on the Zone 1 reach because you do not want Zone 1 distance protection to overreach during an external fault.

$$\begin{aligned} \text{SIR} &= \frac{|Z_{1S}|}{0.8 \bullet |Z_{1L1} + Z_{1L2}|} \\ &= \frac{0.67\ \Omega}{0.8 \bullet (2\ \Omega + 2\ \Omega)} \\ &= 0.209,\ \text{SIR}<5 \end{aligned}$$

Equation 1.21

ECVT := **N** CVT Transient Detection (Y, N)

NOTE: The SEL-421-1 and the SEL-421-2 do not provide series-compensated line protection logic.

The transmission line is not series compensated.

ESERCMP := **N** Series-Compensated Line Logic (Y, N)

You can select a common time delay or an independent time delay per zone for phase and ground distance protection. If you choose independent timing, evolving faults (such as those changing from single phase to multiphase) cause the timer to reset and result in additional delay. Select common time delay for this application.

ECDTD := **Y** Distance Element Common Time Delay (Y, N)

The SOTF logic permits tripping by specified protection elements for a settable time after the circuit breaker closes.

ESOTF := **Y** Switch-Onto-Fault (Y, N)

Do not enable the Out-of-Step logic for this application example.

EOOS : = **N** Out-of-Step (Y, N)

The relay has a load-encroachment feature that prevents operation of the phase distance elements during heavy load. This unique feature permits the load to enter a predefined area of the phase distance characteristics without causing unwanted tripping.

ELOAD := **Y** Load Encroachment (Y, N)

Use Level 1 high-set instantaneous phase overcurrent element for SOTF protection.

E50P := **1** Phase Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

Use residual ground overcurrent elements for the DCB trip scheme. The Level 2 residual ground overcurrent element (67G2) is forward-looking and provides communications-assisted tripping. The Level 3 residual overcurrent element (67G3) is reverse-looking and blocks the tripping at Station R during out-of-section faults behind Station S. Enable three levels of residual ground overcurrent protection.

E50G := **3** Residual Ground Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

This application does not require negative-sequence overcurrent protection.

E50Q := **N** Negative-Sequence Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

Use inverse-time overcurrent protection to provide backup protection for high-resistance ground faults. The 51S1 element provides backup protection for unbalanced faults if both the communications-assisted and step distance protection fail to operate.

E51S := **1** Selectable Inverse-Time Overcurrent Element (N, 1–3)

Set E32 to AUTO and the relay automatically calculates the settings corresponding to the ground directional element (32G).

E32 := **AUTO** Directional Control (Y, AUTO)

Use the DCB tripping scheme.

ECOMM := **DCB** Communications-Assisted Tripping (N, DCB, POTT, POTT2, POTT3, DCUB1, DCUB2)

Fuses or molded case circuit breakers often protect potential transformers. Operation of one or more fuses, or molded case circuit breakers, results in a loss of polarizing potential inputs to the relay. Loss of one or more phase voltages prevents the relay from properly determining fault distance or direction.

Occasional loss-of-potential to the distance relay, while unavoidable, is detectable. When the relay detects a loss-of-potential condition, the relay can block distance element operation, block or enable forward-looking directional overcurrent elements, and issue an alarm for any true loss-of-potential condition.

If line-side PTs are used, the circuit breaker(s) must be closed for the LOP logic to detect an LOP condition. Therefore, if three-phase potential to the relay is lost while the circuit breaker(s) is open (e.g., the PT fuses are removed while the line is de-energized), the relay cannot detect a loss-of-potential condition when the circuit breaker(s) closes again. At circuit breaker closing, the relay can detect one or two missing potentials that occurred while the circuit breaker was open. See *Loss-of-Potential Logic on page R.1.24* for more information.

Table 1.16 lists the three choices for enabling LOP.

Table 1.16 LOP Enable Options

Option	Description
N	The LOP logic operates but does not disable voltage-polarized directional elements, distance elements, and forward-looking directional overcurrent elements. Use LOP in this case for alarm only.
Y	The relay disables all voltage-polarized directional elements and distance elements, but enables forward-looking directional overcurrent elements. These forward-looking directional overcurrent elements effectively become nondirectional and provide overcurrent protection during an LOP condition.
Y1	The relay disables all voltage-polarized directional elements and distance elements. The relay also disables the overcurrent elements controlled by the voltage-polarized directional elements.

Set ELOP to Y1 for this application example. This choice reduces the chances of false tripping because of a loss-of-potential condition.

ELOP := **Y1** Loss-of-Potential (Y, Y1, N)

You do not need Advanced Settings for this application example.

EADVS := **N** Advanced Settings (Y, N)

Phase Distance Elements (21P)

Mho Phase Distance Element Reach

Employ each zone of mho phase distance protection as follows:

- ➤ Zone 1—Instantaneous underreaching tripping
- ➤ Zone 2—DCB scheme tripping
- ➤ Zone 3—DCB scheme blocking

Zone 1 Phase Distance Element Reach. Zone 1 phase distance protection provides instantaneous protection for phase-to-phase, phase-to-phase-to-ground, and three-phase faults for 80 percent of the distance from Station S to Station R because this is the shortest line segment from one terminal to another. Errors in the current transformers, potential transformers, modeled transmission line data, and fault study data do not permit Zone 1 to be set equal to 100 percent of the distance to Station R. Otherwise, unwanted tripping could occur for faults just beyond the remote terminal.

Set Zone 1 phase distance protection equal to 80 percent of the positive-sequence impedance from Station S to Station R.

$$\begin{aligned} Z1P &= 0.8 \bullet (Z_{1L1} + Z_{1L2}) \\ &= 0.8 \bullet (2 + 2)\ \Omega \\ &= 3.2\ \Omega \end{aligned} \quad \textbf{Equation 1.22}$$

Z1P := **3.2** Zone 1 Reach (OFF, 0.05–64 Ω secondary)

Zone 2 Phase Distance Element Reach. Set Zone 2 phase distance reach to include the tapped autotransformer.

Perform the following fault study to determine the apparent fault impedance the SEL-421 distance elements measure for faults at the 138 kV terminals of the autotransformer. Use these measurements to set the distance reach settings. Station R should be in service to account for infeed. Place an AG and ABC fault at the 138 kV terminals of the autotransformer and record the secondary voltage and current the relay measures at Station S. Apply these quantities in *Equation 1.23* and *Equation 1.26*, to determine the fault impedance the relay measures for the two fault types shown in *Table 1.17*. Use *Equation 1.23* for an A-phase-to-ground fault and *Equation 1.26* for the three-phase fault.

$$|Z_{AG}| = \left| \frac{V_A}{I_A + k_0 \bullet 3I_0} \right| \quad \textbf{Equation 1.23}$$

where:

V_A = A-phase-to-neutral voltage
I_A = A-phase current
k_0 = zero-sequence compensation factor
$3I_0$ = zero-sequence current

The relay uses the zero-sequence compensation factor to measure zero-sequence quantities in terms of positive-sequence quantities.

$$k_0 = \frac{Z_{0L1} - Z_{1L1}}{3 \bullet Z_{1L1}} \quad \textbf{Equation 1.24}$$

The zero-sequence current is the sum of the phase currents.

$$3I_0 = I_A + I_B + I_C \quad \textbf{Equation 1.25}$$

The magnitude of the impedance for B-phase-to-C-phase, B-phase-to-C-phase-to-ground, and three-phase faults is $|Z_{BC}|$.

$$|Z_{BC}| = \left| \frac{V_{BC}}{I_{BC}} \right| \quad \textbf{Equation 1.26}$$

where:

V_{BC} = B-phase-to-C-phase voltage
I_{BC} = B-phase-to-C-phase current

Table 1.17 lists the results of the Z_{AG} and Z_{BC} calculations.

Table 1.17 Local Zone 2 Fault Impedance Measurements

Fault Type	$\|Z_{AG}\|$	$\|Z_{BC}\|$
AG	7.77 Ω	NA
ABC	NA	8.8 Ω

Select the phase-to-phase measurement from *Table 1.17*. Multiply this value by a safety factor of 125 percent to obtain Zone 2 phase distance element reach.

$$Z2P = 1.25 \cdot 8.8\ \Omega$$
$$= 11.00\ \Omega \qquad \text{Equation 1.27}$$

Z2P := **11.00** Zone 2 Reach (OFF, 0.05–64 Ω secondary)

Zone 3 Phase Distance Element Reach

Zone 3 phase distance protection is reverse-looking. Zone 3 at Station S must have adequate reach to prevent unwanted tripping by the SEL-421 relays at Stations R or T during external faults behind the local terminal. The Zone 3 reach at Station S must cover overreach from the furthest reaching remote Zone 2 for reverse faults when there is no infeed from the other remote terminal.

Figure 1.13 illustrates this coordination issue. You must set the Zone 2 reach at Station T to account for infeed during faults beyond the tap on the 345 kV system. However, when one 345 kV station is out of service, the Zone 2 at Station T overreaches for faults on the other side of the tap on the 345 kV system.

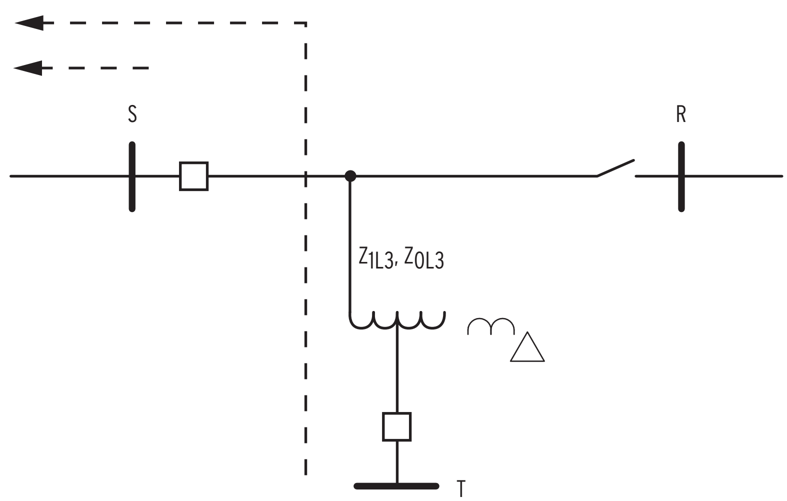


Figure 1.13 Reverse Zone 3 Coordination

Place AG and ABC faults at Station T and use *Equation 1.23* and *Equation 1.26* with respect to Station R to record the results in primary. Next place AG and ABC faults at Station R and use *Equation 1.23* and *Equation 1.26* with respect to Station T to record the results in primary. *Table 1.18* lists the results in primary and per unit.

Table 1.18 Apparent Impedance Measurement for Remote Faults

Station	$\lvert Z_{AG} \rvert$	$\lvert Z_{BC} \rvert$
Relay at Station R, Fault at Station T	152.7 Ω (0.128 per unit)	196.65 Ω (0.165 per unit)
Relay at Station T, Fault at Station S	79.605 Ω (0.418 per unit)	76.845 Ω (0.404 per unit)
Relay at Station T, Fault at Station R	103.86 Ω (0.545 per unit)	115.86 Ω (0.608 per unit)

The SEL-421 at Station T measures the largest apparent fault impedance for faults at Station R because the source at Station S is stronger than the source at Station R. Therefore, Zone 2 at Station T must be set to 115.86 Ω primary (plus a safety margin) so that the relay can detect faults at Station R when the source at Station S is in-service; this is the largest Zone 2 reach.

Figure 1.14 is an impedance diagram of the 345 kV tapped overhead transmission line; only the reactances (per unit) are shown.

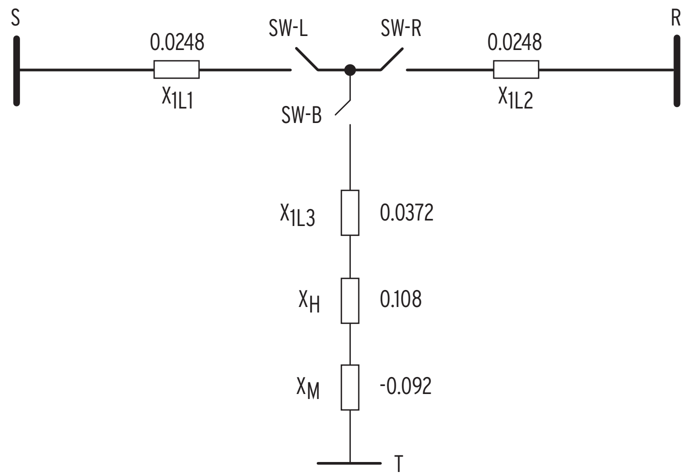


Figure 1.14 Impedance Diagram

To determine the greatest amount of overreach from a remote terminal during reverse faults with respect to Station S, subtract the fault impedance from the corresponding apparent impedance measurement from *Table 1.18*.

Calculate the overreach at Station R (SW-B open; SW-L and SW-R closed).

$$\begin{aligned}\text{Overreach} &= |Z_{APP}| - X_{1L1} - X_{1L2} \\ &= 0.165 - 0.0248 - 0.0248 \\ &= 0.115 \text{ per-unit}\end{aligned}$$

Equation 1.28

Calculate the overreach at Station T (SW-R open; SW-L and SW-B closed).

$$\begin{aligned}\text{Overreach} &= |Z_{APP}| - X_M - X_H - X_{1L3} - X_{1L1} \\ &= 0.608 - (-0.092) - 0.108 - 0.0372 - 0.0248 \\ &= 0.53 \text{ per-unit}\end{aligned}$$

Equation 1.29

Station T has the greatest overreach. Use *Equation 1.30* to set Zone 3 phase distance element reach.

$$\begin{aligned}Z3P &= \frac{CTR}{PTR} \cdot Z(\text{per-unit}) \cdot Z_{base} \cdot 120\% \\ &= \frac{200}{3000} \cdot 0.53 \cdot 1190.25 \cdot 1.2 \\ &= 50.5\ \Omega\end{aligned}$$

Equation 1.30

where:

$$Z_{base} = \frac{(345\text{kV})^2}{100 \text{ MVA}} = 1190.25\ \Omega$$

Z3P := **50.50** Zone 3 Reach (OFF, 0.05–64 Ω secondary)

Ground Distance Elements (21MG and 21XG)

Mho Ground Distance Element Reach

Employ each zone of mho ground distance protection as follows:

- Zone 1—Instantaneous underreaching tripping
- Zone 2—DCB scheme tripping
- Zone 3—DCB scheme blocking

Zone 1 Mho Ground Distance Element Reach. Zone 1 mho ground distance element reach must meet the same requirement as that for Zone 1 mho phase distance protection; the reach setting can be no greater than 80 percent of the protected line.

Z1MG = Z1P = 3.2 Ω

Z1MG := **3.20** Zone 1 (OFF, 0.05–64 Ω secondary)

Zone 2 Mho Ground Distance Element Reach. Set Zone 2 ground distance element reach equal to Zone 2 phase distance element reach; this ensures that Zone 2 ground distance elements can see faults internal to the tapped autotransformer. Zone 2 phase distance element reach was set to see the largest apparent fault impedance for faults at the 138 kV terminal of the tapped autotransformer.

Z2MG = Z2P = 11 Ω

Z2MG := **11.00** Zone 2 (OFF, 0.05–64 Ω secondary)

Zone 3 Mho Ground Distance Element Reach. Set Zone 3 ground distance element reach equal to Zone 3 phase distance element reach; this ensures that Zone 3 ground distance elements coordinate with the remote Zone 2 ground distance elements at Stations R and T for out-of-section faults behind the local terminal. Zone 3 phase distance element reach was set to coordinate with the largest remote Zone 2 phase distance element reach.

Z3MG = Z3P = 50.50 Ω

Z3MG := **50.50** Zone 3 (OFF, 0.05–64 Ω secondary)

Zero-Sequence Current Compensation Factors

Zero-sequence current compensation helps to keep the phase and ground distance elements at the same reach if you set the reach equal per zone (for example, Z1P = Z1MG). Ground distance elements should measure fault impedance in terms of positive-sequence impedance only. The relay automatically calculates the setting for the Zone 1 zero-sequence current compensation factor when you set k0M1 to AUTO.

k0M1 := **AUTO** Zone 1 ZSC Factor Magnitude (AUTO, 0.000–10)

When you enter AUTO as the setting for k0M1, the relay calculates the zero-sequence current compensation as follows:

$$k01 = \frac{Z0MAG\angle Z0ANG - Z1MAG\angle Z1ANG}{3 \cdot Z1MAG\angle Z1ANG} \quad \textbf{Equation 1.31}$$

Zone 2 and Zone 3 use the same zero-sequence current compensation factor as that for Zone 1 because Advanced Settings are disabled.

The relay displays the following values for k0M1 and k0MA:

k0M1 := **0.750** Zone 1 ZSC Factor Magnitude (AUTO, 0.000–10)

k0MA := **-16.87** Zone 1 ZCS Factor Angle (–180.0 to +180.0 degrees)

Distance Element Common Time Delay

Set the appropriate timers Z1D, Z2D, and Z3D for both phase and ground distance elements.

You do not need to delay Zone 1 distance protection; it trips instantaneously.

Z1D := **0.000** Zone 1 Time Delay (OFF, 0.000–16000 cycles)

Zone 2 distance protection provides time-delayed tripping as a backup function. Set this delay to 20 cycles.

Z2D := **20.000** Zone 2 Time Delay (OFF, 0.000–16000 cycles)

Zone 3 distance protection is reverse-looking and you do not need to apply it for tripping in this application. Set Zone 3 for zero time delay.

Z3D := **0.000** Zone 3 Time Delay (OFF, 0.000–16000 cycles)

SOTF Scheme

SOTF (Switch-Onto-Fault) logic is enabled when the circuit breaker closes. This logic provides protection for a short duration (setting SOTFD) until other protection (such as tripping from SELOGIC control equations TR and TRCOMM) is available. The TRSOTF SELOGIC control equation defines which protection elements cause the relay to trip when the SOTF scheme is active. Assertion of the protection elements assigned to TRSOTF during the SOTFD time causes the relay to trip instantaneously.

Apply SOTF when using line-side potentials for relaying. Use nondirectional overcurrent protection to clear close-in faults. Also use instantaneous overreaching distance protection to clear faults along the line. Assign instantaneous Zone 2 mho phase and ground distance protection plus Level 1 phase overcurrent element to TRSOTF.

TRSOTF := **M2P OR Z2G OR 50P1** Switch-Onto-Fault Trip (SELOGIC Equation)

Single-Pole SOTF

This is a three-pole tripping application example; confirm that the SOTF protection is for three-pole tripping.

ESPSTF := **N** Single-Pole Switch-Onto-Fault (Y, N)

Voltage Reset

You can configure the logic so the SOTF enable duration resets within at least 5 cycles after it first asserted, but before the SOTFD timer expires. To quickly reset the SOTF period:

> the relay must sense that the positive-sequence voltage is greater than 85 percent of the nominal voltage.

Use setting EVRST (Switch-Onto-Fault Voltage Reset) to enable fast reset. The advantage of resetting SOTF protection quickly is that unwanted tripping does not occur for subsequent faults external to the remote terminals during the SOTF period; these trips can occur if you set instantaneous Zone 2 distance protection elements in the TRSOTF SELOGIC control equation. Enable the voltage reset option.

EVRST := **Y** Switch-Onto-Fault Voltage Reset (Y, N)

SOTF Initiation

The SOTF logic asserts via one or both of the following methods:

- ➤ A change in the normally open auxiliary contact 52A status showing that the circuit breaker has just opened
- ➤ Assertion of the relay control input assigned to the circuit breaker close bus

The 52A method works well for both single and multiple circuit breaker applications and does not require an input from the close bus. However, the close bus method only enables SOTF protection immediately following the close command to the circuit breaker. For more information, see *Switch-Onto-Fault Logic on page R.1.86*.

Turn off 52AEND, 52A Pole Open Time Delay, because the 52A method is not used.

52AEND := **OFF** 52A Pole Open Time Delay (OFF, 0.000–16000 cycles)

Select the close bus option for this application and set the close enable delay (CLOEND) shorter than the shortest reclose open interval.

CLOEND := **10.000** CLSMON or Single-Pole Open Delay (OFF, 0.000–16000 cycles)

SOTF Duration

Setting SOTFD determines the longest period the SOTF logic can assert after the circuit breaker closes.

SOTFD := **10.000** Switch-Onto-Fault Enable Duration (0.500–16000 cycles)

Close Signal Monitor

Assign the Relay Word bit CLSMON to a control input, so the relay can detect execution of the close command.

CLSMON := **IN102** Close Signal Monitor (SELOGIC Equation)

Load Encroachment

The relay uses a load-encroachment feature that prevents operation of the phase distance elements during heavy load. This unique feature permits the load to enter a predefined area of the phase distance characteristics without causing unwanted tripping. *Figure 1.15* illustrates the load-encroachment function superimposed on the mho phase distance protection characteristics.

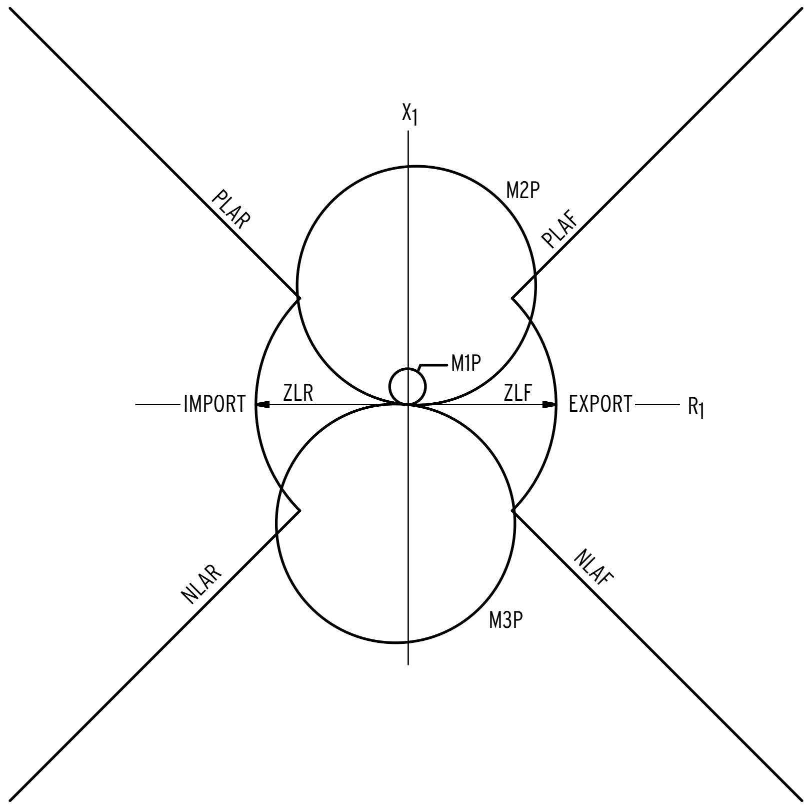


Figure 1.15 Load-Encroachment Function

Define the load-encroachment characteristic with load impedance settings in the forward (ZLF) and reverse (ZLR) directions. Define the two load sectors, export and import, with angle settings PLAF, NLAF, PLAR, and NLAR in the forward and reverse directions.

The transformer MVA rating is the maximum load. Assume that Station S can supply the total load the autotransformer draws. Set load encroachment according to maximum load for the protected line (4.2 A secondary). The bus voltage at Station S is 65.7 V line-to-neutral during maximum load.

$V_{LN} = 65.7\ V$

$I_{\phi} = 4.2\ A$

Therefore, the minimum load impedance the relay measures is as follows:

$$\begin{aligned} Z_{load} &= \frac{V_{LN}}{I_{\phi}} \\ &= \frac{65.7\ V}{4.2\ A} \\ &= 15.6\ \Omega \end{aligned}$$

Equation 1.32

Note that this load impedance is well inside the Zone 3 mho ground distance element reach, Z3MG, or 50.5 Ω.

Multiply Z_{load} by a safety factor of 80 percent to account for overload conditions.

$$\begin{aligned} Z_{load} &= 0.8 \bullet 15.6\ \Omega \\ &= 12.5\ \Omega \end{aligned}$$

Equation 1.33

Set the forward and reverse load impedance thresholds (ZLF and ZLR, respectively) according to the minimum load impedance.

ZLF := **12.5** Forward Load Impedance (0.05–64 Ω secondary)

ZLR := **12.5** Reverse Load Impedance (0.05–64 Ω secondary)

To be conservative, assume a load angle range of ±45°. Assume both forward (export) and reverse (import) load ranges to be the same.

PLAF := **45.0** Forward Load Positive Angle (–90.0 to +90.0 degrees)

NLAF := **–45.0** Forward Load Negative Angle (–90.0 to +90.0 degrees)

PLAR := **135.0** Reverse Load Positive Angle (+90.0 to +270.0 degrees)

NLAR := **225.0** Reverse Load Negative Angle (+90.0 to +270.0 degrees)

Phase Instantaneous/Definite-Time Overcurrent Elements

Use 50P1, Level 1 phase instantaneous overcurrent element, as a nondirectional high-set phase overcurrent element for SOTF protection. If the local circuit breaker closes into a close-in three-phase bolted fault with line-side potential transformers, the polarizing voltage for the phase distance elements is zero. Therefore, the distance protection does not operate. In this case, the 50P1 element quickly trips the circuit breaker because this overcurrent element does not rely on the polarizing voltage.

To rapidly clear faults, set 50P1P equal to 50 percent of the fault current measured at the local terminal for a close-in three-phase fault; use weak source conditions to ensure the relay operates for low-level fault current.

50P1P := **49.80** Level 1 Pickup (OFF, 0.25–100 A secondary)

This application uses 50P1 as an instantaneous overcurrent element; you do not need time delay.

67P1D := **0.000** Level 1 Time Delay (0.000–16000 cycles)

This application uses 50P1 as a nondirectional overcurrent element; you do not need torque control.

67P1TC := **1** Level 1 Torque Control (SELOGIC Equation)

Residual Ground Instantaneous/Definite-Time Overcurrent Elements

This application example has three levels of residual ground overcurrent elements. You will use these overcurrent elements later in the DCB scheme. The Level 2 residual ground overcurrent element is set forward-looking to serve as a tripping element. The Level 3 residual ground overcurrent element is set as both a nondirectional (50G3) and reverse-looking (67G3) starting element. Be sure to set residual ground elements above any loading unbalance.

Disable Level 1 residual ground overcurrent element; this particular application does not use this element.

50G1P := **OFF** Level 1 Pickup (OFF, 0.25–100 A secondary)

Enable Level 2 residual ground overcurrent element for DCB tripping. Ground distance elements measure fault resistance consisting of arcing resistance and ground return resistance. Ground return resistance can consist of tower footing resistance and tree resistance. The total ground fault resistance can lie outside of the ground distance characteristics. Residual overcurrent protection is the best method available for detecting high-resistance ground faults because this method of protection provides the greatest sensitivity. Set the pickup to 20 percent of the nominal current (5 A).

50G2P := **1.00** Level 2 Pickup (OFF, 0.25–100 A, secondary)

Enable Level 3 residual ground overcurrent element to send the blocking signal for out-of-section faults. Set the pickup of Level 3 residual ground overcurrent element (50G3) at Station S to half the remote forward-looking residual ground overcurrent element (50G2) at Station R.

$$50G3P_S = \frac{50G2P_R}{2}$$ **Equation 1.34**

This measure provides security during out-of-section faults, because the blocking elements are twice as sensitive as the tripping elements.

50G3P := **0.50** Level 3 Pickup (OFF, 0.25–100 A secondary)

You do not need to add intentional time delays for Level 2 and Level 3 pickups.

67G2D := **0.000** Level 2 Time Delay (0.000–16000 cycles)

67G3D := **0.000** Level 3 Time Delay (0.000–16000 cycles)

Set Level 2 torque control equation to the forward decision from the ground directional element, 32GF.

67G2TC := **32GF** Level 2 Torque Control (SELOGIC Equation)

Set Level 3 torque control equation to the reverse decision from the ground directional element, 32GR.

67G3TC := **32GR** Level 3 Torque Control (SELOGIC Equation)

Selectable Operating Quantity Time Overcurrent Element 1

Use inverse-time overcurrent protection to provide backup protection for high-resistance ground faults. The 51S1 element provides backup protection for unbalanced faults if both the communications-assisted and step distance protection fail to operate.

NOTE: Use your company practices and philosophy when determining these settings.

Select zero-sequence line current as the operating quantity.

51S1O := **3I0L** 51S1 Operating Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0*n*)

The *n* in the 51S1O setting is L for line, 1 for BK1, and 2 for BK2.

The relay measures 4.8 A secondary of $3I_0$ for a bolted single-phase-to-ground fault at the 345 kV terminals of the autotransformer. Set the pickup to 20 percent of $3I_0$.

51S1P := **0.96** 51S1 Overcurrent Pickup (0.25–16 A secondary)

Use the following formula to determine approximately how much primary fault resistance coverage (R_F) is provided by 51S1P on a radial basis:

$$\begin{aligned} R_F &= \frac{PTR}{CTR} \bullet \frac{VNOMY/\sqrt{3}}{51S1P} \\ &= \frac{3000}{200} \bullet \frac{115V/\sqrt{3}}{0.96A} \\ &= 1037\ \Omega \text{ primary} \end{aligned}$$

Equation 1.35

Use the following as a guide to set the curve and time dial; for secure backup protection, perform a coordination study.

Set the local overcurrent element to coordinate with the downstream overcurrent element such that there is an 18-cycle (60 Hz nominal) safety margin for ground faults in front of the first downstream overcurrent element. Assume the operating time of the downstream overcurrent element is 12 cycles for a close-in ground fault. Therefore, set the local time-overcurrent element to operate approximately 30 cycles for ground faults in front of the first downstream overcurrent element.

51S1C := **U3** 51S1 Inverse-Time Overcurrent Curve (U1–U5)

51S1TD := **2.0** 51S1 Inverse-Time Overcurrent Time Dial (0.50–15.0)

Set the overcurrent element to emulate electromechanical reset, so the overcurrent element coordinates properly with electromechanical overcurrent relays.

51S1RS := **Y** 51S1 Inverse-Time Overcurrent Electromechanical Reset (Y, N)

Torque control the overcurrent element with the forward decision from the ground directional element.

51S1TC := **32GF** 51S1 Torque Control (SELOGIC Equation)

Zone/Level Direction

Zone 1 and Zone 2 distance element directions are fixed in the forward direction. You can select the other zones independently as forward-looking (F) or reverse-looking (R). Set Zone 3 distance elements reverse-looking because these are blocking elements for the DCB trip scheme.

DIR3 := **R** Zone/Level 3 Directional Control (F, R)

Directional Control

The SEL-421 uses an array of directional elements to supervise the ground distance elements and residual directional overcurrent elements during ground fault conditions. Internal logic automatically selects the best choice for the ground directional element (32G) from among the negative-sequence voltage-polarized directional element (32QG), zero-sequence voltage-polarized directional element (32V), and the zero-sequence current-polarized directional element (32I).

The relay setting ORDER determines the order in which the relay selects directional elements to provide ground directional decisions. You can set ORDER with any combination of Q, V, and I. The listed order of these directional elements determines the priority in which these elements operate to provide the ground directional element. Only one specific directional element operates at any one time. Directional element classification is as follows:

- Q—Negative-sequence voltage-polarized directional element
- V—Zero-sequence voltage-polarized directional element
- I—Zero-sequence current-polarized directional element

Set ORDER to QV. The first listed directional element choice, Q, is the first priority directional element to provide directional control for the ground distance elements and residual directional overcurrent elements. If Q is not operable, the second listed directional element choice, V, provides directional control for the ground distance elements and residual directional overcurrent elements. A polarizing quantity was not available for choice I, so I is not selected for this particular application example.

ORDER := **QV** Ground Directional Element Priority (combine Q, V, I)

SELOGIC control equation E32IV must assert to logical 1 to enable V or I for directional control of the ground distance elements and residual directional overcurrent elements. Set E32IV to logical 1.

E32IV := **1** Zero-Sequence Voltage and Current Enable (SELOGIC Equation)

Reverse Ground Directional Checks

32QG and 32V makes forward and reverse directional decisions during unbalanced faults based upon the following four settings:

- Z2F—Forward Directional Z2 Threshold
- Z2R—Reverse Directional Z2 Threshold
- Z0F—Forward Directional Z0 Threshold
- Z0R—Reverse Directional Z0 Threshold

For 32QG, if the apparent negative-sequence impedance measured by the relay (z2) is less than Z2F, the unbalanced fault is declared forward. If z2 is greater than Z2R, the unbalanced fault is declared reverse.

For 32V, if the apparent zero-sequence impedance measured by the relay (z0) is less than Z0F, the unbalanced fault is declared forward. If z0 is greater than Z0R, the unbalanced fault is declared reverse.

The SEL-421 automatically calculates these four settings as follows when Advanced Settings are disabled and setting E32 is AUTO:

$$\begin{aligned} Z2F &= 0.5 \cdot Z1MAG \\ &= 0.5 \cdot 4.00\ \Omega \\ &= 2.00\ \Omega \end{aligned}$$

Equation 1.36

$$\begin{aligned} Z2R &= Z2F + \frac{0.5}{I_{nom}} \\ &= 2.00\ \Omega + 0.10\ \Omega \\ &= 2.10\ \Omega \end{aligned}$$

Equation 1.37

$$\begin{aligned} Z0F &= 0.5 \cdot Z0MAG \\ &= 0.5 \cdot 12.88\ \Omega \\ &= 6.44\ \Omega \end{aligned}$$

Equation 1.38

$$\begin{aligned} Z0R &= Z0F + \frac{0.5}{I_{nom}} \\ &= 6.44\ \Omega + 0.10\ \Omega \\ &= 6.54\ \Omega \end{aligned}$$ **Equation 1.39**

Perform the following two checks to make sure the ground directional element does not incorrectly make a forward decision during a reverse unbalanced fault.

32QG Reverse Directional Check. You set Z1MAG equal to Z_{1L1} plus Z_{1L2} so the fault locator provides correct results for internal faults not located on the tap (i.e., source T is extremely weak and provides practically no infeed).

Figure 1.16 is the negative-sequence network for the 345 kV tapped overhead transmission line. Assume that the negative-sequence impedances are equal to the positive-sequence impedances.

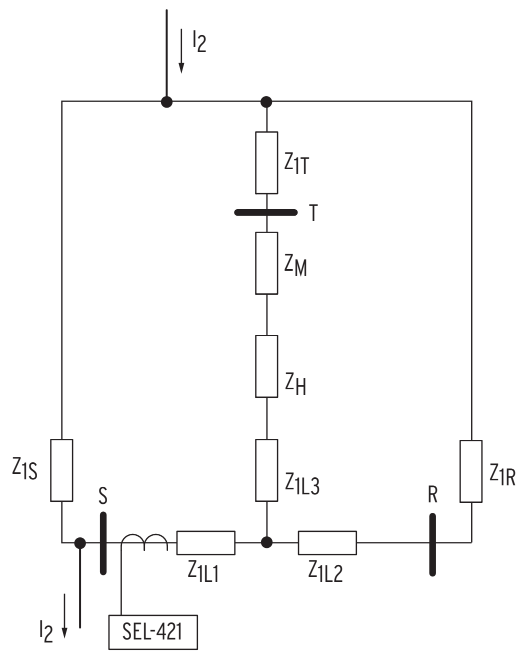


Figure 1.16 345 kV Tapped Line Negative-Sequence Network

Zn is an approximation of the impedance calculation for the n-sequence voltage-polarized directional statement for a reverse fault.

If z2 is less than Z2F during a reverse unbalanced fault, 32QG incorrectly declares that the fault is forward with respect to the relay location (CT shown in *Figure 1.16*). The relay automatically sets Z2F equal to one-half Z1MAG. *Equation 1.40* is the apparent negative-sequence impedance z2 measured by the 32QG element during a reverse unbalanced fault.

$$z2 = Z_{1L1} + Z_{2P}$$ **Equation 1.40**

where:

Z_{2P} = parallel combination of the Line 3 impedance, transformer reactances (neglect resistance), and the Bus T impedance with Line 2 and the Bus R impedance

X_H = transformer high-side winding reactance

where:

X_M = transformer low-side winding reactance
X_L = transformer tertiary winding reactance

The downstream parallel impedance, Z_{2P}, is the Line 3 impedance, the transformer reactances, and the Bus R impedance.

$$Z_{2P} = (Z_{1L3} + jX_H + jX_M + jX_{1T}) \parallel (Z_{1L2} + Z_{1R}) \quad \textbf{Equation 1.41}$$

Use the following two assumptions to simplify the calculations:

1. Assume the power system is purely reactive
2. Ignore source impedances Z_{1R} and Z_{1T} (a conservative assumption)

Calculate the transformer reactances.

$$\begin{aligned} X_H &= 0.5 \bullet (X_{HM} + X_{HL} - X_{ML}) \\ &= 0.5 \bullet (0.016 + 0.6 - 0.4) \\ &= 0.108 \text{ per-unit} \end{aligned}$$

$$\begin{aligned} X_M &= 0.5 \bullet (X_{HM} + X_{ML} - X_{HL}) \\ &= 0.5 \bullet (0.016 + 0.4 - 0.6) \\ &= -0.092 \text{ per-unit} \end{aligned}$$

$$\begin{aligned} X_L &= 0.5 \bullet (X_{HL} + X_{ML} - X_{HM}) \\ &= 0.5 \bullet (0.6 + 0.4 - 0.016) \\ &= 0.492 \text{ per-unit} \end{aligned} \quad \textbf{Equation 1.42}$$

Use these assumptions from *Equation 1.41* to create a simplified form of the downstream parallel impedance.

$$\begin{aligned} Z_{2P} &= j([X_{1L3} + X_H + X_M] \parallel [X_{1L2}]) \\ &= j\left(\frac{(X_{1L3} + X_H + X_M) \bullet X_{1L2}}{(X_{1L3} + X_H + X_M) + X_{IL2}}\right) \\ &= j\left(\frac{(0.038 + 0.108 - 0.092) \bullet 0.025}{(0.038 + 0.108 - 0.092) + 0.025}\right) \\ &= j0.017 \text{ per-unit primary} \end{aligned} \quad \textbf{Equation 1.43}$$

The secondary base impedance is calculated as follows:

$$\begin{aligned} Z_{base} &= \frac{CTR \bullet (345\ kV)^2}{PTR \bullet 100\ MVA} \\ &= \frac{200 \bullet (345\ kV)^2}{3000 \bullet 100\ MVA} \\ &= 79.35\ \Omega \end{aligned} \quad \textbf{Equation 1.44}$$

Calculate the parallel impedance in secondary ohms.

$$
\begin{aligned}
Z_{2P(secondary)} &= Z_{2P(primary)} \bullet Z_{base} \\
&= J0.017 \bullet 79.35\ \Omega \\
&= 1.35\ \Omega \text{ secondary}
\end{aligned}
\qquad \textbf{Equation 1.45}
$$

To determine whether the 32QG element always operates correctly during reverse unbalanced faults, check the following condition:

$Z2F < |Z_{1L1}| + |Z_{2P}|$

$2\ \Omega < 2\ \Omega + 1.35\ \Omega$

$2\ \Omega < 3.35\ \Omega$

The condition is satisfied; the reverse negative-sequence voltage-polarized directional element decision is correct during reverse unbalanced faults.

32V Reverse Directional Check. You set Z0MAG equal to Z_{0L1} plus Z_{0L2} so the fault locator provides correct results for internal faults not located on the tap (that is, source T is extremely weak and provides practically no infeed).

Figure 1.17 is the zero-sequence network for the 345 kV tapped overhead transmission line.

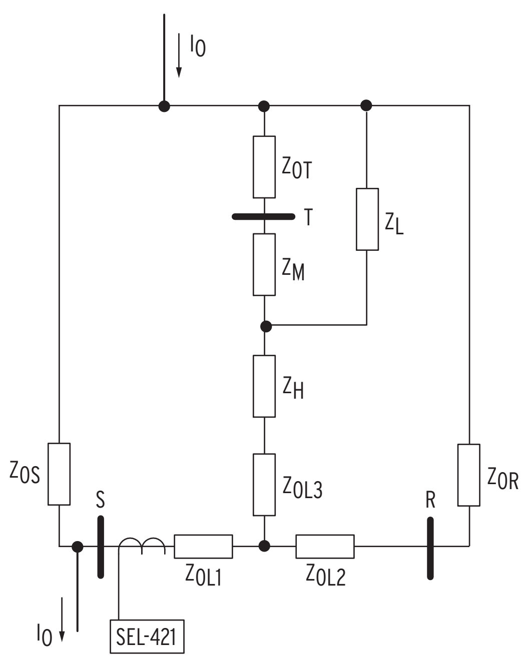


Figure 1.17 345 kV Tapped Line Zero-Sequence Network

If z0 is less than Z0F during a reverse unbalanced fault, 32V incorrectly declares that the fault is forward with respect to the relay location (CT shown in *Figure 1.17*). The relay automatically sets Z0F equal to one-half Z0MAG. *Equation 1.46* is the apparent zero-sequence impedance measured by 32V during reverse unbalanced faults:

$$z_0 = Z_{0L1} + Z_{0P} \qquad \textbf{Equation 1.46}$$

where:

Z_{0P} = parallel combination of the Line 3 impedance, transformer high-side reactance (neglect resistance), and the parallel combination of the transformer low-side and Bus T impedance in parallel with the transformer tertiary impedance, in parallel with Line 2 and the Bus R impedance (see *Figure 1.17*).

$$Z_{0P} = (Z_{0L3} + jX_H + Z_{0PP}) \parallel (Z_{0L2} + Z_{0R}) \qquad \textbf{Equation 1.47}$$

where:

Z_{0PP} = the parallel combination of the transformer low-side and Bus T impedance in parallel with the transformer tertiary impedance

Use the following two assumptions to simplify the calculations:

1. Assume the power system is purely reactive
2. Ignore source impedances Z_{0R} and Z_{0T} (a conservative assumption)

Calculate the effect of transformer low side and transformer tertiary impedances.

$$\begin{aligned} Z_{0PP} &= (Z_M + Z_{0T}) \parallel Z_L \\ &= \frac{j^2 X_M \cdot X_L}{j \cdot (X_M + X_L)} \\ &= \frac{-j \cdot -1 \cdot -0.092 \cdot 0.492}{-0.092 + 0.492} \\ X_{0PP} &= -j0.113 \text{ per-unit, } X_{0PP} \end{aligned} \qquad \textbf{Equation 1.48}$$

Use these assumptions to create a simplified form of the downstream parallel impedance (from *Equation 1.47*).

$$\begin{aligned} Z_{0P} &= (X_{0L3} + X_H + X_{0PP}) \parallel (X_{0L2}) \\ &= j\left(\frac{(X_{0L3} + X_H + X_{0PP}) \cdot X_{0L2}}{(X_{0L3} + X_H + X_{0PP}) + X_{0L2}}\right) \\ &= j\left(\frac{(0.122 + 0.108 - 0.113) \cdot 0.081}{(0.122 + 0.108 - 0.113) + 0.081}\right) \\ &= j0.048 \text{ per unit} \end{aligned} \qquad \textbf{Equation 1.49}$$

Calculate the parallel impedance using Z_{base} from *Equation 1.44*.

$$\begin{aligned} Z_{0P} &= Z_{0P} \cdot Z_{base} \\ &= j0.048 \cdot 79.35\ \Omega \\ &= 3.8\ \Omega \text{ secondary} \end{aligned} \qquad \textbf{Equation 1.50}$$

To determine whether the zero-sequence voltage-polarized 32V element always operates correctly during reverse unbalanced faults, check the following condition:

$$Z0F < |Z_{0L1}| + |Z_{0P}|$$

$$6.44\ \Omega < 6.44\ \Omega + 3.8\ \Omega$$

$$6.44\ \Omega < 10.24\ \Omega$$

The condition is satisfied; the reverse zero-sequence voltage-polarized directional element decision is correct during reverse unbalanced faults.

Pole Open Detection

The setting EPO, Enable Pole-Open logic, offers two options for deciding what conditions signify an open pole, as listed in *Table 1.19*.

Table 1.19 Options for Enabling Pole-Open Logic

Option	Description
EPO := V	The logic declares a single-pole open if the corresponding phase undervoltage element asserts and the open phase detection logic declares the pole is open. Select this option only if you use line-side potential transformers for relaying purposes. A typical setting for the 27PO, pole-open undervoltage threshold, is 60 percent of the nominal line-to-neutral voltage. Do not select this option when shunt reactors are applied because the voltage slowly decays after the circuit breaker opens. With this option selected, the relay cannot declare an open pole during assertion of LOP.
EPO := 52	The logic declares a single-pole open if the corresponding 52A contact (e.g., 52AA1) from the circuit breaker deasserts and the open phase detection logic declares that the pole is open.

Select the second option because a 52A contact is available. The relay uses both open phase detection and status information from the circuit breaker to make the most secure decision.

EPO := **52** Pole Open Detection (52, V)

Pole-Open Time Delay on Dropout

The setting 3POD establishes the time delay on dropout after the Relay Word bit 3PO deasserts. This delay is important when you use line-side potential transformers for relaying. Use the 3POD setting to stabilize the ground distance elements in case of pole scatter during closing of the circuit breaker(s).

3POD := **0.500** Three Pole Open Time Dropout Delay (0.000–60 cycles)

DCB Trip Scheme

This application example uses DCB trip scheme. In this scheme high-speed tripping occurs during internal autotransformer faults when the communications channel is not available.

The DCB trip scheme consists of the following three sections:

- Starting elements
- Coordination timers
- Extension of the blocking signal

Starting Elements

You can select nondirectional elements (NSTRT), directional elements (DSTRT), or both to detect out-of-section faults behind the local terminal. These elements send a blocking signal to Station R to prevent unwanted tripping during out-of-section faults. Nondirectional elements are always faster than directional elements, because directional elements need additional time to process the directional decision. Select both types of elements for this application.

Assign Relay Word bit NSTRT (Nondirectional Start) to OUT102 to start transmission of the blocking signal. NSTRT asserts if Level 3 residual ground overcurrent element (50G3) picks up. However, Relay Word bit STOP has priority over Relay Word bit NSTRT. If a M2P, Z2G, or 67G2 assert, the relay halts transmission of the blocking signal that nondirectional overcurrent elements started.

You have enabled three levels of residual ground overcurrent elements. The Level 2 residual ground directional overcurrent element provides communications-assisted tripping for internal unbalanced faults. The Level 3 residual ground overcurrent element provides nondirectional start (50G3) and directional start (67G3).

The Relay Word bit DSTRT asserts if any of the following elements pick up:

- Zone 3 phase distance elements (M3P)
- Zone 3 ground distance elements (Z3MG)
- Level 3 residual ground directional overcurrent element (67G3)

Relay Word bit DSTRT is useful when a bolted close-in three-phase fault occurs behind the relay. If the polarizing voltage for the distance elements collapses to zero, the corresponding Zone 3 supervisory phase-to-phase current level detectors latch the Zone 3 phase distance elements. Therefore, the Zone 3 phase distance characteristics do not need a reverse offset for this particular situation.

Assign Relay Word bit DSTRT (Directional Start) to OUT102 to start transmission of the blocking signal.

OUT102 := **NSTRT AND NOT STOP OR DSTRT**

OUT103 stops the local transmitter from sending the blocking signal to the remote terminal.

OUT103 := **STOP OR 3PT**

Time delay on pickup prevents transmission of the blocking signal if a transient causes a reverse-looking element to pick up momentarily. Set the corresponding timer to 1 cycle.

Z3XPU := **1.000** Zone 3 Reverse Pickup Time Delay (0.000–16000 cycles)

You can also extend the blocking signal during current reversals. Set the corresponding dropout timer to 5 cycles.

Z3XD := **5.000** Zone 3 Reverse Dropout Delay (0.000–16000 cycles)

Coordination Timers

The forward-looking elements that provide high-speed tripping at Station S must be delayed momentarily so the local circuit breaker does not trip for external faults behind Station R. This time delay provides time for the nondirectional and reverse-looking blocking elements at Station R to send a signal to Station S during out-of-section faults. This particular time delay is the coordination time for the DCB trip scheme. There are separate coordination timers for Zone 2 distance elements (21SD) and Level 2 residual directional overcurrent elements (67SD).

The recommended setting for the 21SD timer is the sum of the following three times:

- Control input recognition time (including debounce timer)
- Remote Zone 3 distance protection maximum operating time
- Maximum communications channel time

If the control input time delay on pickup debounce timer is zero, the maximum recognition time for the control input is 0.125 cycles. Assume a remote Zone 3 distance protection pickup time of one cycle; the remote Zone 3 distance protection should operate faster than the local Zone 2 distance protection because the apparent fault impedance is deeper inside the remote Zone 3 distance protection characteristic. Finally, assume a communications channel time of 0.5 cycle. The sum of these times provides a conservative setting of 1.63 cycles.

21SD := **1.625** Zone 2 Distance Short Delay (0.000–16000 cycles)

The recommended setting for the 67SD timer is the sum of the following three times:

- Control input recognition time (including debounce timer)
- Remote Level 3 nondirectional low-set overcurrent element maximum operating time
- Maximum communications channel time

If the control input time delay on pickup debounce timer is zero, the maximum recognition time for the control input is 0.125 cycles. Assume a 1-cycle pickup for remote Level 3 nondirectional blocking elements; the remote Level 3 current level detectors operate faster than the local Level 2 current level detectors because the remote Level 3 current level detectors pickup is lower. Finally, assume a communications channel time of 0.5 cycle. The sum of these times provides a conservative setting of 1.63 cycles.

67SD := **1.625** Level 2 Overcurrent Short Delay (0.000–16000 cycles)

Blocking Signal Extension

Assign a control input to recognize when the local terminal receives a blocking signal from the remote terminal during external faults.

BT := **IN103** Block Trip Received (SELOGIC Equation)

The DCB trip scheme uses an on/off carrier signal to block high-speed tripping at Stations S and R for out-of-section faults. Connect the carrier receive block signal output from the teleprotection equipment to a control input assigned to the SELOGIC control equation BT. This control input must remain asserted to block the forward-looking tripping elements after the coordination timers expire. If the blocking signal drops out momentarily, the distance relay can trip for out-of-section faults.

A built-in timer, BTXD, delays dropout of the control input assigned to BT. This timer maintains the blocking signal at the receiving relay by delaying the dropout of BT. However, delayed tripping can occur for internal faults because this DCB protection scheme employs nondirectional elements; the relay always sends a blocking signal regardless of fault location. Therefore, set this timer to zero so that high-speed tripping occurs when the nondirectional starting elements assert for an internal autotransformer fault.

BTXD := **0.000** Block Trip Received Extension Time (0.000–16000 cycles)

Figure 1.18 illustrates the dc schematic for the DCB trip scheme.

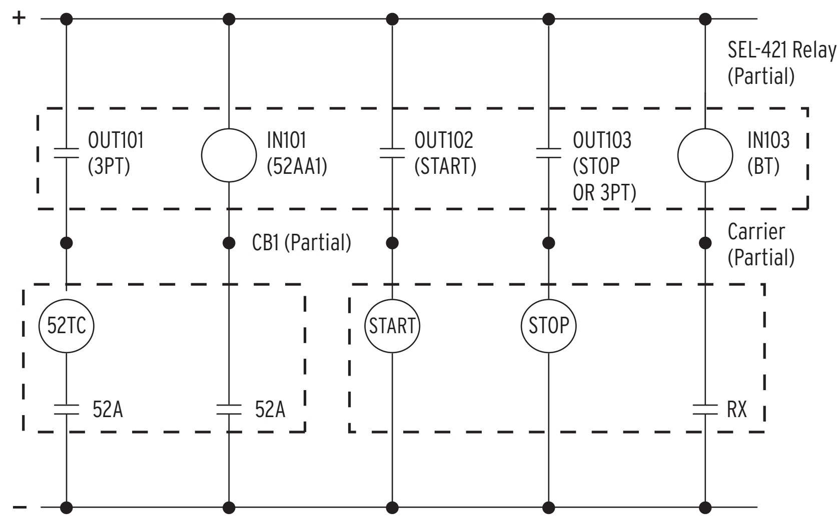


Figure 1.18 DC Schematic for DCB Trip Scheme

Trip Logic

Trip logic configures the relay for tripping. There are four trip logic settings:

- Trip equations
- Trip unlatch options
- Trip timers
- Three-pole tripping enable

Trip Equations

Set these three SELOGIC control equations for tripping:

- TR (unconditional)
- TRCOMM (communications-assisted)
- TRSOTF (Switch-Onto-Fault)

TR. The TR SELOGIC control equation determines which protection elements cause the relay to trip unconditionally. Set TR to the Zone 1 instantaneous distance protection (Z1T), Zone 2 time-delayed distance protection, and the inverse-time overcurrent element (51S1) for backup protection. For information on setting 51S1, see *Selectable Operating Quantity Time Overcurrent Element 1 on page A.1.67*.

TR := **Z1T OR Z2T OR 51S1T** Trip (SELOGIC Equation)

TRCOMM. The TRCOMM SELOGIC control equation determines which protection elements cause the relay to trip via the communications-assisted tripping scheme logic. Set delayed Zone 2 mho phase and ground distance protection (Z2PGS) plus delayed Level 2 negative-sequence residual ground directional overcurrent element (67QGS2) in the TRCOMM SELOGIC control equation. See *Directional Comparison Blocking Scheme on page R.1.90* for more information.

TRCOMM := **Z2PGS OR 67QG2S** Communications-Assisted Trip (SELOGIC Equation)

TRSOFT. The TRSOTF SELOGIC control equation defines which protection elements cause the relay to trip when the SOTF scheme is active. Assertion of these protection elements during the SOTFD time causes the relay to trip instantaneously (see *SOTF Scheme on page A.1.63*). Set instantaneous Zone 2 distance protection (M2P and Z2G) and Level 1 phase instantaneous overcurrent element (50P1) in the TRSOTF SELOGIC control equation.

TRSOTF := **M2P OR Z2G OR 50P1** Switch-Onto-Fault Trip (SELOGIC Equation)

Trip Unlatch Options

Unlatch the control output you programmed for tripping (OUT101) after the circuit breaker auxiliary “a” contacts break the dc current. The SEL-421 provides two methods for unlatching control outputs following a protection trip:

- ULTR—all three poles
- TULO—phase selective

ULTR. Use ULTR, the Unlatch Trip SELOGIC control equation, to unlatch all three poles. Use the default setting, which asserts ULTR when you push the front-panel target reset button.

ULTR := **TRGTR** Unlatch Trip (SELOGIC Equation)

TULO. Use TULO (Trip Unlatch Option) to select the conditions that cause the SEL-421 to unlatch the control outputs that you programmed for tripping. *Table 1.20* shows the four trip unlatch options for setting TULO.

Table 1.20 Setting TULO Unlatch Trip Options

Option	Description
1	Unlatch the trip when the relay detects that one or more poles of the line terminal are open and Relay Word bit 3PT has deasserted.
2	Unlatch the trip when the relay detects that the corresponding 52A contact(s) from both circuit breakers (e.g., 52AA1 and 52AA2) are deasserted.
3	Unlatch the trip when the relay detects that the conditions for Options 1 and 2 are satisfied.
4	Do not run this logic.

Select Option 3 because a 52A contact is available; the relay uses both open phase detection and status information from the circuit breaker to make the most secure decision. For information on the pole-open logic, see *Pole Open Logic on page R.1.21*.

TULO := **3** Trip Unlatch Option (1, 2, 3, 4)

Trip Timers

The SEL-421 provides dedicated timers for minimum trip duration.

Minimum Trip Duration. The minimum trip duration timer setting, TDUR3D, determines the minimum time that Relay Word bit 3PT asserts. For this application example, Relay Word bit 3PT is assigned to OUT101. The corresponding control output closes for TDUR3D time or the duration of the trip condition, whichever is longer.

A typical setting for this timer is 9 cycles.

TDUR3D := **9.000** Three-Pole Trip Minimum Trip Duration Time Delay (2.000–8000 cycles)

Three-Pole Tripping Enable

The relay contains both three-pole and single-pole tripping logic. Set E3PT (Three-Pole Trip Enable) to logical 1 to enable three-pole tripping only.

E3PT := **1** Three-Pole Trip Enable (SELOGIC Equation)

Also set the appropriate three-pole tripping SELOGIC control equation for Circuit Breaker BK1.

E3PT1 := **1** Breaker 1 3PT (SELOGIC Equation)

Control Outputs

Main Board

OUT101 trips Circuit Breaker 1.

OUT101 := **3PT**

OUT102 keys the local transmitter to send the blocking signal to the remote terminal during out-of-section faults behind Station S.

OUT102 := **NSTRT AND NOT STOP OR DSTRT**

OUT103 stops the local transmitter from sending the blocking signal to the remote terminal.

OUT103 := **STOP OR 3PT**

Example Completed

This completes the application example that describes setting of the SEL-421 for communications-assisted protection of a 345 kV tapped overhead transmission line. Analyze your particular power system to determine the appropriate settings.

Relay Settings

Table 1.21 lists all protection relay settings for this example.

Table 1.21 Settings for 345 kV Tapped TX Example (Sheet 1 of 5)

Setting	Description	Entry
General Global (Global)		
SID	Station Identifier (40 characters)	KELLOG -- 345 kV
RID	Relay Identifier (40 characters)	SEL-421 Relay
NUMBK	Number of Breakers in Scheme (1, 2)	1
BID1	Breaker 1 Identifier (40 characters)	Circuit Breaker 1
NFREQ	Nominal System Frequency (50, 60 Hz)	60
PHROT	System Phase Rotation (ABC, ACB)	ABC
DATE_F	Date Format (MDY, YMD, DMY)	MDY
FAULT	Fault Condition Equation (SELOGIC Equation)	50P1 OR 51S1 OR M2P OR Z2G OR M3P OR Z3G
Current and Voltage Source Selection Settings (Global)		
ESS	Current and Voltage Source Selection (Y, N, 1, 2, 3, 4)	N
Breaker Configuration (Breaker Monitoring)		
EB1MON	Breaker 1 Monitoring (Y, N)	N
BK1TYP	Breaker 1 Trip Type (Single Pole = 1, Three Pole = 3)	3
Breaker 1 Inputs (Breaker Monitoring)		
52AA1	A-Phase N/O Contact Input—BK1 (SELOGIC Equation)	IN101
Line Configuration (Group)		
CTRW	Current Transformer Ratio—Input W (1–50000)	200
CTRX	Current Transformer Ratio—Input X (1–50000)	200
PTRY	Potential Transformer Ratio—Input Y (1–10000)	3000
VNOMY	PT Nominal Voltage (L-L)—Input Y (60–300 V secondary)	115
PTRZ	Potential Transformer Ratio—Input Z (1–10000)	3000
VNOMZ	PT Nominal Voltage (L-L)—Input Z (60–300 V secondary)	115
Z1MAG	Positive-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)	4.00
Z1ANG	Positive-Sequence Line Impedance Angle (5.00–90 degrees)	84.7
Z0MAG	Zero-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)	12.88
Z0ANG	Zero-Sequence Line Impedance Angle (5.00–90 degrees)	73.0
EFLOC	Fault Location (Y, N)	Y
LL	Line Length (0.10–999)	100.00
Relay Configuration (Group)		
E21P	Mho Phase Distance Zones (N, 1–5)	3
E21MG	Mho Ground Distance Zones (N, 1–5)	3
E21XG	Quadrilateral Ground Distance Zones (N, 1–5)	N

Table 1.21 Settings for 345 kV Tapped TX Example (Sheet 2 of 5)

Setting	Description	Entry
ECVT	CVT Transient Detection	N
ESERCMP	Series-Compensated Line Logic (Y, N)	N
ECDTD	Distance Element Common Time Delay (Y, N)	Y
ESOTF	Switch-Onto-Fault (Y, N)	Y
EOOS	Out-of-Step (Y, Y2, N)	N
ELOAD	Load Encroachment (Y, N)	Y
E50P	Phase Inst./Def.-Time O/C Elements (N, 1–4)	1
E50G	Residual Ground Inst./Def.-Time O/C Elements (N, 1–4)	3
E50Q	Negative-Sequence Inst./Def.-Time O/C Elements (N, 1–4)	N
E51S	Selectable Inverse-Time O/C Elements (N, 1–3)	1
E32	Directional Control (Y, AUTO)	AUTO
ECOMM	Communications-Assisted Tripping (N, DCB, POTT, POTT2, POTT3, DCUB1, DCUB2)	DCB
EBFL1	Breaker 1 Failure Logic (N, 1, 2)	N
E25BK1	Synchronism Check for Breaker 1 (Y, N)	N
E79	Reclosing (Y, Y1, N)	N
EMANCL	Manual Closing (Y, N)	N
ELOP	Loss-of-Potential (Y, Y1, N)	Y1
EDEM	Demand Metering (N, THM, ROL)	N
EADVS	Advanced Settings (Y, N)	N
Mho Phase Distance Element Reach (Group)		
Z1P	Zone 1 Reach (OFF, 0.05–64 Ω secondary)	3.20
Z2P	Zone 2 Reach (OFF, 0.05–64 Ω secondary)	11.00
Z3P	Zone 3 Reach (OFF, 0.05–64 Ω secondary)	50.5
Mho Phase Distance Element Time Delay (Group)		
Z1PD	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z2PD	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z3PD	Zone 3 Time Delay (OFF, 0.000–16000 cycles)	OFF
Mho Ground Distance Element Reach (Group)		
Z1MG	Zone 1 (OFF, 0.05–64 Ω secondary)	3.20
Z2MG	Zone 2 (OFF, 0.05–64 Ω secondary)	11.00
Z3MG	Zone 3 (OFF, 0.05–64 Ω secondary)	50.5
Zero-Sequence Current Compensation Factor (Group)		
k0M1	Zone 1 ZSC Factor Magnitude (AUTO, 0.000–10)	0.750
k0A1	Zone 1 ZSC Factor Angle (–180.00 to +180 degrees)	–16.87
Ground Distance Element Time Delay (Group)		
Z1GD	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z2GD	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z3GD	Zone 3 Time Delay (OFF, 0.000–16000 cycles)	OFF

Table 1.21 Settings for 345 kV Tapped TX Example (Sheet 3 of 5)

Setting	Description	Entry
Distance Element Common Time Delay (Group)		
Z1D	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	0.000
Z2D	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	20.000
Z3D	Zone 3 Time Delay (OFF, 0.000–16000 cycles)	0.000
SOTF Scheme (Group)		
ESPSTF	Single-Pole Switch-Onto-Fault (Y, N)	N
EVRST	Switch-Onto-Fault Voltage Reset (Y, N)	Y
52AEND	52A Pole Open Time Delay (OFF, 0.000–16000 cycles)	OFF
CLOEND	CLSMON or Single Pole Open Delay (OFF, 0.000–16000 cycles)	10.000
SOTFD	Switch-Onto-Fault Enable Duration (0.500–16000 cycles)	10.000
CLSMON	Close Signal Monitor (SELOGIC Equation)	IN102
Load Encroachment (Group)		
ZLF	Forward Load Impedance (0.05–64 Ω secondary)	12.50
ZLR	Reverse Load Impedance (0.05–64 Ω secondary)	12.50
PLAF	Forward Load Positive Angle (–90.0 to +90 degrees)	45.0
NLAF	Forward Load Negative Angle (–90.0 to +90 degrees)	–45.0
PLAR	Reverse Load Positive Angle (+90.0 to +270 degrees)	135.0
NLAR	Reverse Load Negative Angle (+90.0 to +270 degrees)	225.0
Phase Instantaneous Overcurrent Pickup (Group)		
50P1P	Level 1 Pickup (OFF, 0.25–100 A secondary)	49.80
Phase Overcurrent Definite-Time Delay (Group)		
67P1D	Level 1 Time Delay (0.000–16000 cycles)	0.000
Phase Overcurrent Torque Control (Group)		
67P1TC	Level 1 Torque Control (SELOGIC Equation)	1
Residual Ground Instantaneous Overcurrent Pickup (Group)		
50G1P	Level 1 Pickup (OFF, 0.25–100 A secondary)	OFF
50G2P	Level 2 Pickup (OFF, 0.25–100 A secondary)	1.00
50G3P	Level 3 Pickup (OFF, 0.25–100 A secondary)	0.50
Residual Ground Overcurrent Definite-Time Delay (Group)		
67G2D	Level 2 Time Delay (0.000–16000 cycles)	0.000
67G3D	Level 3 Time Delay (0.000–16000 cycles)	0.000
Residual Ground Overcurrent Torque Control (Group)		
67G2TC	Level 2 Torque Control (SELOGIC Equation)	32GF
67G3TC	Level 3 Torque Control (SELOGIC Equation)	32GR
Selectable Operating Quantity Inverse-Time Overcurrent Element 1 (Group)		
51S1O	51S1 Operating Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0*n*)[a]	3I0L
51S1P	51S1 Overcurrent Pickup (0.25–16 A secondary)	0.96

Table 1.21 Settings for 345 kV Tapped TX Example (Sheet 4 of 5)

Setting	Description	Entry
51S1C	51S1 Inverse Time Overcurrent Curve (U1–U5)	U3
51S1TD	51S1 Inverse Time Overcurrent Time Dial (0.50–15.00)	2.0
51S1RS	51S1 Inverse Time Overcurrent Electromagnetic Reset (Y, N)	Y
51S1TC	51S1 Torque Control (SELOGIC Equation)	32GF
Zone/Level Direction (Group)		
DIR3	Zone/Level 3 Directional Control (F, R)	R
Directional Control (Group)		
ORDER	Ground Directional Element Priority (combine Q, V, I)	QV
E32IV	Zero-Sequence Voltage and Current Enable (SELOGIC Equation)	1
Pole-Open Detection (Group)		
EPO	Pole Open Detection (52, V)	52
SPOD	Single Pole Open Dropout Delay (0.000–60 cycles)	0.500
3POD	Three Pole Open Dropout Delay (0.000–60 cycles)	0.500
DCB Trip Scheme (Group)		
Z3XPU	Zone 3 Reverse Pickup Time Delay (0.000–16000 cycles)	1.000
Z3XD	Zone 3 Reverse Dropout Delay (0.000–16000 cycles)	5.000
21SD	Zone 2 Distance Short Delay (0.000–16000 cycles)	1.625
67SD	Level 2 Overcurrent Short Delay (0.000–16000 cycles)	1.625
BT	Block Trip Received (SELOGIC Equation)	IN103
BTXD	Block Trip Receive Extension Time (0.000–16000 cycles)	0.000
Trip Logic (Group)		
TR	Trip (SELOGIC Equation)	Z1T OR Z2T OR 51S1T
TRCOMM	Communications-Assisted Trip (SELOGIC Equation)	Z2PGS OR 67QG2S
TRSOTF	Switch-Onto-Fault Trip (SELOGIC Equation)	M2P OR Z2G OR 50P1
DTA	Direct Transfer Trip A-Phase (SELOGIC Equation)	NA
DTB	Direct Transfer Trip B-Phase (SELOGIC Equation)	NA
DTC	Direct Transfer Trip C-Phase (SELOGIC Equation)	NA
BK1MTR	Manual Trip–Breaker 1 (SELOGIC Equation)	OC1 OR PB8_PUL
ULTR	Unlatch Trip (SELOGIC Equation)	TRGTR
ULMTR1	Unlatch Manual Trip–Breaker 1 (SELOGIC Equation)	NOT (52AA1 AND 52AB1 AND 52AC1)
TOPD	Trip During Open Pole Time Delay (2.000–8000 cycles)	2.000

Table 1.21 Settings for 345 kV Tapped TX Example (Sheet 5 of 5)

Setting	Description	Entry
TULO	Trip Unlatch Option (1, 2, 3, 4)	3
Z2GTSP	Zone 2 Ground Distance Time Delay for Single-Pole Tripping (Y, N)	N
67QGSP	Zone 2 Directional Negative-Sequence/Residual Overcurrent Single-Pole Trip (Y, N)	N
TDUR1D	Single-Pole Trip Minimum Trip Duration Time Delay (2.000–8000 cycles)	6.000
TDUR3D	Three-Pole Trip Minimum Trip Duration Time Delay (2.000–8000 cycles)	9.000
E3PT	Three-Pole Trip Enable (SELOGIC Equation)	1
E3PT1	Breaker 1 Three-Pole Trip (SELOGIC Equation)	1
ER	Event Report Trigger (SELOGIC Equation)	R_TRIG M2P OR R_TRIG Z2G OR R_TRIG 51S1 OR R_TRIG M3P OR R_TRIG Z3G
Main Board (Outputs)		
OUT101	(SELOGIC Equation)	3PT
OUT102	(SELOGIC Equation)	NSTRT AND NOT STOP OR DSTRT
OUT103	(SELOGIC Equation)	STOP OR 3PT

[a] Parameter n is 1 for BK1, 2 for BK2, and L for Line.

EHV Parallel 230 kV Underground Cables Example

This application example presents an underground cable system with double-ended 230 kV parallel cables (see *Figure 1.19*). SEL-421 relays protect each end of the first circuit. This example explains settings calculations for the SEL-421 at Station S that protects Cable 1 between Station S and Station R.

The SEL-421 uses communications-assisted high-speed tripping to provide protection for faults along the 230 kV underground cable.

The two 230 kV underground cables run from Station S to Station R. Each circuit consists of three single-phase cables, each having an oil-filled copper conductor (hollow core). The cables are insulated with impregnated paper and have a lead sheath to prevent intrusion of moisture and to withstand fluid pressure. The cables are also grounded at both ends. Depending on the nature of a ground fault, ground fault current can return via the sheath, the ground, or both the sheath and ground.

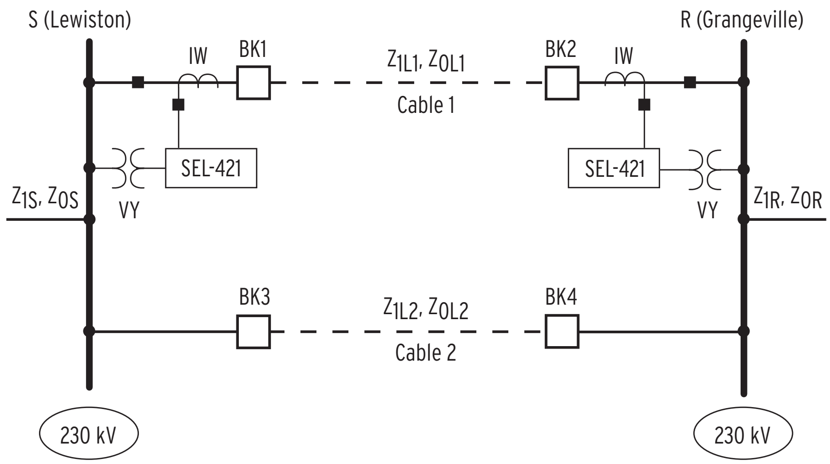


Figure 1.19 230 kV Parallel Underground Cables

Power System Data

Table 1.22 lists the power system data for this application example. Substitute the values and parameters that correspond to your system when you set the relay, using this example as a guide.

Table 1.22 System Data—230 kV Parallel Underground Cables

Parameter	Value
Nominal System Line-to-Line Voltage	230 kV
Nominal Relay Current	5 A secondary
Nominal Frequency	60 Hz
Cable Length	25 miles
Cable Impedances:	
$Z_{1L1} = Z_{1L2}$	4.78 Ω ∠42.5° primary
$Z_{0L1\text{ (sheath return)}} = Z_{0L2\text{ (sheath return)}}$	9.45 Ω ∠17.4° primary
$Z_{0L1\text{ (ground return)}} = Z_{0L2\text{ (ground return)}}$	91.4 Ω ∠84.9° primary
$Z_{0L1\text{ (sheath and ground return)}} = Z_{0L2\text{ (sheath and ground return)}}$	9.58 Ω ∠21.7° primary
Cable Admittances:	
$Y_{1L1} = Y_{1L2}$	$j6.71 \cdot 10^{-6}$ S primary (susceptance)
$Y_{0L1} = Y_{0L2}$	$j6.71 \cdot 10^{-6}$ S primary (susceptance)
Source S Impedances:	
$Z_{1S} = Z_{0S}$	50 Ω ∠87° primary
Source R Impedances:	
$Z_{1R} = Z_{0R}$	35 Ω ∠87° primary
PTR (potential transformer ratio)	230 kV:115 V = 2000
CTR (current transformer ratio)	1000:5 = 200
Phase Rotation	ABC

Convert the power system impedances from primary to secondary so you can later calculate protection settings. *Table 1.23* lists the corresponding secondary quantities. Convert the impedances to secondary ohms as follows:

$$k = \frac{CTR}{PTR} = \frac{200}{2000} = 0.1$$

Equation 1.51

$$\begin{aligned} Z_{1L1(\text{secondary})} &= k \bullet Z_{1L1(\text{primary})} \\ &= 0.10 \bullet 4.78\ \Omega\angle 42.5° \\ &= 0.48\ \Omega\angle 42.5° \end{aligned}$$ **Equation 1.52**

Table 1.23 Secondary Impedances

Parameter	Value
Cable Impedances:	
$Z_{1L1} = Z_{1L2}$	0.48 Ω ∠42.5° secondary
$Z_{0L1\,(\text{sheath return only})} = Z_{0L2\,(\text{sheath return only})}$	0.95 Ω ∠17.4° secondary
$Z_{0L1\,(\text{ground return only})} = Z_{0L2\,(\text{ground return only})}$	9.14 Ω ∠84.9° secondary
$Z_{0L1\,(\text{sheath and ground return})} = Z_{0L2\,(\text{sheath and ground return})}$	0.96 Ω ∠21.7° secondary
Cable Admittance:	
$Y_{1L1} = Y_{1L2}$	$6.71 \bullet 10^{-5}$ S ∠90° secondary
$Y_{0L1} = Y_{0L2}$	$6.71 \bullet 10^{-5}$ S ∠90° secondary
Source S Impedances:	
$Z_{1S} = Z_{0S}$	5.0 Ω ∠87° secondary
Source R Impedances:	
$Z_{1R} = Z_{0R}$	3.5 Ω ∠87° secondary

The maximum load current of 777 A primary occurs when the parallel cable is out of service.

Application Summary

This particular example is for a single circuit breaker, three-pole tripping application with the following functions:

- POTT (permissive overreaching transfer trip) scheme
- Three zones of phase (mho) and ground (quadrilateral) distance protection
  - Zone 1—forward-looking, provides instantaneous underreaching protection
  - Zone 2—forward-looking, provides communications-assisted and time-delayed tripping
  - Zone 3—reverse-looking, prevents unwanted tripping during current reversals
- Two levels of negative-sequence directional overcurrent protection
  - Level 2—forward-looking, provides communications-assisted high-speed tripping
  - Level 3—reverse-looking, prevents unwanted tripping during current reversals
- Inverse-time directional negative-sequence overcurrent backup protection
- SOTF protection (fast tripping when the circuit breaker closes)

Relay settings that are not mentioned in this example do not apply to this application example.

Global Settings

General Global Settings

The SEL-421 has settings for identification. These settings allow you to identify the following:

- Station (SID)
- Relay (RID)
- Circuit Breaker 1 (BID1)

You can enter as many as 40 characters per identification setting.

SID := **LEWISTON -- 230 kV** Station Identifier (40 characters)

RID := SEL-421 **Relay** Relay Identifier (40 characters)

Configure the SEL-421 for the one circuit breaker that this particular application uses:

NUMBK := **1** Number of Breakers in Scheme (1, 2)

BID1 := **Circuit Breaker 1** Breaker 1 Identifier (40 characters)

Set the relay for nominal frequency and phase rotation.

NFREQ := **60** Nominal System Frequency (50, 60 Hz)

PHROT := **ABC** System Phase Rotation (ABC, ACB)

Current and Voltage Source Selection

The voltage and current source selection is for one circuit breaker. The relay derives the line current source from current input IW when you set ESS to N.

ESS := **N** Current and Voltage Source Selection (Y, N, 1, 2, 3, 4)

Figure 1.20 illustrates the current and voltage sources for this particular application. The relay uses potential input VY and current input IW for line relaying.

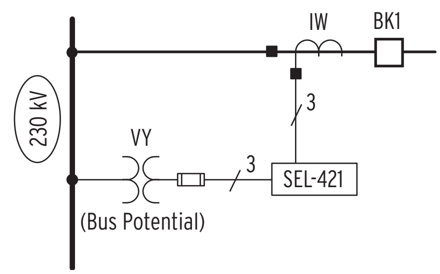


Figure 1.20 Circuit Breaker Arrangement at Station S, Cable 1

Breaker Monitor

Circuit Breaker Configuration

Set the Circuit Breaker BK1 type for a three-pole trip circuit breaker.

BK1TYP := **3** Breaker 1 Trip Type (Single-Pole = 1, Three-Pole = 3)

Circuit Breaker 1 Inputs

The SEL-421 uses a normally open auxiliary contact (52A) from the circuit breaker to determine whether the circuit breaker is open or closed.

52AA1 := **IN101** N/O Contact Input—BK1 (SELOGIC Equation)

Group Settings

Line Configuration

The SEL-421 has four transformer turns ratio settings that convert the secondary potentials and currents the relay measures to the corresponding primary values. These settings are the potential transformer and current transformer ratios (PTRY, PTRZ, CTRW, and CTRX). Use the VY potential input for line relaying; these come from the bus potentials (see *Figure 1.20*). Use the IW current input for line current. Relay setting VNOMY is the nominal secondary line-to-line voltage of the potential transformers.

PTRY := **2000** Potential Transformer Ratio—Input Y (1–10000)

VNOMY := **115** PT Nominal Voltage (L–L)—Input Y (60–300 V secondary)

CTRW := **200** Current Transformer Ratio—Input W (1–50000)

Enter the secondary values of the positive-sequence impedance of the protected cable. See *Table 1.23* for the secondary cable impedances.

Z1MAG := **0.48** Positive-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)

Z1ANG := **42.5** Positive-Sequence Line Impedance Angle (5.00–90 degrees)

Enter the secondary values of the zero-sequence impedance of the protected cable. The zero-sequence impedance should correspond to the parallel sheath and ground fault return path (see $Z0_{L1(\text{sheath and ground})}$ in *Table 1.23*).

$$ZOMAG = k \cdot \left|Z0_{L1(\text{sheath and ground})}\right| \quad \textbf{Equation 1.53}$$

where:

k = the result of *Equation 1.51*

$$ZOMAG = 0.1 \cdot |Z0_{L1(\text{sheath and ground})}| = 0.1 \cdot |9.58\ \Omega \angle 21.7°| = 0.96\ \Omega$$

Z0MAG := **0.96** Zero-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)

Z0ANG := **21.7** Zero-Sequence Line Impedance Angle (5.00–90 degrees)

Enable the fault locator.

EFLOC := **Y** Fault Location (Y, N)

The LL setting is the line length. This value has no defined unit; you can set the line length in miles, kilometers, ohms, etc. Set the length in miles.

LL := **25.00** Line Length (0.10–999)

The relay fault locator uses the values you enter for Z1MAG, Z1ANG, Z0MAG, Z0ANG, and LL.

Relay Configuration

You can select from zero to five phase mho (E21P), ground mho (E21MG), and ground quadrilateral (E21XG) distance zones. The number of zones per type of distance protection is independently selectable. Select only the number of zones you need. For this application example, use three zones of mho phase distance protection and three zones of quadrilateral ground distance protection.

E21P := **3** Mho Phase Distance Zones (N, 1–5)

E21MG := **N** Mho Ground Distance Zones (N, 1–5)

E21XG := **3** Quadrilateral Ground Distance Zones (N, 1–5)

You do not need CVT (capacitive voltage transformer) transient detection because PTs with wound windings are used for this particular application example.

ECVT := **N** CVT Transient Detection (Y, N)

NOTE: The SEL-421-1 and the SEL-421-2 do not provide series-compensated line protection logic.

The underground cable is not series-compensated.

ESERCMP := **N** Series-Compensated Line Logic (Y, N)

You can select a common time delay or an independent time delay per zone for phase and ground distance protection. If you choose independent timing, evolving faults (such as those changing from single phase to multiphase) cause the timer to reset and result in additional delay. Select common time delay for this application.

ECDTD := **Y** Distance Element Common Time Delay (Y, N)

The SOTF (switch-onto-fault) protection logic permits tripping by specified protection elements for a settable time after the circuit breaker closes.

ESOTF := **Y** Switch-Onto-Fault (Y, N)

Do not enable the out-of-step logic for this application example.

EOOS : = **N** Out-of-Step (Y, N)

Do not enable the load-encroachment logic; the minimum apparent load impedance is outside the mho phase distance characteristics.

ELOAD := **N** Load Encroachment (Y, N)

Use Level 1 high-set instantaneous phase overcurrent element for SOTF protection.

E50P := **1** Phase Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

This application does not require residual ground overcurrent protection.

E50G := **N** Residual Ground Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

Enable three levels of negative-sequence overcurrent protection. Use these negative-sequence current level detectors in conjunction with the communications-assisted tripping scheme.

E50Q := **3** Negative-Sequence Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

Use inverse-time overcurrent protection to provide backup protection for high-resistance ground faults. The 51S1 element provides backup protection for unbalanced faults if both the communications-assisted and step distance protection fail to operate.

E51S := **1** Selectable Operating Quantity Inverse-Time Overcurrent Element (N, 1–3)

The relay automatically calculates all of the ground directional elements settings when you select AUTO.

E32 := **AUTO** Directional Control (Y, AUTO)

Use the POTT trip scheme to quickly clear faults internal to the protected line.

ECOMM := **POTT** Communications-Assisted Tripping (N, DCB, POTT, POTT2, POTT3, DCUB1, DCUB2)

Fuses or molded case circuit breakers often protect potential transformers. Operation of one or more fuses, or molded case circuit breakers, results in a loss of polarizing potential inputs to the relay. Loss of one or more phase voltages prevents the relay from properly determining fault distance or direction.

Occasional loss-of-potential to the distance relay, while unavoidable, is detectable. When the relay detects a loss-of-potential condition, the relay can block distance element operation, block or enable forward-looking directional overcurrent elements, and issue an alarm for any true loss-of-potential condition.

If line-side PTs are used, the circuit breaker(s) must be closed for the LOP logic to detect a loss-of-potential condition. Therefore, if three-phase potential to the relay is lost while the circuit breaker(s) is open (e.g., the PT fuses are removed while the line is de-energized), the relay cannot detect a loss-of-potential condition when the circuit breaker(s) closes again. At circuit breaker closing, the relay can detect one or two missing potentials that occurred while the circuit breaker was open. See *Loss-of-Potential Logic on page R.1.24* for more information.

Table 1.24 lists the three choices for enabling LOP protection.

Table 1.24 LOP Enable Options

Option	Description
N	The LOP logic operates but does not disable voltage-polarized directional elements, distance elements, and forward-looking directional overcurrent elements. Use LOP in this case for alarm only.
Y	The relay disables all voltage-polarized directional elements and distance elements, but enables forward-looking directional overcurrent elements. These forward-looking directional overcurrent elements effectively become nondirectional and provide overcurrent protection during a loss-of-potential condition.
Y1	The relay disables all voltage-polarized directional elements and distance elements. The relay also disables the overcurrent elements controlled by the voltage-polarized directional elements.

Set ELOP to Y1 for this application example. This choice reduces the chances of false tripping because of a loss-of-potential condition.

ELOP := **Y1** Loss-of-Potential (Y, Y1, N)

Enable the Advanced Settings so you can properly set the zero-sequence compensation factors.

EADVS := **Y** Advanced Settings (Y, N)

Phase Distance Elements (21P)

Mho Phase Distance Element Reach

Employ each zone of distance protection as follows:

- Zone 1—Instantaneous underreaching tripping
- Zone 2—Forward-looking fault detector for the POTT scheme and backup time delayed tripping
- Zone 3—Current reversal guard for the POTT scheme, echo tripping, and weak infeed logic

Zone 1 Phase Distance Element Reach. Zone 1 phase distance protection provides instantaneous protection for phase-to-phase, phase-to-phase-to-ground, and three-phase faults in the first 80 percent of the cable. Errors in the current transformers, potential transformers, modeled cable data, and fault study data do not permit a Zone 1 setting for 100 percent of the cable; unwanted tripping could occur for faults just beyond the remote end of the cable.

Set Zone 1 phase distance protection to 80 percent of the cable positive-sequence impedance.

$$Z1P = 0.8 \bullet Z_{1L1} = 0.8 \bullet 0.48\ \Omega = 0.38\ \Omega$$

Z1P := **0.38** Zone 1 Reach (OFF, 0.05–64 Ω secondary)

Zone 2 Phase Distance Element Reach. Zone 2 phase distance protection must have adequate reach to detect all phase-to-phase, phase-to-phase-to-ground, and three-phase faults along the protected cable. Set Zone 2 phase distance protection to 120 percent of the cable positive-sequence impedance. With this reach, high-speed tripping occurs via the communications channel for faults located in the last 20 percent of the cable.

$$Z2P = 1.2 \bullet Z_{1L1} = 1.2 \bullet 0.48\ \Omega = 0.58\ \Omega$$

Z2P := **0.58** Zone 2 Reach (OFF, 0.05–64 Ω secondary)

Zone 3 Phase Distance Element Reach. Zone 3 phase distance protection must have adequate reach to prevent unwanted tripping during current reversals when the parallel line is in service because this example uses a POTT scheme. So that Zone 3 has greater fault coverage than Zone 2 at the remote terminal, set the reach to remote Zone 2 and rely upon the length of the protected cable as the safety margin.

$$Z3P = Z2P = 0.58\ \Omega$$

Z3P := **0.58** Zone 3 Reach (OFF, 0.05–64 Ω secondary)

Ground Distance Elements (21XG)

Quadrilateral Ground Distance Element Reach

The main advantage of ground distance protection is that Zone 1 provides instantaneous protection independent of the communications channel. Typically cable faults have little fault resistance; it is advantageous to conservatively set the resistance reach for quadrilateral ground distance protection. Supplement quadrilateral ground distance protection with directional negative-sequence overcurrent elements. The directional negative-sequence overcurrent elements employed in the communications-assisted tripping scheme provide excellent resistive coverage for high-resistance ground faults (e.g., a contaminated pothead flashes over).

The reactive reach for each zone of quadrilateral ground distance protection lies on the relay characteristic angle (Z1ANG), rather than on the ordinate (reactance) of the impedance plane (see *Figure 1.21*).

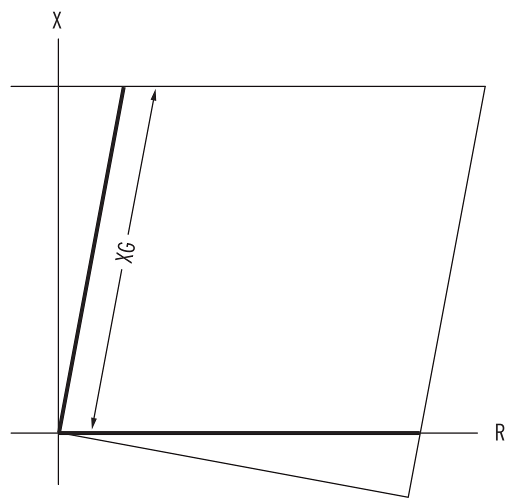


Figure 1.21 Quadrilateral Ground Distance Element Reactive Reach Setting

Employ each zone of distance protection as follows:

- Zone 1—Instantaneous underreaching direct tripping
- Zone 2—Forward-looking tripping elements for the POTT scheme and backup tripping
- Zone 3—Current reversal guard for the POTT scheme, echo tripping, and weak infeed logic

Zone 1 Reactance. The reach of the Zone 1 reactance measurement of the quadrilateral ground distance elements must meet the same requirement as that for Zone 1 mho phase distance protection; the reach setting can be no greater than 80 percent of the cable.

$XG1 = 0.8 \cdot |Z_{1L1}| = 0.8 \cdot 0.48\ \Omega = 0.38\ \Omega$

XG1 := **0.38** Zone 1 Reactance (OFF, 0.05–64 Ω secondary)

Zone 1 Resistance. Find RG1 (Zone 1 Resistance) from the per-unit reach *m* of the Zone 1 reactance. Use *Equation 1.54*, which is Equation (3) in *Appendix A—Quadrilateral Reactive Reach Versus Resistive Reach Setting Guideline* from the paper *Digital Communications for Power System Protection: Security, Availability, and Speed* (go to www.selinc.com for a copy of this paper):

$$m = 1 - \frac{R}{X_{1L1} \cdot 20}$$ **Equation 1.54**

where:

m = per-unit reach of XG1
R = RG1 (the Zone 1 resistance)
X_{1L1} = positive-sequence transmission line reactance

XG1 is set at 80 percent of the underground cable (i.e., *m* = 0.8 per-unit); the positive-sequence reactance of the cable, X_{1L1}, is 0.323 Ω secondary (from the rectangular form of Z_{1L1} in *Table 1.23*).

$$\begin{aligned} Z_{1L1} &= R_{1L1} + jX_{1L1} \\ &= 0.48\ \Omega \angle 42.5° \\ &= 0.354 + j0.323\ \Omega \end{aligned}$$

Rearrange *Equation 1.54* to calculate RG1:

$$\begin{aligned} RG1 &= (1 - m) \bullet 20 \bullet X_{1L1} \\ &= (1 - 0.8) \bullet 20 \bullet 0.323\ \Omega \\ &= 1.29\ \Omega \end{aligned} \qquad \textbf{Equation 1.55}$$

RG1 := **1.29** Zone 1 Resistance (0.05–50 Ω secondary)

Zone 2 Reactance. Zone 2 quadrilateral ground distance reach must meet the same requirement as that for Zone 2 mho phase distance protection; the reach setting is 120 percent of the cable.

$XG2 = 1.2 \bullet |Z_{1L1}| = 1.2 \bullet 0.48 = 0.58\ \Omega$

XG2 := **0.58** Zone 2 Reactance (OFF, 0.05–64 Ω secondary)

Zone 2 Resistance. Use the following formula to set RG2:

$$\begin{aligned} RG2 &= XG2 \bullet \frac{RG1}{XG1} \\ &= 0.58\ \Omega \bullet \frac{1.29\ \Omega}{0.38\ \Omega} \\ &= 0.58\ \Omega \bullet 3.4 \\ &= 1.97\ \Omega \end{aligned} \qquad \textbf{Equation 1.56}$$

RG2 := **1.97** Zone 2 Resistance (0.05–50 Ω secondary)

Zone 3 Reactance. Zone 3 quadrilateral ground distance reach must meet the same requirement as that for Zone 3 mho phase distance protection; it equals Zone 2 reach.

$XG3 = XG2 = 0.58\ \Omega$

XG3 := **0.58** Zone 3 Reactance (OFF, 0.05–64 Ω secondary)

Zone 3 Resistance. Set the Zone 3 resistance reach equal to Zone 2 resistance reach and multiply the reach by 125 percent for a safety margin to account for external resistive ground faults.

$RG3 = 1.25 \bullet RG2 = 1.25 \bullet 1.97 = 2.46\ \Omega$

RG3 := **2.46** Zone 3 Resistance (0.05–50 Ω secondary)

Quadrilateral Ground Polarizing Quantity

Advanced Settings are enabled, so you must enter two final settings for the quadrilateral ground distance protection. With setting XGPOL, you can choose the polarizing quantity for the quadrilateral ground distance protection. You can choose either negative-sequence current (I2) or zero-sequence current (IG). Choose the appropriate quantity to reduce overreach and underreach of the reactance line. The reactance line can underreach or overreach during high-resistance single phase-to-ground faults because of nonhomogeneous negative-sequence or zero-sequence networks, and prefault load flow.

Figure 1.22 shows the network to determine negative-sequence or zero-sequence homogeneity.

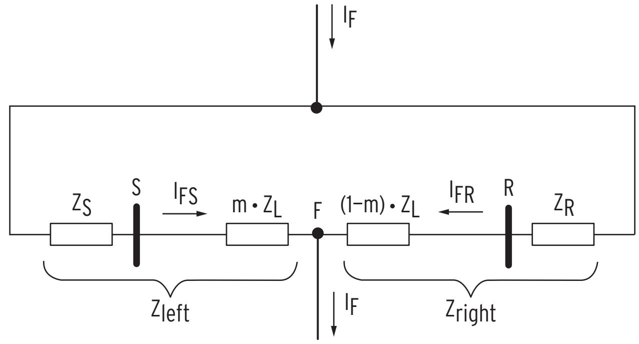


Figure 1.22 Circuit to Determine Network Homogeneity

Z_{left} is the total impedance up to the fault (F) on the left side of the fault location, while Z_{right} is the total impedance up to the fault on the right side of the network. A network is homogeneous with respect to the particular fault location if *Equation 1.57* is satisfied:

$$\frac{X_{left}}{R_{left}} = \frac{X_{right}}{R_{right}}$$ **Equation 1.57**

Use *Equation 1.58* and *Equation 1.59* to determine the zero-sequence and negative-sequence homogeneity:

$$T_0 = ARG\left(\frac{Z_{0S} + Z_{0L} + Z_{0R}}{(1-m) \cdot Z_{0L} + Z_{0R}}\right)$$ **Equation 1.58**

$$T_2 = ARG\left(\frac{Z_{1S} + Z_{1L} + Z_{1R}}{(1-m) \cdot Z_{1L} + Z_{1R}}\right)$$ **Equation 1.59**

The values T_0 and T_2 represent how much the apparent fault impedance measured by XAG tilts up or down (electrical degrees) due to the nonhomogeneity of the corresponding network. *Figure 1.23* illustrates the possible tilt situations caused by a nonhomogeneous network.

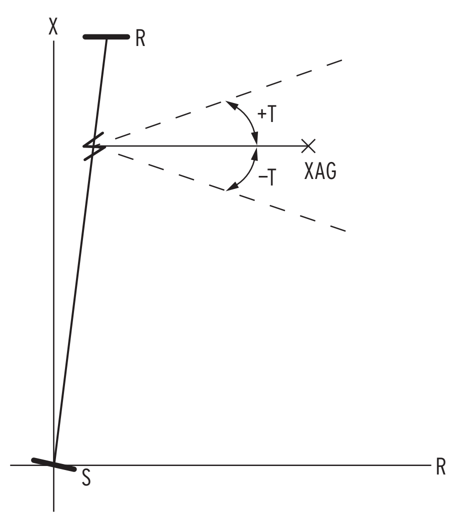


Figure 1.23 Apparent Fault Impedance Resulting From Nonhomogeneity

Table 1.25 provides the results of *Equation 1.58* and *Equation 1.59* for both the negative-sequence and zero-sequence networks. Remember that T_0 depends on the return path of the ground fault; i.e., sheath, ground, or a parallel combination of both. The distance to fault is assumed to be 100 percent (*m* equals 1).

Table 1.25 Tilt Resulting From Nonhomogeneity

Angle	T_2	T_0 (sheath)	T_0 (ground)	T_0 (ground and sheath)
Negative-Sequence Network	–2.2°			
Zero-Sequence Network		–5.8°	–1.1°	–5.6°

The negative-sequence network is more homogeneous than the zero-sequence network when compared with two of the three corresponding cable zero-sequence impedances. Choose negative-sequence current for polarizing the quadrilateral ground distance protection.

XGPOL := **I2** Quadrilateral Ground Polarizing Quantity (I2, IG)

Selection I2 indicates that the negative-sequence current flowing in the cable is the polarizing quantity for the reactance line.

Nonhomogeneous Correction Angle

TANG, the nonhomogeneous angle setting, also helps prevent overreach or underreach for ground faults at a specific fault location by compensating the angle of the reactance line.

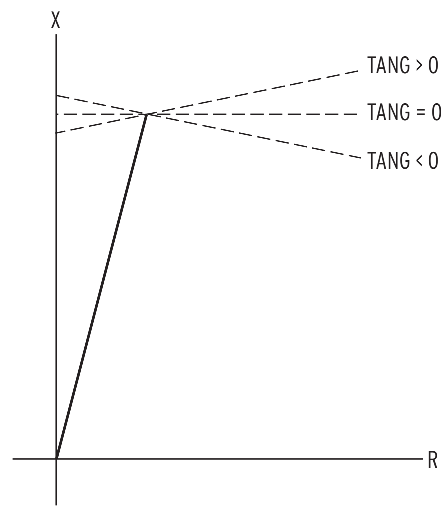


Figure 1.24 Nonhomogeneous Angle Setting

Set TANG to prevent the Zone 1 quadrilateral ground distance reactance measurement from overreaching for ground faults located at the remote bus. Use the result from *Equation 1.59* (T_2 in *Quadrilateral Ground Polarizing Quantity on page A.1.93*).

TANG := **–2.2** Nonhomogeneous Correction Angle (–40.0 to +40.0 degrees)

Zero-Sequence Current Compensation Factors

Zero-sequence current compensation helps keep the phase and ground distance elements at the same reach if you set the phase reach and the ground reach equal per zone (e.g., Z1P = XG1). Ground distance elements should measure fault impedance in terms of positive-sequence impedance only.

The relay has three zero-sequence current compensation factors (k01, k0, and k0R). The Zone 1 ground distance element has a dedicated zero-sequence current compensation factor (k01). Advanced Settings are enabled for this particular example (EADVS := Y), so you must set two additional independent zero-sequence current compensation factors, one for forward-looking zones (k0) and one for reverse-looking zones (k0R).

The zero-sequence cable impedance depends on the return path of the ground fault current during ground faults. The zero-sequence current compensation factors must be set so the Zone 1 ground distance elements do not see ground faults external to the protected cable, while Zone 2 and Zone 3 ground distance elements must see all internal ground faults.

The SEL-421 uses *Equation 1.60* to calculate the A-phase-to-ground distance reactance measurement.

$$XAG = \frac{\mathrm{Im}[V_A \cdot (I_{POL} \cdot e^{j \cdot TANG})^*]}{\mathrm{Im}[z1 \cdot (I_A + k01 \cdot 3I_0) \cdot (I_{POL} \cdot e^{j \cdot TANG})^*]}$$ **Equation 1.60**

where:

V_A = A-phase-to-ground voltage measured at Station S
I_A = A-phase current measured through Cable 1 at Station S
$3I_0$ = zero-sequence current measured through Cable 1 at Station S
I_{POL} = negative-sequence or zero-sequence current measured through Cable 1 at Station S (based on the XGPOL setting, see *Quadrilateral Ground Polarizing Quantity on page A.1.93*)
TANG = nonhomogeneous correction angle
Im[ ] = imaginary part
* = complex conjugate

$$z1 = \frac{Z_1}{|Z_1|}$$ **Equation 1.61**

where:

Z_1 = Cable 1 positive-sequence impedance

$$k01 = \frac{Z_{0L1} - Z_{1L1}}{3 \cdot Z_{1L1}}$$ **Equation 1.62**

k01. You can set k01 based on three values for the zero-sequence cable impedance: $Z_{0L1(sheath)}$, $Z_{0L1(ground)}$, or $Z_{0L1(sheath\ and\ ground)}$. Select the zero-sequence cable impedance that prevents Zone 1 ground distance element overreach.

To determine the best setting for k01, place an A-phase-to-ground fault at Station R with the parallel cable out of service. Find the ground distance reactance measurement XAG that does not overreach for this fault. Perform this evaluation using $Z_{0L1(sheath\ and\ ground)}$ and $Z_{0L1(sheath)}$ for the zero-sequence cable impedance. There is no need to determine the XAG measurement for ground faults at the remote terminal when k01 is set based on $Z_{0L1(ground)}$ because severe overreach occurs in all cases for the ground-only path.

Sheath and Ground Return Path. First apply *Equation 1.60* with k01 based on $Z_{0L1(sheath\ and\ ground)}$ (k01 equal to 0.374 ∠–39.2°). This is the most common ground fault return path. Set TANG equal to zero and assume that I_{POL} is equal to negative-sequence current (i.e., XGPOL is equal to I2).

Table 1.26 lists the corresponding XAG (reactance of the phase-to-ground fault) calculations for the remote single phase-to-ground fault for each of the three possible zero-sequence cable impedances when the k01 calculation is based on the parallel return path. Use *Equation 1.63* to determine the amount of overreach/underreach:

$$\text{Overreach/Underreach} = \frac{XAG}{|Z_{1L1}|} \cdot 100\%$$

Equation 1.63

Table 1.26 XAG Measurement for Remote AG Fault (k01 = 0.374 ∠–39.2°, sheath and ground return path)

Calculation	$Z_{0L1(sheath)}$	$Z_{0L1(ground)}$	$Z_{0L1(sheath\ and\ ground)}$
XAG (secondary ohms)	0.45 Ω	3.04 Ω	0.48 Ω
Overreach/Underreach[a]	93.8% (O)	633% (U)	100%

[a] O indicates overreach, U indicates underreach.

The results in *Table 1.26* show that the XAG calculation overreaches by 6.2 percent (i.e., 100% – 93.8% = 6.2%) if the sheath is the return path for the ground fault; therefore, you should not set k01 based on the sheath and ground (parallel) return path.

Sheath Return Path. *Table 1.27* lists the corresponding XAG (reactance of the phase-to-ground fault) calculations for the remote single phase-to-ground fault for each of the three possible zero-sequence cable impedances when the k01 calculation is based on the sheath return path.

Table 1.27 XAG Measurement for Remote AG Fault (k01 = 0.385 ∠–46.7°, sheath return path)

Calculation	$Z_{0L1(sheath)}$	$Z_{0L1(ground)}$	$Z_{0L1(sheath\ and\ ground)}$
XAG (secondary ohms)	0.48 Ω	3.17 Ω	0.51 Ω
Overreach/Underreach[a]	100%	660% (U)	106% (U)

[a] O indicates overreach, U indicates underreach.

The results in *Table 1.27* show that there is no Zone 1 ground distance overreach. Therefore, set k01 based on $Z_{0L1(sheath)}$.

k0M1 := **0.385** Zone 1 ZSC Factor Magnitude (AUTO, 0.000–10)

k0A1 := **-46.7** Zone 1 ZSC Factor Angle (–180.0 to +180.0 degrees)

k0 and k0R. Set the forward (k0) and reverse (k0R) zero-sequence current compensation factors so that the overreaching zones of ground distance protection do not underreach for any internal ground fault. Put both parallel cables in service. *Table 1.28* lists the corresponding XAG calculations for a remote (Station R) ground fault for each of the three possible zero-sequence cable impedances when the k0 calculation is based on $Z_{0L1(ground)}$. (Replace k01 with k0 or replace k01 with k0R in *Equation 1.60* and *Equation 1.62*.)

Table 1.28 XAG Measurement for Remote AG Fault (k0 = 6.105 ∠44.5°, ground return path)

Calculation	$Z_{0L1(sheath)}$	$Z_{0L1(ground)}$	$Z_{0L1(sheath\ and\ ground)}$
XAG (secondary ohms)	0.04 Ω	0.48 Ω	0.05 Ω
Overreach/Underreach[a]	8.33% (O)	100%	10.4% (O)

[a] O indicates overreach, U indicates underreach

The results of *Table 1.28* show that the XAG calculation does not underreach when you set k0 based on the ground return path. Set k0 and k0R based on $Z_{0L1(ground)}$.

k0M := **6.105** Forward Zones ZSC Factor Magnitude (0.000–10)

k0A := **44.5** Forward Zones ZSC Factor Angle (–180.0 to +180.0 degrees)

k0MR := **6.105** Reverse Zones ZSC Factor Magnitude (0.000–10)

k0AR := **44.5** Reverse Zones ZSC Factor Angle (–180.0 to +180.0 degrees)

Distance Element Common Time Delay

Set the operation time delay of both the phase and ground distance elements.

Zone 1

There is no need to delay Zone 1 distance protection; the relay trips instantaneously for faults in Zone 1.

Z1D = **0.000** Zone 1 Time Delay (OFF, 0.000–16000 cycles)

Zone 2

Zone 2 distance protection must coordinate with downstream Zone 1 distance protection plus the downstream circuit breaker operating time and a safety margin. A typical Zone 2 phase and ground distance time delay setting is 20 cycles.

Z2D := **20.000** Zone 2 Time Delay (OFF, 0.000–16000 cycles)

Short Adjacent Lines. You do not need to consider the following fault current return path scenario for this application example; this information is provided here for applications with short adjacent lines. *Figure 1.25* illustrates an important consideration if you apply time-delayed Zone 2 ground distance protection to backup downstream Zone 1 ground distance protection.

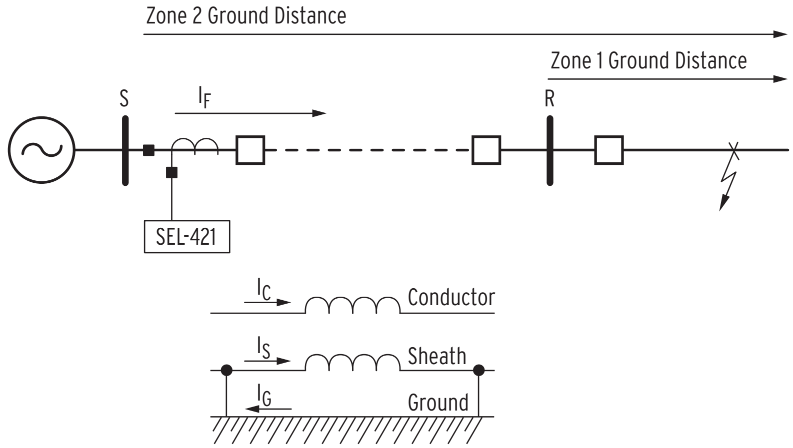


Figure 1.25 External Ground Fault

Fault current flows through the sheath and ground with respect to the cable because the sheath is grounded at each end during external ground faults. However, because you must make sure that Zone 2 ground distance elements see all ground faults at remote Station R, the k0 setting was for the ground path only. Therefore, Zone 2 ground distance protection may overreach for external ground faults, especially for the case of a short adjacent line. The solution is to increase Zone 2 time delay.

Zone 3

Zone 3 has reverse-looking distance protection that you do not need to apply for tripping in this application. Set Zone 3 for zero time delay.

Z3D := **0.000** Zone 3 Time Delay (OFF, 0.000–16000 cycles)

SOTF Protection

SOTF (Switch-Onto-Fault) logic is enabled when the circuit breaker closes. This logic provides protection for a short duration (setting SOTFD) until other protection (such as tripping from SELOGIC control equations TR and TRCOMM) is available. The TRSOTF SELOGIC control equation defines which protection elements cause the relay to trip when the SOTF scheme is active. Assertion of the protection elements assigned to TRSOTF during the SOTFD time causes the relay to trip instantaneously.

Use nondirectional overcurrent protection to clear close-in faults. Also use instantaneous overreaching distance protection to clear faults along the line. Assign instantaneous Zone 2 mho phase and ground distance protection plus Level 1 phase overcurrent element to TRSOTF.

TRSOTF := **M2P OR Z2G OR 50P1** Switch-Onto-Fault Trip (SELOGIC Equation)

Voltage Reset

You can configure the logic so the SOTF enable duration resets within at least 5 cycles after it first asserted but before the SOTFD timer expires. To quickly reset the SOTF period before this time, the relay must sense that the positive-sequence voltage V_1 is greater than 85 percent of nominal voltage.

Use setting EVRST (Switch-Onto-Fault Voltage Reset) to enable fast reset. The advantage of resetting SOTF protection quickly is that unwanted tripping does not occur for subsequent faults external to the remote terminals during the SOTF period; these trips can occur if you set instantaneous Zone 2 distance protection elements in the TRSOTF SELOGIC control equation. Enable the voltage reset option.

EVRST := **Y** Switch-Onto-Fault Voltage Reset (Y, N)

SOTF Initiation

The SOTF logic asserts via one or both of the following methods:

- ➤ A change in the normally open auxiliary contact 52A status showing that the circuit breaker has just opened
- ➤ Assertion of the relay control input assigned to the circuit breaker close bus

The 52A method initiation works well for both single and multiple circuit breaker applications and does not require an input from the close bus. However, close bus only initiation enables SOTF protection immediately following the close command to the circuit breaker. For more information see *Switch-Onto-Fault Logic on page R.1.86*.

Turn off 52AEND (52A Pole Open Time Delay).

52AEND := **OFF** 52A Pole Open Time Delay (OFF, 0.000–16000 cycles)

Select the close bus option for this application and set the close enable delay (CLOEND) shorter than the shortest reclose open interval.

CLOEND := **10.000** CLSMON or Single-Pole Open Delay (OFF, 0.000–16000 cycles)

SOTF Duration

Setting SOTFD determines the longest period the SOTF logic can assert after the circuit breaker closes.

SOTFD := **10.000** Switch-Onto-Fault Enable Duration (0.500–16000 cycles)

Close Signal Monitor

Assign the Relay Word bit CLSMON to a control input, so the relay can detect execution of the close command.

CLSMON := **IN102** Close Signal Monitor (SELOGIC Equation)

Phase Instantaneous/Definite-Time Overcurrent Elements

Use Level 1 instantaneous phase overcurrent element (50P1) as a nondirectional high-set phase overcurrent element for SOTF protection. To rapidly clear faults, set pickup threshold 50P1P equal to 50 percent of the fault current measured at the local terminal for a close-in three-phase fault; use weak source conditions so that the relay operates for low-level fault current.

50P1P := **9.57** Level 1 Pickup (OFF, 0.25–100 A secondary)

This application uses 50P1 as an instantaneous overcurrent element; you do not need time delay.

67P1D := **0.000** Level 1 Time Delay (0.000–16000 cycles)

This application uses 50P1 as a nondirectional overcurrent element; you do not need torque control.

67P1TC := **1** Level 1 Torque Control (SELOGIC Equation)

Negative-Sequence Instantaneous/Definite-Time Overcurrent Elements

Negative-sequence directional overcurrent protection is an excellent choice for underground cable. The cable zero-sequence impedance depends on the current return paths, but the cable negative-sequence impedance does not. Negative-sequence directional overcurrent protection provides reliable and sensitive protection for cables against all unbalanced faults. Be sure to set negative-sequence overcurrent elements above system unbalances.

Negative-Sequence Overcurrent Elements

Enable three levels of negative-sequence overcurrent elements.

E50Q := **3** Negative-Sequence Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

Disable Level 1 negative-sequence overcurrent element. This application does not use 50Q1.

50Q1P := **OFF** Level 1 Pickup (OFF, 0.25–100 A secondary)

The Level 2 negative-sequence directional overcurrent element (67Q2) provides communications-assisted tripping for internal unbalanced faults. This element detects unbalanced faults in the forward direction and trips via the communications channel. The 50Q2P setting is the pickup for the directional overcurrent element 67Q2. Apply a setting equal to the default for the pickup of 32QG (Negative-Sequence Voltage Polarized Directional Element), which is 50FP (Forward Supervisory Overcurrent Pickup)

$$50Q2P = 50FP = 0.12 \bullet I_{nom} = 0.12 \bullet 5\ A = 0.6\ A$$

50Q2P := **0.60** Level 2 Pickup (OFF, 0.25–100 A secondary)

The Level 3 negative-sequence directional overcurrent element (67Q3) provides current reversal guard during unbalanced faults on the parallel cable to prevent unwanted tripping. The 50Q3P setting is the pickup for directional overcurrent element 67Q3. Set the pickup of Level 3 negative-sequence overcurrent element equal to the default for the pickup of 32QG (Negative-Sequence Voltage Polarized Directional Element), which is 50RP (Reverse Supervisory Overcurrent Pickup). The reverse-looking element is 150 percent more sensitive than the forward-looking element.

$$50Q3P = 50RP = 0.08 \bullet I_{nom} = 0.08 \bullet 5\ A = 0.4\ A$$

50Q3P := **0.40** Level 3 Pickup (OFF, 0.25–100 A secondary)

Negative-Sequence Overcurrent Pickup Coordination Check.

Figure 1.26 illustrates why you need to check the sensitivity of the forward (50Q2P) and reverse (50Q3P) negative-sequence overcurrent pickup settings.

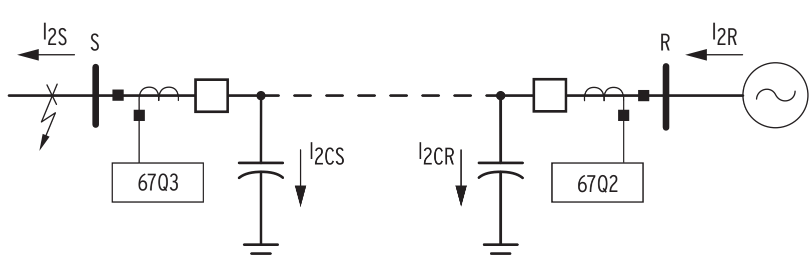


Figure 1.26 Negative-Sequence Fault Current Distribution-External Ground Fault

The shunt capacitance of the 230 kV cable causes the SEL-421 at Station S to measure less negative-sequence fault current for a reverse out-of-section ground fault than at Station R.

$$I_{2S} = I_{2R} - I_{2CR} - I_{2CS} \quad \textbf{Equation 1.64}$$

where:

I_{2R} = negative-sequence fault current supplied from Source R
I_{2S} = negative-sequence fault current flowing through the line terminal at Station S
I_{2CR} = negative-sequence shunt current at Station R
I_{2CS} = negative-sequence shunt current at Station S

Therefore, if the reverse-looking directional element at the local station is not more sensitive than the forward-looking directional element at the remote station, unwanted tripping can occur during external ground faults; the local 67Q3 element can fail to detect a reverse unbalanced fault that the remote 67Q2 element sees.

Use a short-circuit study to determine I_{2S} for a close-in reverse single phase-to-ground fault with respect to Station S; make sure to perform the fault calculations for the parallel cable both in service and out of service. The results of the study for this particular application show that the maximum difference between I_{2S} and I_{2R} for any close-in reverse unbalanced fault at Station S is 8.5 mA secondary. Therefore, the existing settings provided for 50Q2P and 50Q3P maintain coordination for external unbalanced faults.

There is no need to add any intentional time delay on pickup for Level 2 or 3 negative-sequence overcurrent elements.

67Q2D := **0.000** Level 2 Time Delay (0.000–16000 cycles)

67Q3D := **0.000** Level 3 Time Delay (0.000–16000 cycles)

Set the Level 2 torque control equation to the forward decision from the ground directional element.

67Q2TC := **32GF** Level 2 Torque Control (SELOGIC Equation)

Set the Level 3 torque control equation to the reverse decision from the ground directional element.

67Q3TC := **32GR** Level 3 Torque Control (SELOGIC Equation)

Selectable Operating Quantity Time Overcurrent Element 1

Use inverse-time overcurrent protection to provide backup protection for unbalanced faults including high-resistance ground faults. Selectable Operating Quantity Time Overcurrent Element 1 51S1 provides backup protection for unbalanced faults if both the communications-assisted and step distance protection fail to operate.

NOTE: Use your company practices and philosophy when determining these settings.

Select negative-sequence line current 3I2L as the operating quantity rather than 3I0L because ground current return paths vary.

51S1O := **3I2L** 51S1 Operating Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0*n*)

The fault current ($3I_2$) that the relay measures for a bolted single phase-to-ground fault at the end of the longest line from the remote station with the parallel cable in service at minimum generation is 3.0 A secondary (this is the minimum of minimums). Set the pickup between 30 to 50 percent of this current.

51S1P = 1/3 • $3I_{2FAULT}$ = 1/3 • 3.00 A = 1.00 A

51S1P = **1.00** 51S1 Overcurrent Pickup (0.25–16 A secondary)

Use the following formula to determine approximately how much primary fault resistance coverage (R_F) that 51S1P provides on a radial basis:

$$\begin{aligned} R_F &= \frac{PTR}{CTR} \bullet \frac{\left|\frac{VNOMY}{\sqrt{3}}\right|}{51S1P} \\ &= \frac{2000}{200} \bullet \frac{\frac{115\ V}{\sqrt{3}}}{1.00\ A} \\ &= 664\ \Omega \text{ primary} \end{aligned}$$

Equation 1.65

Use the following as a guide to set the curve and time dial; for secure backup protection, perform a coordination study. Set the local overcurrent element to coordinate with the downstream overcurrent element so there is a 12-cycle (60 Hz nominal) safety margin for phase-to-phase (high current) faults in front of the first downstream overcurrent element. Assume the operating time of the downstream overcurrent element is 12 cycles for close-in phase-to-phase faults. Therefore, set the local time-overcurrent element to operate at approximately 24 cycles for phase-to-phase faults in front of the first downstream overcurrent element.

The fault current ($3I_2$) that the relay measures for a bolted close-in phase-to-phase fault at the remote station with the parallel cable out of service is 18.67 A secondary. The pickup multiple is shown in *Equation 1.66*.

$$\begin{aligned} M &= \frac{I_{2FAULT}}{51S1P} \\ &= \frac{18.67\ A}{1.00\ A} \\ &= 18.67 \end{aligned}$$

Equation 1.66

Use the parameters of 24 cycles operating time and M = 18.67 to choose the curve and time dial settings for the 51S1 element. For curve and timing information, see *Inverse-Time Overcurrent Elements on page R.1.72*.

51S1C = **U3** 51S1 Inverse-Time Overcurrent Curve (U1–U5)

51S1TD = **3.72** 51S1 Inverse-Time Overcurrent Time Dial (0.50–15.0)

Set the overcurrent element to emulate electromechanical reset.

51S1RS = **Y** 51S1 Inverse-Time Overcurrent EM Reset (Y, N)

Torque control the overcurrent element with the forward decision from the ground directional element.

51S1TC = **32GF** 51S1 Torque Control (SELOGIC Equation)

Zone/Level Direction

Zone 1 and Zone 2 distance element directions are fixed in the forward direction. You can select the other zones independently as forward-looking (F), or reverse-looking (R). Set Zone 3 distance elements reverse-looking; these are blocking elements for the POTT scheme.

DIR3 := **R** Zone/Level 3 Directional Control (F, R)

Directional Control

The SEL-421 uses an array of directional elements to supervise the ground distance elements and residual directional overcurrent elements during ground fault conditions. Internal logic automatically selects the best choice for the ground directional element (32G) from among the negative-sequence voltage-polarized directional element (32QG), zero-sequence voltage-polarized directional element (32V), and the zero-sequence current-polarized directional element (32I).

The relay setting ORDER determines the order in which the relay selects directional elements to provide the ground directional decisions. You can set ORDER with any combination of Q, V, and I. The listed order of these directional elements determines the priority in which these elements operate to provide ground directional decisions. Only one specific directional element operates at any one time. Directional element classification is as follows:

- Q—Negative-sequence voltage-polarized directional element
- V—Zero-sequence voltage-polarized directional element
- I—Zero-sequence current-polarized directional element

Set ORDER to Q. This setting selects only the negative-sequence voltage-polarized directional element. You rely on 32QG to provide high-speed reliable and sensitive protection during unbalanced faults via the communications channel. Cable zero-sequence impedance depends on the fault current return path; the negative-sequence impedance of the cable does not.

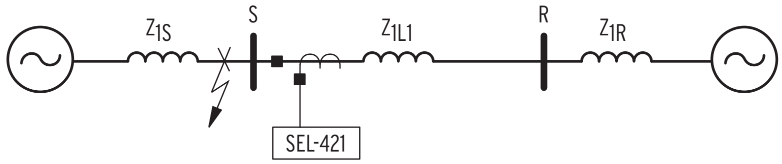
ORDER := **Q** Ground Directional Element Priority (combine Q, V, I)

The relay hides the Z0F, Z0R, a0, and E32IV settings because ORDER does not contain V or I.

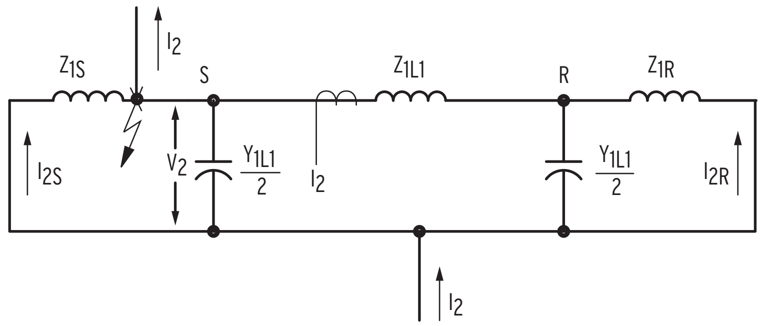
Negative-Sequence Voltage-Polarized Directional Element Reverse Decision (R32QG) Check

The setting Z2R is the reverse threshold for the negative-sequence voltage-polarized directional element. If the apparent negative-sequence impedance (z2) that the relay measures is greater than Z2R, the relay declares that an unbalanced fault is reverse. For overhead transmission lines, ignore the shunt admittance that represents the charging capacitance. The shunt negative-sequence admittance of the underground cable is significant and modifies the z2 measurement during reverse faults. You must include this admittance in the cable model to verify proper operation of the default setting.

Figure 1.27 illustrates the effect of the shunt admittance at both ends of the circuit for a reverse unbalanced fault.



Impedance Diagram



Negative-Sequence Network

Figure 1.27 Reverse Unbalanced Fault on Cable Circuit (Shunt Admittance)

The technical paper *Underground/Submarine Cable Protection Using a Sequence Directional Comparison Scheme* (see www.selinc.com for a copy of this paper) provides an equation that allows you to express the apparent negative-sequence impedance at the relay terminal for a reverse unbalanced fault when accounting for charging capacitance:

$$\begin{aligned}|Z_{2S}| &= \left|\frac{-V_{2S}}{I_{2S}}\right| \\ &= \frac{4 \bullet Z_{1L1} + 2 \bullet Y_{1L1} \bullet Z_{1L1} \bullet Z_{1R} + 4 \bullet Z_{1R}}{4 + 4 \bullet Y_{1L1} \bullet Z_{1R} + 2 \bullet Y_{1L1} \bullet Z_{1L1} + Y^2_{1L1} \bullet Z_{1L1} \bullet Z_{1R}} \\ &= 3.86\ \Omega\end{aligned}$$

Equation 1.67

The SEL-421 uses *Equation 1.68* to calculate the apparent negative-sequence impedance during unbalanced faults:

$$z2 = \frac{\mathrm{Re}[V_2 \bullet (I_2 \bullet \angle Z1ANG)^*]}{|I_2|^2}$$

Equation 1.68

Equation 1.68 yields a more conservative result for the negative-sequence impedance when the parallel cable is out of service:

$|Z_{2S}| = 2.97\ \Omega$

The result of *Equation 1.68* is greater than the default setting for Z2R; Z2R = (Z2F + 1/(2 • I_{nom}). (See *Ground Directional Element on page R.1.28* for more information.)

Pole-Open Detection

The setting EPO, Enable Pole-Open logic, offers two options for deciding what conditions signify an open pole, as listed in *Table 1.29*.

Table 1.29 Options for Enabling Pole-Open Logic

Option	Description
EPO := V	The logic declares a single-pole open if the corresponding phase undervoltage element asserts and the open phase detection logic declares the pole is open. Select this option only if you use line-side potential transformers for relaying purposes. A typical setting for the 27PO, pole-open undervoltage threshold, is 60 percent of the nominal line-to-neutral voltage. Do not select this option when shunt reactors are applied because the voltage slowly decays after the circuit breaker opens. With this option selected, the relay cannot declare an open pole during assertion of LOP.
EPO := 52	The logic declares a single-pole open if the corresponding 52A contact (52AA1) from the circuit breaker deasserts and the open phase detection logic declares that the pole is open.

Select the second option because a 52A contact is available. The relay uses both open phase detection and status information from the circuit breaker to make the most secure decision.

EPO := **52** Pole-Open Detection (52, V)

Pole-Open Time Delay on Dropout

The setting 3POD is the time delay on dropout after the Relay Word bit 3PO deasserts. The setting 3POD stabilizes the ground distance elements during pole scatter when the circuit breaker closes.

3POD := **0.500** Three-Pole Open Dropout Delay (0.000–60 cycles)

POTT Trip Scheme

This application example presents the permissive overreaching transfer trip (POTT) scheme to high-speed trip for faults along the protected cable.

The POTT scheme logic consists of the following sections:

- Current reversal guard logic
- Echo
- Weak infeed logic
- Permission to trip received

Current Reversal Guard Logic

This is a parallel cable application, so you must use current reversal guard. When the reverse-looking elements detect an external fault, the relay does not key the transmitter and ignores reception of a permissive signal from the remote terminal. The Zone 3 Reverse Block Delay (Z3RBD) timer extends these two operations after a current reversal occurs and the reverse-looking elements drop out.

Set the Z3RBD timer to accommodate the following:

- Remote Station R circuit breaker maximum opening time
- Maximum communications channel reset time
- Remote Station R Zone 2 relay maximum reset time

Assume a circuit breaker opening time of 3 cycles, a communications channel reset time of 1 cycle, and remote Zone 2 relay reset time of 1 cycle. The sum of these times gives a conservative setting of 5 cycles for a three-cycle circuit breaker.

Z3RBD := **5.000** Zone 3 Reverse Block Time Delay (0.000–16000 cycles)

Echo

If the circuit breaker is open, or a weak infeed condition exists at the local terminal, the received permissive signal can echo back to the remote relay and cause it to issue a high-speed trip for faults beyond the remote relay Zone 1 reach. The SEL-421 includes logic that echoes the received permissive trip signal back to the remote terminal after specific conditions are satisfied. The echo logic includes timers for blocking the echo logic as well as timers for qualifying the permissive signal.

Use EBLKD (Echo Block Time Delay) to block the echo logic after dropout of local permissive elements. The recommended setting for the EBLKD timer is the sum of the following:

- Remote Station R circuit breaker opening time
- Communications channel round trip time
- Safety margin

Assume a circuit breaker opening time of 3 cycles, a communications channel round trip time of 2 cycles, and a safety margin of 5 cycles. The sum of these times gives a conservative setting of 10 cycles for a three-cycle circuit breaker.

EBLKD := **10.000** Echo Block Time Delay (OFF, 0.000–16000 cycles)

The echo time delay, setting ETDPU, makes certain that the reverse-looking elements at the receiving end have sufficient time to operate and block the received echo signal for external faults behind the remote terminal. The delay also guards the echo and weak infeed logic against noise bursts that can occur on the communications channel during close-in external faults.

Because of the brief duration of noise bursts and the pickup time for the reverse-looking elements, a received signal must be present for a short time to allow the POTT scheme to echo the permissive signal back to the remote terminal. The ETDPU (Echo Time Delay Pickup) timer specifies the time a permissive trip signal must be present. The ETDPU setting depends upon your communications equipment, but a conservative setting for this timer is 2 cycles.

ETDPU := **2.000** Echo Time Delay Pickup (OFF, 0.000–16000 cycles)

The setting EDURD (Echo Duration Time Delay) limits the duration of the echoed permissive signal. Once an echo signal initiates, it should remain for a minimum period of time and then stop, even if a terminal receives a continuous permissive signal. This cessation of the echo signal prevents the permissive trip signal from latching between the two terminals. Assume a 3-cycle circuit breaker at the remote terminal and a 1-cycle channel delay. The sum of these two is a setting of 4 cycles.

EDURD := **4.000** Echo Duration Time Delay (0.000–16000 cycles)

Weak Infeed

The SEL-421 provides weak-infeed logic to high-speed trip both line terminals for internal faults near the weak terminal. The weak terminal echoes the permissive signal back to the strong terminal and causes the strong terminal to trip. The weak terminal trips by converting the echoed permissive signal to a trip signal if specific conditions are satisfied.

This application example does not use the weak-infeed feature.

EWFC := **N** Weak Infeed Trip (Y, N, SP)

Permission to Trip Received

Assign a control input to receive trip permission from the remote terminal.

PT1 := **IN103** General Permissive Trip Received (SELOGIC control equation)

Trip Logic

Trip logic configures the relay for tripping. There are four trip logic settings components:

- Trip equations
- Trip unlatch options
- Trip timers
- Three-pole tripping enable

Trip Equations

Set these three SELOGIC control equations for tripping:

- TR (unconditional)
- TRCOMM (communications-assisted)
- TRSOTF (SOTF)

TR. The TR SELOGIC control equation determines which protection elements cause the relay to trip unconditionally. Set TR to the Zone 1 instantaneous distance protection (Z1T), Zone 2 time-delayed distance protection, and the inverse-time overcurrent element (51S1) for backup protection. For information on setting 51S1, see *Selectable Operating Quantity Time Overcurrent Element 1 on page A.1.102*.

TR := **Z1T OR Z2T OR 51S1T** Trip (SELOGIC control equation)

TRCOMM. The TRCOMM SELOGIC control equation determines which elements trip via the communication-assisted tripping logic. In the TRCOMM SELOGIC control equation, set Zone 2 mho phase distance protection (M2P) for phase faults, and Level 2 negative-sequence directional overcurrent element (67Q2) for ground faults.

TRCOMM := **M2P OR 67Q2** Communications-Assisted Trip (SELOGIC control equation)

TRSOTF. The TRSOTF SELOGIC control equation defines which protection elements cause the relay to trip when the SOTF scheme is active. Assertion of these protection elements during the SOTFD time causes the relay to trip instantaneously (see *SOTF Protection on page A.1.99*). Set instantaneous Zone 2 distance protection (M2P and Z2G) and Level 1 phase instantaneous overcurrent element (50P1) in the TRSOTF SELOGIC control equation.

TRSOTF := **M2P OR Z2G OR 50P1** Switch-Onto-Fault Trip (SELOGIC control equation)

Trip Unlatch Options

Unlatch the control output you programmed for tripping (OUT101) after the circuit breaker auxiliary a contacts break the dc current. The SEL-421 provides two methods for unlatching control outputs following a protection trip:

- ULTR—all three poles
- TULO—phase selective

ULTR. Use ULTR, the Unlatch Trip SELOGIC control equation, to unlatch all three poles. Use the default setting to assert ULTR when you push the front-panel target reset button.

ULTR := **TRGTR** Unlatch Trip (SELOGIC control equation)

TULO. Use TULO (Trip Unlatch Option) to select the conditions that cause the SEL-421 to unlatch the control outputs that you programmed for tripping. *Table 1.30* shows the four trip unlatch options for setting TULO.

Table 1.30 Setting TULO Unlatch Trip Options

Option	Description
1	Unlatch the trip when the relay detects that one or more poles of the line terminal are open, and Relay Word bit 3PT has deasserted.
2	Unlatch the trip when the relay detects that the corresponding 52A contact(s) from both circuit breakers (52AA1 and 52AA2) are deasserted.
3	Unlatch the trip when the relay detects that the conditions for Options 1 and 2 are satisfied.
4	Do not run this logic.

Select Option 3 because a 52A contact is available; the relay uses both open phase detection and status information from the circuit breaker to make the most secure decision. For information on the pole-open logic, see *Pole Open Logic on page R.1.21*.

TULO := **3** Trip Unlatch Option (1, 2, 3, 4)

Trip Timers

The SEL-421 provides dedicated timers for minimum trip duration.

Minimum Trip Duration. The minimum trip duration timer setting, TDUR3D, determines the minimum time that Relay Word bit 3PT asserts. For this application example, Relay Word bit 3PT is assigned to OUT101. The corresponding control output closes for TDUR3D time or the duration of the trip condition, whichever is longer.

A typical setting for this timer is 9 cycles.

TDUR3D := **9.000** Three-Pole Trip Minimum Trip Duration Time Delay (2.000–8000 cycles)

Three-Pole Tripping Enable

The relay contains both three-pole and single-pole tripping logic. Set E3PT (Three-Pole Trip Enable) to logical 1 to enable the SEL-421 for three-pole tripping only.

E3PT := **1** Three-Pole Trip Enable (SELOGIC control equation)

Also set the appropriate three-pole tripping SELOGIC control equation for Circuit Breaker BK1.

E3PT1 := **1** Breaker 1 3PT (SELOGIC control equation)

Control Outputs

Main Board

Use SELOGIC control equations to assign the control output for tripping.

Use the main board control outputs for tripping and keying the transmitter of the external teleprotection equipment.

OUT101 := **3PT** (SELOGIC control equation)

OUT102 := **KEY** (SELOGIC control equation)

Example Completed

This completes the application example that describes setting of the SEL-421 for communications-assisted protection of 230 kV underground cables. You can use this example as a guide when setting the relay for similar applications. Analyze your particular power system to determine the proper settings for your application.

Relay Settings

Table 1.31 lists the protection relay settings available for this example.

Table 1.31 Settings for 230 kV Parallel Cables Example (Sheet 1 of 6)

Setting	Description	Entry
General Global Settings (Global)		
SID	Station Identifier (40 characters)	LEWISTON -- 230 kV
RID	Relay Identifier (40 characters)	SEL-421 Relay
NUMBK	Number of Breakers in Scheme (1, 2)	1
BID1	Breaker 1 Identifier (40 characters)	Circuit Breaker 1
NFREQ	Nominal System Frequency (50, 60 Hz)	60
PHROT	System Phase Rotation (ABC, ACB)	ABC
DATE_F	Date Format (MDY, YMD, DMY)	MDY
FAULT	Fault Condition Equation (SELOGIC Equation)	50P1 OR 51S1 OR M2P OR Z2G OR M3P OR Z3G
Current and Voltage Source Selection (Global)		
ESS	Current and Voltage Source Selection (Y, N, 1, 2, 3, 4)	N
Breaker Configuration (Breaker Monitoring)		
EB1MON	Breaker 1 Monitoring (Y, N)	N
BK1TYP	Breaker 1 Trip Type (Single Pole = 1, Three Pole = 3)	3

Table 1.31 Settings for 230 kV Parallel Cables Example (Sheet 2 of 6)

Setting	Description	Entry
Breaker 1 Inputs (Breaker Monitoring)		
52AA1	N/O Contact Input—BK1 (SELOGIC Equation)	IN101
Line Configuration (Group)		
CTRW	Current Transformer Ratio—Input W (1–50000)	200
CTRX	Current Transformer Ratio—Input X (1–50000)	200
PTRY	Potential Transformer Ratio—Input Y (1–10000)	2000
VNOMY	PT Nominal Voltage (L-L)—Input Y (60–300 V secondary)	115
PTRZ	Potential Transformer Ratio—Input Z (1–10000)	2000
VNOMZ	PT Nominal Voltage (L-L)—Input Z (60–300 V secondary)	115
Z1MAG	Positive-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)	0.48
Z1ANG	Positive-Sequence Line Impedance Angle (5.00–90 degrees)	42.5
Z0MAG	Zero-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)	0.96
Z0ANG	Zero-Sequence Line Impedance Angle (5.00–90 degrees)	21.7
EFLOC	Fault Location (Y, N)	Y
LL	Line Length (0.10–999)	25
Relay Configuration Settings (Group)		
E21P	Mho Phase Distance Zones (N, 1–5)	3
E21MG	Mho Ground Distance Zones (N, 1–5)	N
E21XG	Quadrilateral Ground Distance Zones (N, 1–5)	3
ECVT	CVT Transient Detection (Y, N)	N
ESERCMP	Series-Compensated Line Logic (Y, N)	N
ECDTD	Distance Element Common Time Delay (Y, N)	Y
ESOTF	Switch-Onto-Fault (Y, N)	Y
EOOS	Out-of-Step (Y, Y2, N)	N
ELOAD	Load Encroachment (Y, N)	N
E50P	Phase Inst./Def.-Time O/C Elements (N, 1–4)	1
E50G	Res. Ground Inst./Def. Time O/C Elements (N, 1–4)	N
E50Q	Negative-Sequence Inst./Def. Time O/C Elements (N, 1–4)	3
E51S	Selectable Inverse Time O/C Element (N, 1–3)	1
E32	Directional Control (Y, AUTO)	AUTO
ECOMM	Comm.-Assisted Tripping (N, DCB, POTT, POTT2, POTT3, DCUB1, DCUB2)	POTT
EBFL1	Breaker 1 Failure Logic (N, 1, 2)	N
E25BK1	Synchronism Check for Breaker 1 (Y, N)	N
E79	Reclosing (Y, Y1, N)	N

Table 1.31 Settings for 230 kV Parallel Cables Example (Sheet 3 of 6)

Setting	Description	Entry
EMANCL	Manual Closing (Y, N)	N
ELOP	Loss-of-Potential (Y, Y1, N)	Y1
EDEM	Demand Metering (N, THM, ROL)	N
EADVS	Advanced Settings (Y, N)	Y
Mho Phase Distance Element Reach (Group)		
Z1P	Zone 1 Reach (OFF, 0.05–64 Ω secondary)	0.38
Z2P	Zone 2 Reach (OFF, 0.05–64 Ω secondary)	0.58
Z3P	Zone 3 Reach (OFF, 0.05–64 Ω secondary)	0.58
Mho Phase Distance Element Time Delay (Group)		
Z1PD	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z2PD	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z3PD	Zone 3 Time Delay (OFF, 0.000–16000 cycles)	OFF
Quadrilateral Ground Distance Element Reach (Group)		
XG1	Zone 1 Reactance (OFF, 0.05–64 Ω secondary)	0.38
RG1	Zone 1 Resistance (0.05–50 Ω secondary)	1.29
XG2	Zone 2 Reactance (OFF, 0.05–64 Ω secondary)	0.58
RG2	Zone 2 Resistance (0.05–50 Ω secondary)	1.97
XG3	Zone 3 Reactance (OFF, 0.05–64 Ω secondary)	0.58
RG3	Zone 3 Resistance (0.05–50 Ω secondary)	2.46
XGPOL	Quad Ground Polarizing Quantity (I2, IG)	I2
TANG	Nonhomogeneous Correction Angle (–40.0 to +40 degrees)	–2.2
Zero-Sequence Current Compensation Factor (Group)		
k0M1	Zone 1 ZSC Factor Magnitude (AUTO, 0.000–10)	0.385
k0A1	Zone 1 ZSC Factor Angle (–180.0 to +180 degrees)	–46.7
k0M	Forward Zones ZSC Factor Magnitude (0.000–10)	6.105
k0A	Forward Zones ZSC Factor Angle (–180.0 to +180 degrees)	44.5
k0MR	Reverse Zones ZSC Factor Magnitude (0.000–10)	6.105
k0AR	Reverse Zones ZSC Factor Angle (–180.0 to +180 degrees)	44.5
Ground Distance Element Time Delay (Group)		
Z1GD	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z2GD	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z3GD	Zone 3 Time Delay (OFF, 0.000–16000 cycles)	OFF
Distance Element Common Time Delay (Group)		
Z1D	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	0.000
Z2D	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	20.000
Z3D	Zone 3 Time Delay (OFF, 0.000–16000 cycles)	0.000

Table 1.31 Settings for 230 kV Parallel Cables Example (Sheet 4 of 6)

Setting	Description	Entry
SOTF Scheme (Group)		
ESPSTF	Single-Pole Switch-Onto-Fault (Y, N)	N
EVRST	Switch-Onto-Fault Voltage Reset (Y, N)	Y
52AEND	52A Pole Open Time Delay (OFF, 0.000–16000 cycles)	OFF
CLOEND	CLSMON or Single Pole Open Delay (OFF, 0.000–16000 cycles)	10.000
SOTFD	Switch-Onto-Fault Enable Duration (0.500–16000 cycles)	10.000
CLSMON	Close Signal Monitor (SELOGIC Equation)	IN102
Phase Instantaneous Overcurrent Pickup (Group)		
50P1P	Level 1 Pickup (OFF, 0.25–100 A secondary)	9.57
Phase Overcurrent Definite-Time Delay (Group)		
67P1D	Level 1 Time Delay (0.000–16000 cycles)	0.000
Phase Overcurrent Torque Control (Group)		
67P1TC	Level 1 Torque Control (SELOGIC Equation)	1
Negative-Sequence Instantaneous Overcurrent Pickup (Group)		
50Q1P	Level 1 Pickup (OFF, 0.25–100 A secondary)	OFF
50Q2P	Level 2 Pickup (OFF, 0.25–100 A secondary)	0.60
50Q3P	Level 3 Pickup (OFF, 0.25–100 A secondary)	0.40
Negative-Sequence Overcurrent Definite-Time Delay (Group)		
67Q2D	Level 2 Time Delay (0.000–16000 cycles)	0.000
67Q3D	Level 3 Time Delay (0.000–16000 cycles)	0.000
Negative-Sequence Overcurrent Torque Control (Group)		
67Q2TC	Level 2 Torque Control (SELOGIC Equation)	32GF
67Q3TC	Level 3 Torque Control (SELOGIC Equation)	32GR
Selectable Operating Quantity Inverse-Time Overcurrent Element 1 (Group)		
51S1O	51S1 Op. Qty (IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0*n*)[a]	3I2L
51S1P	51S1 O/C Pickup (0.25–16 A secondary)	1.00
51S1C	51S1 Inverse Time O/C Curve (U1–U5)	U3
51S1TD	51S1 Inverse Time O/C Time Dial (0.50–15)	3.72
51S1RS	51S1 Inverse Time O/C EM Reset (Y, N)	Y
51S1TC	51S1 Torque Control (SELOGIC Equation)	32GF
Zone/Level Direction (Group)		
DIR3	Zone/Level 3 Directional Control (F, R)	R
Directional Control (Group)		
ORDER	Ground Dir. Element Priority (combine Q, V, I)	Q

Table 1.31 Settings for 230 kV Parallel Cables Example (Sheet 5 of 6)

Setting	Description	Entry
Pole Open Detection (Group)		
EPO	Pole Open Detection (52, V)	52
SPOD	Single Pole Open Dropout Delay (0.000–60 cycles)	0.500
3POD	Three Pole Open Dropout Delay (0.000–60 cycles)	0.500
POTT Trip Scheme (Group)		
Z3RBD	Zone 3 Reverse Block Time Delay (0.000–16000 cycles)	5.000
EBLKD	Echo Block Time Delay (OFF, 0.000–16000 cycles)	10.000
ETDPU	Echo Time Delay Pickup (OFF, 0.000–16000 cycles)	2.000
EDURD	Echo Duration Time Delay (0.000–16000 cycles)	4.000
EWFC	Weak Infeed Trip (Y, N, SP)	N
PT1	General Permissive Trip Received (SELOGIC Equation)	IN103
Trip Logic (Group)		
TR	Trip (SELOGIC Equation)	Z1T OR Z2T OR 51S1T
TRCOMM	Communications-Assisted Trip (SELOGIC Equation)	M2P OR 67Q2
TRSOTF	Switch-Onto-Fault Trip (SELOGIC Equation)	M2P OR Z2G OR 50P1
DTA	Direct Transfer Trip A-Phase (SELOGIC Equation)	NA
DTB	Direct Transfer Trip B-Phase (SELOGIC Equation)	NA
DTC	Direct Transfer Trip C-Phase (SELOGIC Equation)	NA
BK1MTR	Manual Trip–Breaker 1 (SELOGIC Equation)	OC1 OR PB8_PUL
ULTR	Unlatch Trip (SELOGIC Equation)	TRGTR
ULMTR1	Unlatch Manual Trip–Breaker 1 (SELOGIC Equation)	NOT (52AA1 AND 52AB1 AND 52AC1)
TOPD	Trip During Open Pole Time Delay (2.000–8000 cycles)	2.000
TULO	Trip Unlatch Option (1, 2, 3, 4)	3
Z2GTSP	Zone 2 Ground Distance Time Delay SPT (Y, N)	N
67QGSP	Zone 2 Dir. Negative-Sequence/Residual Overcurrent Single Pole Trip (Y, N)	N
TDUR1D	SPT Min Trip Duration Time Delay (2.000–8000 cycles)	6.000
TDUR3D	3PT Min Trip Duration Time Delay (2.000–8000 cycles)	9.000
E3PT	Three-Pole Trip Enable (SELOGIC Equation)	1
E3PT1	Breaker 1 3PT (SELOGIC Equation)	1

Table 1.31 Settings for 230 kV Parallel Cables Example (Sheet 6 of 6)

Setting	Description	Entry
ER	Event Report Trigger (SELogic Equation)	R_TRIG M2P OR R_TRIG Z2G OR R_TRIG 51S1 OR R_TRIG M3P OR R_TRIG Z3G
Main Board (Outputs)		
OUT101	(SELogic Equation)	3PT
OUT102	(SELogic Equation)	KEY

[a] Parameter n is 1 for BK1, 2 for BK2, and L for Line.

Out-of-Step Logic Application Examples

The SEL-421 features OOS (out-of-step) logic for the following two functions:

- OSB (out-of-step blocking) logic blocks phase distance elements and Zone 1 ground distance elements during power swings.
- OST (out-of-step tripping) logic trips the circuit breaker(s) during unstable swings.

There are two application examples that explain how to apply OOS logic: an out-of-step blocking scheme and an out-of-step tripping and blocking scheme. The examples provide detailed setting procedures for a 5 A relay.

These examples are for three-pole tripping in a 500 kV power system. Applications for single-pole tripping are similar. Refer to *Figure 1.28* for a one-line diagram of the 500 kV system.

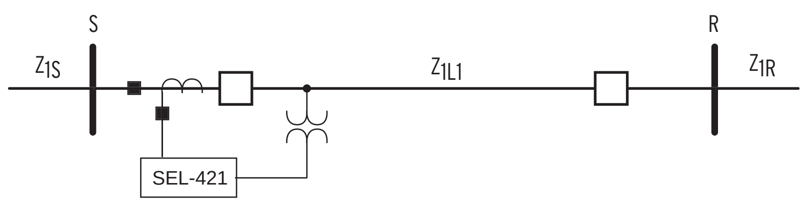


Figure 1.28 500 kV Power System

Power System Parameters

Table 1.32 lists the power system parameters.

Table 1.32 Positive-Sequence Impedances (Secondary) (Sheet 1 of 2)

Parameter	Value
Line impedances:	
Z_{1L1}	8.00 Ω ∠87.6° secondary (Z1MAG Ω ∠Z1ANG°)
Zone 2 Phase Distance Reach:	
Z2P	9.60 Ω secondary
Source S impedances:	
Z_{1S}	8.8 Ω ∠88° secondary
Source R impedances:	
Z_{1R}	3.52 Ω ∠88° secondary

Table 1.32 Positive-Sequence Impedances (Secondary) (Sheet 2 of 2)

Parameter	Value
Nominal frequency (f_{nom})	60 Hz
Nominal current (I_{nom})	5 A secondary
Line Length	100 miles

Out-of-Step Blocking

This example demonstrates setting OSB function for both EOOS = Y and EOOS = Y2. Use this logic to discriminate between power swings and faults to prevent unwanted distance element trips. This application example assumes that you have set the phase-to-phase mho distance element Zone 2 reach. First, enable the OOS logic. Next, calculate the impedance reach settings for Zones 6 and 7 (R1R6, R1R7, X1T6, and X1T7), and then calculate OSBD (out-of-step block time delay). All of the OOS settings appear in *Table 1.33* and *Table 1.34* at the end of this example.

Enable OOS Logic

NOTE: The relay automatically calculates and hides settings when you set EADVS to N and EOOST to N. Table 1.33 lists these settings.

Access Group settings to enable the out-of-step logic.

EOOS := **Y** Out-of-Step (Y, N)

You do not need to enable the Advanced Settings for this application example.

EADVS := **N** Advanced Settings (Y, N)

Out-of-Step Tripping

Disable the OST logic for this particular application example.

EOOST := **N** Out-of-Step Tripping (N, I, O)

Phase Distance Element Blocking

OSB logic blocks phase distance protection during a swing when the measured positive-sequence impedance enters the operating characteristics of the phase distance elements (see Zone 1 and Zone 2 in *Figure 1.29*). In practice, it is not necessary to block all zones. In this application example, the OSB logic blocks zones that generate instantaneous tripping. The OSB logic blocks instantaneous Zone 1 and Zone 2 (Zone 2 is part of the communications-assisted tripping scheme).

The OSB logic typically supervises forward-looking Zones 1 and 2 because the operation time of these two zones is ordinarily shorter than the time period during which the impedance of a power swing resides in these protection zones. For example, if the period of a swing is 1.5 seconds, OSB logic should supervise instantaneous Zone 1 and communications-assisted Zone 2.

During a power swing, the relay typically does not block overreaching zones of protection that provide time-delayed tripping. Do not block reverse-looking Zone 3 when this zone serves as a starting element for the DCB (directional comparison blocking) scheme or when this zone provides current reversal guard for the POTT (permissive overreaching transfer tripping) scheme. For example, if the OSB logic inhibits the DCB blocking signal during swings that pass behind the local relay, over-tripping can occur at the remote terminal. If a power swing enters both the local reverse-looking Zone 3 and the remote overreaching Zone 2, high-speed tripping occurs at the remote terminal because OSB logic removes the local Zone 3 element DCB scheme block.

Set the relay to block Zone 1 and Zone 2.

OOSB1 := **Y** Block Zone 1 (Y, N)

OOSB2 := **Y** Block Zone 2 (Y, N)

OOSB3 := **N** Block Zone 3 (Y, N)

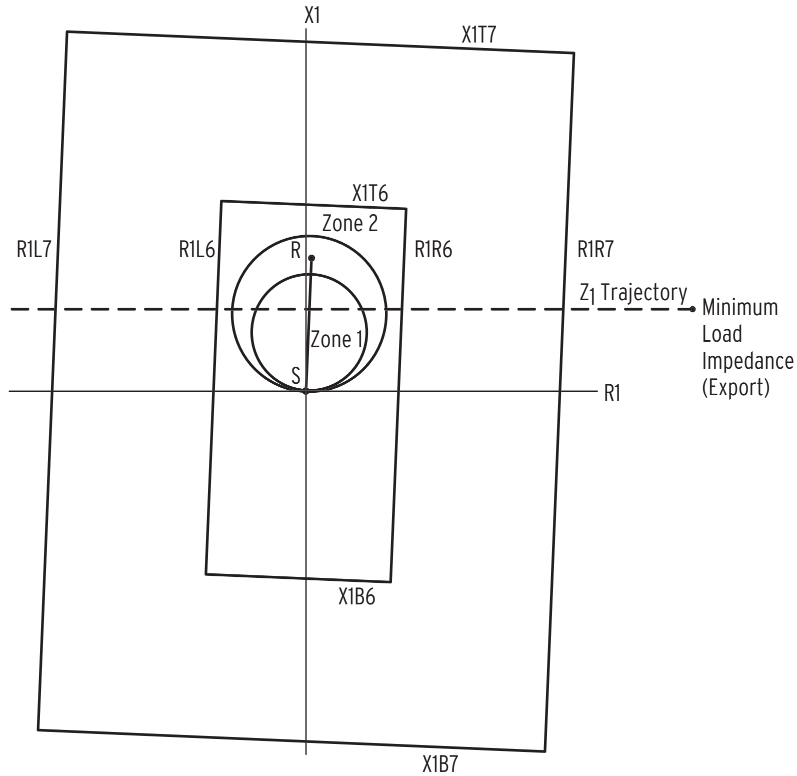


Figure 1.29 OOS Characteristic Settings Parameters

Zone 6 and Zone 7 Impedance Settings

The OOS logic uses two zones of concentric polygons, outer Zone 7 and inner Zone 6 (see *Figure 1.29*). The relay uses Zone 6 and Zone 7 for OOS logic timing to differentiate between power swings and faults. The relay measures a traveling positive-sequence impedance locus (Z_1) in Zone 6 and Zone 7 when a power swing or fault occurs. Two factors affect the Zone 6 and Zone 7 impedance settings:

- The outermost overreaching zone of phase distance protection that you want to block.
- The load impedance that the relay measures during maximum load (minimum load impedance locus).

NOTE: This settings philosophy provides the most time for the relay to decide whether a fault or a power swing has occurred.

Set inner Zone 6 (X1T6, R1R6, X1B6, and R1L6) to encompass the outermost zone of phase distance protection that you have selected for out-of-step blocking. Set Zone 7 so that the closest minimum load impedance locus is outside the Zone 7 characteristic for all loading conditions.

Resistance Blinders

Zone 2 is the outermost characteristic for this particular example. Include a safety margin (20 percent for this example).

$$
\begin{aligned}
R1R6 &= 1.2 \bullet \frac{Z2P}{2 \bullet \sin(Z1ANG)} \\
&= 1.2 \bullet \frac{9.60\ \Omega}{2 \bullet \sin(87.6°)} \\
&= 5.77\ \Omega
\end{aligned}
$$

Equation 1.69

where:

Z2P = Zone 2 mho phase distance element reach (see *Table 1.32*).

R1R6 := **5.77** Zone 6 Resistance—Right (0.05–70 Ω secondary)

Set Zone 7 outer resistance blinders according to maximum load. In other words, set the Zone 7 outer right-hand resistance blinder just inside the corresponding minimum export load impedance locus (maximum load locus). The maximum load current is 2.41 A secondary, determined from load studies. The corresponding line-to-neutral voltage during maximum load at Station S is 61.44 V secondary.

$$
\begin{aligned}
I_{L(max)} &= 2.41\ A \\
V_{LN} &= 61.44\ V
\end{aligned}
$$

Determine the minimum load impedance that the relay measures:

$$
\begin{aligned}
Z_{L_{min}} &= \frac{V_{LN}}{I_{L(MAX)}} \\
&= \frac{61.44\ V}{2.41\ A} \\
&= 25.49\ \Omega
\end{aligned}
$$

Equation 1.70

Assume that the maximum load angle is ±45°. Use trigonometry to calculate R1R7, which is the distance from the origin to the right-hand resistance blinder along line OP, the c side of the right triangle (see *Figure 1.30*). The resistance blinders are parallel to the line characteristic impedance Z_{1L1}, for which the angle is setting Z1ANG.

$$
\cos(A) = \frac{c}{b}
$$

Equation 1.71

where:

A = 45° + (90°–∠Z1ANG)
b = $Z_{L(min)}$
c = setting R1R7

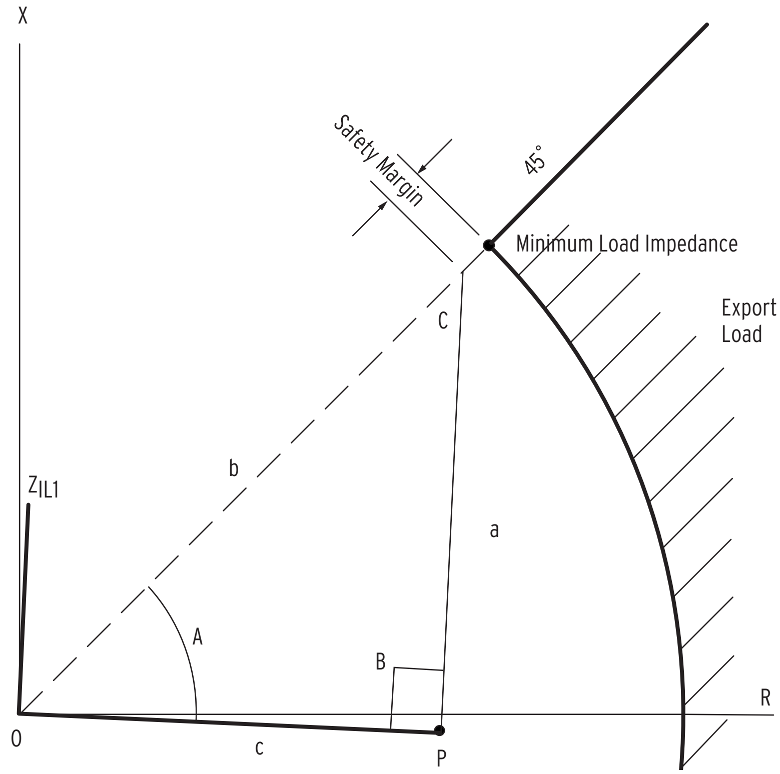


Figure 1.30 Calculating Setting R1R7

Rearrange *Equation 1.71* and multiply by a safety factor of 90 percent to calculate R1R7.

$$\begin{aligned} R1R7 &= 0.9 \cdot Z_{L(min)} \cdot \cos(A) \\ &= 0.9 \cdot Z_{L(min)} \cdot \cos[45° + (90° - Z1ANG)] \\ &= 0.9 \cdot 25.49 \cdot \cos[45° + (90° - 87.6°)] \\ &= 0.9 \cdot 25.49 \cdot \cos(47.4°) \\ &= 15.53\ \Omega \end{aligned}$$

Equation 1.72

R1R7 := **15.53** Zone 7 Resistance—Right (0.05–70 Ω secondary)

Reactance Lines

Zone 6 inner reactance lines X1T6 and X1B6 should completely encompass the outermost zone of phase distance protection that you want to block from tripping during a power swing. Include a safety margin (20 percent).

$$\begin{aligned} X1T6 &= 1.2 \cdot Z2P \\ &= 1.2 \cdot 9.60\ \Omega \\ &= 11.52\ \Omega \end{aligned}$$

Equation 1.73

where:

Z2P = Zone 2 mho phase distance element reach

X1T6 := **11.52** Zone 6 Reactance—Top (0.05–96 Ω secondary)

The distance between Zones 6 and 7 top reactance lines should equal the distance between Zones 6 and 7 right-hand resistance blinders.

NOTE: The value for X1T7 must be at least 0.1 Ω greater than that for X1T6.

$$\begin{aligned} X1T7 &= X1T6 + (R1R7 - R1R6) \\ &= 11.52\ \Omega + (15.53\ \Omega - 5.76\ \Omega) \\ &= 21.29\ \Omega \end{aligned}$$ **Equation 1.74**

X1T7 := **21.29** Zone 7 Reactance—Top (0.05–96 Ω secondary)

Out-of-Step Block Time Delay

When the Z_1 impedance locus initially moves inside Zone 7, the relay starts the OSBD (out-of-step block time delay) timer. The Z_1 impedance trajectory is shown in *Figure 1.31* for the case of $|E_A| = |E_B|$ (E_A is the voltage at Node A and E_B is the voltage at Node B). The OSBD timer detects slow swings. If the OSBD timer expires before the Z_1 trajectory enters Zone 6, the relay detects a power swing blocking condition.

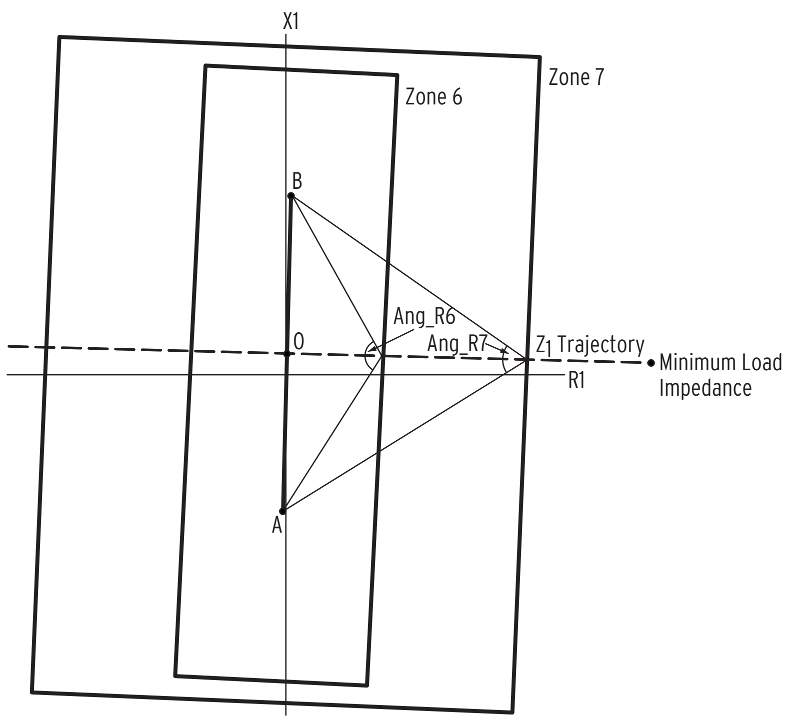


Figure 1.31 Swing Trajectory to Determine the OSBD Setting

Use *Equation 1.75* through *Equation 1.78* to calculate the OSBD setting. These equations are derived from the impedance trajectory shown in *Figure 1.31*. Line section AB is the transfer impedance, Z_T. The horizontal dashed line represents the trajectory of the power swing perpendicular to line section AB. The trajectory passes through the midpoint of line section AB.

$$Z_T = Z_{1S} + Z_{1L1} + Z_{1R}$$ **Equation 1.75**

where:

Z_T = transfer impedance
$Z1_S$ = positive-sequence source impedance
$Z1_{L1}$ = positive-sequence impedance for Line 1
$Z1_R$ = positive-sequence remote impedance

$$\begin{aligned}
\text{Ang_R6} &= 2 \cdot \operatorname{atan}\left[\frac{\frac{|Z_T|}{2}}{(R1R6)}\right] \\
&= 2 \cdot \operatorname{atan}\left[\frac{\frac{|8.8\ \Omega\angle 88° + 8.00\ \Omega\angle 87.6° + 3.52\ \Omega\angle 88°|}{2}}{5.77\ \Omega}\right] \\
&= 120.9°
\end{aligned}$$

Equation 1.76

$$\begin{aligned}
\text{Ang_R7} &= 2 \cdot \operatorname{atan}\left[\frac{\frac{|Z_T|}{2}}{R1R7}\right] \\
&= 2 \cdot \operatorname{atan}\left[\frac{\frac{|8.8\ \Omega\angle 88° + 8.00\ \Omega\angle 87.6° + 3.52\ \Omega\angle 88°|}{2}}{15.53\ \Omega}\right] \\
&= 66.4°
\end{aligned}$$

Equation 1.77

A typical stable swing frequency is f_{slip} = 5 Hz. Use this value in *Equation 1.78* to find setting OSBD.

$$\begin{aligned}
\text{OSBD} &= \frac{(\text{Ang_R6} - \text{Ang_R7}) \cdot f_{nom}}{\frac{360°}{\text{cycle}} \cdot f_{slip}} \text{ cycles} \\
&= \frac{(120.9° - 66.4°) \cdot 60\ \text{Hz}}{\frac{360°}{\text{cycle}} \cdot 5\ \text{Hz}} \text{ cycles} \\
&= 1.82 \text{ cycles}
\end{aligned}$$

Equation 1.78

where:

f_{nom} = nominal power system frequency (Hz)
f_{slip} = maximum slip frequency (Hz)

The OSBD timer settings are in increments of 0.125 cycle; round up to the nearest valid relay setting.

OSBD := **1.875** Out-of-Step Block Time Delay (0.500–8000 cycles)

Latch Out-of-Step Blocking

The SEL-421 automatically resets the OSB logic if this logic asserts for more than two seconds while the positive-sequence impedance locus is inside Zone 7. During an unstable power swing, the relay also resets the OSB logic each time the swing impedance exits Zone 7. You can latch on the OSB function during an unstable power swing to continue blocking the distance elements if the power swing impedance locus moves outside of Zone 7 and before it comes back inside Zone 7 on its next swing cycle. If latched, the OSB logic resets one second after the power system stops the out-of-step. Latching the OSB gives you an advantage in that the relay can successfully block uncontrolled distance element operations if a fault occurs when the unstable swing impedance is outside of Zone 7. Relay elements detect internal faults that occur during a power swing and take the appropriate action (unblock).

OSBLTCH := **Y** Latch Out-of-Step Blocking (Y, N)

Out-of-Step Unblocking

The relay disables out-of-step blocking automatically when a fault occurs during a power swing. Therefore, the distance protection successfully detects all fault types and trips the circuit breaker(s) during internal faults.

Out-of-Step Unblocking During Three-Phase Faults. The trajectories of a three-phase fault and a power swing appear the same to phase distance elements because both a three-phase fault and a power swing consist of positive-sequence quantities only (V_1 and I_1). Therefore, if a power swing evolves into an internal three-phase fault, typical OSB logic cannot detect the occurrence of the balanced fault. The SEL-421 includes an additional set of inner blinders to provide proper detection of the internal three-phase fault (see *Figure 1.32*). If the positive-sequence impedance resides between these blinders for a specific duration, OSB logic unblocks. The relay calculates this duration (UBOSBD) each time the power swing enters Zone 7. A short timer setting is adequate for fast swings, but the relay needs a longer timer setting for slow power swings. For example, if the positive-sequence impedance passes gradually between the two inner blinders during a slow swing, a short timer setting would cause unwanted tripping.

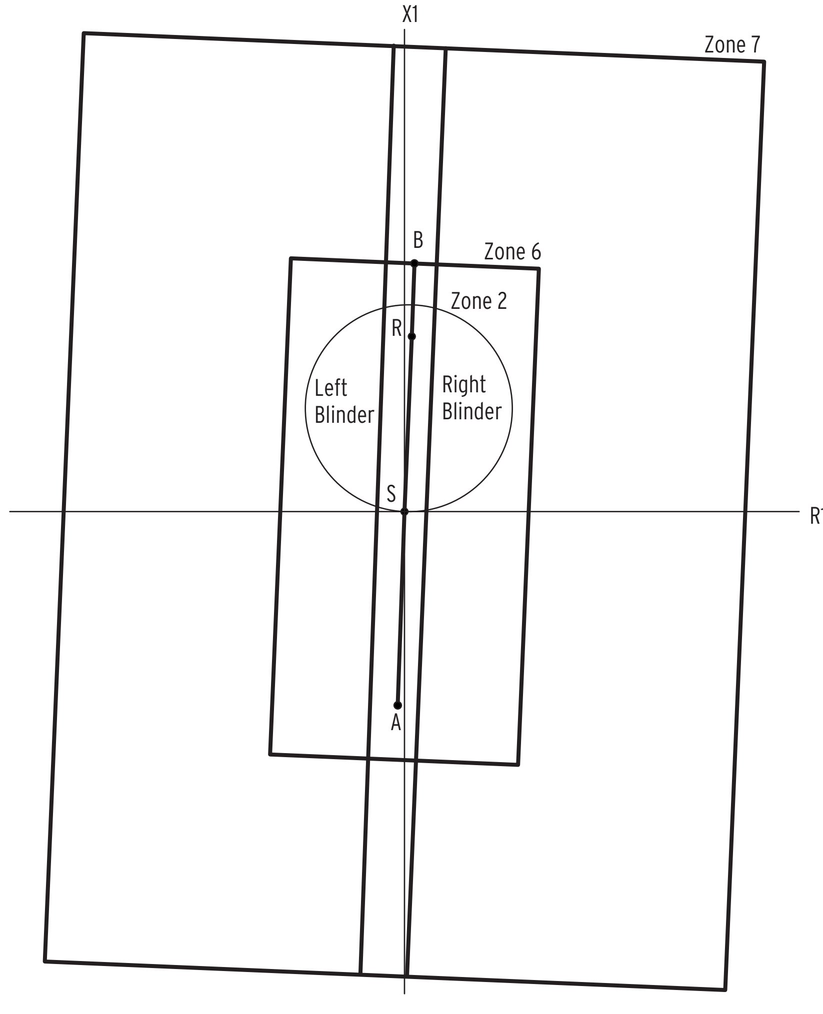


Figure 1.32 Inner Blinders

The UBOSBD timer length is the expected duration of the power swing within the inner blinders. The relay bases the calculation on the actual time required for the swing to traverse from Zone 7 to Zone 6, before entering the inner blinders. If the swing remains inside the inner blinders for a period greater than UBOSBD, an unblock signal asserts.

You can increase the adaptive UBOSBD timer calculation in multiples of setting UBOSBF. If UBOSBF is a multiplier of one, the relay calculates the expected time to traverse across the inner blinders based on the rate at which the swing moved from Zone 7 to Zone 6. Similarly, if UBOSBF is a multiplier of four, the relay multiplies UBOSBD by four.

Out-of-Step Unblocking During Unbalanced Faults. The SEL-421 treats Zone 1 phase and ground distance elements differently than phase distance elements of other zones.

Operation of either of two negative-sequence directional elements, 67QUBF (forward-looking), or 67QUBR (reverse-looking), defeats the OSB logic and unblocks the phase distance elements (except the Zone 1 elements if EOOS = Y) when an unbalanced fault occurs following a power swing. The 67QUBF element unblocks forward-looking zones and 67QUBR unblocks reverse-looking zones.

When EOOS = Y, the relay supervises the 67QUBF and 67QUBR (67Q1T for Zone 1) elements with negative-sequence pickup setting 50QUBP (50Q1P for Zone 1). When you set the 50QUBP (50Q1P for Zone 1) pickup level to other than OFF, the level of negative sequence current exceeds the 50QUBP (50Q1P for Zone 1) setting threshold, and the relay has made a valid directional decision (32 elements), the relay asserts either the 67QUBF (67Q1T for Zone 1) or the 67QUBR directional element after time delay setting UBD (67Q1D for Zone 1 or 1.5 cycles when EOOS = Y2). In this manner the relay removes out-of-step blocking for phase distance elements (other than Zone 1 elements if EOOS = Y) during unbalanced faults.

The 50QUBP setting is an advanced setting and must be coordinated with the distance protection for the protected line. Setting UBD is also an advanced setting; set the UBD timer to coordinate clearing times with protection external to the protected line.

If you set EOOS = Y, do the following for out-of-step unblocking on unbalanced faults:

Step 1. Set EADVS := **Y** to enable advanced settings.

Step 2. Set the negative sequence unblocking element pickup with setting 50QUBP (Negative-Sequence Current Supervision).

Coordinate with line distance protection.

Step 3. Set the unblock delay timer UBD (Negative-Sequence Current Unblock Delay).

Coordinate clearing times with other protection.

If you set EOOS = Y2, set the positive-sequence current restraint factor a2 to compensate for highly unbalanced systems. Typically, you can apply the default values (see *Detailed Settings Description on page R.1.30* and *Table 1.29 on page R.1.29*). No other settings are required.

When EOOS = Y or Y2, if a power swing center is on the line under protection, the Zone 1 distance elements at one or both terminals may operate if the OSB is removed. For example, during an unstable swing, if an external A-phase ground fault occurs beyond the remote terminal R in *Figure 1.28*, the A-phase ground distance elements at both terminals operate correctly; that is, A-phase distance element picks up in Zone 2 at the S terminal, and in reverse Zone 3 at the R terminal. However, all Zone 1 phase and ground distance elements at both terminals may also operate if the swing center is within the Zone 1 reach and a negative-sequence overcurrent element removes the OSB. The undesirable operations of Zone 1 elements may trip all three phases at both terminals for an external A-phase fault.

When setting EOOS = Y, the SEL-421 uses a directional negative-sequence element (67Q1T) to supervise the out-of-step blocking of Zone 1 distance elements. 67Q1T is independent from 67QUBF and 67QUBR, which are used to defeat the OSB for distance elements other than Zone 1 elements. This separation gives you a choice to control the Zone 1 element operations during an unstable swing situation.

When setting EOOS = Y2, the relay uses 67QUBF to also supervise the Zone 1 distance elements. In this case, there is no separation between the Zone 1 elements and the other zone elements.

If your application requires this separation (i.e., to block the Zone 1 distance elements for internal faults during a power swing with EOOS = Y2), add the following settings:

Set L (Logic settings)

PSV01 := **(MAG1 OR XAG1 OR MAB1) AND NOT OSB1**

PSV02 := **(MBG1 OR XBG1 OR MBC1) AND NOT OSB1**

PSV03 := **(MCG1 OR XCG1 OR MCA1) AND NOT OSB1**

Trip equation (Group settings)

TR:= **PSV01 OR PSV02 OR PSV03**

With these settings, the Zone 1 distance elements are blocked for as long as OSB1 is asserted. The relay relies on Zone 2 overreaching elements together with the POTT scheme to trip for internal faults.

For those applications (EOOS = Y) that allow the relay to operate for any internal and external faults on a system during a power swing, set the 67Q1T element similar to the 67QUBF element:

50Q1P := **same value as of 50QUBP** Level 1 Pickup (OFF, 0.25–100 amps sec.)

67Q1D := **same value as of UBD** Level 1 Time Delay (0.000–16000 cycles)

67Q1TC := **1** Level 1 Torque Control (SELOGIC Equation)

For those applications that require the relay only trip for internal faults during a power swing, disable the 67Q1T element by setting 50Q1P to OFF or E50Q = N. This way (EOOS = Y), the Zone 1 distance elements are always blocked by the OSB logic. The relay relies on Zone 2 overreaching elements together with the POTT scheme to make high-speed trips for internal faults.

Example Completed

This completes the application example that describes setting the SEL-421 for out-of-step blocking. Analyze your particular power system to determine the appropriate settings for your application.

Relay Settings

Table 1.33 lists the settings that the relay automatically calculates and hides when you set EADVS to N and EOOST to N.

Table 1.33 Automatically Calculated/Hidden Settings

Setting	Description	Default Setting
X1B7	Zone 7 Reactance—Bottom (–0.05 to –96 Ω secondary)	X1B7 = –X1T7
X1B6	Zone 6 Reactance—Bottom (–0.05 to –96 Ω secondary)	X1B6 = –X1T6
R1L7	Zone 7 Resistance—Left (–0.05 to –70 Ω secondary)	R1L7 = –R1R7
R1L6	Zone 6 Resistance—Left (–0.05 to –70 Ω secondary)	R1L6 = –R1R6
OSTD	Out-of-Step Trip Delay (0.500–8000 cycles)	0.500
50ABCP	Positive-Sequence Current Supervision (1.00–100 A secondary)	50ABCP = 0.2 • I_{nom}
50QUBP	Negative-Sequence Current Supervision (OFF, 0.50–100 A secondary)	OFF
UBD[a]	Negative-Sequence Current Unblock Delay (0.500–120 cycles)	0.500
UBOSBF[a]	Out-of-Step Angle Unblock Rate (1–10)	4

[a] EOOS = Y

Table 1.34 and *Table 1.35* list the protection relay settings available in this example.

Table 1.34 Relay Configuration (Group)

Setting	Description	Entry
EOOS	Out-of-Step (Y, Y2, N)	Y
EADVS	Advanced Settings (Y, N)	N

Table 1.35 Out-of-Step Tripping/Blocking

Setting	Description	Entry
OOSB1	Block Zone 1 (Y, N)	Y
OOSB2	Block Zone 2 (Y, N)	Y
OOSB3	Block Zone 3 (Y, N)	N
OSBD	Out-of-Step Block Time Delay (0.500–8000 cycles)	1.875
OSBLTCH	Latch Out-of-Step Blocking (Y, N)	Y
EOOST	Out-of-Step Tripping (N, I, O)	N
X1T7	Zone 7 Reactance—Top (0.05 to 96 Ω secondary)	21.29
X1T6	Zone 6 Reactance—Top (0.05 to 96 Ω secondary)	11.52
R1R7	Zone 7 Resistance—Right (0.05 to 70 Ω secondary)	15.53
R1R6	Zone 6 Resistance—Right (0.05 to 70 Ω secondary)	5.77
X1B7	Zone 7 Reactance—Bottom (–0.05 to –96 Ω secondary)	–21.29
X1B6	Zone 6 Reactance—Bottom (–0.05 to –96 Ω secondary)	–11.52
R1L7	Zone 7 Resistance—Left (–0.05 to –70 Ω secondary)	–15.53
R1L6	Zone 6 Resistance—Left (–0.05 to –70 Ω secondary)	–5.77
50ABCP	Positive-Sequence Current Supervision (1.00–100 A secondary)	1.00
50QUBP[a]	Negative-Sequence Current Supervision (OFF, 0.50–100 A secondary)	OFF
UBD[a]	Negative-Sequence Current Unblock Delay (0.500–120 cycles)	0.500
UBOSBF	Out-of-Step Angle Unblock Rate (1–10)	4
50Q1P[a]	Level Pickup (OFF, 0.25–100 amps sec.)	OFF
67Q1D[a]	Level 1 Time Delay (0.000–16000 cycles)	0.000
67Q1TC[a]	Level 1 Torque Control (SELOGIC Equation)	1

[a] EOOS = Y

Out-of-Step Tripping

This example demonstrates how to set the OST (out-of-step tripping) function. Use OST logic to detect an unstable power swing and trip the local terminal. With OST logic, you can split the power system at predetermined locations after an OST condition occurs.

The Zone 6 and Zone 7 settings for the OST logic depend on the positive sequence impedance (Z_1) trajectory of the power swing (see *Figure 1.33*). Set inner Zone 6 at the point along the trajectory where the power system cannot regain stability. Set Zone 7 so that the impedance due to maximum load conditions is outside the Zone 7 characteristic for all loading conditions.

NOTE: This setting philosophy provides the most time for the relay to decide whether the power swing is unstable.

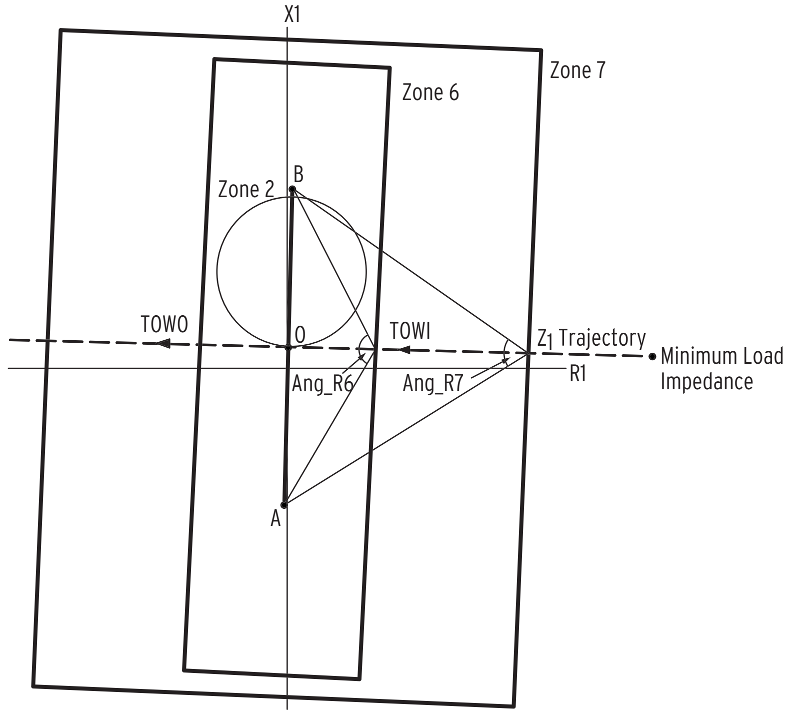


Figure 1.33 OST Characteristics

To configure the OOS logic for out-of-step tripping, enable the OOS logic. Next, calculate the impedance reach settings for Zones 6 and 7 (R1R6, R1R7, X1T6, and X1T7), and then calculate OSTD (out-of-step trip delay) and OSBD (out-of-step block time delay). All of the OOS settings appear in *Table 1.37* and *Table 1.38*.

Enable OOS Logic

Access Group settings to enable the out-of-step logic.

EOOS := **Y** Out-of-Step (Y, Y2, N)

NOTE: Table 1.36 lists the settings that the relay automatically calculates and hides when you set EADVS to N.

You do not need to enable the Advanced Settings for this application example.

EADVS := **N** Advanced Settings (Y, N)

Out-of-Step Tripping

When the positive-sequence impedance locus enters Zone 7, both OOS logic timers (OSBD and OSTD) start (see *Figure 1.33*). If OSTD expires before OSBD and Zone 6 asserts, the relay declares an out-of-step tripping condition. Enable the relay to trip when Zone 6 drops out (Trip-On-the-Way-Out). See *Out-of Step Tripping and Blocking on page A.1.129* for OSTD and OSBD calculations.

EOOST := **O** Out-of-Step Tripping (N, I, O)

where:

I = Enable out-of-step tripping (Trip-On-the-Way-In)
O = Enable out-of-step tripping (Trip-On-the-Way-Out)
N = Disable out-of-step tripping

Phase Distance Element Blocking

Enable the OSB function to prevent tripping when the positive-sequence impedance locus enters the Zone 1 and Zone 2 distance protection characteristics during an unstable power swing. Therefore, in this application example, the relay trips after the Z_1 impedance locus exits Zone 6 (Zone 6 drops out).

Block Zone 1 and Zone 2 distance protection elements during power swings.

OOSB1 := **Y** Block Zone 1 (Y, N)

OOSB2 := **Y** Block Zone 2 (Y, N)

OOSB3 := **N** Block Zone 3 (Y, N)

Zone 6 and Zone 7 Impedance Settings

The purpose of this OOS application example is to configure the relay to trip when the power system reaches a critical angle limit to prevent system collapse. Thus, the Zone 6 impedance setting differs from *Out-of-Step Blocking on page A.1.116*.

Resistance Blinders

If the angle of the power swing Z_1 trajectory passes 120 degrees with respect to the transfer impedance, the power system cannot recover. The transfer impedance is the total impedance of the power system (line AB in *Figure 1.33*). Set the Zone 6 right-hand inner resistance blinder R1R6 so Ang_R6 equals 120 degrees. Rearrange *Equation 1.76* as shown in *Equation 1.79*:

$$\begin{aligned} R1R6 &= \frac{\frac{|Z_T|}{2}}{\tan\left(\frac{Ang\_R6}{2}\right)} \\ &= \frac{\frac{|8.80\ \Omega\angle 88° + 8.00\ \Omega\angle 87.6° + 3.52\ \Omega\angle 88°|}{2}}{\tan\left(\frac{120°}{2}\right)} \\ &= \frac{10.16}{\tan\left(\frac{120°}{2}\right)} \\ &= 5.87\ \Omega \end{aligned}$$

Equation 1.79

R1R6 := **5.87** Zone 6 Resistance—Right (0.05 to 70 Ω secondary)

Use the minimum load impedance $Z_{L(min)}$ (*Equation 1.70*) and the 90 percent safety margin criterion (see *Equation 1.72*) applied earlier in *Resistance Blinders on page A.1.117* to set the Zone 7 right-hand resistance blinder.

$$\begin{aligned} R1R7 &= 0.9 \bullet Z_{L(min)} \bullet \cos[45° + (90° - Z1ANG)] \\ &= 0.9 \bullet 25.49 \bullet \cos[45° + (90° - 87.6°)] \\ &= 0.9 \bullet 25.49 \bullet \cos[47.4°] \\ &= 15.53\ \Omega \end{aligned}$$

R1R7 := **15.53** Zone 7 Resistance—Right (0.05–70 Ω secondary)

Reactance Lines

Set the reactance lines equal to the maximum values to help the relay detect power swings far from the relay location.

Set the Zone 7 top reactance line equal to the maximum setting.

X1T7 := **96** Zone 7 Reactance—Top (0.05–96 Ω secondary)

Set the Zone 6 top reactance line to the maximum setting minus one ohm.

$$\begin{aligned} X1T6 &= X1T7 - 1\ \Omega \\ &= 96\ \Omega - 1\ \Omega \\ &= 95\ \Omega \end{aligned}$$

Equation 1.80

X1T6 := **95** Zone 6 Reactance—Top (0.05–96 Ω secondary)

Out-of Step Tripping and Blocking

The OOS logic uses two zones of concentric polygons, outer Zone 7 and inner Zone 6 (see *Figure 1.33*). The relay uses Zone 6 and Zone 7 for OOS logic timing to differentiate OOS blocking conditions, OOS tripping conditions, and faults. The relay measures a traveling positive-sequence impedance locus (Z_1) in Zone 6 and Zone 7 when a power swing or fault occurs. When the impedance locus initially moves inside Zone 7, the relay starts two OOS logic timers. One OOS timer detects OOS blocking conditions (OSBD), while the other timer detects OOS tripping conditions (OSTD).

NOTE: You must set OSTD shorter than OSBD by at least a half cycle.

The OOS logic declares a blocking condition if OSBD expires before the positive-sequence impedance locus enters Zone 6. The logic declares a tripping condition if OSTD expires and the positive-sequence impedance locus enters Zone 6 prior to OSBD timing out.

Trip-On-Way-In/Trip-On-Way-Out

You can select one of two methods to trip during an unstable swing. You can enable the relay to trip if OSTD expires and the positive-sequence impedance enters Zone 6; this method is Trip-On-the-Way-In (TOWI in *Figure 1.33*). The relay asserts Relay Word bits OSTI and OST for a Trip-On-the-Way-In condition.

You can also enable the relay to trip if OSTD expires and the positive-sequence impedance enters and exits Zone 6; this second method is Trip-On-the-Way-Out (TOWO in *Figure 1.33*). The relay asserts Relay Word bits OSTO and OST for a Trip-On-the-Way-Out condition. Relay Word bit OST is the OR combination of OSTI and OSTO (see *Out-of-Step Logic on page R.1.44*).

Trip-On-the-Way-Out (TOWO) is selected for this application example (see *Enable OOS Logic on page A.1.127*).

Out-of-Step Tripping Time Delay

Use *Equation 1.81*, *Equation 1.82*, and *Equation 1.83* to calculate the OSTD setting. These equations are derived from the impedance trajectory shown in *Figure 1.33*. Line section AB is the transfer impedance, Z_T. The horizontal dashed line represents the trajectory of the power swing perpendicular to line section AB. The trajectory passes through the midpoint of line section AB.

$$Z_T = Z_{1S} + Z_{1L1} + Z_{1R}$$

Equation 1.81

where:

Z_T = transfer impedance
$Z1_S$ = positive-sequence source impedance
$Z1_{L1}$ = positive-sequence impedance for Line 1
$Z1_R$ = Positive-sequence remote impedance

Angle Ang_R6 was specified at 120.0° as a design criterion for this application example (see *Zone 6 and Zone 7 Impedance Settings on page A.1.128*).

$$
\begin{aligned}
\mathrm{Ang\_R7} &= 2 \bullet \operatorname{atan}\left[\frac{\frac{|Z_T|}{2}}{\mathrm{R1R7}}\right] \\
&= 2 \bullet \operatorname{atan}\left[\frac{\frac{|8.80\ \Omega\angle 88° + 8.00\ \Omega\angle 87.6° + 3.52\ \Omega\angle 88°|}{2}}{15.53\ \Omega}\right] \\
&= 66.4°
\end{aligned}
$$

Equation 1.82

Apply a fast unstable swing frequency and calculate OSTD (for this application example, f_{slip} = 10 Hz for an unstable power swing).

$$
\begin{aligned}
\mathrm{OSTD} &= \frac{(\mathrm{Ang\_R6} - \mathrm{Ang\_R7}) \bullet f_{nom}}{\frac{360°}{\mathrm{cycle}} \bullet f_{slip}} \\
&= \frac{(120.0° - 66.4°) \bullet 60\ \mathrm{Hz}}{\frac{360°}{\mathrm{cycle}} \bullet 10\ \mathrm{Hz}} \\
&= 0.89\ \mathrm{cycles}
\end{aligned}
$$

Equation 1.83

where:

f_{nom} = nominal power system frequency (Hz)
f_{slip} = maximum slip frequency (Hz)

The OSTD timer settings are in increments of 0.125 cycle; round up to the nearest valid relay setting.

OSTD := **0.875** Out-of-Step Trip Delay (0.500–8000 cycles)

To find the effective slip rate for OOS tripping, solve *Equation 1.83* for f_{slip}:

$$
\begin{aligned}
f_{slip} &= \frac{(\mathrm{Ang\_R6} - \mathrm{Ang\_R7}) \bullet f_{nom}}{\frac{360°}{\mathrm{cycle}} \bullet f_{slip}} \\
&= \frac{(120° - 66.4°) \bullet 60\ \mathrm{Hz}}{\frac{360°}{\mathrm{cycle}} \bullet 10\ \mathrm{Hz}} \\
&= 10.2\ \mathrm{Hz}
\end{aligned}
$$

Equation 1.84

Out-of-Step Block Time Delay

Set OSBD longer than OSTD by the next timer setting step (0.125-cycle step size) greater than 0.500 cycle. Thus, the OSBD setting is calculated in *Equation 1.85*.

$$\begin{aligned} \text{OSBD} &= \text{OSTD} + 0.500 \text{ cycle} + \text{timer step} \\ &= 0.875 + 0.500 + 0.125 \\ &= 1.500 \text{ cycles} \end{aligned}$$

Equation 1.85

OSBD := **1.500** Out-of-Step Block Time Delay (0.500–8000 cycles)

To find the effective slip rate for OOS blocking, solve *Equation 1.86* for f_{slip}.

$$\begin{aligned} f_{slip} &= \frac{(\text{Ang\_R6} - \text{Ang\_R7}) \cdot f_{nom}}{\frac{360°}{\text{cycle}} \cdot \text{OSBD}} \\ &= \frac{(120.0° - 66.4°) \cdot 60 \text{ Hz}}{\frac{360°}{\text{cycle}} \cdot 1.500 \text{ cycle}} \\ &= 5.5 \text{ Hz} \end{aligned}$$

Equation 1.86

The relay detects OOS blocking conditions for power swing slip frequencies up to 5.95 Hz and OOS tripping conditions for power swing slip frequencies from 5.95 Hz to 10.2 Hz (see *Equation 1.84*). Zone 1 and Zone 2 elements remain blocked during these OSB and OST conditions. The event is not a swing condition if the Z_1 impedance locus crosses Zone 7 and Zone 6 before the OSTD and OSBD timers time out. The relay identifies this event as a fault condition.

Latch Out-of-Step Blocking

Latch out-of-step blocking to maintain the blocking condition throughout the entire swing cycle. See *Latch Out-of-Step Blocking on page A.1.121* for information on OSB latching and relay tripping during this condition.

OSBLTCH := **Y** Latch Out-of-Step Blocking (Y, N)

Control Outputs

For local OOS tripping, configure the relay control outputs for tripping and remote notification of an out-of-step condition. Include Relay Word bit OST in the direct tripping SELOGIC control equation TR. (Add **OR OST** to the existing TR equation; the default is shown here.)

TR := **M1P OR Z1G OR M2PT OR Z2GT OR OST** Trip (SELOGIC Equation)

Set a control output for remote notification of the out-of-step tripping condition. This example uses OUT205. Select a relay control output that is appropriate for your particular application.

OUT205 := **OST** Output OUT205 (SELOGIC Equation)

Example Completed

This completes the application example that describes setting the SEL-421 for out-of-step tripping. Analyze your particular power system to determine the appropriate settings for your application.

Relay Settings

Table 1.36 lists the settings that the relay automatically calculates and hides when you set EADVS to N.

Table 1.36 Automatically Calculated/Hidden Settings

Setting	Description	Default Setting
X1B7	Zone 7 Reactance—Bottom (–0.05 to –96 Ω secondary)	X1B7 = –X1T7
X1B6	Zone 6 Reactance—Bottom (–0.05 to –96 Ω secondary)	X1B6 = –X1T6
R1L7	Zone 7 Resistance—Left (–0.05 to –70 Ω secondary)	R1L7 = –R1R7
R1L6	Zone 6 Resistance—Left (–0.05 to –70 Ω secondary)	R1L6 = –R1R6
50ABCP	Positive-Sequence Current Supervision (1.00–100 A secondary)	50ABCP = 0.2 • I_{nom}
50QUBP[a]	Negative-Sequence Current Supervision (OFF, 0.50–100 A secondary)	OFF
UBD[a]	Negative-Sequence Current Unblock Delay (0.500–120 cycles)	0.500
UBOSBF	Out-of-Step Angle Unblock Rate (1–10)	4

[a] EOOS = Y

Table 1.37 and *Table 1.38* list the protection relay settings available in this example.

Table 1.37 Relay Configuration (Group)

Setting	Description	Entry
EOOS	Out-of-Step	Y
EADVS	Advanced Settings (Y, N)	N

Table 1.38 Out-of-Step Tripping/Blocking (Sheet 1 of 2)

Setting	Description	Entry
OOSB1	Block Zone 1 (Y, N)	Y
OOSB2	Block Zone 2 (Y, N)	Y
OOSB3	Block Zone 3 (Y, N)	N
OSBD	Out-of-Step Block Time Delay (0.500–8000 cycles)	1.500
OSBLTCH	Latch Out-of-Step Blocking (Y, N)	Y
EOOST	Out-of-Step Tripping (N, I, O)	O
OSTD	Out-of-Step Trip Delay (0.500–8000 cycles)	0.875
X1T7	Zone 7 Reactance—Top (0.05 to 96 Ω secondary)	96.00
X1T6	Zone 6 Reactance—Top (0.05 to 96 Ω secondary)	95.00
R1R7	Zone 7 Resistance—Right (0.05 to 70 Ω secondary)	15.53
R1R6	Zone 6 Resistance—Right (0.05 to 70 Ω secondary)	5.87
X1B7	Zone 7 Reactance—Bottom (–0.05 to –96 Ω secondary)	–96.00
X1B6	Zone 6 Reactance—Bottom (–0.05 to –96 Ω secondary)	–95.00
R1L7	Zone 7 Resistance—Left (–0.05 to –70 Ω secondary)	–15.53

Table 1.38 Out-of-Step Tripping/Blocking (Sheet 2 of 2)

Setting	Description	Entry
R1L6	Zone 6 Resistance—Left (–0.05 to –70 Ω secondary)	–5.87
50ABCP	Positive-Sequence Current Supervision (1.00–100 A secondary)	1.00
50QUBP[a]	Negative-Sequence Current Supervision (OFF, 0.50–100 A secondary)	OFF
UBD[a]	Negative-Sequence Current Unblock Delay (0.500–120 cycles)	0.500
UBOSBF	Out-of-Step Angle Unblock Rate (1–10)	4
50Q1P	Level Pickup (OFF, 0.25–100 amps sec.)	OFF
67Q1D	Level 1 Time Delay (0.000–16000 cycles)	0.000
67Q1TC	Level 1 Torque Control (SELOGIC Equation)	1
TR	Trip (SELOGIC Equation)	M1P OR Z1G OR M2PT OR Z2GT OR OST
OUT205	Output OUT205 (SELOGIC Equation)	OST

[a] EOOS = Y

Auto-Reclose Example

This application example is for a double-ended 230 kV overhead transmission line with SEL-421 protection at each end. The one-line drawing for this circuit is shown in *Figure 1.34*. This example shows settings for the SEL-421 at Station S (Harvard) in *Figure 1.35*.

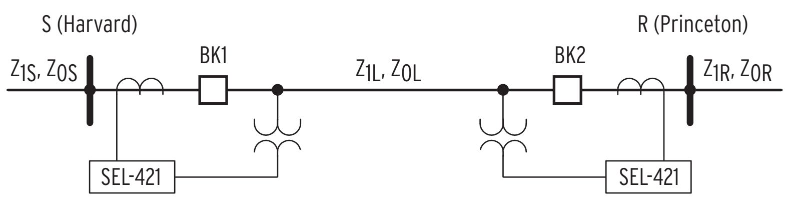


Figure 1.34 230 kV Example Power System

Application

Auto-Reclose Mode of Operation

Apply the SEL-421 for one shot of three-pole auto-reclose.

Solution

Auto-Reclose Conditions

The relay initiates three-pole auto-reclosing if a Zone 1 trip occurs because of a multiphase fault.

Circuit Breaker1 attempts the three-pole reclose if Bus 1 is hot and the line is dead. For this application example, block auto-reclose if any of the following events occur:

- ➤ Manual trip
- ➤ Time-delayed trip
- ➤ Bus trip
- ➤ Circuit breaker failure trip

If the SEL-421 detects an LOP (loss-of-potential) condition, the auto-reclose logic drives the auto-reclose function to lockout.

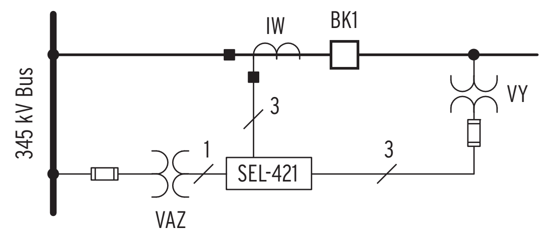


Figure 1.35 Circuit Breaker Arrangement at Station S

Relay Settings

Select the relay settings for this application example.

Relay Configuration

NOTE: Setting E79 := Y1 is intended for certain double circuit breaker applications. Use E79 := Y for a single circuit breaker.

Enable reclosing:

E79 := **Y** Reclosing (Y, Y1, N)

Recloser Closing

Select one shot of three-pole auto-reclose.

N3PSHOT := **1** Number of Three-Pole Reclosures (N, 1–4)

Use an external switch to select when Circuit Breaker 1 is enabled for three-pole auto-reclose.

E3PR1 := **IN106** Three-Pole Reclose Enable -BK1 (SELOGIC Equation)

If Circuit Breaker 1 fails to close within 10 seconds after the reclose command is received, the auto-reclose logic goes to lockout.

BKCFD := **600** Breaker Close Failure Delay (1–99999 cycles)

Unlatch the reclose command to Circuit Breaker 1 when all three poles are closed.

ULCL1 := **52AA1 AND 52AB1 AND 52AC1** Unlatch Closing for Circuit Breaker 1 (SELOGIC Equation)

Drive the auto-reclose logic to lockout if the SEL-421 detects an LOP condition.

79DTL := **LOP** Recloser Drive to Lockout (SELOGIC Equation)

You can block the reclaim timing. However, it is not necessary for this single shot application example.

79BRCT := **NA** Block Reclaim Timer (SELOGIC Equation)

When leaving the lockout condition, the recloser goes to the Ready or Reset state after the 3PMRCD (Manual Close Reclaim Time Delay) timer has expired.

3PMRCD := **900** Manual Close Reclaim Time Delay (1–99999 cycles)

If Circuit Breaker 1 reclose supervision conditions fail to occur within 300 cycles after the three-pole open interval time delay expires, BK1CLST will assert, and the auto-reclose logic goes to lockout.

BK1CLSD := **300** BK1 Reclose Supervision Delay (OFF, 1–99999 cycles)

Three-Pole Reclose

Set the three-pole open interval time equal to 30 cycles.

3POID1 := **30** Three-Pole Open Interval 1 Delay (1–99999 cycles)

There is no need to enable fast three-pole auto-reclose because we have already used the first and only three-pole shot for this purpose.

3PFARC := **NA** Three-Pole Fast ARC Enable (SELOGIC Equation)

Set the reset time following a three-pole auto-reclose cycle equal to 900 cycles.

3PRCD := **900** Three-Pole Reclaim Time Delay (1–99999 cycles)

Initiate a three-pole auto-reclose cycle when the SEL-421 three-pole trips because of Zone 1 phase distance protection. Communications-assisted tripping is not enabled.

3PRI := **3PT AND M1P** Three-Pole Reclose Initiation (SELOGIC Equation)

You can force the auto-reclose logic to skip a three-pole shot. However, it is not necessary for this application example.

79SKP := **NA** Skip Reclosing Shot (SELOGIC Equation)

Only attempt to reclose Circuit Breaker 1 if the bus is hot and the line is dead (setting cannot be set to NA or logical 0).

3P1CLS := **DLLB1** Three Pole BK 1 Reclose Supervision (SELOGIC Equation)

Voltage Elements

The SEL-421 checks the Bus and Line conditions when you enable the voltage check elements. *Figure 1.36* shows a typical checking scheme. Potentials VAY and VAX are the default synchronism inputs for V_P (setting SYNCP) and V_{S1} (setting SYNCS1), respectively (see *PT Connections on page R.2.55*).

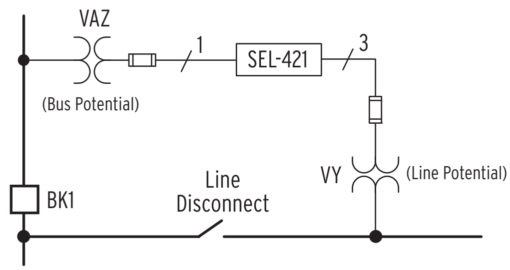


Figure 1.36 Potential Sources

Enable the voltage check elements.

EVCK := **Y** Reclosing Voltage Check (Y, N)

Set the dead line voltage threshold equal to 15 V secondary.

27LP := **15.0** Dead Line Voltage (1.0–200 V secondary)

Set the live line voltage threshold equal to 50 V secondary.

59LP := **50.0** Live Line Voltage (1.0–200 V secondary)

Set the dead bus voltage threshold for Circuit Breaker 1 equal to 15 V secondary.

27BK1P := **15.0** Breaker 1 Dead Busbar Voltage (1.0–200 V secondary)

Set the live bus voltage threshold for Circuit Breaker 1 equal to 50 V secondary.

59BK1P := **50.0** Breaker 1 Live Busbar Voltage (1.0–200 V secondary)

Example Complete

This completes the application example that describes setting the SEL-421 for one shot of three-pole reclosing for a single circuit breaker. Analyze your particular power system to determine the appropriate settings for your application.

Relay Settings

Table 1.39 provides a list of all the SEL-421 auto-reclose settings. Those settings that were applied for this particular application appear in boldface.

Table 1.39 Settings for Auto-Reclose Example (Sheet 1 of 2)

Setting	Description	Entry
Relay Configuration		
E79	Reclosing (Y, Y1, N)	Y
Recloser Closing (Group)		
NSPSHOT	Number of Single-Pole Reclosures (N, 1, 2)	N
N3PSHOT	Number of Three-Pole Reclosures (N, 1–4)	1
E3PR1	Three-Pole Reclose Enable—BK1 (SELOGIC Equation)	IN106
BKCFD	Breaker Close Failure Delay (OFF, 1–99999 cycles)	600
ULCL1	Unlatch Closing for Breaker 1 (SELOGIC Equation)	52AA1
79DTL	Recloser Drive to Lockout (SELOGIC Equation)	LOP
79BRCT	Block Reclaim Timer (SELOGIC Equation)	NA
3PMRCD	Manual Close Reclaim Time Delay (1–99999 cycles)	900
BK1CLSD	BK1 Reclose Supervision Delay (OFF, 1–99999 cycles)	300
Three-Pole Reclose (Group)		
3POID1	Three-Pole Open Interval 1 Delay (1–99999 cycles)	30
3PFARC	Three-Pole Fast Automatic Reclose Enable (SELOGIC Equation)	NA
3PRCD	Three-Pole Reclaim Time Delay (1–99999 cycles)	900

Table 1.39 Settings for Auto-Reclose Example (Sheet 2 of 2)

Setting	Description	Entry
3PRI	Three-Pole Reclose Initiation (SELOGIC Equation)	3PT AND M1P
79SKP	Skip Reclosing Shot (SELOGIC Equation)	NA
3P1CLS[a]	Three-Pole BK 1 Reclose Supervision (SELOGIC Equation)	DLLB1
Voltage Elements (Group)		
EVCK	Reclosing Voltage Check (Y, N)	Y
27LP	Dead Line Voltage (1.0–200 V secondary)	15.0
59LP	Live Line Voltage (1.0–200 V secondary)	50.0
27BK1P	Breaker 1 Dead Busbar Voltage (1.0–200 V secondary)	15.0
59BK1P	Breaker 1 Live Busbar Voltage (1.0–200 V secondary)	50.0

[a] This setting cannot be set to NA or logical 0.

Auto-Reclose and Synchronism Check Example

Use the SEL-421 to provide automatic reclosing and synchronism check for overhead transmission lines. This application example is for double-ended 500 kV parallel lines with SEL-421 protection at each end of the first circuit as shown in *Figure 1.37*. This example shows the settings for the SEL-421 at Station S protecting Line 1 in *Figure 1.38* between Buses S (Moscow) and R (Pullman).

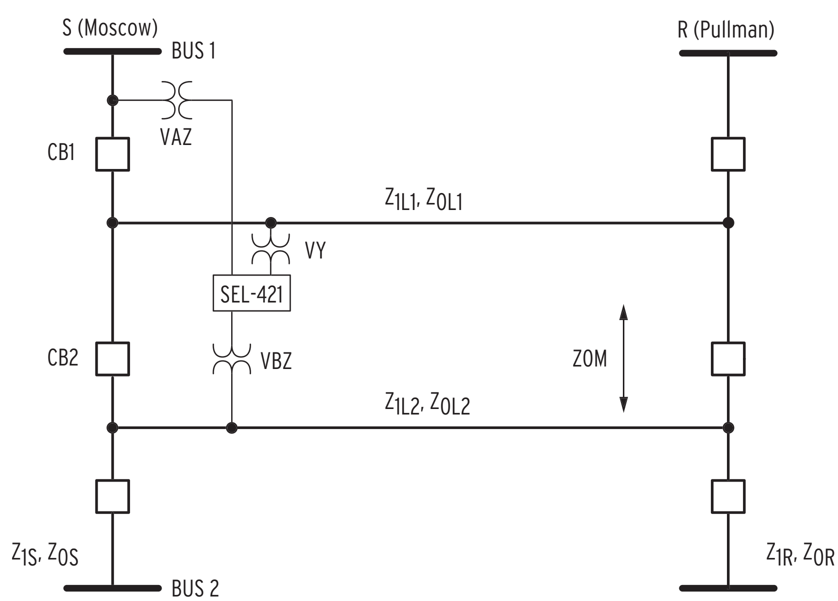


Figure 1.37 500 kV Power System

First set the auto-reclose logic, and then set the synchronism-check function.

Auto-Reclose Application

Apply the SEL-421 for one shot of single-pole reclosing and one shot of three-pole reclosing.

Select the recloser mode with the enable setting E79 := Y or Y1, and set E3PR1 and E3PR2 to logical 1.

Modes of Operation

The SEL-421 auto-reclose logic operates in one of two modes at all times:

- ➤ Single-pole mode (SPAR)
- ➤ Three-pole mode (3PAR)

Single-pole trips initiate single-pole reclosing. For this application example, if the single-pole reclose is unsuccessful, the second trip is a three-pole trip. Three-pole trips initiate three-pole reclosing. If a single-pole auto-reclose cycle is in progress and the relay receives an initiation for three-pole reclosing, the relay immediately starts a three-pole auto-reclose cycle.

Select the recloser mode with the three-pole enable settings and the single-pole enable settings E3PR1, E3PR2, ESPR1, and ESPR2.

Auto-Reclose Sequence

The relay performs one shot of reclosing for both single-pole and three-pole automatic reclosing.

When E79 := Y, the leader circuit breaker (CB1) recloses if the line is dead and Bus 1 is hot. If the leader successfully recloses, the follower circuit breaker (CB2) also attempts a reclose if the synchronism check is successful. CB2 can also close if the line is dead and Bus 2 is hot if CB1 is out of service. A similar SEL-421 installation would protect line 2, and provide auto-reclose capabilities.

When E79 := Y1, if CB2 trips from the line 2 protection (not shown), the SEL-421 on line 1 would attempt to reclose CB2. This configuration would typically employ a hot bus check.

Open interval timing does not begin until the faulted phase(s) is opened.

If another trip occurs while the single-pole auto-reclose cycle is in progress the relay trips the other two poles.

The auto-reclose logic resets after the reclaim timer (SPRCD or 3PRCD) expires.

Dynamic Determination of the Leader Circuit Breaker

If Circuit Breaker 1 (the leader breaker) is out of service, the leader settings are automatically routed to Circuit Breaker 2. Circuit Breaker 2 operates as the leader circuit breaker when Circuit Breaker 1 is out of service. When Circuit Breaker 2 is the leader, this circuit breaker can single-pole reclose.

Auto-Reclose Solution

Auto-Reclose Conditions

The relay initiates single-pole auto-reclose if a Zone 1 trip or a communications-assisted trip occurs for a single phase-to-ground fault. The relay initiates three-pole auto-reclose if a Zone 1 trip or a communications-assisted trip occurs for a multiphase fault.

Circuit Breaker 1 can attempt a reclose if Bus 1 is hot and the line is dead. Circuit Breaker 2 can attempt a reclose if the synchronism check is successful or if Circuit Breaker 1 is out of service and the line is dead and Bus 2 is hot.

Block auto-reclose if any of the following events occur:

- Manual trip
- Time-delayed trip
- Bus trip
- Circuit breaker failure trip

If the SEL-421 detects a loss-of-potential condition, the auto-reclose logic drives the auto-reclose function to lockout.

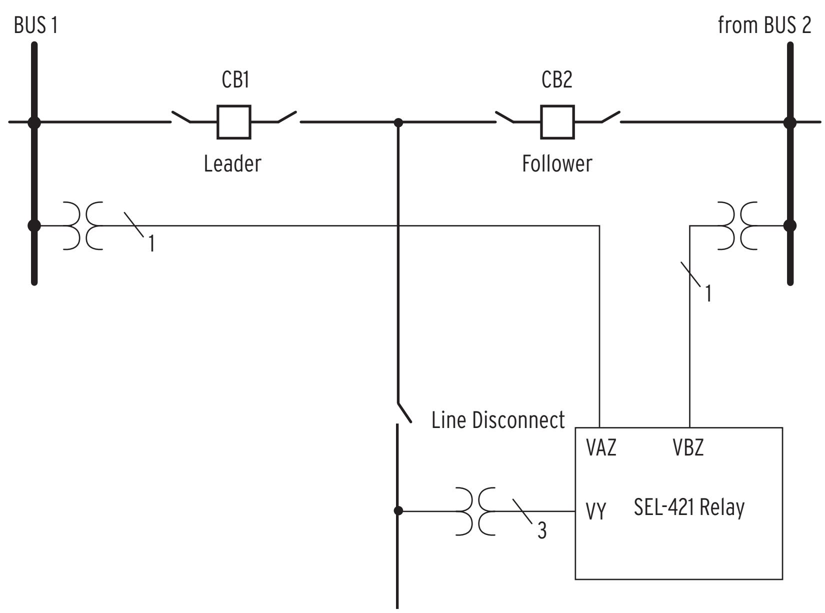


Figure 1.38 Partial Circuit Breaker-and-a-Half Arrangement at Station S, Line 1

Auto-Reclose Relay Settings

Select the auto-reclose relay settings for this application example.

Relay Configuration

Enable reclosing.

E79 := **Y** Reclosing (Y, Y1, N)

Selection Y1 can be used in circumstances where CB2 can be tripped externally, yet the SEL-421 is to be able to auto-reclose.

Recloser Closing

Select one shot of single-pole auto-reclose.

NSPSHOT := **1** Number of Single-Pole Reclosures (N, 1, 2)

Use an external switch to select when the leader or follower circuit breaker is enabled for single-pole auto-reclose.

ESPR1 := **IN205** Single-Pole Reclose Enable—BK1 (SELOGIC Equation)

ESPR2 := **IN206** Single-Pole Reclose Enable—BK2 (SELOGIC Equation)

Select one shot of three-pole auto-reclose.

N3PSHOT := **1** Number of Three-Pole Reclosures (N, 1–4)

Use an external switch to select when the leader or follower circuit breaker is enabled for three-pole auto-reclose.

E3PR1 := **IN207** Three-Pole Reclose Enable—BK1 (SELOGIC Equation)

E3PR2 := **IN208** Three-Pole Reclose Enable—BK2 (SELOGIC Equation)

The time delay before Circuit Breaker 2 attempts a reclose after Circuit Breaker 1 has successfully reclosed is 15 cycles. The short delay prevents both circuit breakers closing back into a permanent fault.

TBBKD := **15** Time Between Breakers for ARC (1–99999 cycles)

If either circuit breaker fails to close within 10 seconds after the reclose command is received, the auto-reclose logic goes to lockout for the failed circuit breaker.

BKCFD := **600** Breaker Close Failure Delay (OFF, 1–99999 cycles)

You can use a normally closed a auxiliary contact from the Circuit Breaker 1 disconnect switch to denote that this circuit breaker is the leader when in service. Use the contact to energize a control input; if the disconnect switch is closed, the input is energized.

SLBK1 := **IN107** Lead Breaker = Breaker 1 (SELOGIC Equation)

We have selected Circuit Breaker 1 as the leader. The auto-reclose logic automatically recognizes Circuit Breaker 2 as the leader when Circuit Breaker 1 is out of service.

SLBK2 := **0** Lead Breaker = Breaker 2 (SELOGIC Equation)

Circuit Breaker 2 is the follower circuit breaker. The follower can attempt to reclose if all three poles of Circuit Breaker 2 are actually open or if Circuit Breaker 1 is out of service.

FBKCEN := **3POBK2 OR (NOT LEADBK1)** Follower Breaker Closing Enable (SELOGIC Equation)

Unlatch the reclose command to Circuit Breaker 1 when all three poles are closed.

ULCL1 := **52AA1 AND 52AB1 AND 52AC1** Unlatch Closing for Breaker 1 (SELOGIC Equation)

Unlatch the reclose command to Circuit Breaker 2 when all three poles are closed.

ULCL2 := **52AA2 AND 52AB2 AND 52AC2** Unlatch Closing for Breaker 2 (SELOGIC Equation)

Drive the auto-reclose logic to lockout if the SEL-421 detects a loss-of-potential condition.

79DTL := **LOP** Recloser Drive to Lockout (SELOGIC Equation)

You can block reclaim timing. However, it is not necessary for this application example.

79BRCT := **NA** Block Reclaim Timer (SELOGIC Equation)

When leaving the lockout condition, the recloser goes to the Ready or Reset state after the 3PMRCD (Manual Close Reclaim Time Delay) timer has expired.

3PMRCD := **900** Manual Close Reclaim Time Delay (1–99999 cycles)

If Circuit Breaker 1 reclose supervision conditions (settings SP1CLS and 3P1CLS) fail to occur within 300 cycles after the three-pole open interval time delay expires, the auto-reclose logic goes to lockout.

BK1CLSD := **300** BK1 Reclose Supervision Delay (OFF, 1–99999 cycles)

If Circuit Breaker 2 reclose supervision conditions (settings SP2CLS and 3P2CLS) fail to occur within 300 cycles after the three-pole open interval time delay expires, the auto-reclose logic goes to lockout.

BK2CLSD := **300** BK2 Reclose Supervision Delay (OFF, 1–99999 cycles)

Single-Pole Auto-Reclose Logic

Initiate a single-pole auto-reclose cycle whenever the SEL-421 single-pole trips. Auto-reclose is blocked if a manual, time-delayed, bus, or circuit breaker failure trip occurs. None of these events generate a single-pole trip (see *Auto-Reclose Conditions on page A.1.139*).

Set the single-pole open interval time equal to one second.

SPOID := **60** Single-Pole Open Interval Delay (1–99999 cycles)

Set the reclaim time following a single-pole auto-reclose cycle equal to 900 cycles.

SPRCD := **900** Single-Pole Reclaim Time Delay (1–99999 cycles)

Initiate a single-pole auto-reclose cycle whenever the SEL-421 single-pole trips.

SPRI := **SPT AND (Z1G OR COMPRM)** Single-Pole Reclose Initiation (SELOGIC Equation)

No supervision is required before Circuit Breaker 1 attempts a single-pole reclose. The SEL-421 auto-reclose logic only applies synchronism supervision during a single-pole auto-reclose cycle in this application example (setting cannot be set to NA or logical 0).

SP1CLS := **1** Single-Pole BK1 Reclose Supervision (SELOGIC Equation)

No supervision is required before Circuit Breaker 2 attempts a single-pole reclose when this circuit breaker is the leader. The SEL-421 auto-reclose logic only applies synchronism supervision during a single-pole auto-reclose cycle in this application example (setting cannot be set to NA or logical 0).

SP2CLS := **NOT LEADBK1** Single-Pole BK2 Reclose Supervision (SELOGIC Equation)

Three-Pole Auto-Reclose Logic

Set the three-pole open interval time equal to 30 cycles.

3POID1 := **30** Three-Pole Open Interval 1 Delay (1–99999 cycles)

There is no need to enable fast three-pole auto-reclose because we have already used the first and only three-pole shot for this purpose.

3PFARC := **NA** Three-Pole Fast ARC Enable (SELOGIC Equation)

Set the reclaim time following a three-pole auto-reclose cycle equal to 900 cycles.

3PRCD := **900** Three-Pole Reclaim Time Delay (1–99999 cycles)

Initiate a three-pole auto-reclose cycle when the SEL-421 three-pole trips because of Zone 1 phase distance protection or a communications-assisted trip. No manual, time-delayed, bus, or circuit breaker failure trips are included in the 3PRI SELOGIC control equation for this application example.

3PRI := **3PT AND (M1P OR COMPRM)** Three-Pole Reclose Initiation (SELOGIC Equation)

You can force the auto-reclose logic to skip a three-pole shot. However, it is not necessary for this application example.

79SKP := **NA** Skip Reclosing Shot (SELOGIC Equation)

Only attempt to reclose Circuit Breaker 1 if Bus 1 is hot and the line is dead. The SEL-421 auto-reclose logic only applies this supervision during a three-pole auto-reclose cycle (you cannot set this setting to NA or logical 0; see *Voltage Elements on page A.1.135*).

3P1CLS := **DLLB1** Three Pole BK 1 Reclose Supervision (SELOGIC Equation)

Only attempt to reclose Circuit Breaker 2 if the synchronism check is successful or if Circuit Breaker 1 is out of service and the line is dead and Bus 2 is hot. The SEL-421 auto-reclose logic only applies synchronism supervision during a three-pole auto-reclose cycle in this application example (you cannot set this setting to NA or logical 0).

3P2CLS := **25A2BK2 OR (NOT LEADBK1 AND DLLB2)** Three Pole BK 2 Reclose Supervision (SELOGIC Equation)

Voltage Elements

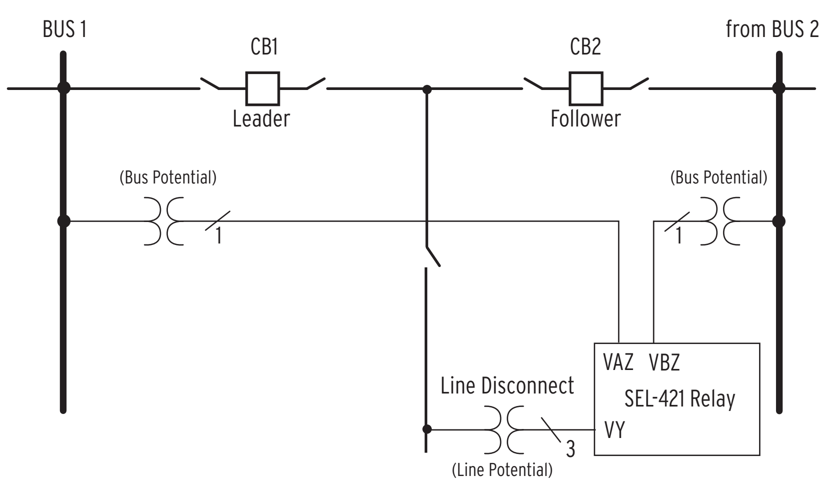


Figure 1.39 Potential Sources

Enable the voltage check elements.

EVCK := **Y** Reclosing Voltage Check (Y, N)

Set the dead line voltage threshold equal to 15 V secondary.

27LP := **15.0** Dead Line Voltage (1.0–200 V secondary)

Set the live line voltage threshold equal to 50 V secondary.

59LP := **50.0** Live Line Voltage (1.0–200 V secondary)

Set the dead bus voltage threshold for Circuit Breakers 1 and 2 equal to 15 volts secondary.

27BK1P := **15.0** Breaker 1 Dead Busbar Voltage (1.0–200 V secondary)

27BK2P := **15.0** Breaker 2 Dead Busbar Voltage (1.0–200 V secondary)

Set the live bus voltage threshold for Circuit Breakers 1 and 2 equal to 50 V secondary.

59BK1P := **50.0** Breaker 1 Live Busbar Voltage (1.0–200 V secondary)

59BK2P := **50.0** Breaker 2 Live Busbar Voltage (1.0–200 V secondary)

Trip Logic

If you want Circuit Breaker 2 to always three-pole trip, except when Circuit Breaker 2 is the leader, program SELOGIC control equation E3PT2 as follows:

E3PT2 := **NOT LEADBK2** Breaker 2 3PT (SELOGIC Equation)

Synchronism-Check Application

Reclose Circuit Breaker 1 following a three-pole trip if the line is dead and Bus 1 is hot. Reclose Circuit Breaker 2 following a three-pole trip if a synchronism check across the hot line to Bus 2 is successful or Circuit Breaker 1 is out of service and the line is dead and Bus 2 is hot.

In this application example, the relay does not perform a synchronism check on single-pole reclosing.

Synchronism-Check Solution

Apply the synchronism-check function as follows for Circuit Breaker 2:

- ➤ Use the A-Phase voltages from the line and Bus 2 for the synchronism check across Circuit Breaker 2.
- ➤ Select the high voltage magnitude and low voltage magnitude thresholds for the synchronism check.
- ➤ Select the maximum voltage angle difference allowed for both reclosing and manual closing.
- ➤ Select conditions that block the synchronism check.

Synchronism-Check Relay Settings

Select the relay settings for this application example.

Relay Configuration

Enable synchronism check for Circuit Breaker 2 only.

E25BK1 := **N** Synchronism Check for Breaker 1 (Y, N)

E25BK2 := **Y** Synchronism Check for Breaker 2 (Y, N)

Synchronism-Check Element Reference

Select A-Phase voltage from the line source for the synchronism check reference. VAY is the reference for the synchronism check because this analog input is connected to the line potential.

SYNCP := **VAY** Synch Reference (VAY, VBY, VCY, VAZ, VBZ, VCZ)

Set the low voltage threshold that supervises synchronism check equal to 60 V secondary.

25VL := **60.0** Voltage Window Low Threshold (20.0–200 V secondary)

Set the high voltage threshold that supervises synchronism check equal to 70 V secondary.

25VH := **70.0** Voltage Window High Threshold (20.0–200 V secondary)

Circuit Breaker 2 Synchronism Check

Select A-Phase voltage from Bus 2 for the synchronism check source. VBZ is the source for the synchronism check because this is the bus potential.

SYNCS2 := **VBZ** Synch Source 2 (VAY, VBY, VCY, VAZ, VBZ, VCZ)

Both the line reference and bus source voltages are measured line-to-neutral. Set the ratio factor equal to unity.

KS2M : = **1.00** Synch Source 2 Ratio Factor (0.000–30)

You do not need to shift the angle of the synchronism check because both the source and reference voltage are measured A-Phase-to-neutral.

KS2A := **0** Synch Source 2 Angle Shift (0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, 330 degrees)

There is no alternate synchronism source for Circuit Breaker 2 in this application example.

ALTS2 := **NA** Alternative Synch Source 2 (SELOGIC Equation)

Assume that there is no slip between the source and reference voltages.

25SFBK2 := **OFF** Maximum Slip Frequency—BK2 (OFF, 0.005–0.5 Hz)

Set the maximum allowable voltage angular difference between the source and reference voltages equal to 20 degrees when attempting to reclose Circuit Breaker 2.

ANG1BK2 := **20.0** Maximum Angle Difference 1—BK2 (3.0–80 degrees)

Set the maximum allowable voltage angular difference between the source and reference voltages equal to 20 degrees when attempting to manually close Circuit Breaker 2.

ANG2BK2 := **20.0** Maximum Angle Difference 2—BK2 (3.0–80 degrees)

The relay does not compensate the synchronism check to account for circuit breaker closing time because setting 25SFBK2 is OFF. Leave the close time compensation setting at the default.

TCLSBK2 := **1.00** Breaker 2 Close Time (1.00–30 cycles)

Block the synchronism check if Circuit Breaker 2 is closed.

BSYNBK2 := **52AA2 AND 52AB2 AND 52AC2** Block Synchronism Check—BK2 (SELOGIC Equation)

Example Complete

This completes the application example that describes setting the SEL-421 for one shot of high-speed single-pole reclosing and one shot of three-pole reclosing for two circuit breakers. This example showed a configuration for synchronism check, as well. Analyze your particular power system to determine the appropriate settings for your application.

Relay Settings

Table 1.40 provides a list of all the SEL-421 auto-reclose settings.

Table 1.40 Settings for Auto-Reclose and Synchronism Check Example (Sheet 1 of 3)

Setting	Description	Entry
Recloser Closing (Group)		
E79	Reclosing (Y, Y1, N)	Y
NSPSHOT	Number of Single-Pole Reclosures (N, 1, 2)	1
ESPR1	Single-Pole Reclose Enable—BK1 (SELOGIC Equation)	IN205
ESPR2	Single-Pole Reclose Enable—BK2 (SELOGIC Equation)	IN206
N3PSHOT	Number of Three-Pole Reclosures (N, 1–4)	1
E3PR1	Three-Pole Reclose Enable—BK1 (SELOGIC Equation)	IN207
E3PR2	Three-Pole Reclose Enable—BK2 (SELOGIC Equation)	IN208
TBBKD	Time Between Breakers for Automatic Reclose (1–99999 cycles)	15
BKCFD	Breaker Close Failure Delay (OFF, 1–99999 cycles)	600
SLBK1	Lead Breaker = Breaker 1 (SELOGIC Equation)	IN107
SLBK2	Lead Breaker = Breaker 2 (SELOGIC Equation)	0
FBKCEN	Follower Breaker Closing Enable (SELOGIC Equation)	3POBK2 OR NOT LEADBK1
ULCL1	Unlatch Closing for Breaker 1 (SELOGIC Equation)	52AA1 AND 52AB1 AND 52AC1
ULCL2	Unlatch Closing for Breaker 2 (SELOGIC Equation)	52AA2 AND 52AB2 AND 52AC2
79DTL	Recloser Drive to Lockout (SELOGIC Equation)	LOP
79BRCT	Block Reclaim Timer (SELOGIC Equation)	NA
3PMRCD	Manual Close Reclaim Time Delay (1–99999 cycles)	900
BK1CLSD	BK1 Reclose Supervision Delay (OFF, 1–99999 cycles)	300
BK2CLSD	BK2 Reclose Supervision Delay (OFF, 1–99999 cycles)	300

Table 1.40 Settings for Auto-Reclose and Synchronism Check Example (Sheet 2 of 3)

Setting	Description	Entry
Single-Pole Reclose (Group)		
SPOID	Single-Pole Open Interval Delay (1–99999 cycles)	60
SPRCD	Single-Pole Reclaim Time Delay (1–99999 cycles)	900
SPRI	Single-Pole Reclose Initiation (SELOGIC Equation)	SPT AND (Z1G AND COMPRM)
SP1CLS[a]	Single-Pole BK1 Reclose Supervision (SELOGIC control equation)	1
SP2CLS[a]	Single-Pole BK2 Reclose Supervision (SELOGIC Equation)	NOT LEADBK1
Three-Pole Reclose (Group)		
3POID1	Three-Pole Open Interval 1 Delay (1–99999 cycles)	30
3PFARC	Three-Pole Fast Auto-Reclose Enable (SELOGIC Equation)	NA
3PRCD	Three-Pole Reclaim Time Delay (1–99999 cycles)	900
3PRI	Three-Pole Auto-Reclose Initiate (SELOGIC Equation)	3PT AND (M1P OR COMPRM)
79SKP	Skip Reclosing Shot (SELOGIC Equation)	NA
3P1CLS[a]	Three-Pole BK 1 Reclose Supervision (SELOGIC Equation)	DLLB1
3P2CLS[a]	Three-Pole BK 2 Reclose Supervision (SELOGIC Equation)	25A2BK2 OR (NOT LEADBK1 AND DLLB2)
Voltage Elements (Group)		
EVCK	Reclosing Voltage Check (Y, N)	Y
27LP	Dead Line Voltage (1.0–200 V secondary)	15.0
59LP	Live Line Voltage (1.0–200 V secondary)	50.0
27BK1P	Breaker 1 Dead Busbar Voltage (1.0–200 V secondary)	15.0
59BK1P	Breaker 1 Live Busbar Voltage (1.0–200 V secondary)	50.0
27BK2P	Breaker 2 Dead Busbar Voltage (1.0–200 V secondary)	15.0
59BK2P	Breaker 2 Live Busbar Voltage (1.0–200 V secondary)	50.0
Trip Logic (Group)		
E3PT2	Breaker 2 3PT (SELOGIC Equation)	NOT LEADBK2
Relay Configuration (Group)		
E25BK1	Synchronism Check for Breaker 1 (Y, N)	N
E25BK2	Synchronism Check for Breaker 2 (Y, N)	Y

Table 1.40 Settings for Auto-Reclose and Synchronism Check Example (Sheet 3 of 3)

Setting	Description	Entry
Synchronism-Check Element Reference (Group)		
SYNCP	Synchronism Reference (VAY, VBY, VCY, VAZ, VBZ, VCZ)	VAY
25VL	Voltage Window Low Threshold (20.0–200 V secondary)	60.0
25VH	Voltage Window High Threshold (20.0–200 V secondary)	70.0
Breaker 2 Synchronism Check (Group)		
SYNCS2	Synchronism Source 2 (VAY, VBY, VCY, VAZ, VBZ, VCZ)	VBZ
KS2M	Synchronism Source 2 Ratio Factor (0.10–3)	1.00
KS2A	Synchronism Source 2 Angle Shift (0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, 330 degrees)	0
ALTS2	Alternative Synchronism Source 2 (SELOGIC Equation)	NA
25SFBK2	Maximum Slip Frequency—BK2 (OFF, 0.005–0.5 Hz)	OFF
ANG1BK2	Maximum Angle Difference 1—BK2 (3.0–80 degrees)	20.0
ANG2BK2	Maximum Angle Difference 2—BK2 (3.0–80 degrees)	20.0
TCLSBK2	Breaker 2 Close Time (1.00–30 cycles)	1.00
BSYNBK2	Block Synchronism Check—BK2 (SELOGIC Equation)	52AA2 AND 52AB2 AND 52AC2

[a] These settings cannot be set to NA or logical 0.

Circuit Breaker Failure Application Examples

NOTE: The following discussion designates Circuit Breaker 1. For Circuit Breaker 2, replace the **1** with **2**.

Under normal operating conditions, local station primary protection operates to remove faulted equipment from service. Zones of protection are arranged to minimize service disruption when local primary protection operates. Backup protection clears the fault when local protection fails to do so, typically removing more equipment from service than the primary protection would have removed for a correct operation.

Protection systems typically employ both local and remote backup protection. Local backup protection uses dedicated additional equipment to clear a fault if the local primary protection fails. Remote backup protection consists of overlapping, time-coordinated protection zones situated at remote locations with respect to the local terminal. Remote backup protection operates if a fault outside the local protection zone persists. Circuit breaker failure relaying is local backup protection.

The SEL-421 features four types of circuit breaker failure and retrip protection capability:

1. Failure to interrupt fault current for phase currents
2. No current/residual current circuit breaker failure protection
3. Failure to interrupt load current
4. Flashover circuit breaker failure protection

Protection against failure to interrupt fault current for phase currents is the most common implementation. This subsection describes failure to interrupt fault current circuit breaker failure protection.

Failure to Interrupt Fault Current for Phase Currents

The SEL-421 provides two schemes for failure to interrupt fault current for phase currents. Scheme 1 is protection for basic cases involving both multiphase faults and single-phase faults with a common breaker failure time delay. Scheme 2 is for more elaborate protection that discriminates between multiphase and single-phase faults and features separate circuit breaker failure time delays. Use Scheme 2 for separate circuit breaker failure timing for three-pole and single-pole faults.

Basic Operation—Scheme 1 and Scheme 2

NOTE: The following discussion specifies three elements. There is one element for each phase: ϕ =A, B, and C).

A trip output from the local primary or backup line protection typically initiates the failure to interrupt fault current circuit breaker failure scheme (BFI3P1 and BFIϕ1 for Scheme 1 or BFIϕ1 for Scheme 2). When initiated, the relay starts circuit breaker failure timing; the time delay is BFPU1 (Breaker Failure Time Delay—BK1). The SEL-421 does not require an external BFI contact when applied for local circuit breaker failure protection because the relay detects line faults. In addition, you can add external BFI from an input in parallel with the circuit breaker trip coil to capture additional trip initiations to increase scheme dependability.

Set the instantaneous overcurrent element pickup threshold 50FP1 to pick up for all line faults. The relay asserts Relay Word bit 50Fϕ1 when the phase current exceeds the 50FP1 threshold. The 50Fϕ1 element must reset quickly even during the presence of subsidence current at the circuit breaker opening.

If 50Fϕ1 is asserted when timer BFPU1 expires, the relay asserts circuit breaker failure protection Relay Word bit FBF1 (Breaker 1 Breaker Failure). Assign FBF1 to SELOGIC control equation BFTR1 (Breaker Failure Trip—BK1) as one of the circuit breaker failure elements that can cause a circuit breaker failure trip. When SELOGIC control equation BFTRI asserts, the relay asserts corresponding Relay Word bit BFTRIP1 (Breaker 1 Failure Trip Output). Assign BFTRIP1 to a high current interrupting control output to perform circuit breaker failure tripping or to a standard control output to operate an 86 lockout relay.

Scheme Components

The following are components of the circuit breaker failure schemes in the SEL-421:

- Circuit Breaker Failure Initiation (BFI3P1 or BFIϕ1)
- Phase Fault Current Pickup (50FP1)
- Breaker Failure Pickup Time Delay (BFPU1)

For a detailed description see *Circuit Breaker Failure Trip Logic on page R.1.123*.

Circuit Breaker Failure Initiation (BFI3P1 or BFIϕ1)

All circuit breaker trips typically initiate the circuit breaker failure scheme. The SEL-421 detects power system faults; the relay does not need an external BFI contact for local circuit breaker failure protection applications.

Scheme 1. Scheme 1 uses initiation SELOGIC control equation BFI3P1 for three-pole tripping applications and BFIϕ1 for single-pole tripping applications.

Scheme 2. Scheme 2 uses initiation SELOGIC control equations BFIϕ1 for both three-pole (multiphase) and single-phase faults.

Phase Fault Current Pickup (50FP1)

Circuit breaker failure protection must pick up for all faults on the protected line. Two settings philosophies are prevalent. One philosophy is to set the instantaneous overcurrent element (50Fϕ1) to pick up above load current and below the minimum fault current (under minimum generation), if possible ($I_{load\ max} < 50FP1 < I_{minimum\ fault}$). Another settings philosophy is to set the threshold to match the line protection sensitivity; this increases circuit breaker failure protection dependability.

In the following application examples, we use the first settings philosophy because this approach gives greater security. In either case, when input phase currents exceed the overcurrent element threshold, the relay asserts Relay Word bit 50Fϕ1.

Subsidence current results from the energy trapped in the CT magnetizing branch after the circuit breaker opens to clear a fault or interrupt load. Subsidence current exponentially decays and delays resetting of instantaneous overcurrent elements. However, the open phase detection logic causes the SEL-421 50Fϕ1 element to reset in less than one cycle during subsidence current conditions. The open phase detection logic determines that a pole is open during the presence of subsidence current and immediately resets the corresponding current level detectors.

Breaker Failure Pickup Time Delay (BFPU1)

Scheme 1. Relay Word bit FBF1 (Breaker 1 Breaker Failure) asserts when the time delay on pickup timer BFPU1 expires and the corresponding 50Fϕ1 element is asserted.

Scheme 2. Relay Word bit FBF1 (Breaker 1 Breaker Failure) asserts for these conditions:

➤ *A single phase-to-ground fault occurs:* FBF1 asserts when time delay on pickup timers BFPU1 (Breaker Failure Time Delay—BK1) followed by SPBFPU1 (SPT Breaker Failure Time Delay—BK1) expire. The corresponding 50FPϕ1 element and only one single-phase breaker failure initiation (for example, BFIA1) are asserted.

➤ *A multiphase fault occurs:* FBF1 asserts when time delay on pickup timer BFPU1 (Breaker Failure Time Delay—BK1) expires. The corresponding 50Fϕ1 elements and at least two single-phase breaker failure initiations (for example, BFIA1 and BFIB1) are asserted.

Timing Sequence

Figure 1.40 and *Figure 1.41* illustrate the timing sequence for circuit breaker failure schemes.

Scheme 1

Scheme 1 follows *Figure 1.40*.

Scheme 2

Scheme 2 uses both timing sequences in *Figure 1.40* and *Figure 1.41*, depending on the fault type (multiphase fault and single-phase fault, respectively).

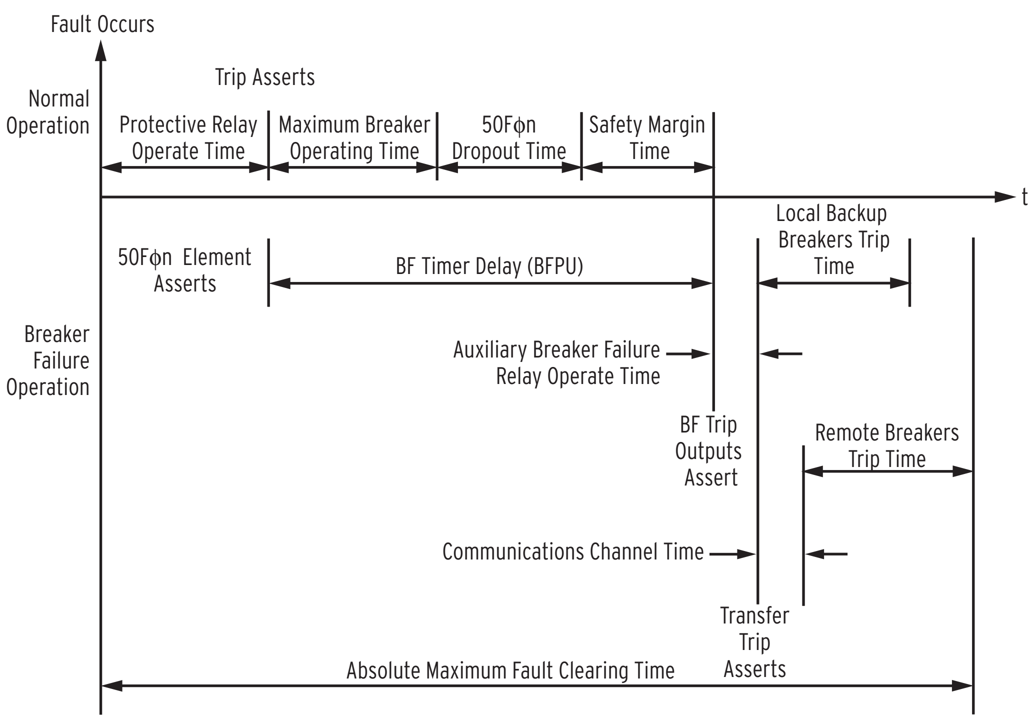


Figure 1.40 Scheme 1 All Faults and Scheme 2 Multiphase Fault Timing Diagram

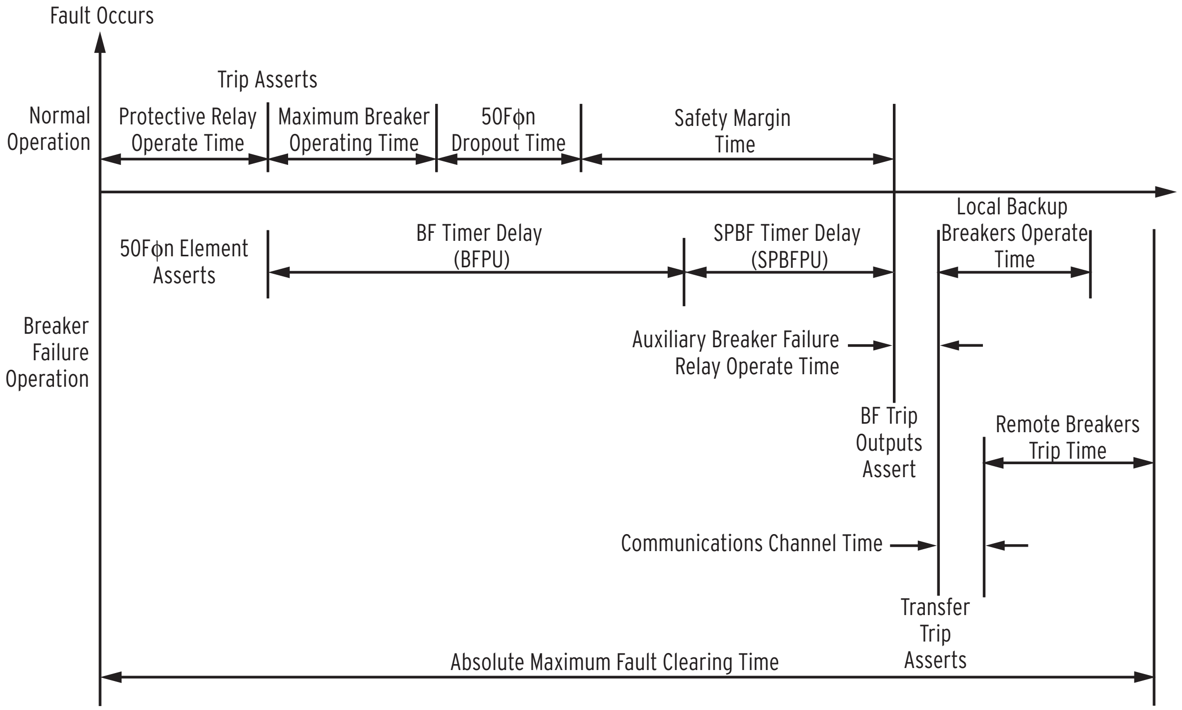


Figure 1.41 Scheme 2 Single-Phase Fault Timing Diagram

The absolute maximum fault clearing time depends on power system transient stability and the thermal withstand capability of the equipment. If a circuit breaker fails, the total time required to trip all electrically adjacent circuit breakers must be less than this absolute maximum clearing time. Set the time delay on pickup timer to allow time for the protected circuit breaker to operate and the instantaneous overcurrent element (50Fϕ1) to reset. Always include a safety margin, remembering that the operating time of the line relays and the electrically adjacent circuit breakers limit this margin.

Circuit Breaker Failure Protection—Example 1

Use the SEL-421 to provide circuit breaker failure protection for one circuit breaker. This is a circuit breaker failure protection Scheme 1 application example for three-pole tripping circuit breakers (you can also use this scheme for single-pole tripping applications). For a single-pole tripping circuit breaker application example (Scheme 2), see *Circuit Breaker Failure Protection—Example 2 on page A.1.157*. This example uses a 230 kV power system similar to the system in *230 kV Overhead Transmission Line Example on page A.1.2*. *Figure 1.42* shows the SEL-421 at the S terminal of the two-terminal line between Harvard and Princeton. *Table 1.41* provides the related power system parameters.

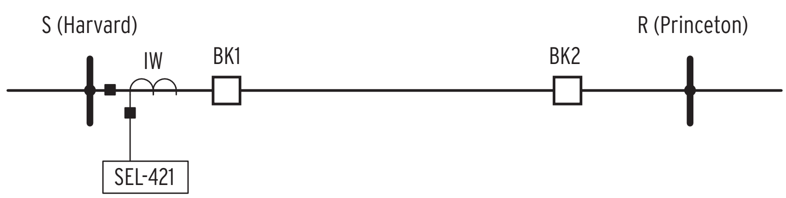


Figure 1.42 230 kV Power System for Circuit Breaker Failure Scheme 1

Table 1.41 Secondary Quantities

Parameter	Value
Line impedances	
Z_{1L}	1.95 Ω ∠84° secondary
Z_{0L}	6.2 Ω ∠81.5° secondary
Source S impedances	
$Z_{1S} = Z_{0S}$	2.5 Ω ∠86° secondary
Source R impedances	
$Z_{1R} = Z_{0R}$	2.5 Ω ∠86° secondary
Nominal frequency (f_{nom})	60 Hz
Maximum operating current load (I_{load})	4.95 A secondary

Relay Configuration

Enable Scheme 1 circuit breaker failure protection for Circuit Breaker BK1.

EBFL1 := **1** Breaker 1 Failure Logic (N, 1, 2)

Circuit Breaker 1 Failure Logic

Phase Current Level Detector

NOTE: This is one method for calculating setting 50FP1. Use your company practices and policies for determining the pickup setting for your particular application.

Set the phase current level detector equal to 120 percent of the maximum load current I_{load}. Check that this setting is less than the minimum fault current (ϕϕ fault) with minimum generation. Circuit breaker failure protection for faults involving ground (SLG and ϕϕG faults) is covered in this application example by no current/residual current circuit breaker failure protection (see *Residual Current Circuit Breaker Failure Protection on page A.1.162*). This settings philosophy provides security for the circuit breaker failure protection. For this power system, the maximum load current is 4.95 A secondary and the minimum ϕϕ fault current is 13.0 A secondary.

$$50FP1 = 120\% \bullet I_{load} = 120\% \bullet 4.95 \text{ A} = 5.94 \text{ A}$$

50FP1 := **5.94** Phase Fault Current Pickup—BK1 (0.50–50 A secondary)

Circuit Breaker Failure Protection Time Delay

The recommended setting for BFPU1 (Breaker Failure Time Delay—BK1) is the sum of the following (see *Figure 1.43*):

- Maximum circuit breaker operating time
- 50FA1 maximum dropout time
- Safety margin

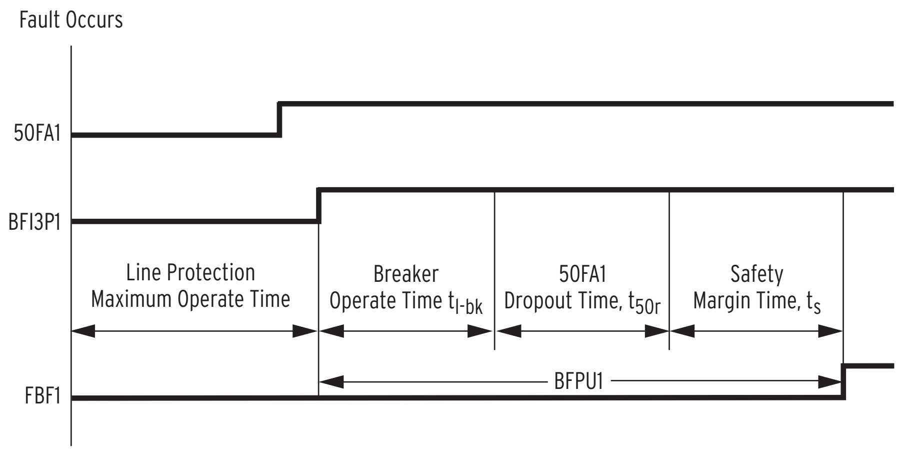


Figure 1.43 Timing Diagram for Setting BFPU1—Scheme 1

To maintain system stability, the relay must clear the fault within the total clearing time. Use the maximum operating time of the local and remote circuit breakers. The maximum operating time of the circuit breaker, $t_{l\text{-}bk}$, is 3 cycles for this example. Also, use the maximum dropout time for Relay Word bit 50FA1; the maximum dropout time of the phase current level detector, t_{50r}, is 1 cycle. 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. Determine the safety margin from *Figure 1.40*:

$$\begin{aligned} t_s &= t_t - (t_{1r} + t_{1-bk} + t_{50r} + t_{86} + t_{ch} + t_{r-bk}) \\ &= 17 - (2 + 3 + 1 + 1 + 1 + 3) \\ &= 6 \text{ cycles} \end{aligned}$$

Equation 1.87

where:

t_s = safety margin
t_t = total clearing time (17 cycles)
t_{lr} = line protection maximum operating time (2 cycles)
$t_{l\text{-}bk}$ = local circuit breaker maximum operating time (3 cycles)
t_{50r} = circuit breaker failure overcurrent element 50FA1 maximum reset time (1 cycle)
t_{86} = auxiliary breaker failure relay operating time (1 cycle)
t_{ch} = communications channel maximum operating time (1 cycle)
$t_{r\text{-}bk}$ = remote circuit breaker maximum operating time (3 cycles)

Use the safety margin result from *Equation 1.87* to calculate BFPU1:

$$\begin{aligned} \text{BFPU1} &= t_{1-bk} + t_{50r} + t_s \\ &= 3 + 1 + 6 \\ &= 10 \text{ cycles} \end{aligned}$$

Equation 1.88

BFPU1 := **10.000** Breaker Failure Time Delay—BK1 (0.000–6000 cycles)

Retrip Time Delay

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. Wait 4 cycles for the retrip.

RTPU1 := **4.000** Retrip Time Delay—BK1 (0.000–6000 cycles)

Circuit Breaker Failure Protection Initiation

To initiate circuit breaker failure protection for Circuit Breaker BK1, assign the protection elements to Relay Word bit BFI3P1 (Three-Pole Breaker Failure Initiate—BK1). This protection example uses three-pole tripping only.

BFI3P1 := **3PT** Three-Pole Breaker Failure Initiate—BK1 (SELOGIC Equation)

BFIA1 := **NA** A-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)

BFIB1 := **NA** B-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)

BFIC1 := **NA** C-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)

Circuit Breaker Failure Protection Initiation Dropout Delay

Set the circuit breaker failure initiate dropout time delay to zero. Disable this feature for this application example because this is not a dual circuit breaker scheme.

BFIDO1 := **0.000** Breaker Fail Initiate Dropout Delay—BK1 (0.000–1000 cycles)

Circuit Breaker Failure Protection Initiation Seal-In Delay

Set the latch logic circuit breaker failure pickup time delay to zero. Disable this feature for this application example. Relay Word bit 3PT internally initiates circuit breaker failure protection and has a minimum duration three-pole time delay on dropout (that is, TDUR3D).

BFISP1 := **0.000** Breaker Fail Initiate Seal-In Delay—BK1 (0.000–1000 cycles)

Residual Current Circuit Breaker Failure Protection

Enable no current/residual circuit breaker failure protection for Circuit Breaker BK1. Use this logic to detect a circuit breaker failure and take appropriate action when a weak source drives the fault or if the protected circuit breaker fails to trip during a high-resistance ground fault.

ENCBF1 := **Y** No Current/Residual Current Logic—BK1 (Y, N)

Residual Current Pickup

Set the pickup of the residual current level detector greater than maximum system unbalance; assume a 15 percent maximum unbalance.

$$50RP1 = 0.15 \cdot I_{load} = 0.15 \cdot 4.95 \text{ A} = 0.74 \text{ A}$$

50RP1 := **0.74** Residual Current Pickup—BK1 (0.25–50 A secondary)

Residual Current Circuit Breaker Failure Time Delay

Setting NPU1 is the time delay on pickup before the relay asserts a low current circuit breaker failure trip for Circuit Breaker BK1. You can set this delay greater than BFPU1; a high-resistance ground fault is not as much a threat to power system transient stability as is a phase fault, because synchronizing power still flows through the two unfaulted phases.

NPU1 := **12.000** No Current Breaker Failure Delay—BK1 (0.000–6000 cycles)

Residual Current Circuit Breaker Failure Initiation

This particular application uses the residual current circuit breaker failure scheme only to detect when the circuit breaker fails to trip during high-resistance ground faults. Set SELOGIC control equation BFIN1 (No Current Breaker Failure Initiate) to NA.

If you want to apply this scheme for no current conditions (e.g., weak source), assign the 52A contact from Circuit Breaker BK1 (52AA1) to the SELOGIC control equation BFIN1 (No Current Breaker Failure Initiate).

BFIN1 := **NA** No Current Breaker Failure Initiate—BK1 (SELOGIC Equation)

Load Current Circuit Breaker Failure Protection

Disable load current circuit breaker failure protection for Circuit Breaker BK1.

ELCBF1 := **N** Load Current Breaker Failure Logic—BK1 (Y, N)

Flashover Circuit Breaker Failure Protection

Disable flashover current circuit breaker failure protection for Circuit Breaker BK1.

EFOBF1 := **N** Flashover Breaker Failure Logic—BK1 (Y, N)

Circuit Breaker Failure Protection Trip Logic

Circuit Breaker 1 Failure Trip Equation

The SEL-421 has dedicated circuit breaker failure trip logic. Set SELOGIC control equation BFTR1 (Breaker Failure Trip—BK1) to assert for either Circuit Breaker BK1 circuit breaker failure trip or Circuit Breaker BK1 residual current circuit breaker failure trip. When this SELOGIC control equation asserts, the relay sets Relay Word bit BFTRIP1 to logical 1 until BFTR1 deasserts, the TDUR3D timer times out, and an unlatch or reset condition is active.

BFTR1 := **FBF1 OR NBF1** Breaker Failure Trip—BK1 (SELOGIC Equation)

Unlatch Circuit Breaker 1 Failure Trip Equation

Use SELOGIC control equation BFULTR1 (Breaker Failure Unlatch Trip—BK1) to define the conditions that unlatch the control outputs that assert during a circuit breaker failure trip. BFULTR1 unlatches the circuit breaker trip condition BFTRIP1 (Breaker Failure Trip for Circuit Breaker BK1). Assign a control input that is energized externally to signal the relay when the circuit breaker failure trip clears the fault successfully.

BFULTR1 := **IN104** Breaker Failure Unlatch Trip—BK1 (SELOGIC Equation)

Control Outputs

Use SELOGIC control equations to assign control outputs for tripping Circuit Breaker BK1, retripping Circuit Breaker BK1, and circuit breaker failure tripping. *Figure 1.44* shows dc connections for the circuit breaker failure trip and circuit breaker trip/retrip.

Use the main board high current interrupting control output for the retrip signal (RT1) because this output can interrupt large circuit breaker coil currents. There is no TDUR3D (3PT Minimum Trip Duration Time Delay) for RT1; the RT1 signal can drop out while there is current flowing through the trip coil, if the auxiliary circuit breaker contacts have not yet opened.

OUT101 := **3PT**

OUT103 := **RT1**

OUT107 := **BFTRIP1**

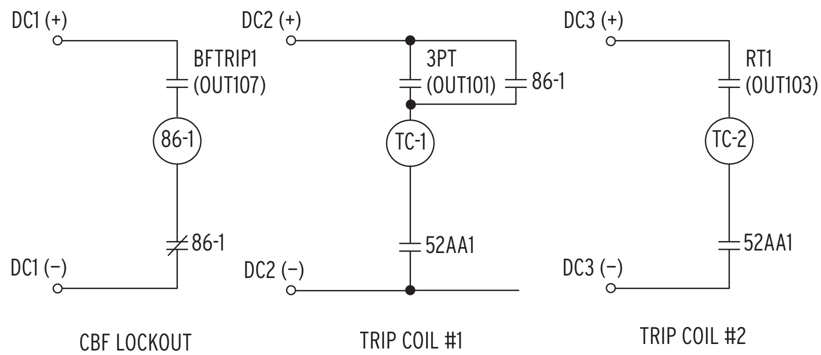


Figure 1.44 Circuit Breaker Failure Trip and Circuit Breaker Trip DC Connections

Example Completed

This completes the application example that describes setting of the SEL-421 for circuit breaker failure protection. Analyze your particular power system to determine the appropriate settings for your application.

Relay Settings

Table 1.42 lists all protection relay settings applied for this example.

Table 1.42 Settings for Circuit Breaker Failure Example 1 (Sheet 1 of 2)

Setting	Description	Entry
Relay Configuration (Group)		
EBFL1	Breaker 1 Failure Logic (N, 1, 2)	1
Breaker 1 Failure Logic (Group)		
50FP1	Phase Fault Current Pickup—BK1 (0.50–50 A secondary)	5.94
BFPU1	Breaker Failure Time Delay—BK1 (0.000–6000 cycles)	10.000
RTPU1	Retrip Time Delay—BK1 (0.000–6000 cycles)	4.000
BFI3PI	Three-Pole Breaker Failure Initiate—BK1 (SELOGIC Equation)	3PT
BFIA1	A-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)	NA

Table 1.42 Settings for Circuit Breaker Failure Example 1 (Sheet 2 of 2)

Setting	Description	Entry
BFIB1	B-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)	NA
BFIC1	C-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)	NA
BFIDO1	Breaker Fail Initiate Dropout Delay—BK1 (0.000–1000 cycles)	0.000
BFISP1	Breaker Fail Initiate Seal-In Delay—BK1 (0.000–1000 cycles)	0.000
ENCBF1	No Current/Residual Current Logic—BK1 (Y, N)	Y
50RP1	Residual Current Pickup—BK1 (0.25–50 A secondary)	0.74
NPU1	No Current Breaker Failure Delay—BK1 (0.000–6000 cycles)	12.000
BFIN1	No Current Breaker Failure Initiate—BK1 (SELOGIC Equation)	NA
ELCBF1	Load Current Breaker Failure Logic—BK1 (Y, N)	N
EFOBF1	Flashover Breaker Failure Logic—BK1 (Y, N)	N
BFTR1	Breaker Failure Trip—BK1 (SELOGIC Equation)	FBF1 OR NBF1
BFULTR1	Breaker Failure Unlatch Trip—BK1 (SELOGIC Equation)	IN104
Main Board (Outputs)		
OUT101		3PT
OUT103		RT1
OUT107		BFTRIP1

Circuit Breaker Failure Protection—Example 2

Use the SEL-421 to provide circuit breaker failure protection for both circuit breakers in breaker-and-a-half schemes. This application example explains setting the relay for Circuit Breaker BK1 (see *Figure 1.45*). You can apply these same settings for Circuit Breaker BK2. You can apply circuit breaker failure Scheme 2 protection for single-pole trip circuit breakers. Scheme 2 provides separate timers for multiphase faults (BFPU1) and single-phase faults (SPBFPU1). For more information on Scheme 2 circuit breaker failure protection, see *Failure to Interrupt Fault Current: Scheme 2 on page R.1.119*.

NOTE: This application example is for two circuit breakers. Apply the same settings for Circuit Breaker BK2 as for Circuit Breaker BK1. For Circuit Breaker BK2, substitute 2 for 1 in the following settings.

This example uses a 500 kV power system with single-pole tripping enabled (see *Figure 1.45*). *Table 1.43* provides the power system parameters.

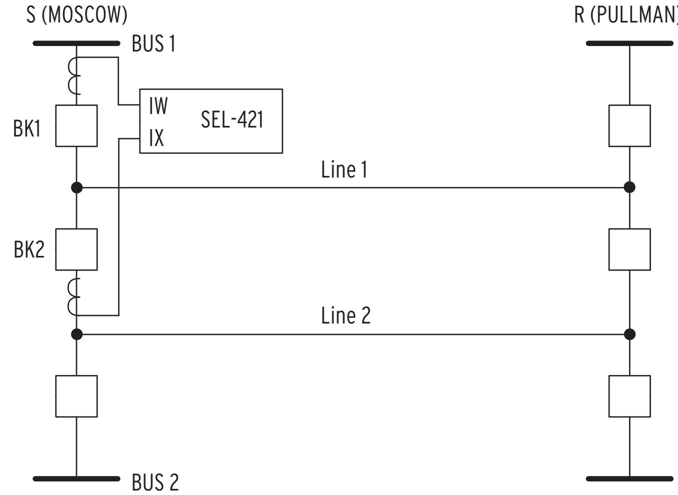


Figure 1.45 500 kV Power System for Circuit Breaker Failure Scheme 2

Table 1.43 Secondary Quantities

Parameter	Value
Line impedances	
Z_{1L1}	3.98 Ω ∠87.6° secondary
Z_{0L1}	14.48 Ω ∠82.1° secondary
Source S impedances	
$Z_{1S} = Z_{0S}$	4.4 Ω ∠88° secondary
Source R impedances	
$Z_{1R} = Z_{0R}$	1.78 Ω ∠88° secondary
Nominal frequency (f_{nom})	60 Hz
Maximum operating current (I_{load})	3.25 A secondary

Relay Configuration

Enable Scheme 2 circuit breaker failure protection for two circuit breakers.

EBFL1 := **2** Breaker 1 Failure Logic (N, 1, 2)

EBFL2 := **2** Breaker 2 Failure Logic (N, 1, 2)

Circuit Breaker 1 Failure Logic

Phase Current Level Detector

NOTE: This is one method for calculating setting 50FP1. Use your company practices and policies for determining the pickup setting for your particular application.

Set the phase fault current pickup greater than maximum load and less than the fault current that flows through Circuit Breaker BK1 ($I_{S(BK1)}$). Maximum load current, I_S, is 3.25 A secondary.

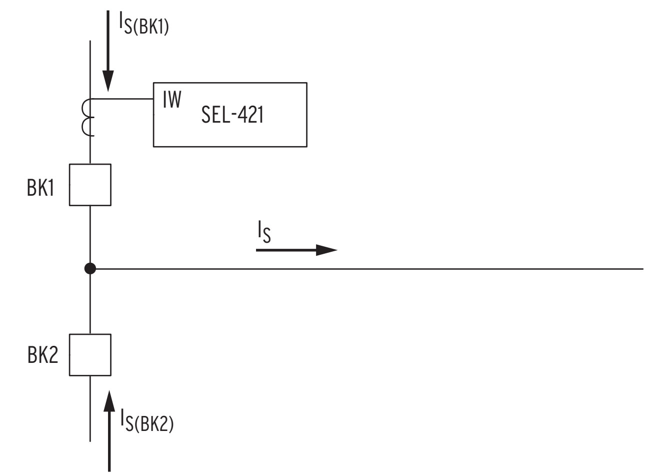


Figure 1.46 Fault Current Distribution Through Faulted Line at Station S

Assume that the total load current (I_S) supplied from Substation S flows through BK1 only; $I_{S(BK1)} = I_S$ (see *Figure 1.46*). Calculate setting 50FP1 with all the load current I_S through Circuit Breaker BK1.

$$\begin{aligned} 50FP1 &= 120\% \cdot (\text{Percent Current} \cdot I_S) \\ &= 120\% \cdot (100\% \cdot 3.25 \text{ A}) \\ &= 3.91 \text{ A secondary} \end{aligned}$$ **Equation 1.89**

A fault study shows that the minimum ground fault current, $I_{\text{fault mininum}}$, is 4.2 A secondary when the parallel line is in service at minimum generation. Calculate the 50FP1 setting for dependability at 1/2 of the minimum fault current.

$$\begin{aligned} 50FP1 &= 0.5 \cdot (\text{Percent Current} \cdot I_{\text{fault-minimum}}) \\ &= 0.5 \cdot (100\% \cdot 4.20 \text{ A}) \\ &= 2.10 \text{ A secondary} \end{aligned}$$ **Equation 1.90**

Although the result of this setting calculation is below maximum load (see *Equation 1.89*), use this calculation to set the 50FP1 element for dependability.

50FP1 := **2.10** Phase Fault Current Pickup—BK1 (0.50–50 A secondary)

Circuit Breaker Failure Time Delay

BFPU1 (Breaker Failure Time Delay—BK1) is the time delay on pickup for a circuit breaker trip following a multiphase fault. You can also add an additional delay, SPBFPU1 (SPT Breaker Failure Time Delay—BK1).

The recommended setting for BFPU1 is the sum of the following (see *Figure 1.47*):

- ➤ Maximum circuit breaker operating time
- ➤ 50FA1 maximum dropout time
- ➤ Safety margin

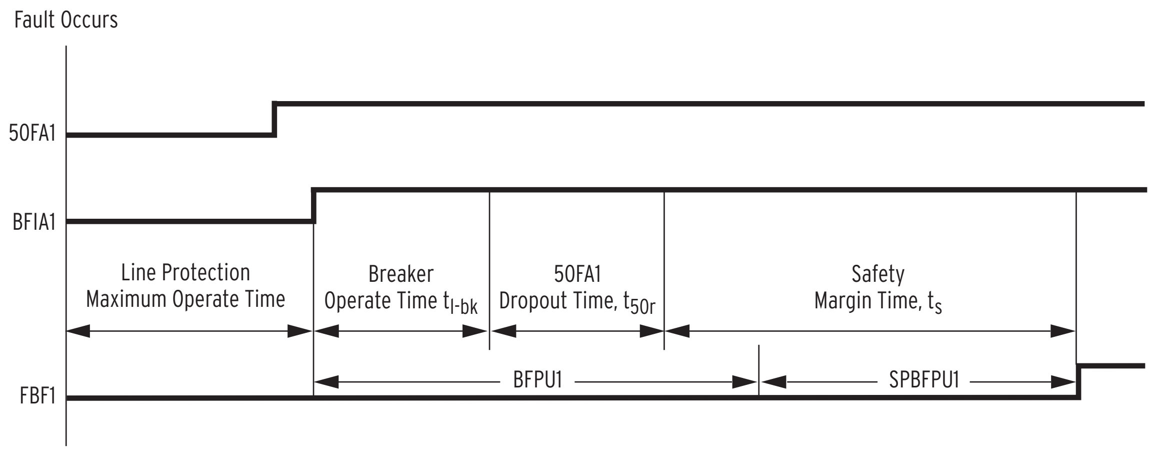


Figure 1.47 Timing Diagram for Setting BFPU1—Scheme 2

To maintain system stability, you must clear the fault within the total clearing time. Use the maximum operating time of the local and remote circuit breakers. The maximum operating time of the circuit breaker, $t_{l\text{-}bk}$, is 2 cycles for this example. Also use the maximum reset time of 50FA1; the maximum reset (dropout) time of the phase current level detector, t_{50r}, is 1 cycle. 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. Determine the safety margin from *Figure 1.40*.

$$\begin{aligned} t_s &= t_t - (t_{1r} + t_{1-bk} + t_{50r} + t_{86} + t_{ch} + t_{r-bk}) \\ &= 15 - (2 + 2 + 1 + 1 + 1 + 2) \\ &= 6 \text{ cycles} \end{aligned}$$

Equation 1.91

where:

t_s = safety margin
t_t = total clearing time (15 cycles)
t_{lr} = line protection maximum operating time (2 cycles)
$t_{l\text{-}bk}$ = local circuit breaker maximum operating time (2 cycles)
t_{50r} = circuit breaker failure overcurrent element 50FA1 maximum reset time (1 cycle)
t_{86} = auxiliary breaker failure relay operating time (1 cycle)
t_{ch} = communications channel maximum operating time (1 cycle)
$t_{r\text{-}bk}$ = remote circuit breaker maximum operating time (2 cycles)

Use the safety margin result from *Equation 1.92* to calculate BFPU1:

$$\begin{aligned} \text{BFPU1} &= t_{1-bk} + t_{50r} + t_s \\ &= 3 + 1 + 6 \\ &= 10 \text{ cycles} \end{aligned}$$

Equation 1.92

BFPU1 := **10.000** Breaker Failure Time Delay—BK1 (0.000–6000 cycles)

SPBFPU1 is an additional delay you can cascade to BFPU1 for single-phase faults (see *Figure 1.48*). Set SPBFPU1 to extend breaker failure pickup time delay as long as the total clearing time t_t = 15 cycles.

SPBFPU1 := **5.000** SPT Breaker Failure Time Delay -BK1 (0.000–6000 cycles)

Retrip Time Delay

Scheme 2 provides retrip timers RT3PPU1 for multiphase faults and RTPU1 for single-phase faults. Set the retrip following a single-pole trip to occur 3 cycles after circuit breaker failure initiation.

RTPU1 := **3.000** Retrip Time Delay—BK1 (0.000–6000 cycles)

A three-pole retrip follows a three-pole trip. The relay should attempt to retrip the protected circuit breaker before a circuit breaker failure trip asserts. Apply the default setting for the three-pole retrip time delay on pickup.

RT3PPU1 := **3.000** Three-Pole Retrip Time Delay—BK1 (0.000–6000 cycles)

Figure 1.48 compares the complete timing sequence for single-pole versus three-pole circuit breaker failure operations.

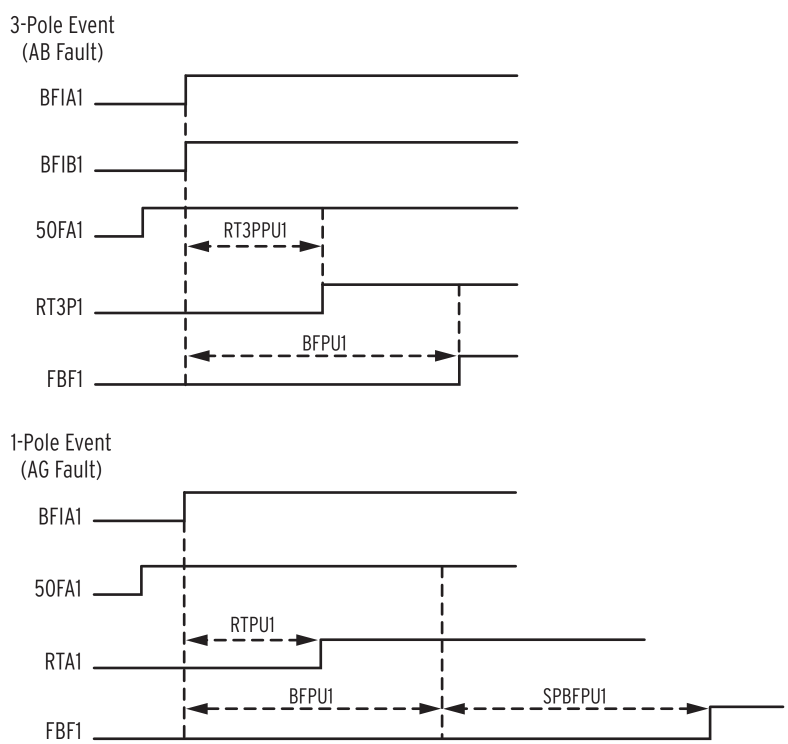


Figure 1.48 Timing Sequences for Circuit Breaker Failure Protection Scheme 2

Circuit Breaker Failure Initiation

Scheme 2 does not use Relay Word bit BFI3P1 to initiate failure to interrupt fault current circuit breaker failure protection.

BFI3P1 := **NA** Three-Pole Breaker Failure Initiate—BK1 (SELOGIC Equation)

Assign the protection elements to Relay Word bits BFIA1, BFIB1, and BFIC1 to initiate single-pole trip circuit breaker failure protection for Circuit Breaker BK1. For a complete description of circuit breaker failure initiation, see *Circuit Breaker Failure Protection on page R.1.117*. This application example uses the POTT tripping scheme, step-distance backup protection, and SOTF protection.

BFIA1 := **BFIAT1 OR TPA1** A-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)

BFIB1 := **BFIBT1 OR TPB1** B-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)

BFIC1 := **BFICT1 OR TPC1** C-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)

Relay Word bits BFIAT1, BFIBT1, and BFICT1 (Circuit Breaker 1 Latched Single-Pole Circuit Breaker Failure Initiation) latch the BFIA1, BFIB1, and BFIC1 inputs to the circuit breaker failure protection.

Circuit Breaker Failure Protection Initiation Dropout Delay

Set the circuit breaker failure initiate time delay on dropout to stretch a short pulsed circuit breaker failure initiation. Enable this feature for this application example because you are protecting dual circuit breakers.

BFIDO1 := **3.000** Breaker Failure Initiate Dropout Delay—BK1 (0.000–1000 cycles)

Circuit Breaker Failure Protection Initiation Seal-In Delay

Set the circuit breaker failure initiate time delay on pickup for the latch logic to qualify extended circuit breaker failure initiation latch seal-in.

BFISP1 := **4.000** Breaker Failure Initiate Seal-In Delay—BK1 (0.000–1000 cycles)

For these BFIDO1 and BFISP1 settings, if the circuit breaker failure initiate is 1 cycle or more, the relay seals in the circuit breaker failure extended initiation after the initiate signal deasserts until the BFIDO1 time (3 cycles) expires and all 50Fϕ1 elements deassert.

Residual Current Circuit Breaker Failure Protection

Disable residual current circuit breaker failure protection for Circuit Breaker BK1 because a strong source drives this terminal.

ENCBF1 := **N** No Current/Residual Current Logic—BK1 (Y, N)

Load Current Circuit Breaker Failure Protection

Disable load current circuit breaker failure protection for Circuit Breaker BK1.

ELCBF1 := **N** Load Current Breaker Failure Logic—BK1 (Y, N)

Flashover Circuit Breaker Failure Protection

Disable flashover current circuit breaker failure protection for Circuit Breaker BK1.

EFOBF1 := **N** Flashover Breaker Failure Logic—BK1 (Y, N)

Circuit Breaker Failure Protection Trip Logic

Circuit Breaker 1 Failure Trip Equation

The SEL-421 has dedicated circuit breaker failure trip logic. Set SELOGIC control equation BFTR1 (Breaker Failure Trip—BK1) to assert for a Circuit Breaker BK1 circuit breaker failure trip. When this SELOGIC control equation asserts, the relay sets Relay Word bit BFTRIP1 to logical 1 until BFTR1 deasserts, the TDUR1D timer times out, and an unlatch or reset condition is active.

BFTR1 := **FBF1** Breaker Failure Trip—BK1 (SELOGIC Equation)

Unlatch Circuit Breaker Failure Trip Equation

Use SELOGIC control equation BFULTR1 (Breaker Failure Unlatch Trip—BK1) to define the conditions that unlatch the control outputs that assert during a circuit breaker failure trip. BFULTR1 unlatches the circuit breaker trip condition BFTRIP1 (Breaker Failure Trip for Circuit Breaker 1). Assign a control input that is energized externally to signal the relay when the circuit breaker failure trip clears the fault successfully.

BFULTR1 := **IN104** Breaker Failure Unlatch Trip—BK1 (SELOGIC Equation)

Use the same input signal to unlatch the circuit breaker failure trip on Circuit Breaker BK2.

Control Outputs

Use SELOGIC control equations to assign the control outputs for tripping and retripping Circuit Breaker BK1 and Circuit Breaker BK2 and circuit breaker failure tripping. These output assignments are for the SEL-421 with an additional INT6 I/O interface board (see *I/O Interface Boards on page U.2.12*).

NOTE: The symbol ϕ indicates A, B, and C for A-phase, B-phase, or C-phase of the power system.

Assign the trip outputs to the hybrid (high current interrupting) control outputs. Use the high current interrupting control outputs for the retrip signal (RTϕ1) because these outputs can interrupt large circuit breaker coil currents. There is no TDUR3D (3PT Minimum Trip Duration Time Delay) for RTϕ1; the RTϕ1 signal can drop out while there is current flowing through the trip coil, if the auxiliary circuit breaker contacts have not yet opened.

OUT101 := **TPA1**

OUT102 := **TPB1**

OUT103 := **TPC1**

OUT107 := **BFTRIP1**

OUT201 := **TPA2**

OUT202 := **TPB2**

OUT203 := **TPC2**

OUT204 := **RTA1**

OUT205 := **RTB1**

OUT206 := **RTC1**

OUT207 := **RTA2**

OUT208 := **RTB2**

OUT209 := **RTC2**

Figure 1.49 illustrates the corresponding dc connections for Circuit Breaker BK1. Circuit Breaker BK2 connections are similar.

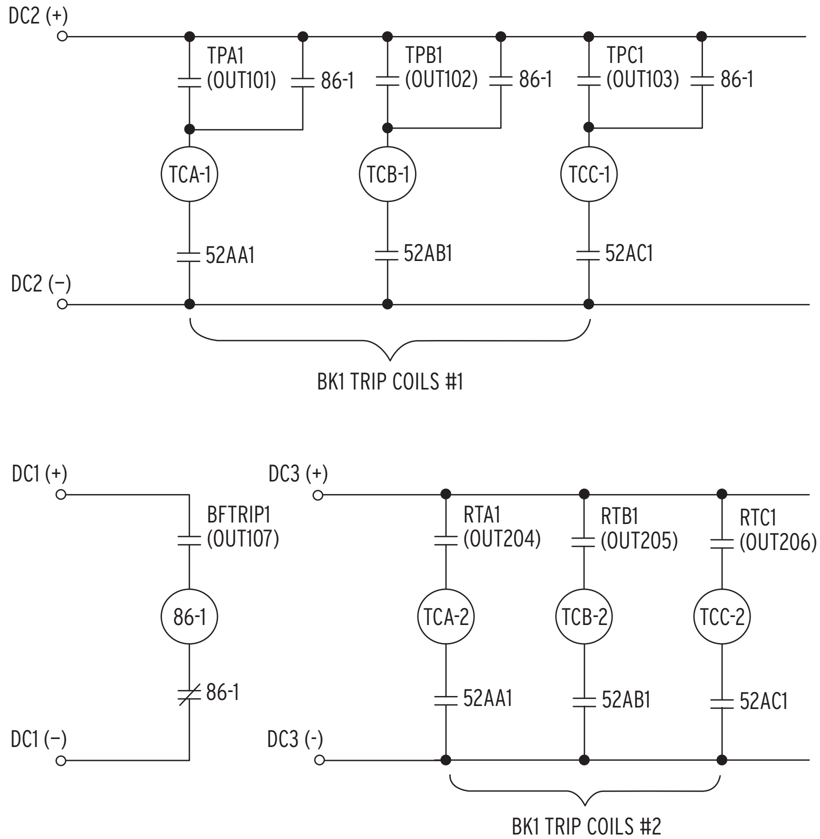


Figure 1.49 Circuit Breaker BK1 DC Connections (Two Trip Coils)

Example Completed

This completes the application example that describes setting the SEL-421 for Scheme 2 circuit breaker failure protection. Analyze your particular power system to determine the appropriate settings for your application.

Relay Settings

Table 1.44 lists all protection relay settings applied for this example. These settings are for Circuit Breaker BK1; settings for Circuit Breaker BK2 are similar unless otherwise noted.

Table 1.44 Settings for Circuit Breaker Failure Example 2 (Sheet 1 of 2)

Setting	Description	Entry
Relay Configuration (Group)		
EBFL1	Breaker 1 Failure Logic (N, 1, 2)	2
EBFL2	Breaker 2 Failure Logic (N, 1, 2)	2
Breaker 1 Failure Logic (Group)		
50FP1	Phase Fault Current Pickup—BK1 (0.50–50 A secondary)	2.10
BFPU1	Breaker Failure Time Delay—BK1 (0.000–6000 cycles)	10.000
SPBFU1	SPT Breaker Failure Time Delay—BK1 (0.000–6000 cycles)	5.000
RTPU1	Retrip Time Delay—BK1 (0.000–6000 cycles)	3.000
RT3PPU1	Three-Pole Retrip Time Delay—BK1 (0.000–6000 cycles)	3.000

Table 1.44 Settings for Circuit Breaker Failure Example 2 (Sheet 2 of 2)

Setting	Description	Entry
BFI3P1	Three-Pole Breaker Failure Initiate—BK1	NA
BFIAI	A-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)	BFIAT1 OR TPA1
BFIB1	B-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)	BFIBT1 OR TPB1
BFIC1	C-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)	BFICT1 OR TPC1
BFIDO1	Breaker Fail Initiate Dropout Delay—BK1 (0.000–1000 cycles)	3.000
BFISP1	Breaker Fail Initiate Seal-In Delay—BK1 (0.000–1000 cycles)	4.000
ENCBF1	No Current/Residual Current Logic—BK1 (Y, N)	N
ELCBF1	Load Current Breaker Failure Logic—BK1 (Y, N)	N
EFOBF1	Flashover Breaker Failure Logic—BK1 (Y, N)	N
BFTR1	Breaker Failure Trip—BK1 (SELOGIC Equation)	FBF1
BFULTR1	Breaker Failure Unlatch Trip—BK1 (SELOGIC Equation)	IN104
Control Outputs		
OUT101		TPA1
OUT102		TPB1
OUT103		TPC1
OUT107		BFTRIP1
OUT201		TPA2
OUT202		TPB2
OUT203		TPC2
OUT204		RTA1
OUT205		RTB1
OUT206		RTC1
OUT207		RTA2
OUT208		RTB2
OUT209		RTC2

Section 2
Monitoring and Metering

The SEL-421 Relay provides extensive capabilities for monitoring substation components and metering important power system parameters. The relay provides the following useful features:

- *Circuit Breaker Monitor on page A.2.1*
- *Station DC Battery System Monitor on page A.2.21*
- *Metering on page A.2.26*

This section explains each of these features and gives practical examples for applying these features in the power system.

Circuit Breaker Monitor

The SEL-421 features advanced circuit breaker monitoring.

This subsection is organized as follows:

- *Overview*
- *Enabling the Circuit Breaker Monitor on page A.2.2*
- *Circuit Breaker Contact Wear Monitor on page A.2.3*
- *Other Circuit Breaker Monitor Functions on page A.2.9*
- *BREAKER Command on page A.2.17*

Overview

NOTE: This section lists settings for Circuit Breaker 1; settings for Circuit Breaker 2 are similar; replace **1** in the setting with **2**.

The SEL-421 features advanced circuit breaker monitoring. *Figure 2.1* 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 SEL-421 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.

One of the many circuit breaker monitor features is the circuit breaker contact wear monitor. The SEL-421 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 SEL-421 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:

- Electrical operating time
- Mechanical operating time
- Circuit breaker inactivity time
- Interrupted current
- Pole scatter
- Pole discrepancy
- Motor run time

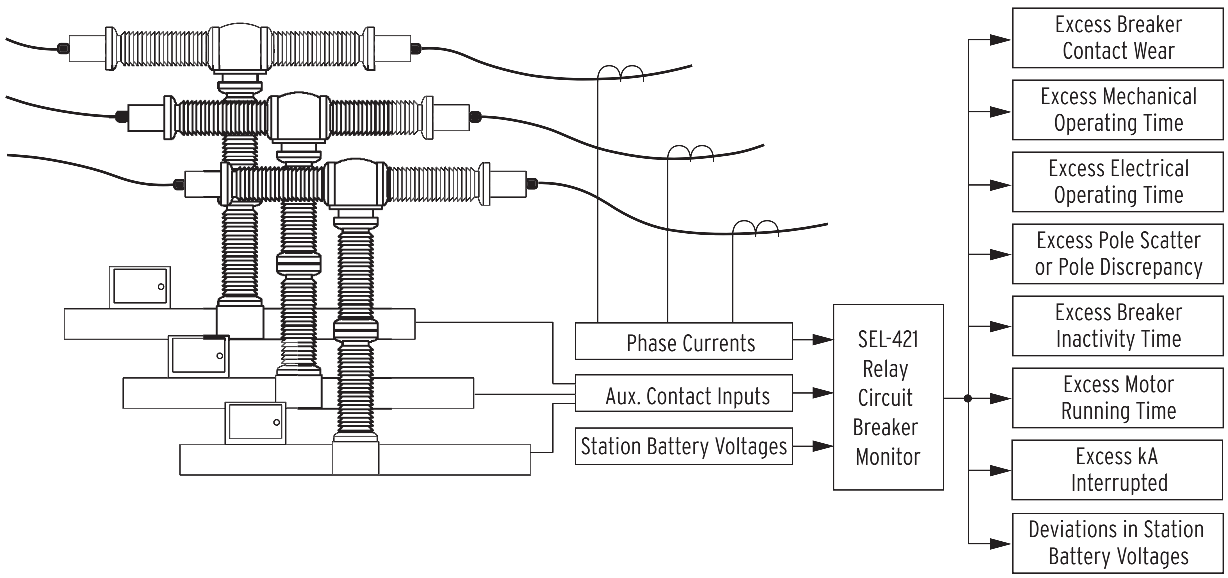


Figure 2.1 SEL-421 Intelligent Circuit Breaker Monitor

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

Enable and configure the SEL-421 circuit breaker monitor by using the settings listed in *Table 2.1* for each of two possible circuit breakers. Power system circuit breakers are either single-pole tripping or three-pole tripping circuit breakers; set the relay for the circuit breaker type that the relay controls. For a single pole tripping circuit breaker, set BK1TYP := 1, and for a three-pole tripping circuit breaker, set BK1TYP := 3. The factory default setting is BK1TYP := 1. Be sure to configure the relay with the settings that match your circuit breakers.

Table 2.1 Circuit Breaker Monitor Configuration

Name	Description	Range	Default
EB1MON	Enable Circuit Breaker 1 monitoring	Y, N	N
BK1TYP	Circuit Breaker 1 type	1, 3	1
EB2MON	Enable Circuit Breaker 2 monitoring	Y, N	N
BK2TYP	Circuit Breaker 2 type	1, 3	1

Circuit Breaker Contact Wear Monitor

The circuit breaker contact wear monitor in the SEL-421 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 SEL-421 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 SEL-421 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 clips or limits the maximum reported circuit breaker wear percentage at 150 percent.

NOTE: In the following discussion, three elements are specified, one for each phase: ϕ = A, B, and C).

The SEL-421 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 U.4.13* for information on setting the relay using these methods.) The default settings cause the contact wear monitor to integrate and increment each time the SEL-421 trip logic asserts.

Using the Circuit Breaker Contact Wear Monitor

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

NOTE: If you want to enable the circuit breaker monitor on Circuit Breaker 2, confirm that the relay is set for two-circuit breaker operation; setting NUMBK must be 2. Once you have set NUMBK := 2, you can set the Circuit Breaker 2 monitor settings, including EB2MON.

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 EB1MON to Y (for Yes). You can set EB1MON by using ASCII command **SET M**, the ACSELERATOR QuickSet **Breaker Monitor** branch of the **Settings** tree view, or with the front-panel SET/SHOW submenu.

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 2.1* shows typical circuit breaker maintenance information from an actual SF6 circuit breaker. The log/log plot of *Figure 2.2* is the circuit breaker maintenance curve, produced from the *Table 2.2* data.

Table 2.2 Circuit Breaker Maintenance Information—Example

Current Interruption Level (kA)	Permissible Close/Open Operations[a]
0.00–1.2	10000
2.00	3700
3.00	1500
5.00	400
8.00	150
10.00	85
20.00	12

[a] The action of a circuit breaker closing and then later opening is considered one close/open operation.

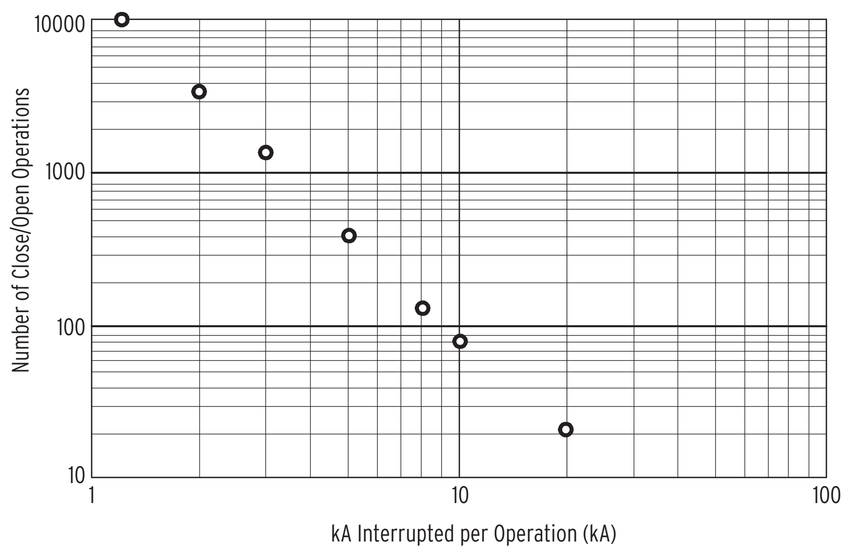


Figure 2.2 Circuit Breaker Maintenance Curve (Manufacturer's Data)

The three set points necessary to reproduce this circuit breaker maintenance curve in the SEL-421 are listed in *Table 2.3* for Circuit Breaker 1. This circuit breaker contact wear curve is shown in *Figure 2.3*.

Table 2.3 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.

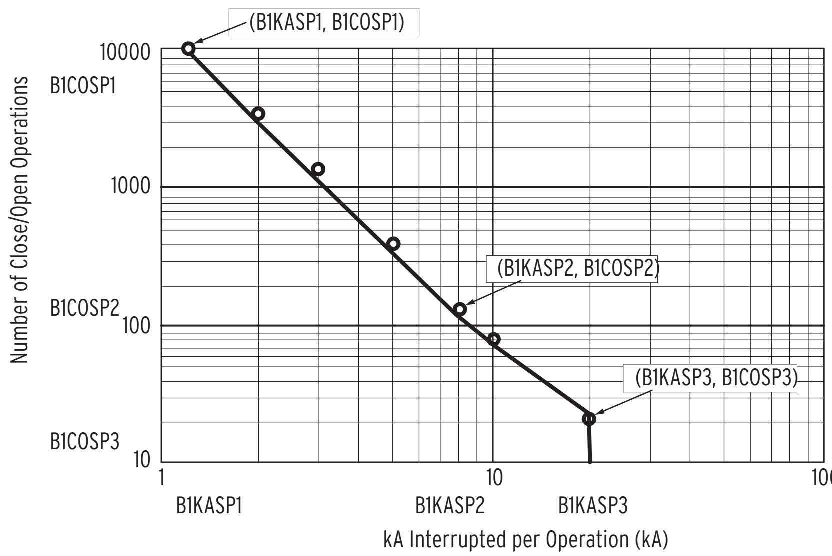


Figure 2.3 Circuit Breaker Contact Wear Curve With SEL-421 Settings

Circuit Breaker Contact Wear Curve Details. Circuit breaker maintenance information from the two end values of *Table 2.2* or *Figure 2.2* determine set point (B1KASP1, B1COSP1) and set point (B1KASP3, B1COSP3) for the contact wear curve of *Figure 2.3*. 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 of *Figure 2.2*. Another philosophy is to set the middle point based on actual experience or fault studies of the typical system faults.

EXAMPLE 2.1 Creating the Circuit Breaker Contact Wear Curve

Acquire the manufacturer's maintenance information (this example uses the data of Table 2.2 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 2.2.

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 2.3*. 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 2.1* 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 2.1* circuit breaker, this is at B1KASP3 := 20.0). If the interrupted current exceeds setting B1KASP3, the relay sets contact wear at 105 percent.

EXAMPLE 2.2 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 nKASP2 at or slightly greater than the expected single-line-to-ground fault current (B1KASP2 := 10.0 kA in this example). From the following equations, calculate these settings points to obtain the number of close/open operations:

$$\mathrm{B1COSP1} = \frac{\sum I^2 t}{(\mathrm{B1KASP1})^2 \bullet t_{arc}} = \frac{750}{2^2 \bullet (0.01667 \bullet 1)} := 11250 \qquad \textbf{Equation 2.1}$$

$$\mathrm{B1COSP2} = \frac{\sum I^2 t}{(\mathrm{B1KASP2})^2 \bullet t_{arc}} = \frac{750}{10^2 \bullet (0.01667 \bullet 1)} := 450 \qquad \textbf{Equation 2.2}$$

$$\mathrm{B1COSP3} = \frac{\sum I^2 t}{(\mathrm{B1KASP3})^2 \bullet t_{arc}} = \frac{750}{40^2 \bullet (0.01667 \bullet 1)} := 28 \qquad \textbf{Equation 2.3}$$

In these equations, t_{arc} is the arcing time in seconds; $t_{arc} = (1/f_{nom})\bullet$ (arc duration in cycles); f_{nom} is the nominal power system frequency (50 Hz or 60 Hz). These calculations show the number of close/open operations rounded to the nearest unit.

Preloading Contact Wear Data

Upon the first commissioning of the SEL-421, the associated circuit breakers can already have some wear. You can preload a separate amount of wear for each pole of each circuit breaker (see *Preload Breaker Wear on page A.2.19* 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

NOTE: In the following discussion, three elements are specified. There is one element for each phase: ϕ = A, B, and C).

Circuit Breaker Monitor Trip Initiation Settings: BM1TRPϕ. The SEL-421 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 2.4* 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 2.4 Circuit Breaker Monitor Initiate SELOGIC Control Equations

Name	Description	Default	Comment[a]
BM1TRPA	BK1 Monitor initiate equation	3PT	If BK1TYP := 3
BM1TRPA	A-phase BK1 Monitor initiate equation	TPA1	If BK1TYP := 1
BM1TRPB	B-phase BK1 Monitor initiate equation	BM1TRPA	If BK1TYP := 1
BM1TRPC	C-phase BK1 Monitor initiate equation	BM1TRPA	If BK1TYP := 1

[a] See Table 2.1.

Initiation settings can include both internal and external tripping conditions. In order to capture trip information initiated by devices other than the SEL-421, you must program the SELOGIC control equation BM1TRPϕ to sense these trips.

EXAMPLE 2.3 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 is located on the SEL-421 I/O Interface Board #1, and is either a direct-coupled or optoisolated input, depending on the specific I/O board that was ordered. Make the control input settings as explained in Control Inputs on page U.2.5.

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 ACSELERATOR 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 2.4 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 2.4 shows an illustration of this method in which IN106 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 IN106; you can use any control inputs that are appropriate for your installation. Vdc for this example is 125 Vdc.

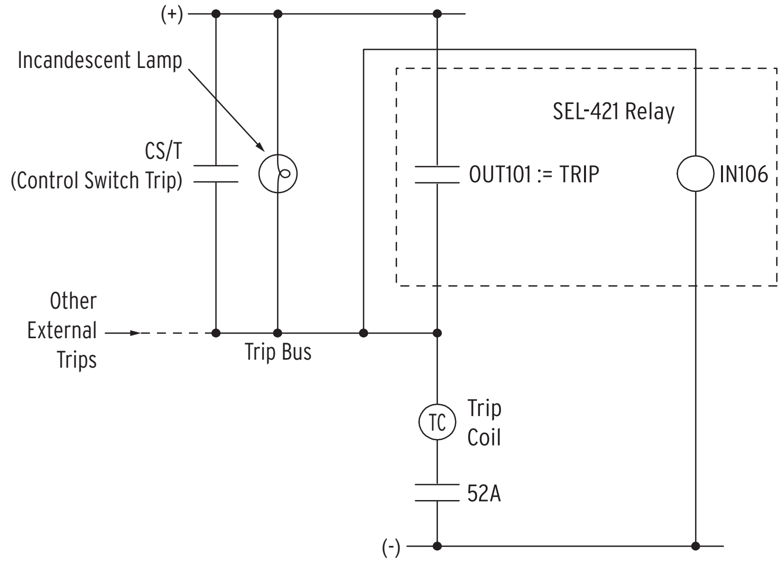


Figure 2.4 Trip Bus Sensing With Relay Input IN106

NOTE: See Control Inputs on page U.2.5 for recommended control input settings.

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 2.4 is open). Use the input assertion level setting IN106P to set the sensitivity of the control input. In most applications, set this input pickup level at 80 percent of the station battery voltage. See Table 2.1 on page U.2.5 for other recommended settings. You can also change the input debounce time IN106D for slow or noisy mechanical switches; the default debounce time of 1/8 cycle should be sufficient for most trip bus arrangements.

For a 125-Vdc station battery system, compute the assertion level as follows:

IN106P = 80% • 125 Vdc = 100 Vdc

In the **SET G** (GLOBAL) command or in the ACSELERATOR QuickSet **Global > Control Inputs Settings** tree view, confirm that the assertion level (setting IN106P) and the debounce time (setting IN106PU and IN106DO) 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)

IN106P := **100** Input IN106 Pickup Level (15–265 Vdc)

IN106PU := **0.1250** Input IN106 Pickup Delay (0.0000–5 cyc)

IN106DO := **0.1250** Input IN106 Dropout Delay (0.0000–5 cyc)

BM1TRPA := **IN106** 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.

NOTE: In the following discussion, three elements are specified. There is one element for each phase: ϕ = A, B, and C).

Circuit Breaker Monitor Close Initiation Settings: BM1CLSϕ. The SEL-421 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 2.5* shows the factory default settings for circuit breaker monitor close initiation.

Table 2.5 Circuit Breaker Monitor Close SELogic Control Equations

Name	Description	Default	Comment[a]
BM1CLSA	Breaker Monitor 1 close equation	BK1CL	If BK1TYP := 3
BM1CLSA	Breaker Monitor 1 A-phase close equation	BK1CL	If BK1TYP := 1
BM1CLSB	Breaker Monitor 1 B-phase close equation	BM1CLSA	If BK1TYP := 1
BM1CLSC	Breaker Monitor 1 C-phase close equation	BM1CLSA	If BK1TYP := 1

[a] See Table 2.1.

As in *Example 2.4* (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 SEL-421 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 Thresh—BK1), the relay asserts breaker monitor alarm Relay Word bit B1KAIAL.

Mechanical Operating Time

NOTE: This section lists settings for Circuit Breaker 1; settings for Circuit Breaker 2 are similar; replace **1** in the setting with **2**.

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 SEL-421 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 SEL-421 issues a mechanical slow operation alarm, B1MSOAL, for 5 seconds when trip or close times exceed these thresholds. See *Figure 2.5* for a Circuit Breaker 1 A-phase timing diagram.

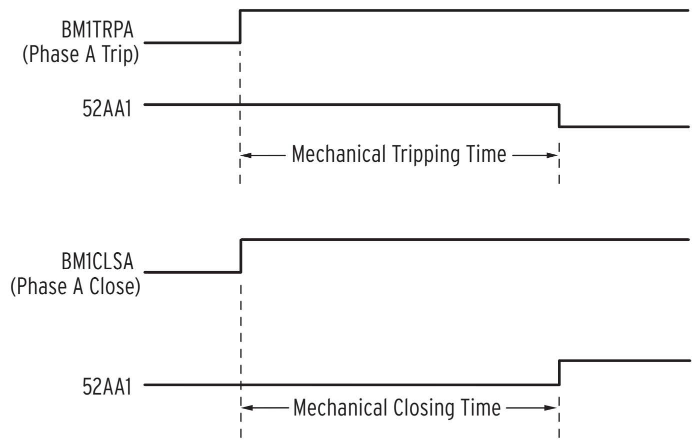


Figure 2.5 Mechanical Operating Time for Circuit Breaker 1 A-Phase

EXAMPLE 2.5 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 IN101, IN102, and IN103. This example uses inputs IN101, IN102, and IN103 for phases A, B, and C, respectively; you can use any control inputs that are appropriate for your installation. The control voltage for this example is 125 Vdc.

Control Inputs IN101–IN103 are located on the SEL-421 main board and are direct-coupled inputs. Make the control input pickup, dropout, and debounce timer settings as explained in Control Inputs on page U.2.5.

Set the Relay Word bits to respond to these inputs.

52AA1 := **IN101** A-Phase N/O Control Input–BK1 (SELogic Equation)

52AB1 := **IN102** B-Phase N/O Control Input–BK1 (SELogic Equation)

52AC1 := **IN103** A-Phase N/O 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. Use the default settings for input conditioning (debounce time and assertion level), as with inputs IN101 to IN103 above.

Set the mechanical operating time threshold for the slow trip alarm (B1MSTRT) at 30 ms, and the slow close alarm threshold (B1MSCLT) at 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 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)

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 SEL-421 issues an electrical slow operation alarm, B1ESOAL, for 5 seconds when trip or close times exceed these thresholds. *Figure 2.6* shows the timing diagram for A-phase pole of Circuit Breaker 1.

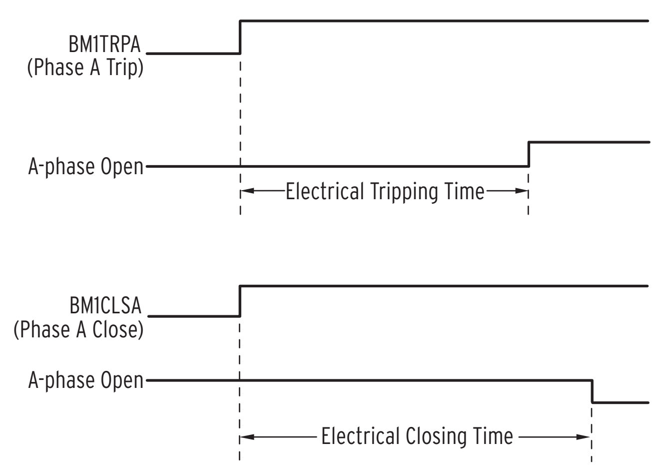


Figure 2.6 Electrical Operating Time for Circuit Breaker 1 A-Phase

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 2.6 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 through 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 SEL-421 I/O Interface board #1 and are either direct-coupled or optoisolated inputs, depending on the specific I/O Interface board that was ordered. Make the control input settings as explained in Control Inputs on page U.2.5.

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)

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

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.

The SEL-421 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.

Figure 2.7 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.

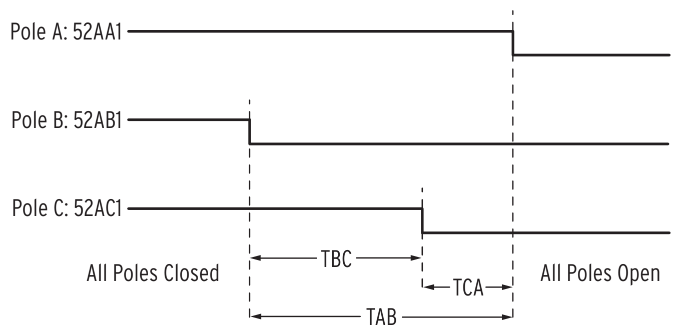


Figure 2.7 Timing Illustration for Pole Scatter at Trip

EXAMPLE 2.7 Pole Scatter Settings

Use Circuit Breaker 1, a single-pole tripping circuit breaker, for this example. This example uses control inputs IN101, IN102, and IN103 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 IN101–IN103 are located on the SEL-421 main board and are direct-coupled inputs. Make the control input pickup, dropout, and debounce timer settings as explained in Control Inputs on page U.2.5. Connect the circuit breaker normally-open auxiliary circuit breaker (52A) contacts through station battery power to IN101, IN102, and IN103.

Set the relay to respond to these inputs by using the ACSELERATOR QuickSet **Breaker Monitor** (**SET M**) settings:

52AA1 := **IN101** A-Phase Normally Open Control Input—BK1 (SELOGIC Equation)

52AB1 := **IN102** B-Phase Normally Open Control Input—BK1 (SELOGIC Equation)

52AC1 := **IN103** 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 through IN206; you can use any control inputs that are appropriate for your installation. Use the default settings for conditioning inputs IN201 through IN206.

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. (See Pole

Discrepancy on page A.2.14 for information on setting B1PDD). 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)

If any of the pole-open times (TAB, TBC, and TCA in Figure 2.7) 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

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.

The SEL-421 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.

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.

$$B1PDD := (SPOID + \text{circuit breaker pole operating time} + \text{contact latency}) \bullet 1.2 \qquad \textbf{Equation 2.4}$$

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. See *Auto-Reclosing and Synchronism Check on page R.2.1* for information on setting the SEL-421 recloser.

Figure 2.8 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.

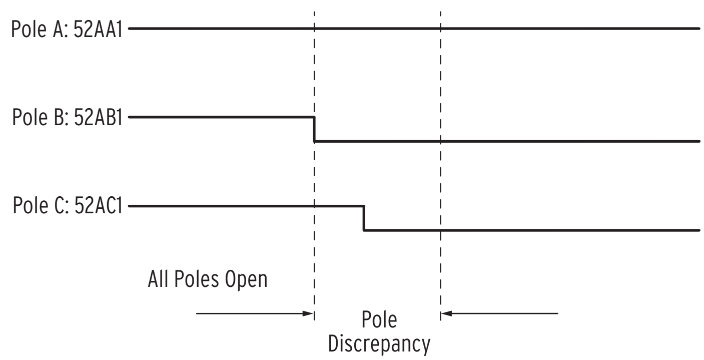


Figure 2.8 Pole Discrepancy Measurement

EXAMPLE 2.8 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 IN101, IN102, and IN103 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 IN101–IN103 are located on the SEL-421 main board and are direct-coupled inputs. Make the control input pickup, dropout, and debounce timer settings as explained in Control Inputs on page U.2.5. Connect the circuit breaker normally-open auxiliary circuit breaker (52A) contacts through station battery power to IN101, IN102, and IN103.

Set the relay internal Relay Word bits to respond to these inputs by using the ACSELERATOR QuickSet **Breaker Monitor** (**SET M**) settings:

52AA1 := **IN101** A-Phase Normally Open Control Input—BK1 (SELOGIC Equation)

52AB1 := **IN102** B-Phase Normally Open Control Input—BK1 (SELOGIC Equation)

52AC1 := **IN103** 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 through IN206; you can use any control inputs that are appropriate for your installation.

Use the default relay Global settings for conditioning inputs IN101 to IN103. 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 SEL-421 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.

EXAMPLE 2.9 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 Thresh—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 1 day of elapsed time.

Motor Running Time

The SEL-421 circuit breaker monitor measures 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 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 2.10 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 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.

The control voltage for this example is 125 Vdc. Control Input IN207 is located on the SEL-421 I/O Interface board #1 and is either a direct-coupled or an optoisolated input, depending on the specific I/O Interface board that was ordered. Make the control input settings as explained in Control Inputs on page U.2.5.

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 SEL-421 monitors two separate circuit breakers; you must specify Circuit Breaker 1 and Circuit Breaker 2 for most **BRE** commands. *Table 2.6* shows the SEL-421 **BRE** commands. For more information on the **BRE** command, see *BREAKER on page R.9.2*.

Table 2.6 BRE Command[a]

Command	Description	Access Level
BRE C A	Clear all circuit breaker monitor data to zero.	B, P, A, O, 2
BRE R A	Clear all circuit breaker monitor data to zero.	B, P, A, O, 2
BRE *n* **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
BRE *n*	Display the breaker report for the most recent Circuit Breaker *n* operation.	1, B, P, A, O, 2
BRE *n* **H**	Display history data for the last 128 Circuit Breaker *n* operations.	1, B, P, A, O, 2
BRE *n* **P**	Preload previously accumulated Circuit Breaker *n* data.	B, P, A, O, 2

[a] n is 1 or 2, representing Circuit Breaker 1 and Circuit Breaker 2, respectively.

The **BRE 1 C, BRE 2 C, BRE 1 R**, and **BRE 2 R** commands reset the accumulated circuit breaker monitor data for Circuit Breaker 1 or Circuit Breaker 2, respectively. If you do not specify Circuit Breaker 1 or Circuit Breaker 2, the clear commands **BRE C A** and **BRE R A** clear all data for both circuit breakers.

The **BRE 1** or **BRE 2** commands display the circuit breaker report for the most recent Circuit Breaker 1 or Circuit Breaker 2 operation, respectively.

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 (EB1MON := N and EB2MON := N).

Circuit Breaker Report

Figure 2.9 is a sample breaker report (shown 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. For example, if you set EDCMON := 1, then the relay does not show the row labeled `Last Op Minimum DC2 (V)`.

```
=>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 2.9 Breaker Report
(For the most recent operation)

Breaker History

The SEL-421 displays the circuit breaker history report when you issue the **BRE 1 H** or **BRE 2 H** commands. The report consists of as many as 128 circuit breaker monitor events stored in nonvolatile memory. These events are determined by settings BM1TRPϕ and BM1CLSϕ (see *Program the SELOGIC Control Equations for Trip and Close Conditions on page A.2.7*). The breaker history report is similar to *Figure 2.10* (shown with typical data).

```
=>BRE 1 H <Enter>
Breaker 1 History Report

Relay 1                                      Date: 03/15/2001  Time: 07:19:27.156
Station A                                    Serial Number: 01001234

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 2.10 Breaker History Report

Preload Breaker Wear

You can preload a separate contact wear value for each pole of each circuit breaker by using the commands **BRE 1 P** or **BRE 2 P** for Circuit Breaker 1 and Circuit Breaker 2, respectively. 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 percent 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 2.11* for both the terminal and ACSELERATOR 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 2.11 Circuit Breaker Preload Data

When performing circuit breaker testing, capture the **BRE 1 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 1 P** command. Using this method, you can eliminate testing operations from actual usage data in the circuit breaker monitor.

Compressed ASCII Circuit Breaker Report

You can retrieve a Compressed ASCII circuit breaker report by using the **CBR** command from any communications port. See *CBREAKER on page R.9.4* for more information on the **CBR** command.

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,stationid,fidstring,"yyyy"
"BID","yyyy"
breakerid,"yyyy"
"AVG_TR_ELEC","LAST_TR_ELEC","AVG_TR_MECH","LAST_TR_MECH","LAST_TR_MINDC2","TR_INAC(
    days)","MAX_TR_SCAT(ms)","LAST_TR_SCAT(ms)","yyyy"
fff,fff,fff,fff,fff,fff,fff,iii,fff,fff,"yyyy"
fff,fff,fff,fff,fff,fff,fff,iii,fff,fff,"yyyy"
fff,fff,fff,fff,fff,fff,fff,iii,fff,fff,"yyyy"
"AVG_CL_ELEC","LAST_CL_ELEC","AVG_CL_MECH","LAST_CL_MECH","LAST_CL_MINDC2","CL_INAC(
    days)","MAX_CL_SCAT(ms)","LAST_CL_SCAT(ms)","yyyy"
fff,fff,fff,fff,fff,fff,fff,iii,fff,fff,"yyyy"
fff,fff,fff,fff,fff,fff,fff,iii,fff,fff,"yyyy"
fff,fff,fff,fff,fff,fff,fff,iii,fff,fff,"yyyy"
"ACC_CURR(kA)","ACC_WEAR(%)","MAX_INT_CURR(%)","LAST_INT_CURR(%)","NUM_OPERS","yyyy"
fff,fff,fff,fff,iii,"yyyy"
fff,fff,fff,fff,iii,"yyyy"
fff,fff,fff,fff,iii,"yyyy"
"AVG_MOT_RUNTIME","LAST_MOT_RUNTIME","RESET_MONTH","RESET_DAY","RESET_YEAR","RESET_H
    OUR","RESET_MIN","RESET_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 SEL-421 automatically monitors station battery system health by measuring the dc voltage, ac ripple, and voltage between each battery terminal and ground. The relay provides two dc monitor channels, Vdc1 and Vdc2. 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 2.12* shows a typical dual-battery dc system.

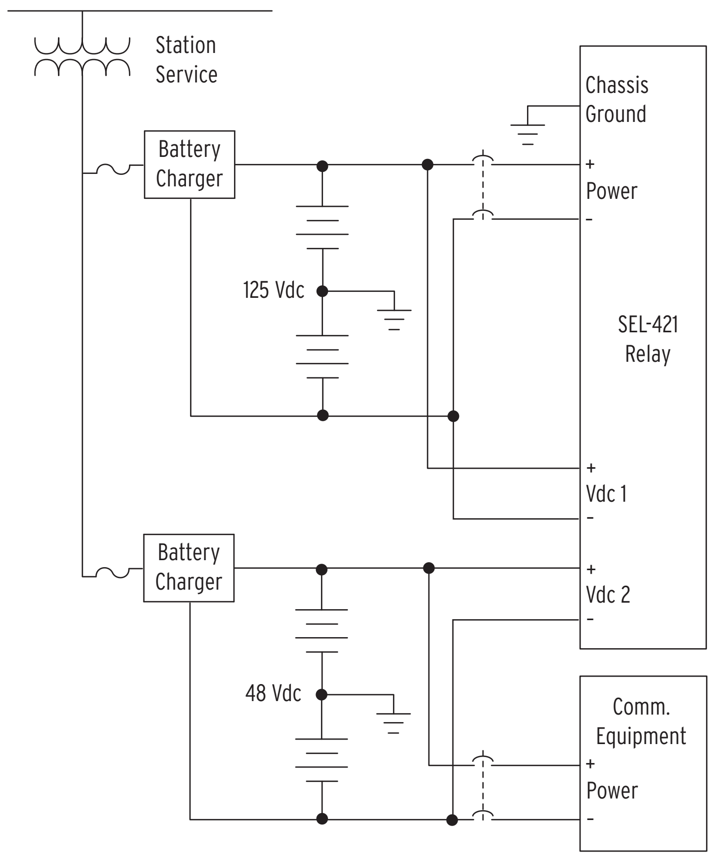


Figure 2.12 Typical Station DC Battery System

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 (see *Circuit Breaker Report on page A.2.18*).

NOTE: First enable Station DC Monitoring (with the Global setting EDCMON) to access station dc battery monitor settings.

Table 2.7 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 ACSELERATOR QuickSet **Global > Station DC Monitoring** branch of the **Settings** tree view to access the DC Monitor settings.

Table 2.7 DC Monitor Settings[a] and Relay Word Bit Alarms

Setting	Definition	Relay Word Bit
DC1LFP	Low Level Fail Pickup (OFF, 15–300 Vdc)[b]	DC1F
DC1LWP	Low Level Warn Pickup (OFF, 15–300 Vdc)[a]	DC1W
DC1HWP	High Level Warn Pickup (OFF, 15–300 Vdc)[a]	DC1W
DC1HFP	High Level Fail Pickup (OFF, 15–300 Vdc)[a]	DC1F
DC1RP	Peak to Peak AC Ripple Pickup (1–300 Vac)[a]	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.
[b] Minimum setting step size is 1 V for voltage settings.

Station DC Battery System Monitor Application

Not only does the station dc monitor provide 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 undervoltage 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 communication 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 pre-selected time in order 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 2.8* lists expected battery voltages under various conditions using commonly accepted per-cell voltages.

Table 2.8 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 2.9* to determine the SEL-421 station dc battery monitor threshold settings. *Table 2.9* 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 2.9 Example DC Battery Monitor Settings—125 Vdc for Vdc1 and 48 Vdc for Vdc2

Setting	Description	Indication	Value (Vdc)
DC1LFP	Low-fail threshold, Mon. 1	Poor battery performance	100
DC1LWP	Low-warning threshold, Mon. 1	Charger malfunction	127
DC1HWP	High-warning threshold, Mon. 1	Equalization	137
DC1HFP	High-fail threshold, Mon. 1	Charger malfunction	142
DC2LFP	Low-fail threshold, Mon. 2	Poor battery performance	38
DC2LWP	Low-warning threshold, Mon. 2	Charger malfunction	50
DC2HWP	High-warning threshold, Mon. 2	Equalization	55
DC2HFP	High-fail threshold, Mon. 2	Charger malfunction	57

AC Ripple

Another method for determining whether the substation battery charger has failed is to monitor the amount of ac ripple on the station dc battery system. The *IEEE C37.90-1989* standard also identifies an "*Allowable AC Component in DC Control Voltage Supply*" *(Section 6.5)* as an alternating component (ripple) of 5 percent peak or less. (This definition is valid if the minimum instantaneous voltage is not less than 80 percent of the rated voltage.) The SEL-421 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 2.10* shows the ac ripple threshold settings for this example.

Table 2.10 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 2.5* 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 2.5

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 2.6* 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 2.6

The SEL-421 uses this voltage ratio to calculate a ground detection factor. *Figure 2.13* shows a graphical representation of the ground detection factor setting and battery system performance.

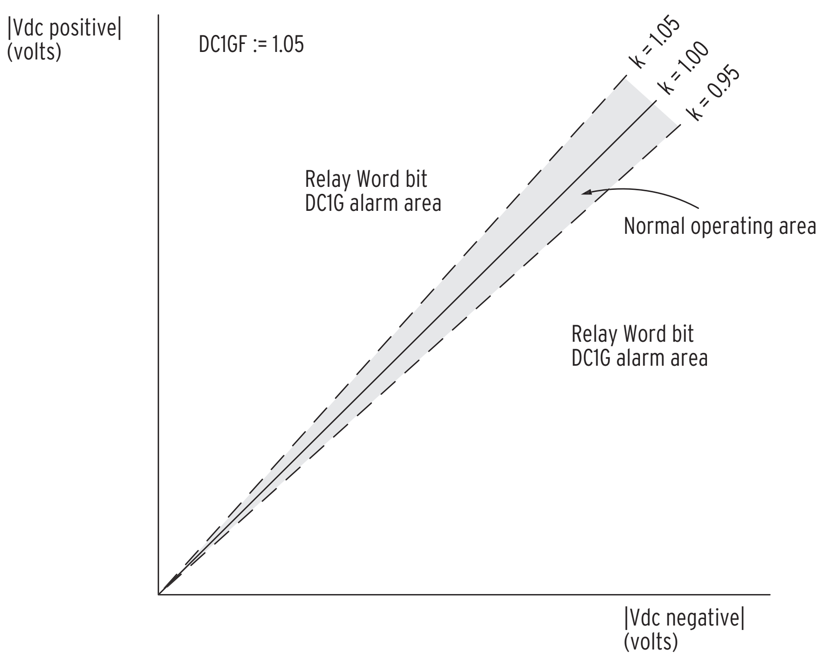


Figure 2.13 Ground Detection Factor Areas

NOTE: Only the upper ground detection factor in Figure 2.12 is entered as a setting. The SEL-421 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 2.11* lists the ground detection factor threshold settings for this example.

Table 2.11 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 b contact of control output OUT108. Set the SELOGIC control equation to include the battery monitor thresholds:

OUT108 := **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. See *Alarm Output on page U.2.43* for more information.

DC Battery Monitor Metering

The SEL-421 monitors battery system voltages and records time stamps for voltage excursions. In addition, the relay records maximum and minimum battery voltages. *Figure 2.14* shows a sample dc battery monitor meter report. Use the **MET BAT** command from a communications terminal to obtain this report. For more information on the **MET** commands, see *METER on page R.9.28*.

```
=>MET BAT <Enter>

Relay 1                                        Date: 03/22/2001  Time: 09:37:10.035
Station A                                      Serial Number: 2001001234

Station Battery         VDC      VDCPO     VDCNE      VAC
   VDC1 (V)             24.17    11.98     -12.19      0.01
   VDC2 (V)             47.68    23.80     -23.88      0.02

             VDC1(V)    Date        Time         VDC2(V)    Date        Time
Minimum        20.12 03/15/2001  14:28:59.172     41.64 03/22/2001  08:46:25.726
Enter L-Zone         03/15/2001  14:28:51.490           03/18/2001  18:46:23.868
Exit L-Zone          03/15/2001  14:29:05.035           03/18/2001  18:47:55.441

Maximum        27.19 03/19/2001  08:34:49.761     50.84 03/22/2001  08:34:55.490
Enter H-Zone         03/19/2001  08:34:27.172           03/22/2001  08:34:27.172
Exit H-Zone          03/19/2001  08:37:01.041           03/22/2001  08:35:00.912

LAST DC RESET:  03/15/2001  12:30:30.492

=>
```

Figure 2.14 Battery Metering: Terminal

Any battery voltage between setting DCnLWP and the dc battery monitor low limit of 15 Vdc is in the L-Zone. Battery voltages in the H-Zone are voltages between setting DCnHWP and the dc battery monitor high limit of 300 Vdc.

Reset DC Battery Monitor Metering

Use the **MET RBM** command from a communications terminal to reset the dc battery monitor. The relay sets the Relay Word bit RST_BAT to reset the dc battery monitor, and clears RST_BAT when the reset has been successfully completed. You can program a SELOGIC control equation RST_BAT (in Global settings) to control dc battery monitor reset. Enable data reset control with global setting EDRSTC := Y.

Metering

The SEL-421 provides five metering modes for measuring power system operations:

- ➤ *Instantaneous Metering on page A.2.27*
- ➤ *Maximum/Minimum Metering on page A.2.31*
- ➤ *Demand Metering on page A.2.33*
- ➤ *Energy Metering on page A.2.37*
- ➤ *Time-Synchronized Metering on page A.2.39*

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 analyses 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 SEL-421 processes three sets of current quantities: LINE, BK1, and BK2 (when configured for two circuit breakers). In one configuration using two circuit breakers, Terminal W is usually connected as BK1, and Terminal X is generally connected as BK2. The line voltage from Terminal Y (VϕY) provides the voltage quantities for LINE. See *Current and Voltage Source Selection on page R.1.2* for more information on configuring the SEL-421 inputs.

Use the **MET** command to access the metering functions. Issuing the **MET** command with no options returns the fundamental frequency measurement quantities listed in *Table 2.13*. 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 either circuit breaker. For example, you can monitor the fundamental currents on Circuit Breaker 1 or Circuit Breaker 2 by entering **MET BK1** or **MET BK2**, respectively. Additionally, the **MET PM** command provides time-synchronized phasor measurements at a specific time, e.g., **MET PM 12:00:00**.

Table 2.12 lists **MET** command variants for instantaneous, maximum/minimum, demand, and energy metering. The *METER on page R.9.28* describes these and other **MET** command options. Other **MET** command options are for viewing protection and automation variables (see *SELOGIC Control Equation Programming on page R.3.4*); analog values from

MIRRORED BITS® communications (see *SEL MIRRORED BITS Communications on page R.5.15*); and synchronism check (see *Section 2: Auto-Reclosing and Synchronism Check in the Reference Manual*).

Table 2.12 MET Command[a]

Name	Description
MET	Display Fundamental Line metering information
MET BK*n*	Display Fundamental Circuit Breaker *n* metering information
MET RMS	Display rms Line metering information
MET BK*n* RMS	Display rms Circuit Breaker *n* metering information
MET M	Display Line Maximum/Minimum metering information
MET BK*n* M	Display Circuit Breaker *n* Maximum/Minimum metering information
MET RM	Reset Line Maximum/Minimum metering information
MET BK*n* RM	Reset Circuit Breaker *n* 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 SYN	Display Synchronism Check voltage and slip angle/frequency information
MET BAT	Display DC Battery Monitor information (see *Figure 2.14*)
MET PM	Display Phasor Measurement (Synchrophasor) metering information

[a] n is 1 or 2, representing Circuit Breaker 1 and Circuit Breaker 2, respectively.

Instantaneous Metering

Use instantaneous metering to monitor power system parameters in real time. The SEL-421 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

You can also monitor these real-time rms quantities (with harmonics included):

- RMS phase voltages and currents
- Real and apparent rms power
- True power factor

Both the fundamental and the rms-metered quantities are available for the LINE input. The relay also provides both the fundamental and rms circuit breaker currents for circuit breakers BK1 and BK2.

Voltages, Currents, Frequency

Table 2.13 summarizes the metered voltage, current, and frequency quantities available in the SEL-421. The relay reports all instantaneous voltage magnitudes, current magnitudes, and frequency as absolute value 10-cycle averages (for example, the LINE A-phase filtered magnitude LIAFM_10c; see *Appendix B: Analog Quantities in the Reference Manual*). Instantaneous metering also reports sequence quantities referenced to A-phase. The SEL-421 references angle measurements to positive-sequence quantities. The relay reports angle measurements in the range of ±180.00 degrees.

Table 2.13 Instantaneous Metering Quantities—Voltages, Currents, Frequency

Metered Quantity	Symbol	Fundamental	RMS
Phase voltage magnitude	$\lvert V_\phi \rvert$	X	X
Phase voltage angle	$\angle(V_\phi)$	X	
Phase current magnitude	$\lvert I_\phi \rvert$	X	X
Phase current angle	$\angle(I_\phi)$	X	
Phase-to-phase voltage magnitude	$\lvert V_{\phi\phi} \rvert$	X	X
Phase-to-phase voltage angle	$\angle(V_{\phi\phi})$	X	
Positive-sequence voltage magnitude	$\lvert V_1 \rvert$	X	
Positive-sequence voltage angle	$\angle(V_1)$	X	
Negative-sequence voltage magnitude	$\lvert 3V_2 \rvert$	X	
Negative-sequence voltage angle	$\angle(3V_2)$	X	
Zero-sequence voltage magnitude	$\lvert 3V_0 \rvert$	X	
Zero-sequence voltage angle	$\angle(3V_0)$	X	
Positive-sequence current magnitude	$\lvert I_1 \rvert$	X	
Positive-sequence current angle	$\angle(I_1)$	X	
Negative-sequence current magnitude	$\lvert 3I_2 \rvert$	X	
Negative-sequence current angle	$\angle(3I_2)$	X	
Zero-sequence current magnitude	$\lvert 3I_0 \rvert$	X	
Zero-sequence current angle	$\angle(3I_0)$	X	
Battery voltages	Vdc	X	
Frequency	f	X	X
Circuit breaker current magnitudes	$\lvert I_\phi \rvert$	X	X
Circuit breaker current angles	$\angle(I_\phi)$	X	

Power

Table 2.14 shows the power quantities that the relay measures. The instantaneous power measurements are derived from 10-cycle averages that the SEL-421 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 2.15*).

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.

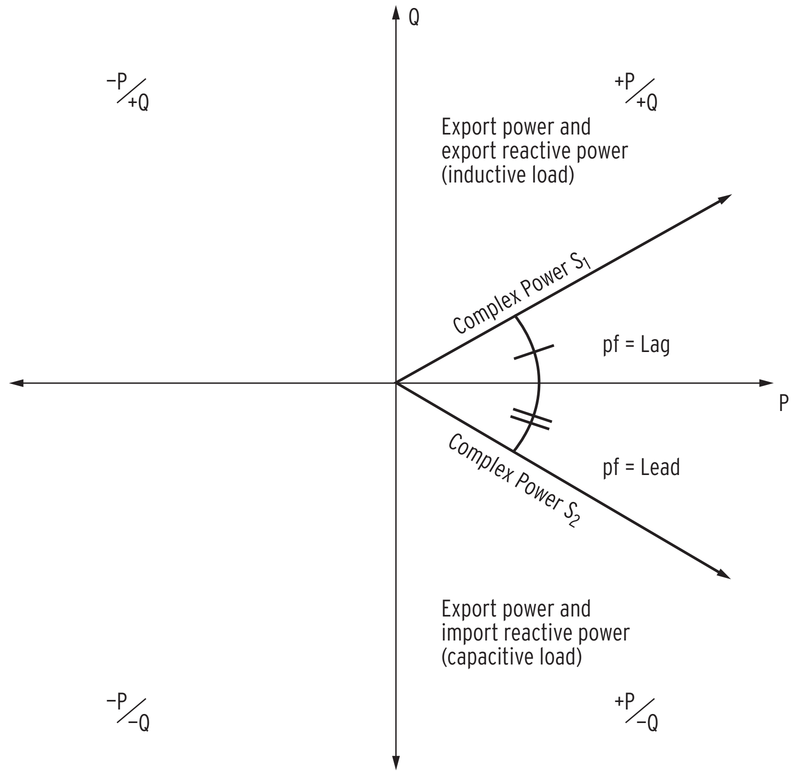


Figure 2.15 Complex Power (P/Q) Plane

Table 2.14 Instantaneous Metering Quantities—Powers

Metered Quantity	Symbol	Fundamental (50 Hz/ 60 Hz Only)	RMS (Harmonics Included)
Per-phase fundamental real power	$P_{\phi 1}$	X	
Per-phase true real power	$P_{\phi rms}$		X
Per-phase reactive power	$Q_{\phi 1}$	X	X
Per-phase fundamental apparent power	$S_{\phi 1}$	X	
Per-phase true apparent power	$U_{\phi rms}$		X
Three-phase fundamental real power	$3P_1$	X	
Three-phase true real power	$3P_{rms}$		X
Three-phase reactive power	$3Q_1$	X	X
Three-phase fundamental apparent power	$3S_1$	X	
Three-phase true apparent power	$3U_{rms}$		X
Per-phase displacement power factor	$PF_{\phi 1}$	X	
Per-phase true power factor	PF_{ϕ}		X
Three-phase displacement power factor	$3PF_1$	X	
Three-phase true power factor	3PF		X

High-Accuracy Instantaneous Metering

The SEL-421 is a high-accuracy metering instrument. *Table 2.15* and *Table 2.16* 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 2.11* to compute exact error coefficients.

Table 2.15 Instantaneous Metering Accuracy—Voltages, Currents, and Frequency

Quantity	Magnitude Accuracy		Phase Accuracy
	Range	Specification	
V_{ϕ}, $V_{\phi\phi}$	33.5 – 200 V_{L-N}	± 0.1%	±0.05°
3V0, V1, 3V2	33.5 – 200 V_{L-N}	± 0.15%	±0.10°
I_{ϕ}	(0.5 – 3)• I_{nom}	±0.2% ± (0.8 mA) • I_{nom}	±0.20°
3I0, I1, 3I2	(0.5 – 3)• I_{nom}	± 0.3% ± (1.0 mA) • I_{nom}	±0.30°
f	40–65 Hz	±0.01 Hz	

Table 2.16 Instantaneous Metering Accuracy—Power[a]

Quantity	Description	Power Factor	Accuracy (%)
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 2.11 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:

$$\begin{aligned} \text{error} &= \pm(0.2\% \bullet 1.0\text{ A}) \pm (0.8\text{ mA} \bullet I_{nom}) \\ &= \pm(0.002 \bullet 1.0\text{ A}) \pm (0.008\text{ A} \bullet 5) \\ &= \pm(0.002\text{A} \pm 0.04\text{A}) \\ &= +0.002\text{ A to }+0.006\text{ A} \\ &\quad \text{and} \\ &= -0.006\text{ A to }-0.002\text{ A} \end{aligned}$$

Equation 2.7

Figure 2.16 represents the calculated accuracy range. The error is very small, indicating that the SEL-421 measures normal operating currents accurately.

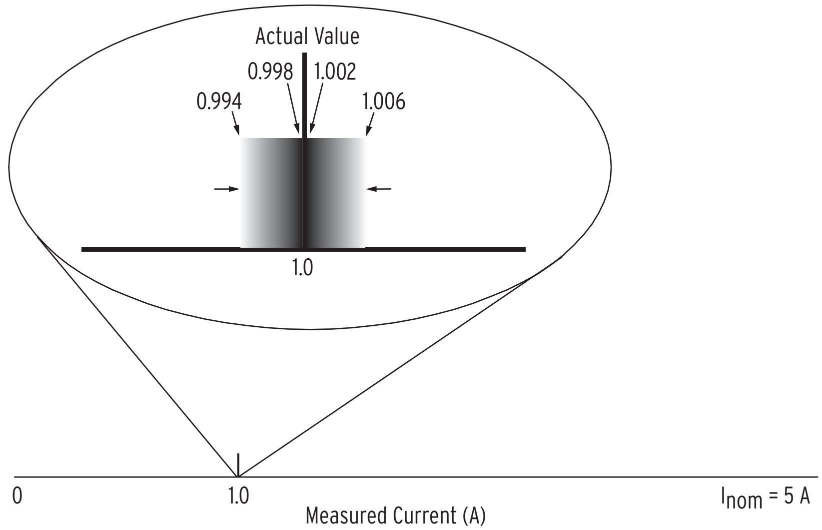


Figure 2.16 Typical Current Measuring Accuracy

When you use *Equation 2.7*, 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 *Example 2.11* are very small and qualify the SEL-421 as a high-accuracy meter.

Maximum/Minimum Metering

The SEL-421 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.

The relay provides maximum/minimum metering for LINE input rms voltages, rms currents, rms powers, and frequency; it also conveys the maximum/minimum rms currents for circuit breakers BK1 and BK2, as well as both dc battery voltage maximums and minimums. The SEL-421 also records the maximum values of the sequence voltages and sequence currents. *Table 2.17* lists these quantities.

Table 2.17 Maximum/Minimum Metering Quantities—Voltages, Currents, Frequency, and Powers (Sheet 1 of 2)

Metered Quantity	Symbol
RMS phase voltage	$V_{\phi rms}$
RMS phase current	$I_{\phi rms}$
Positive-sequence voltage magnitude[a]	$\|V_1\|$
Negative-sequence voltage magnitude[a]	$\|3V_2\|$
Zero-sequence voltage magnitude[a]	$\|3V_0\|$
DC battery voltage	VDC1, VDC2
Positive-sequence current magnitude[a]	$\|I_1\|$
Negative-sequence current magnitude[a]	$\|3I_2\|$
Zero-sequence current magnitude[a]	$\|3I_0\|$
Frequency	f
Circuit breaker rms current	$I_{\phi rms}$

Table 2.17 Maximum/Minimum Metering Quantities—Voltages, Currents, Frequency, and Powers (Sheet 2 of 2)

Metered Quantity	Symbol
Three-phase true real power	$3P_{rms}$
Three-phase reactive power	$3Q_1$
Three-phase true apparent power	$3U_{rms}$

[a] Sequence components are maximum values only.

Maximum/Minimum Metering Accuracy

The accuracy of the maximum/minimum metering quantities is the same as the equivalent instantaneous metering accuracies listed in *Table 2.17* and *Table 2.16*. The SEL-421 maximum/minimum metering values are a true reflection of the extremes that occur in the power system.

View or Reset Maximum/Minimum Metering Information

The relay shows time stamped maximum/minimum quantities when you use a communications port or ACSELERATOR QuickSet to view these quantities. See *Examining Metering Quantities on page U.4.33* for an introduction to reading metering quantities. In addition, you can read the maximum/minimum quantities on the SEL-421 front-panel LCD screen. For more information on using the front panel to view metering quantities, see *Meter on page U.5.15*.

To reset the maximum/minimum values, use the **MET RM** command from a communications terminal, or use the **{RESET}** button in the ACSELERATOR 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 RSTMML, RSTMMB1, and RSTMMB2 (for line, Circuit Breaker 1, and Circuit Breaker 2) when EDRSTC (Data Reset Control) is Y.

Find more information on these methods in *METER on page R.9.28* and *Meter on page U.5.15*.

Maximum/Minimum Metering Updating and Storage

The SEL-421 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 amps)

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.

The factory default setting for SELOGIC control equation FAULT includes specific time-overcurrent and distance elements pickups: FAULT := 50P1 OR 51S1 OR M2P OR Z2G OR M3P OR Z3G.

In addition, the relay also suspends demand metering during the time that Relay Word Bit DFAULT is asserted (see *Demand Metering Updating and Storage on page A.2.37*).

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 SEL-421 provides you this demand information and enables you to operate your power system with an effective economic strategy.

Demand metering and peak demand metering are available only for the LINE quantities. The relay uses longer-term accumulations of the metering quantities for reliable demand data. *Table 2.18* lists the quantities used for demand and peak demand metering.

Table 2.18 Demand and Peak Demand Metering Quantities—(LINE)[a]

Symbol	Units	Description
$I_{\phi rms}$	A, primary	Input rms currents
I_{Grms}	A, primary	Residual ground rms current
$3I_2$	A, primary	Negative-sequence current
P_ϕ	MW, primary	Single-phase real powers (with harmonics)
Q_ϕ	MVAR, primary	Single-phase reactive powers
U_ϕ	MVA, primary	Single-phase total powers (with harmonics)
3P	MW, primary	Three-phase real power (with harmonics)
3Q	MVAR, primary	Three-phase reactive power
3U	MVA, primary	Three-phase total power (with harmonics)

[a] ($I_G = 3I_0 = I_A + I_B + I_C$)

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 2.17* and *Figure 2.18* 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 2.17*).

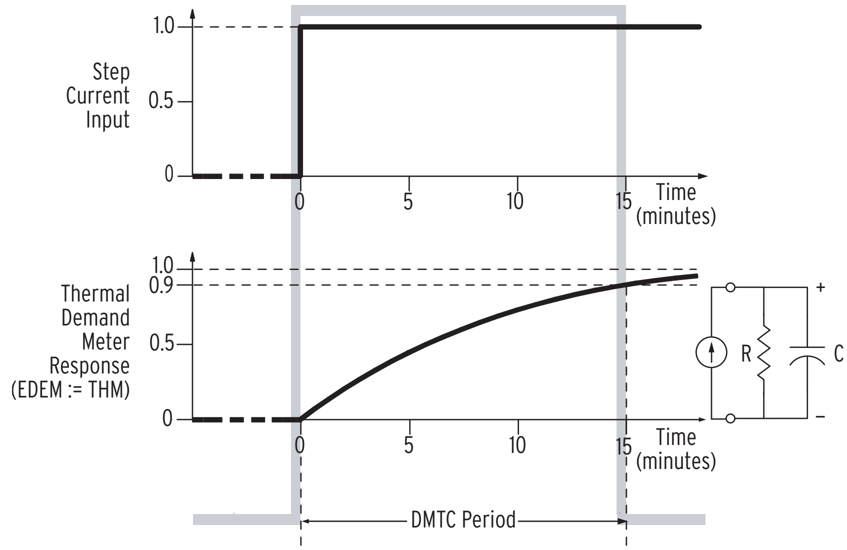


Figure 2.17 Thermal Demand Metering

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 2.18* 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 sub-interval samples every DMTC period. *Table 2.19* lists the rolling demand response for four DMTC periods shown in *Figure 2.18*. 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 2.18*).

Table 2.19 Rolling Demand Calculations

DMTC Period (see Figure 2.18)	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

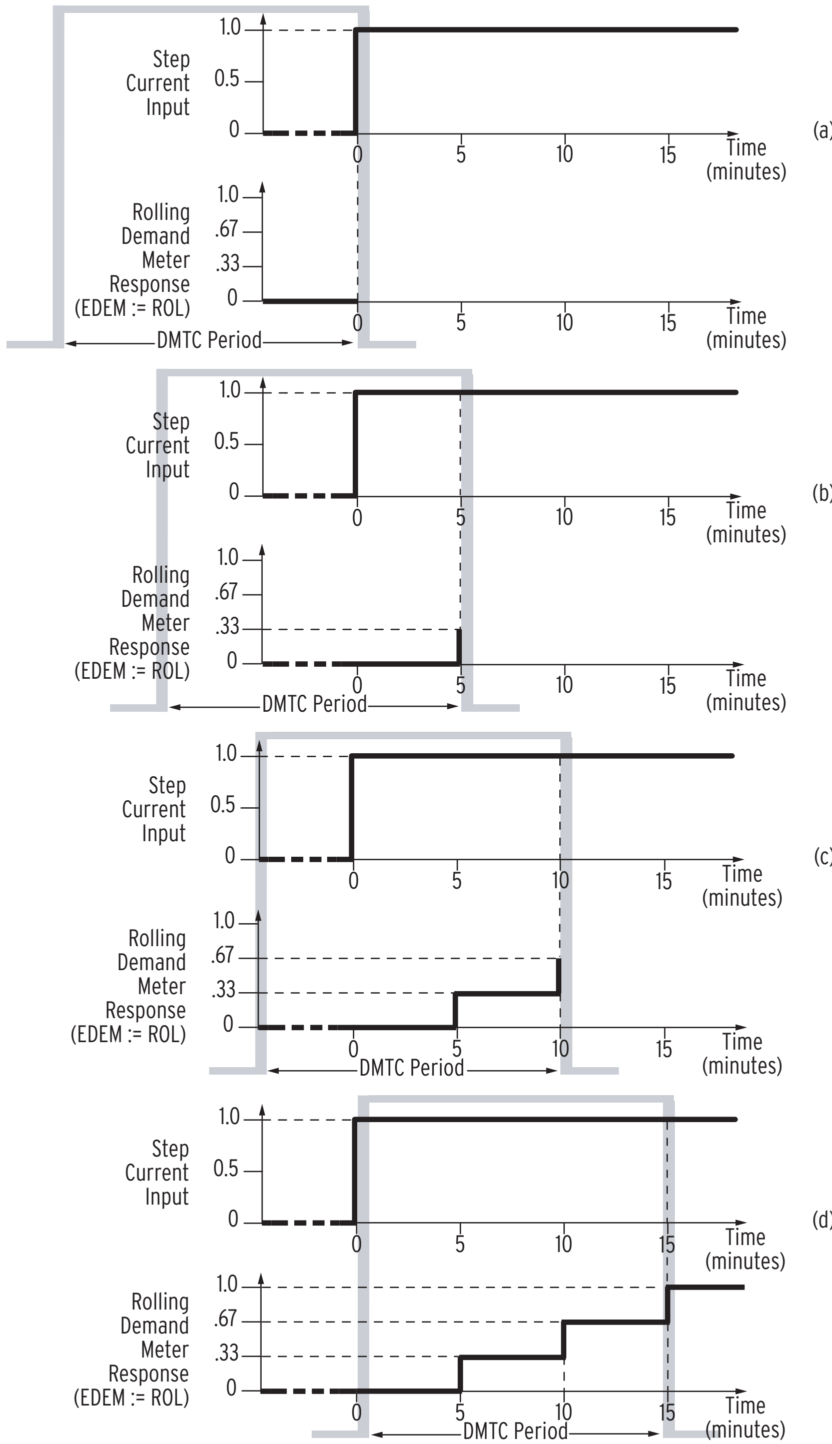


Figure 2.18 Rolling Demand Metering

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 PDEMP, QDEMP, and GDEMP to set alarm thresholds to notify you when demand currents exceed preset operational points. *Table 2.20* shows the demand metering settings.

Table 2.20 Demand Metering Settings[a]

Setting	Description	Range	Default
EDEM	Demand meter type	N, THM = Thermal, ROL = Rolling	N
DMTC	Demand meter time constant	5, 10, 15, …, 300 minutes	15 minutes
PDEMP	Phase demand current pickup	OFF, (0.10–3.20) • I_{nom}, secondary	2.00 • I_{nom}
GDEMP	Residual ground demand current pickup	OFF, (0.10–3.20) • I_{nom}, secondary	0.40 • I_{nom}
QDEMP	Negative-sequence demand current pickup	OFF, (0.10–3.20) • I_{nom}, secondary	0.40 • I_{nom}

[a] Current pickup settings are in steps of 0.01 A, secondary.

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 2.19 shows how the SEL-421 applies the demand current pickup settings of *Table 2.20* over time. When residual ground demand current $I_{G(DEM)}$ 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.

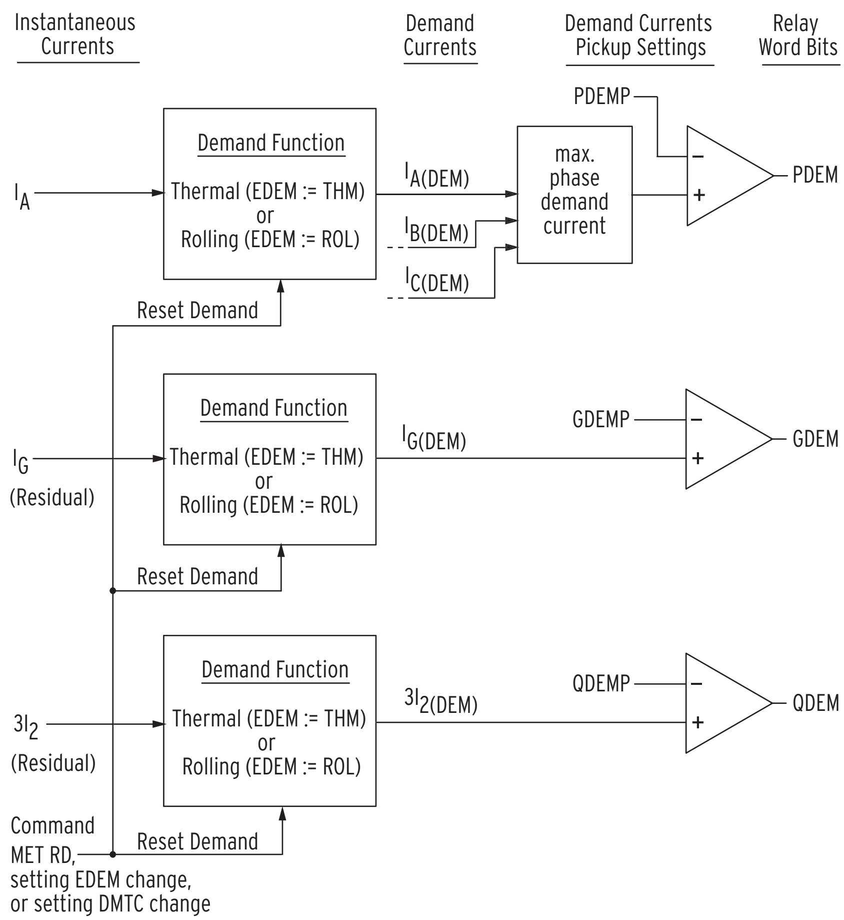


Figure 2.19 Demand Current Logic Outputs

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 ACSELERATOR QuickSet to view these quantities. See *Section 4: Basic Relay Operations in the User's Guide* for an introduction to reading metering quantities. In addition, you can read the demand and peak demand quantities on the SEL-421 front-panel LCD screen. For more information on using the front panel to view metering quantities, see *Meter on page U.5.15*.

To reset the demand metering values use the **MET RD** command from a communications terminal, or use the **{RESET}** button in the ACSELERATOR 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 ACSELERATOR 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.

Find more information on these methods in *METER on page R.9.28* and *Meter on page U.5.15*.

Demand Metering Updating and Storage

The SEL-421 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). (See *FAULT SELOGIC Control Equation on page A.2.33* for more information.)

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. See *Section 4: Time-Synchronized Measurements in the Applications Handbook* for more information on high-accuracy timing applications.

The SEL-421 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. Also similar to demand metering, energy metering is available only for the LINE data. *Table 2.21* lists the energy metering quantities that the relay displays.

Table 2.21 Energy Metering Quantities—(LINE)

Analog Quantity	Units	Description
MWHϕOUT	MWh, primary	Single-phase energy export
MWHϕIN	MWh, primary	Single-phase energy import
MWHϕT	MWh, primary	Single-phase energy total
3MWHOUT	MWh, primary	Three-phase energy export
3MWHIN	MWh, primary	Three-phase energy import
3MWH3T	MWh, primary	Three-phase energy total

Energy Metering Accuracy

At low currents (0.1• I_{nom}), energy metering accuracy at near-unity power factors is ±0.5 percent. At power factors of 0.5 lagging or leading, energy metering accuracy is ±0.7 percent. At high currents (1.0 • I_{nom}), energy metering accuracy at near unity power factors is ± 0.4 percent. At power factors of 0.5 lagging or leading, energy metering accuracy is ±0.4 percent.

View or Reset Energy Metering Information

You can read the energy metering quantities by using a communications port, ACSELERATOR QuickSet, or the SEL-421 front-panel LCD screen. See *Section 4: Basic Relay Operations in the User's Guide* for an introduction to reading metering quantities. For more information on using the front panel to view metering quantities, see *Section 5: Front-Panel Operations in the User's Guide*. The ACSELERATOR QuickSet HMI also displays the energy metering data; see *Section 3: PC Software in the User's Guide*.

To reset the energy values, use the **MET RE** command from a communications terminal, or use the **{RESET}** button in the ACSELERATOR 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.

Find more information on these methods in *METER on page R.9.28* and in *Meter on page U.5.15*.

Energy Metering Updating and Storage

The SEL-421 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.

Time-Synchronized Metering

The SEL-421 provides synchrophasor measurement with an angle reference according to IEEE C37.118. See *Section 7: Synchrophasors in the Reference Manual* for more information on synchrophasor application. The relay calculates the phasor measurement quantities 50 or 60 times per second, depending on the nominal system frequency contained in Global setting NFREQ.

When you issue the **MET PM *time*** command, the SEL-421 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.

See *Figure 7.13 on page R.7.25* for a sample **MET PM** command response.

The SEL-421 Synchrophasor measurements are only valid when a suitable high-accuracy IRIG-B time source is connected to the relay, as indicated by Relay Word bit TSOK = logical 1. See *Configuring High-Accuracy Timekeeping on page U.4.71* for detailed information.

The **MET PM** command is only available when the SEL-421 is configured for phasor measurement functions (Global settings) and the relay is in high-accuracy timekeeping mode.

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Section 3
Analyzing Data

The SEL-421 Relay features comprehensive power system data analysis capabilities. The relay provides these useful analysis tools:

- *Data Processing on page A.3.2*
- *Triggering Data Captures and Event Reports on page A.3.4*
- *Duration of Data Captures and Event Reports on page A.3.5*
- *Oscillography on page A.3.7*
- *Event Reports, Event Summaries, and Event Histories on page A.3.11*
- *SER (Sequential Events Recorder) on page A.3.34*

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, and SER data is very valuable if you are responsible for outage analysis, outage management, or relay settings coordination.

The SEL-421 accepts an IRIG-B clock input for high-accuracy timing. When a suitable external clock is used (such as the SEL-2407), the SEL-421 synchronizes the data acquisition system to the received signal. Knowledge of the precise time of sampling (as shown in COMTRADE files) allows comparisons of data across the power system. Use a coordinated network of SEL-421 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. For more information on this feature, see *Section 4: Time-Synchronized Measurements in the Applications Handbook*.

The SEL-421 can also perform the PMU (Phasor Measurement Unit) function of gathering synchrophasor data when the relay is in high-accuracy timekeeping mode (HIRIG). See *Section 7: Synchrophasors in the Reference Manual*.

Data Processing

The SEL-421 is a numeric, or microprocessor-based, relay that samples power system conditions via the CT and PT inputs. The relay converts these analog inputs to digital information for processing to determine relaying quantities for protection and automation. *Figure 3.1* shows a general overview of the input processing diagram for the SEL-421.

Raw and Filtered Data

The SEL-421 outputs two types of analytical data: high-resolution raw data and filtered data. *Figure 3.1* shows the path a power system signal takes 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 in binary COMTRADE format (see *Oscillography on page A.3.7*).

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 eight samples per power system cycle using additional digital filtering. This 8-samples/cycle information is the filtered data for event reports and other relay functions. The relay selects every other sample of 8-samples/cycle filtered data to present 4-samples/cycle event reports.

The SEL-421 samples the control inputs at a rate of 16 samples per cycle. There are two types of control inputs: direct-coupled and optoisolated, and these are processed differently

The SEL-421 Main Board A and INT1, INT5, and INT6 I/O Interface boards have direct-coupled control inputs with analog-to-digital converters that measure the applied voltage. These analog sample values are available in COMTRADE files and as analog quantities (labeled IN101A–IN107A or IN201A–IN208A or IN301A–IN308A). The relay compares the sampled data against setting-defined pickup and dropout voltage thresholds to create the raw contact status information. This raw digital data can be included in high-resolution (COMTRADE) data files. Contact bounce may be visible when the raw data are viewed.

The SEL-421 Main Board B and INT2, INT3, INT4, INT7, and INT8 I/O Interface boards have optoisolated control inputs with fixed pickup voltages. Optoisolated inputs are ordered with one of six available pickup voltage ratings. No analog voltage information is available. 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 SEL-421 filters both types of control inputs with settable debounce timers, and updates the resulting Relay Word bits 8 times per cycle. 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.

See *Control Input Assignment on page U.4.65* and *Control Inputs on page U.2.5* for details on control inputs.

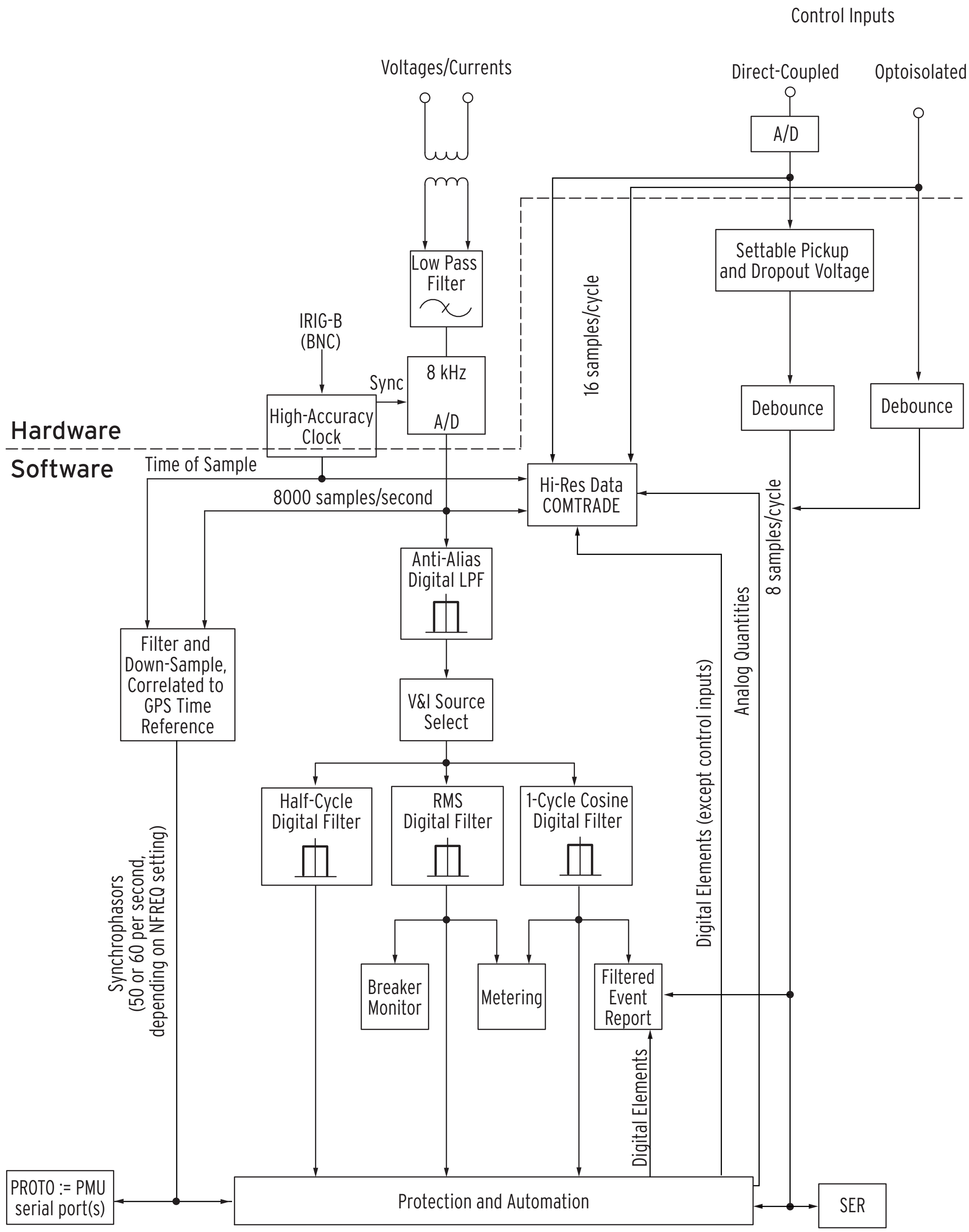

Figure 3.1 SEL-421 Input Processing

Triggering Data Captures and Event Reports

The SEL-421 displays power system data from oscillograms, event reports, event summaries, event histories, and SER data. For information on the SER, see *SER (Sequential Events Recorder) on page A.3.34*. All of these features, except the SER, require sampled or filtered data from the power system, and 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. Both high-resolution raw data oscillography and event reports use the same triggering methods. The trigger for data captures comes from three possible sources:

➤ Relay Word bit TRIP assertions

➤ SELOGIC® control equation ER (Event Report Trigger)

➤ **TRI** command

In previous 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 (see *SELOGIC Control Equation ER* and *Example 3.2*). For more information on the **PUL** command, see *PULSE on page R.9.37* and *Operating the Relay Inputs and Outputs on page U.4.56*.

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. For information on Relay Word bit TRIP see *Trip Logic on page R.1.107*.

SELOGIC Control Equation ER

Program the SELOGIC control equation ER to trigger high-resolution raw data oscillography and standard event reports for conditions other than TRIP conditions. When ER asserts, the SEL-421 begins recording data if the relay is not already capturing data initiated by another trigger.

EXAMPLE 3.1 Triggering Event Report/Data Capture Using the ER SELOGIC Control Equation

This example shows how the elements in the ER SELOGIC control equation initiate relay data capture. See Section 3: SELOGIC Control Equation Programming in the Reference Manual for more information on rising-edge operators and SELOGIC control equations.

The factory default setting for Group setting SELOGIC control equation ER is

ER := **R_TRIG M2P OR R_TRIG Z2G OR R_TRIG 51S1 OR R_TRIG M3P OR R_TRIG Z3G** Event Report Trigger Equation (SELOGIC Equation)

The element transitions in this setting are from the following Relay Word bits:

➤ M2P, M3P: Zone 2 mho phase distance element, Zone 3 mho phase distance element

➤ Z2G, Z3G: Zone 2 mho ground distance element, Zone 3 mho ground distance element

➤ 51S1: Selectable operating quantity time overcurrent element

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 51S1 element).

In the 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. See *Section 3: SELogic Control Equation Programming in the Reference Manual* for more information on falling edge operators.

EXAMPLE 3.2 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 pulses via the **PUL** command. For more information on the **PUL** command, see PULSE on page R.9.37.

Program the Group settings SELogic control equation ER as follows:

ER := **R_TRIG M2P OR R_TRIG Z2G OR R_TRIG 51S1 OR R_TRIG M3P 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 SEL-421 to begin recording high-resolution raw data and event report data. When testing with the **TRI** command, you can gain a glimpse of power system operating conditions that occur immediately after you issue the **TRI** command. See *TRIGGER on page R.9.57* and *Triggering an Event on page U.4.42* for more information on the **TRI** command.

Duration of Data Captures and Event Reports

The SEL-421 stores high-resolution raw data and filtered data. The number of stored high-resolution raw data captures and event reports is a function of the amount of data contained in each capture. 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, listed in *Table 3.1*, 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 effective sampling rate and the event report length are related:

- 8 kHz sampling—2.00 seconds total event report
- 4 kHz sampling—3.00 seconds total event report

- 2 kHz sampling—4.00 seconds total event report
- 1 kHz sampling—5.00 seconds total event report

The length of the data capture/event report (setting LER**)** and the pretrigger or prefault time (setting PRE**)** are related, as shown in *Figure 3.2*. 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 pretrigger (prefault) data. Typically, you set the PRE time to 20 percent of the total LER period. *Table 3.1* shows the relay settings for the data capture recording times at each effective sampling rate.

Table 3.1 Report Settings

Label	Description	Range	Default
SRATE	Effective sample rate of event report	1, 2, 4, 8 kHz	2 kHz
SRATE = 8 kHz			
LER	Length of event report	0.25–2.00 seconds	0.5 seconds
PRE	Length of prefault	0.05–1.95 seconds	0.1 seconds
SRATE = 4 kHz			
LER	Length of event report	0.25–3.00 seconds	0.5 seconds
PRE	Length of prefault	0.05–2.95 seconds	0.1 seconds
SRATE = 2 kHz			
LER	Length of event report	0.25–4.00 seconds	0.5 seconds
PRE	Length of prefault	0.05–3.95 seconds	0.1 seconds
SRATE = 1 kHz			
LER	Length of event report	0.25–5.00 seconds	0.5 seconds
PRE	Length of prefault	0.05–4.95 seconds	0.1 seconds

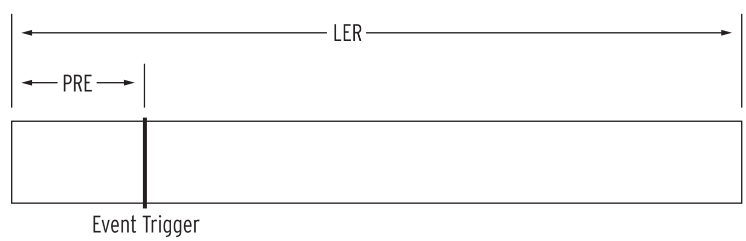

Figure 3.2 Data Capture/Event Report Times

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 non-volatile storage to reenable data capture triggering. Thus, to record sequential events, you must set LER to half or less than half of the maximum LER setting. The relay stores more sequential data captures as you set LER smaller.

Table 3.2 lists the maximum number of data captures/event reports the relay stores in nonvolatile memory 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 := 0.5 or LER := 1.0 the relay records at least two data captures. These and smaller LER settings are sufficient for most power system disturbances.

The relay stores approximately six seconds of high-resolution raw or filtered data in nonvolatile memory at the maximum resolution (8000 samples/second effective sampling rate). If you have selected LER at 0.5 seconds (30 cycles at 60 Hz or 25 cycles at 50 Hz), you can store eleven 1/2-second reports. These 11 reports are at 8000 samples/second resolution (approximately eight times more resolution than the SEL-300 series relays.) *Table 3.2* lists the storage capability of the SEL-421 for common event report lengths:

The lower rows of *Table 3.2* show the number of event reports the relay stores at the maximum data capture times for each SRATE sampling rate setting. Table entries are the maximum number of stored events; these can vary by 10 percent according to relay memory usage.

Table 3.2 Event Report Nonvolatile Storage Capability

Event Report Length	Maximum Number of Stored Reports			
	8 kHz	4 kHz	2 kHz	1 kHz
0.25 seconds	18–20	25–27	31–33	36–39
0.50 seconds	11	16	18–20	23–25
1.0 seconds	6	8	11	15
2.0 seconds	3	4	6	8
3.0 seconds	N/A	3	4	5
4.0 seconds	N/A	N/A	3	4
5.0 seconds	N/A	N/A	N/A	3

Oscillography

The SEL-421 features two types of oscillography:

- Raw data oscillography—effective sampling rate as fast as 8000 samples/second
- Event report oscillography from filtered data—either 8 samples/cycle or 4 samples/cycle

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 (see *Duration of Data Captures and Event Reports on page A.3.5*). The high-resolution raw data oscillograms are available as files through the use of Ymodem file transfer and FTP (file transfer protocol) in the binary COMTRADE file format output (*IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems, IEEE C37.111–1999)*.

The filtered data oscillograms at 8 samples/cycle and 4 samples/cycle give you accurate information on the relay protection and automation processing quantities. The relay outputs 8-samples/cycle and 4-samples/cycle filtered event reports through a terminal or as files in ASCII format, Compressed ASCII format, and binary FTP and Ymodem file outputs. *Figure 3.3* shows a sample filtered-data oscillogram.

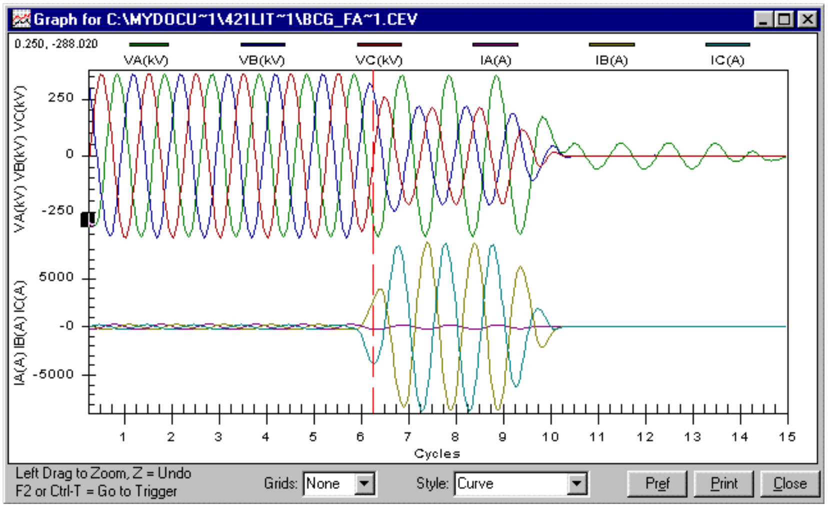

Figure 3.3 Sample SEL-421 Oscillogram

Raw Data Oscillography

Raw data oscillography produces oscillograms that track power system anomalies that occur outside relay digital filtering. Raw data oscillography captures data with content ranging from dc to greater than 3.0 kHz; the –3 dB point of the single-order low-pass analog input filter is 3.0 kHz (with response rolling off at –20 dB per decade).

COMTRADE files include all eight Relay Word bits from each row of the Relay Word that has at least one element included in the event report digital elements setting—see *Table 10.91 on page R.10.45*.

The SEL-421 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 to the IEEE C37.111-1999 COMTRADE standard.

.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 A.3.23* and *Settings Section of the Event Report on page A.3.23*). The settings portion is in a comma-delimited format as illustrated in *Figure 3.4*.

```
Relay 1                                      Date: 03/15/2001  Time: 23:30:49.026
Station A                                    Serial Number: 2001001234

Event: BCG T              Location:  48.17                     Time Source: OTHER
Event Number#: 10007      Shot 1P: 0   Shot 3P: 0        Freq: 60.01     Group: 1
Targets: INST TIME ZONE_1 B_PHASE C_PHASE bk1rs
Breaker 1: OPEN           Trip Time: 23:30:49.026
Breaker 2: OPEN           Trip Time: 23:30:49.026
PreFault:      IA      IB      IC      IG     3I2       VA       VB       VC    V1mem
MAG(A/kV)     276     262     246      65      17  364.704  364.903  364.452  364.614
ANG(DEG)     22.1   -91.7   138.2     5.1   178.5      0.0   -119.9    120.3      0.2
Fault:
MAG(A/kV)     217    8892    8727    5586   11403  361.421  218.687  214.239  321.083
ANG(DEG)    -17.0   167.3    24.8    95.6    94.4      0.1   -129.9    126.7      0.7

SET_G1.TXT
[INFO]
RELAYTYPE=421
FID=SEL-421-R101-V0-Z001001-D20010315
BFID=SLBT-4XX-R100-V0-Z001001-D20010315
PARTNO=04210415X125XHX
[IOBOARDS]
               •
               •
               •
[IOBOARDS]
, , , 8, 8, 0, 0, 1
[COMCARDS]
[G1]
"SID","Station A"
"RID","Relay 1"
"TIDW","Breaker 1"
"TIDX","Breaker 2"
"NUMBK",2
"BID1","Breaker 1"
"BID2","Breaker 2"
"NFREQ",60
```

Summary Event Information

Relay Settings

Figure 3.4 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 3.5*). 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.

```
Station A,FID=SEL-421-R101-V0-Z001001-D20010315,1999     COMTRADE Standard
373,29A,344D                                             Total Channels, Analog, Digital
1,IAW,A,,A,0.007553,0,0,-32767,32767,400.0,1,P
2,IBW,B,,A,0.007553,0,0,-32767,32767,400.0,1,P
3,ICW,C,,A,0.007553,0,0,-32767,32767,400.0,1,P
4,IAX,A,,A,0.007553,0,0,-32767,32767,400.0,1,P
5,IBX,B,,A,0.007553,0,0,-32767,32767,400.0,1,P
6,ICX,C,,A,0.007553,0,0,-32767,32767,400.0,1,P
7,VAY,A,,kV,0.015107,0,0,-32767,32767,3636.0,1,P
8,VBY,B,,kV,0.015107,0,0,-32767,32767,3636.0,1,P
9,VCY,C,,kV,0.015107,0,0,-32767,32767,3636.0,1,P
10,VAZ,A,,kV,0.015107,0,0,-32767,32767,3636.0,1,P
11,VBZ,B,,kV,0.015107,0,0,-32767,32767,3636.0,1,P        Analog Channel Data
12,VCZ,C,,kV,0.015107,0,0,-32767,32767,3636.0,1,P
13,VDC1,,,V,1.000000,0,0,-32767,32767,1,1,P
14,VDC2,,,V,1.000000,0,0,-32767,32767,1,1,P
15,IN101,,,V,1.000000,0,0,-32767,32767,1,1,P
16,IN102,,,V,1.000000,0,0,-32767,32767,1,1,P
17,IN103,,,V,1.000000,0,0,-32767,32767,1,1,P
18,IN104,,,V,1.000000,0,0,-32767,32767,1,1,P
19,IN105,,,V,1.000000,0,0,-32767,32767,1,1,P
20,IN106,,,V,1.000000,0,0,-32767,32767,1,1,P
21,IN107,,,V,1.000000,0,0,-32767,32767,1,1,P
22,IN201,,,V,1.000000,0,0,-32767,32767,1,1,P
23,IN202,,,V,1.000000,0,0,-32767,32767,1,1,P
24,IN203,,,V,1.000000,0,0,-32767,32767,1,1,P
25,IN204,,,V,1.000000,0,0,-32767,32767,1,1,P
26,IN205,,,V,1.000000,0,0,-32767,32767,1,1,P
27,IN206,,,V,1.000000,0,0,-32767,32767,1,1,P
28,IN207,,,V,1.000000,0,0,-32767,32767,1,1,P
29,IN208,,,V,1.000000,0,0,-32767,32767,1,1,P
1,27BPO,,,0
2,27APO,,,0
3,3PO,,,0                                                Digital (Status)
4,SPO,,,0                                                 Channel Data
5,SPOC,,,0
6,SPOB,,,0
7,SPOA,,,0
     •
     •
     •
337,OUT101,,,0
338,OUT102,,,0
339,OUT103,,,0
340,OUT104,,,0
341,OUT105,,,0                                           First Data Point
342,OUT106,,,0                                           Trigger Point
343,OUT107,,,0
344,OUT108,,,0
60
1
2000,1000
15/03/2001,23:30:48.925200
15/03/2001,23:30:49.026800
BINARY
1
```

Figure 3.5 COMTRADE .CFG Configuration File Data

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

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 Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems, IEEE C37.111–1999* for more information. Many programs read the binary COMTRADE files. These programs include the SEL-5601 Analytic Assistant and the ACSELERATOR QuickSet® SEL-5030 software program.

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 A.3.4*. Use the settings SRATE, LER, and PRE to set the SEL-421 for the appropriate data sampling rate and data capture time (see *Duration of Data Captures and Event Reports on page A.3.5*).

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. See *Retrieving High-Resolution COMTRADE Data: Terminal on page U.4.46* for the method of identifying and downloading COMTRADE files. You can also use ACSELERATOR QuickSet (see *Retrieving High Resolution COMTRADE Data: ACSELERATOR QuickSet on page U.4.47*).

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. Both ACSELERATOR QuickSet and the SEL-5601 Analytic Assistant read the compressed event files that the relay generates for an event. See *Analyze Events on page U.3.16* for instructions on viewing event report oscillography with ACSELERATOR QuickSet.

Event Reports, Event Summaries, and Event Histories

Event reports simplify postfault 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 (see the **EVE** command in *EVENT on page R.9.17*).

You decide the amount of information and length in an event report (see *Duration of Data Captures and Event Reports on page A.3.5*).

The SEL-421 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, analog quantity, or default terminal name 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 and SER. 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, voltages, polarizing voltage (V1MEM)
- Digital section
  - Relay Word bit elements, control outputs, control inputs
- Event summary
- Settings
  - Group settings
  - Global settings
  - Output settings
  - 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; see *Events on page U.5.18*.) 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 (see *EVENT on page R.9.17*).

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 A.3.31*.)

Event Numbering

Use the **EVE *n*** command to access particular event reports. When parameter ***n*** is 1 through 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 through 42767, ***n*** indicates the absolute serial number of the event report.

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.

Table 3.3 lists a summary of **EVE** commands (see *EVENT on page R.9.17* for complete information on the **EVE** command). *Table 3.4* shows a few examples of command options that you can use with the **EVE** command. The **EVE L** and **EVE C** commands provide compatibility with older command sets.

Table 3.3 EVE Command

Command	Description
EVE	Return the most recent event report (including settings and summary) at full length with 4-samples/cycle data.
EVE *n*[a]	Return a particular *n* event report (including settings and summary) at full length with 4-samples/cycle data.
EVE A	Return only the analog information for the most recent event report.
EVE ACK	Acknowledge the oldest unacknowledged event at the present communications port.
EVE C *n*	Return a particular *n* event report at a 15-cycle length with 8-samples/cycle data.
EVE D *n*	Return only the digital information for a particular *n* event report.
EVE *n* **L**	Return a particular *n* event report at full length with 8-samples/cycle sampling.
EVE *n* **L***yyy*[b]	Return *yyy* cycles of a particular *n* event report with 4-samples/cycle data.
EVE N	Return the oldest unacknowledged event report with 4-samples/cycle data (**N** = next).
EVE *n* **NSET**	Return a particular *n* event report without settings at full length with 4-samples/cycle data.
EVE *n* **NSUM**	Return a particular *n* event report without the event summary at full length with 4-samples/cycle data.
EVE *n* **S***x*[c]	Return a particular *n* event report at full length with *x*-samples/cycle data.
EVE *n* **TE**	Return a particular *n* event report at full length without the report header with 4-samples/cycle data.

[a] The optional parameter n indicates event order or serial number (see Event Numbering).
[b] The parameter yyy represents an event length in cycles.
[c] The parameter x is 4 or 8 to represent data resolution of 4 samples/cycle and 8 samples/cycle, respectively.

Table 3.4 EVE Command Examples

Example	Description
EVE L10 S8	Return 10 cycles of an 8-samples/cycle event report for the most recent event.
EVE L010 A	Return 10 cycles of the analog portion only of the most recent event report at 4-samples/cycle resolution.
EVE 2 NSET	For the second most recent event, return the event report with no settings at 4-samples/cycle data.

You can retrieve event reports with the ACSELERATOR QuickSet **Analysis > View Event History** 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. See *Analyze Events on page U.3.16*, and *Reading the Event History on page U.4.44* for more information on viewing event reports with ACSELERATOR QuickSet.

You can also download event report files from the relay. Use 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. See *Retrieving Event Report Data Files: Terminal on page U.4.50* for file download procedures.

The following discussion shows sample portions of an event report that you download from the relay using a terminal and the **EVE** command. An event report contains analog, digital, summary, and settings sections without breaks.

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 3.6* 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-421 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. See *Firmware Version Number on page U.6.39* for a description of the FID string. 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 CID.

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 amps, respectively. These quantities are instantaneous values scaled by $\sqrt{2}/2$ (0.707) and are described in *Table 3.5*. To obtain phasor rms values, use the methods illustrated in *Obtaining RMS Phasors From 4-Samples/Cycle Event Reports on page A.3.16*, *Figure 3.7*, and *Figure 3.8*.

```
Relay 1                                           Date: 03/15/2001  Time: 23:30:49.026
Station A                                         Serial Number: 2001001234               Header
FID=SEL-421-R101-V0-Z001001-D20010315             Event Number = 10007       CID=0x3425
                                                                                           Firmware ID
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   One Cycle
    266    -166     -45      55   288.2  -337.5    47.5  -215.2  -145.0   288.1    of Data
     76     202    -242      36   223.4   138.7  -361.4   290.5  -331.2   223.5
                                                                                   See Figure 3.7 and Figure 3.8 to
                                      •                                            calculate phasors for this data
                                      •
                                      •
[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>  Trigger
    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*  Largest Current
    129   -5508    8382    3003   286.9  -213.8     3.6  -216.0  -144.0   243.9   (to Event Summary)
    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   Circuit Breaker Open
[11]
     -1      -1      -2      -5    13.8     1.1     0.3   216.8   143.1  -147.1
      2       3       4       9    54.8    -0.7    -0.3  -289.1   332.1   -93.5
      1       1       2       5    -8.1    -1.6    -1.1  -217.0  -142.8   109.8
     -2      -2      -3      -8   -58.2     0.2     0.2   289.0  -332.2    65.3
```

Figure 3.6 Analog Section of the Event Report

Table 3.5 Event Report Metered Analog Quantities

Quantity	Description
IA	Instantaneous filtered line current, A-phase
IB	Instantaneous filtered line current, B-phase
IC	Instantaneous filtered line current, C-phase
IG	Instantaneous filtered line current, residual (or ground)
VA	Instantaneous filtered A-phase voltage
VB	Instantaneous filtered B-phase voltage
VC	Instantaneous filtered C-phase voltage
VS1	Instantaneous filtered synchronization Source 1 voltage
VS2	Instantaneous filtered synchronization Source 2 voltage
V1Mem	Instantaneous memorized positive-sequence polarization voltage

Figure 3.6 contains selected data from the analog section of a 4-samples/cycle event report for a BCG fault on a 400 kV line with CT ratio := 400/1 and PT ratio := 3636/1. The bracketed numbers at the left of the report (for example, [11]) indicate the cycle number; *Figure 3.6* presents seven cycles of 4-samples/cycle data.

The trigger row includes a > character following immediately after the V1Mem column to indicate the trigger point. This is the dividing point between the prefault or PRE time and the fault or remainder of the data capture.

The row that the relay uses for the currents in the event summary is the row with the largest current magnitudes; the relay marks this row on the event report with an asterisk (*) character immediately after the V1Mem column. The (*) takes precedence over the > if both occur on the same row in the analog section of the event report.

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 3.6*. You can process voltage data columns similarly. The drawings in *Figure 3.7* and *Figure 3.8* show one cycle of A-phase current in detail. *Figure 3.7* shows how to relate the event report ac current column data to the sampled waveform and rms values. *Figure 3.8* 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 example demonstrates using a terminal or terminal emulation program. A more convenient method is to use ACSELERATOR QuickSet or the SEL-5601 Analytic Assistant. These programs automate the analysis process presented in this example and provide you with voltage and current phasors as software outputs.

This example assumes that you have successfully established communication with the relay; see *Making an EIA-232 Serial Port Connection on page U.4.5* for step-by-step instructions. In addition, you must understand relay access levels and passwords. See *Changing the Default Passwords on page U.4.6* 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. Identify an event:

a. Type **HIS <Enter>**.

The **HIS** command gives a quick, one-row listing of relay-stored events (see *Event History on page A.3.31* for more information).

This example uses the latest captured event.

b. If no events are available, use the **TRI** command to generate an event (see *Triggering Data Captures and Event Reports on page A.3.4*).

Step 3. Gather data from the event report:

a. Enable terminal data capture (usually a **Transfer > Capture Text** menu) in your terminal or terminal emulation program.

b. Type **EVE <Enter>** at the Access Level 1 => prompt to obtain an event report similar to *Figure 3.6*.

(See *Table 3.3* or *EVENT on page R.9.17* for a summary of **EVENT** commands.)

The relay responds with the entire event report.

Step 4. Calculate the phasor magnitude:

a. Select a cycle of data from the IA column of the event report.

Figure 3.6 Cycle [1] data for this example are shown in *Figure 3.7*.

There are three pairs of scaled instantaneous current samples from Cycle [1].

b. Compute phasor magnitude using the following expression:

$$\sqrt{X^2 + Y^2} = |\text{Phasor}| \qquad \textbf{Equation 3.1}$$

In *Equation 3.1*, 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 3.7* yields 277.0 A.

c. Compute phasor magnitudes from the remaining data pairs for Cycle [1].

d. Confirm that all values are similar.

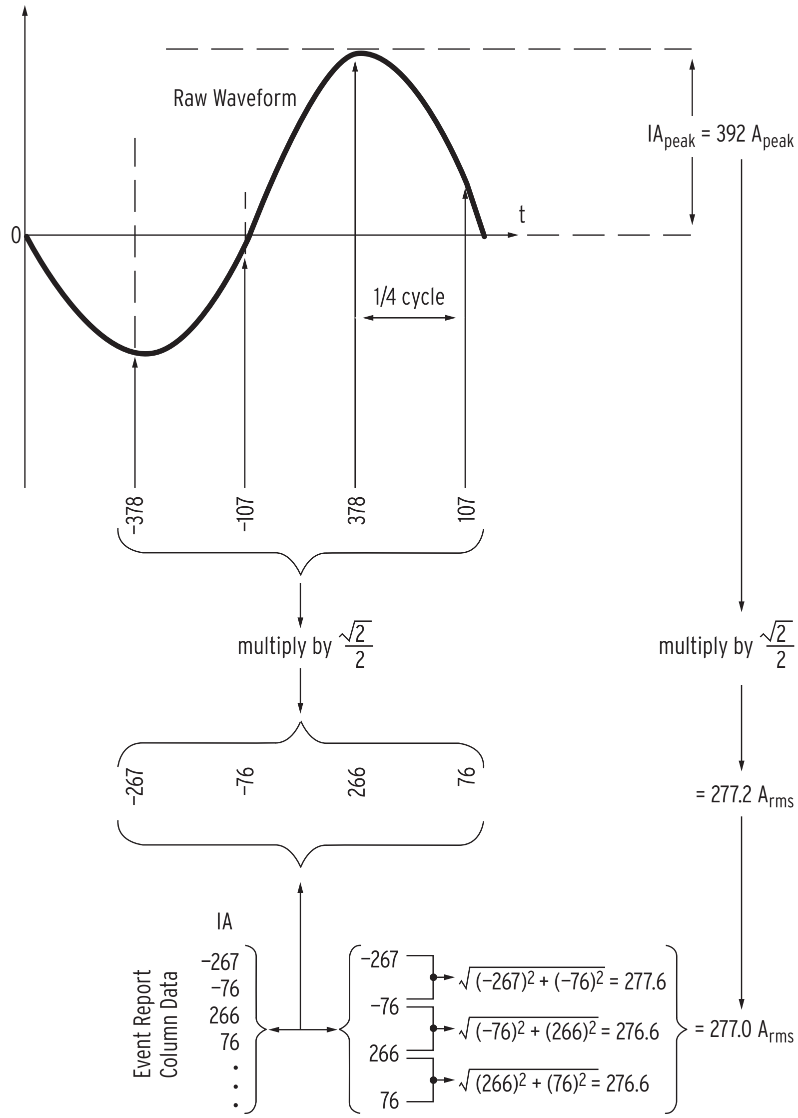

Figure 3.7 Event Report Current Column Data and RMS Current Magnitude

Step 5. 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 using the following expression:

$$\theta = \arctan\left(\frac{Y}{X}\right) = \angle \text{Phasor} \qquad \textbf{Equation 3.2}$$

In *Equation 3.2*, 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 3.8* 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.

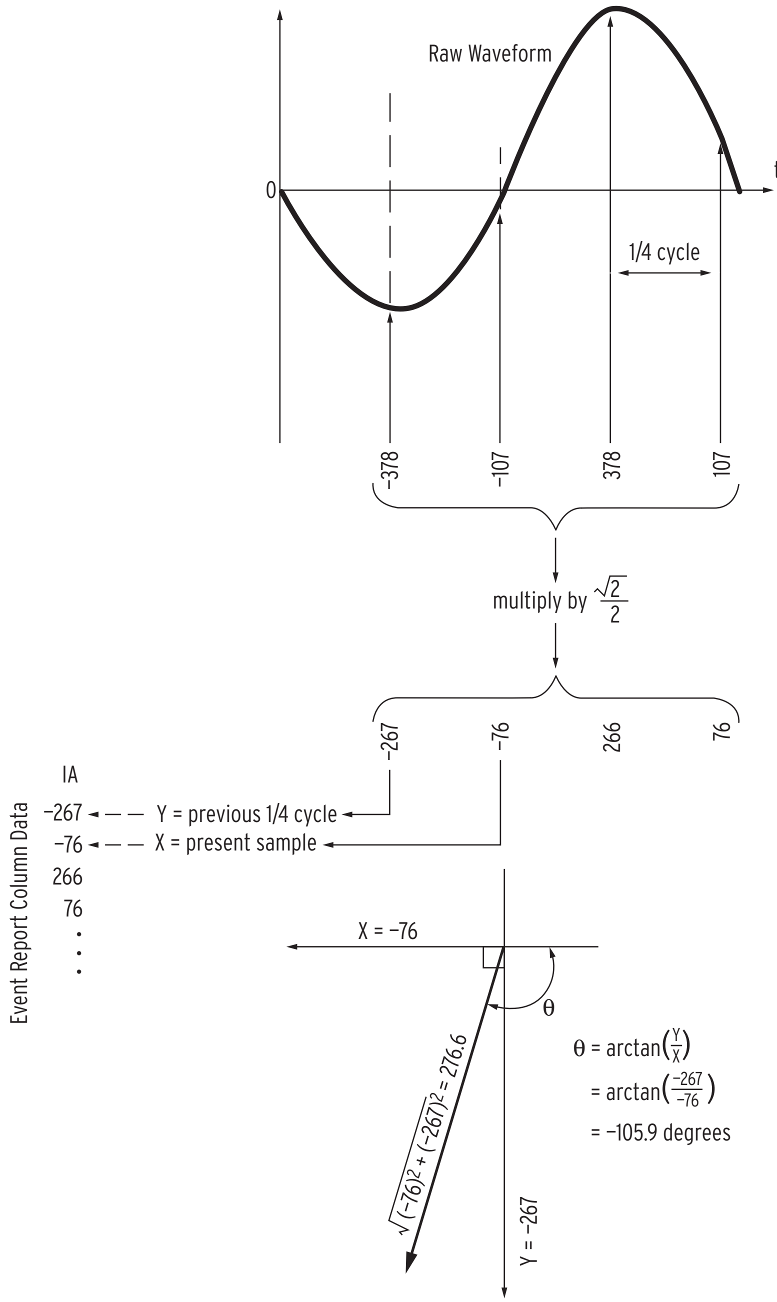

Figure 3.8 Event Report Current Column Data and RMS Current Angle

Step 6. Calculate the reference phase angle. Usually, you compare power system angles to a reference phasor (positive-sequence A-phase voltage, for example):

➢ Repeat *Step 5* for the row data in the VA column that correspond to the IA column data values you used in *Step 5*.

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 3.3**

(This is an example of an arctan calculation that yields the incorrect answer from some calculators and math programs.)

Step 7. 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 3.4**

I_A leads V_A; thus, the rms phasor for current IA at the present sample is 277.0 A ∠21.9°, referenced to V_A.

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

$$X = -76 = 277.0 \cdot \cos(-105.9°)$$ **Equation 3.5**

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 3.9* 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 *Table 3.3* or *Section 9: ASCII Command Reference in the Reference 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 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 IN101, #, RMBA5, M2P, LOKA, #, OUT203, OUT204, and HALARM, the header appears as in *Figure 3.10*. 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 O5 666 77 666 77 511  Z M KKKKKK 11 RFRF
TTT MMMM 234 ZZZZ 234 OOL OO 3S 2222 TO 777 GG 777 QQ 1SS  3KP 121212 BB IBIB
PPP 1234 PPP 1234 GGG LAO SS PP QQGG FP GGG 23 QQQ 23 S11 PRER RRLLCC KK PFPF
ABC PPPP TTT GGGG TTT VDP BT OO FRFR T1 123 TT 123 TT 1TR TBYM SSOOLL 12 1122

[1]
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....

                                   •
                                   •
                                   •
[6]
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
[7]
*** **.. ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....>
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
[8]
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....*
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
[9]
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
[10]
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** .... ... .... ... *.. .. .* .... .. ... .. ... .. ... .... ...... .. ....
*** .... ... .... ... *.. .. *. .... .. ... .. ... .. ... .... ...... .. ....
[11]
*** .... ... .... ... *.. .. *. *.*. .. ... .. ... .. ... .... ...... .. ....
*** .... ... .... ... *.. .. *. .... .. ... .. ... .. ... .... ...... .. ....
*** .... ... .... ... *.. .. *. .... .. ... .. ... .. ... .... ...... .. ....
*** .... ... .... ... *.. .. *. .... .. ... .. ... .. ... .... ...... .. ....
```

Digital Column Labels

One Cycle of Data

Trigger

Largest Current
(to Event Summary)

Circuit Breaker Open

Figure 3.9 Digital Section of the Event Report

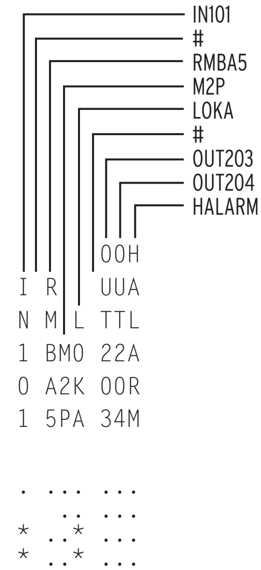

Figure 3.10 Sample Digital Portion of the Event Report

EXAMPLE 3.3 Reading the Digital Portion of the Event Report

This example shows how to read the digital event report shown in Figure 3.9. The sample digital event report shows seven cycles of 4-samples/cycle data for a BCG fault that trips a single-pole-capable circuit breaker.

In this particular report, the mho phase distance elements M1P and M2P pick up in the first sample of Cycle [7]. The relay asserts the tripping Relay Word bits TPA, TPB, and TPC when the distance elements operate because of programming in the TR (Unconditional Tripping) SELogic control equation.

In the next reported sample (the second sample of Cycle [7]), the digital event report shows that the relay has asserted the negative-sequence directional element, 32QF, and the ground directional element, 32GF.

Approximately three cycles later, the digital event report shows that the circuit breaker has tripped. In Cycle [10], Relay Word bit SPO indicates that the relay has detected a single-pole open; one of the poles of the circuit breaker has opened. The remaining poles open and the relay asserts Relay Word bit, 3PO, (Three-Pole Open). Note that the relay polarizing voltage for element security, VPOLV, is always available.

Selecting Event Digital Elements

NOTE: The SEL-421 compressed event reports and COMTRADE files may contain additional digital elements as compared to standard (ASCII) event reports. See CEVENT on page A.3.24.

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 ACSELERATOR QuickSet). You can enter as many as 800 Relay Word bits from 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. See *Report Settings on page R.10.44* for a list of the default programmed digital elements.

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 (INnnn) 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 3.11* for the locations 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 R.9.17*).

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 A.3.28* for a description of the items in the summary portion of the event report.

```
Event: BCG T              Location:  48.17                  Time Source: OTHER
Event Number#: 10007      Shot 1P: 0    Shot 3P: 0        Freq: 60.01      Group: 1
Targets: INST TIME ZONE_1 A_PHASE B_PHASE bklrs
Breaker 1: OPEN           Trip Time: 23:30:49.026
Breaker 2: OPEN           Trip Time: 23:30:49.026
PreFault:      IA      IB      IC      IG     3I2       VA       VB       VC    V1mem
MAG(A/kV)     276     262     246      65      17  364.704  364.903  364.452  364.614
ANG(DEG)     22.1   -91.7   138.2     5.1   178.5      0.0   -119.9    120.3      0.2
Fault:
MAG(A/kV)     217    8892    8727    5586   11403  361.421  218.687  214.239  321.083
ANG(DEG)    -17.0   167.3    24.8    95.6    94.4      0.1   -129.9    126.7      0.7

                                                   L C R     L C R
                                                   B B B R   B B B R
                                                   O A A O   O A A O
                                                   K D D K   K D D K
MB:8->1       RMBA      TMBA      RMBB      TMBB   A A A A   B B B B
  TRIG    00000000  00000000  00000000  00000000   0 0 0 0   0 0 0 0
```

Event Information

Prefault Data

Fault Data

MIRRORED BITS Channel Status

Figure 3.11 Summary Section of the Event Report

Settings Section of the Event Report

The final portion of an event report is the settings section. See *Figure 3.12* 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 (see *EVENT on page R.9.17*).

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 and alias 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. See *SHOW on page R.9.44* for information on the **SHOW** command, and *Making Simple Settings Changes on page U.4.13* for information on relay settings.

```
Group 1

Line Configuration

CTRW    := 400      CTRX    := 400      PTRY    := 3636     VNOMY   := 115
PTRZ    := 3636     VNOMZ   := 115      Z1MAG   := 4.72     Z1ANG   := 82.60
Z0MAG   := 14.50    Z0ANG   := 75.70    EFLOC   := Y        LL      := 100.00
                 •
                 •
                 •
```

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

```
Output

Main Board

OUT101  := 3PT
OUT102  := BK1CL
OUT103  := BK2CL
OUT104  := NA
OUT105  := NA
OUT106  := NA
OUT107  := NA
OUT108  := NA
                 •
                 •
                 •
```

Output 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 3.12 Settings Section of the Event Report

CEVENT

The relay provides a Compressed ASCII event report for SCADA and other automation applications. ACSELERATOR 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**. A sample of the report appears in *Figure 3.13*; 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 (and COMTRADE files) include all eight Relay Word bits from each row of the

Relay Word that has at least one element included in the event report digital elements setting—see *Table 10.91 on page R.10.45*. For the purpose of improving products and services, SEL sometimes changes the items and item order.

See *SEL Compressed ASCII Commands on page R.5.4* and *ASCII Command Reference on page R.9.1* for more information on the Compressed ASCII command set.

Report Header

```
"FID","RID","SID","03E2"
"FID=SEL-421-R101-V0-Z001001-D20010315","Relay 1","Station A","0f0c"
"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","0ACA"
3,15,2001,23,30,49,26,"0400"
```

Summary Labels

```
"EVENT_NUM","EVENT","LOCATION","FREQ","NFREQ","SAM/CYC_A","SAM/CYC_D","NUM_OF_CY
C","SER_NUM","PRIM_VAL","CTR_IA","CTR_IB","CTR_IC","CTR_IG","PTR_VA","PTR_VB","P
TR_VC","PTR_VS1","PTR_VS2","CTRW","CTRX","PTRY","PTRZ","GROUP","BREAKER1","HOUR_
T1","MIN_T1","SEC_T1","MSEC_T1","HOUR_C1","MIN_C1","SEC_C1","MSEC_C1","BREAKER2"
,"HOUR_T2","MIN_T2","SEC_T2","MSEC_T2","HOUR_C2","MIN_C2","SEC_C2","MSEC_C2","T_
LED","TARGETS","MB_TRIGGER","MB_TRIP","IA_PF","IA_DEG_PF","IB_PF","IB_DEG_PF","I
C_PF","IC_DEG_PF","IG_PF","IG_DEG_PF","3I2_PF","3I2_DEG_PF","I1_PF","I1_DEG_PF",
"VA_PF","VA_DEG_PF","VB_PF","VB_DEG_PF","VC_PF","VC_DEG_PF","VS1_PF","VS1_DEG_PF
","VS2_PF","VS2_DEG_PF","V1MEM_PF","V1MEM_DEG_PF","V0_PF","V0_DEG_PF","V2_PF","V
2_DEG_PF","V1_PF","V1_DEG_PF","IA","IA_DEG","IB","IB_DEG","IC","IC_DEG","IG","IG
_DEG","3I2","3I2_DEG","I1","I1_DEG","VA","VA_DEG","VB","VB_DEG","VC","VC_DEG","V
S1","VS1_DEG","VS2","VS2_DEG","V1MEM","V1MEM_DEG","V0","V0_DEG","V2","V2_DEG","V
1","V1_DEG","EFCC"
```

Summary Data

```
10007,"BCG
T",48.17,60.01,60,4,4,15.000,"0000000000","YES",1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,
1.0,400,400,3636,3636,1,"YES",1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,400,400,3636,3
636,1,"OPEN",23,30,49,26,,,,,"OPEN",23,30,49,26,,,,,28872,"INST TIME ZONE_1
A_PHASE B_PHASE bk1rs","0000000000","0000000000",276,22.05,262,-
91.71,246,138.23,784,68.57,17,178.47,261,22.93,365,0.00,365,-
119.87,364,120.30,361,-88.78,362,151.39,365,-0.01,0,-43.94,365,0.14,217,-
16.99,8727,24.82,17836,175.10,11403,94.44,361,0.07,219,-
129.89,214,126.73,321,0.75,31,2.67,321,0.75,31,2.67,67,2.55,263,-0.87,"715D"
```

Column Labels

```
"IA(A)","IB(A)","IC(A)","IG(A)","VA(kV)","VB(kV)","VC(kV)","VS1(kV)","VS2(kV)","
V1MEM(kV)","FREQ","TRIG","LOPHC SPOA SPOB SPOC SPO 3PO 27APO 27BPO SOTFE ILOP
LOP ZLOAD ZLIN ZLOUT FIDEN FSA FSB FSC DFAULT ER EAFSRC * * * M1P M2P M3P M4P
M5P * * * 50Q1 50Q2 50Q3 50Q4 67Q1 67Q2 67Q3 67Q4 51S1 51S1T 51S1R * 51S2 51S2T
51S2R * 51S3 51S3T 51S3R * * * * * Z1G Z2G Z3G Z4G Z5G * * * 67G1 67G2 67G3 67G4
67G1T 67G2T 67G3T 67G4T RMB8A RMB7A RMB6A RMB5A RMB4A RMB3A RMB2A RMB1A TMB8A
TMB7A TMB6A TMB5A TMB4A TMB3A TMB2A TMB1A RMB8B RMB7B RMB6B RMB5B RMB4B RMB3B
RMB2B RMB1B TMB8B TMB7B TMB6B TMB5B TMB4B TMB3B TMB2B TMB1B ROKA RBADA CBADA
LBOKA ANOKA DOKA * * ROKB RBADB CBADB LBOKB ANOKB DOKB * * TPA TPB TPC TRIP 3PT
SPT TPA1 TPB1 TPC1 TPA2 TPB2 TPC2 TOP ULTR ULMTR1 ULMTR2 52ACL1 52BCL1 52CCL1
52AAL1 52BAL1 52CAL1 52AA1 52AB1 52AC1 * 52ACL2 52BCL2 52CCL2 52AAL2 52BAL2
52CAL2 BK2LO BK1CL BK2CL LEADBKO LEADBK1 LEADBK2 FOLBKO FOLBK1 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 M1PT M2PT M3PT M4PT M5PT * * * Z1GT Z2GT Z3GT Z4GT Z5GT
* * * XAG5 XBG5 XCG5 * CVTBL VPOLV * * OSB2 OSB3 OSB4 OSB5 OSB OSTI OSTO OST
F32P R32P F32Q R32Q 32QF 32QR 32SPOF 32SPOR F32I R32I F32V R32V F32QG R32QG 32GF
32GR 50P1 50P2 50P3 50P4 67P1 67P2 67P3 67P4 67Q1T 67Q2T 67Q3T 67Q4T * * * *
59VP 59VS1 25ENBK1 SFZBK1 SFBK1 25W1BK1 25W2BK1 25A1BK1 59VS2 25ENBK2 SFZBK2
SFBK2 25W1BK2 25W2BK2 25A1BK2 25A2BK2 3POBK2 3POLINE 3PLSHT BK1RS BK2RS 79CY1
79CY3 BK1LO RXPRM COMPRM TRPRM DTR SOTFT E3PT E3PT1 E3PT2 PT Z3RB KEY EKEY ECTT
27AWI 27BWI 27CWI RTSA1 RTSB1 RTSC1 RT1 FBFA1 FBFB1 FBFC1 FBF1 FOC1 FOBF1
BFTRIP1 BFTR1 BFULTR1 * * * RTSA2 RTSB2 RTSC2 RT2 FBFA2 FBFB2 FBFC2 FBF2 FOC2
FOBF2 BFTRIP2 BFTR2 BFULTR2 * * * * IN107 IN106 IN105 IN104 IN103 IN102 IN101
PSV08 PSV07 PSV06 PSV05 PSV04 PSV03 PSV02 PSV01 ASV008 ASV007 ASV006 ASV005
ASV004 ASV003 ASV002 ASV001 OUT108 OUT107 OUT106 OUT105 OUT104 OUT103 OUT102
OUT101","CFDC"
```

Event Data (Cycle 1)

```
-267,167,44,-56,-288.02,337.66,-47.82,215.25,144.89,-
287.93,60.00,,"0000000000000000000000000000000003fc00000000000000004000000000000000
00700000000000000000","1E08"
-76,-203,241,-37,-223.70,-138.45,361.32,-290.46,331.28,-
223.70,60.00,,"0000000000000000000000000000000003fc00000000000000004000000000000000
00700000000000000000","1E63"
266,-166,-45,55,288.24,-337.52,47.48,-215.15,-
144.99,288.12,60.02,,"00000000000000000000000000000000003fc0000000000000000400000000
000000000700000000000000000","1E01"
76,202,-242,36,223.44,138.73,-361.35,290.51,-
331.23,223.45,60.02,,"00000000000000000000000000000000003fc0000000000000000400000000
000000000700000000000000000","1DAE"
•
•
•
```

(Continued on next page)

Figure 3.13 Sample Compressed ASCII Event Report

(Continued from previous page)

```
                    •
                    •
                    •
-269,167,46,-56,-289.32,336.87,-45.79,215.46,144.66,-
289.43,60.02,,"0000000000000000000000000000000003fc00000000000004000000000000000
007000000000000000000","1E13"
-74,-202,240,-35,-222.17,-140.21,361.53,-290.20,331.42,-
221.78,60.02,,"0000000000000000000000000000000003fc00000000000004000000000000000
007000000000000000000","1E4F"
268,-165,-45,57,289.38,-336.74,45.57,-215.42,-
144.63,289.53,60.02,,"0000000000000000000000000000000003fc0000000000000400000000
0000000007000000000000000000","1E08"
93,151,-888,-643,221.15,133.53,-335.01,290.18,-
331.43,220.75,60.02,,"0000000000000000000000000000000003fc0000000000000400000000
0000000007000000000000000000","1E15"
-208,2701,-3760,-1267,-288.72,293.71,-24.11,215.51,144.50,-
286.25,60.02,">","000200c00000000000000000000000fbf3fc000000008000040000000000000
000027000000000000000001","206F"
-146,2941,173,2968,-219.57,-87.56,261.56,-290.11,331.44,-
214.05,60.02,,"000300c00000000000000000000000fbf3fc0000c80080000400a80a000000000
027000000000000000001","2043"
134,-5748,8310,2696,286.92,-232.41,3.47,-215.64,-
144.36,273.34,60.02,,"000000c00000000000000000000000fbf3fc0000c80080000400a80a00
0000000027000000000000000001","2015"
179,-6677,1811,-4688,219.83,47.36,-214.22,290.03,-
331.50,202.83,60.02,,"000200c00000000000000000000000fbf3fc0000c80080000400a80a00
0000000027000000000000000001","2047"
-125,5661,-8506,-2971,-286.10,213.60,-3.75,215.77,144.18,-
256.46,60.02,,"000300c00000000000000000000000fbf3fc0000c80080000400a80a000000000
027000000000000000001","206E"
-177,6857,-1950,4730,-220.85,-46.88,214.21,-289.93,331.58,-
193.18,60.02,"*","000300c00000000000000000000000fbf3fc0000c87080000400a80a000000
000027000000000000000001","212C"
129,-5508,8382,3003,286.89,-213.75,3.55,-215.97,-
143.98,243.86,60.02,,"000300c00000000000000000000000fbf3fc0000c87080000400a80a00
0000000027000000000000000001","2031"
174,-6726,1839,-4712,220.39,47.21,-214.22,289.79,-
331.64,185.90,60.02,,"000300c00000000000000000000000fbf3fc0000c87080000400a80a00
0000000027000000000000000001","2058"
-128,5623,-8479,-2984,-287.15,213.94,-3.52,216.15,143.82,-
234.46,60.02,,"000300c00000000000000000000000fbf3fc0000c87080000400a80a000000000
027000000000000000001","2080"
-173,6821,-1924,4724,-219.78,-47.29,214.01,-289.66,331.73,-
180.38,60.02,,"000300c00000000000000000000000fbf3fc0000c87080000400a80a000000000
027000000000000000001","20B4"
126,-5540,8404,2990,286.60,-213.66,3.52,-216.26,-
143.67,227.34,60.02,,"000300c00000000000000000000000fbf3fc0000c87080000400a80a00
0000000027000000000000000001","2015"
177,-6749,1860,-4713,220.04,47.35,-212.90,289.55,-
331.82,176.19,60.02,,"000300c00000000000000000000000fbf3fc0000c87080000400a80a00
0000000027000000000000000001","2056"
-126,4616,-6204,-1714,-282.94,178.63,41.89,216.40,143.49,-
222.05,60.02,,"000300c00000000000000000000000fbf3fc0000c87080000400a80a000000000
027000000000000000001","2075"
-106,4288,-1047,3135,-231.56,-64.52,95.28,-289.40,331.89,-
162.59,60.02,,"800000c00000000000000000000000fbf3fc0000c87080000400a80a000000000
027000000000000000001","2084"
65,-1722,1878,221,140.22,-72.11,-43.65,-216.57,-
143.30,194.58,60.02,,"b80000000000000000000000000000fbf3000000c87000000400000000
0000000007000000000000000001","1EF9"
16,-807,4,-786,105.08,41.29,10.53,289.25,-
331.99,130.70,60.02,,"f40000000000000000000000000000fbf3000000c87000000400800000
0000000007000000000000000001","1DE6"
-1,-1,-2,-5,13.85,1.12,0.29,216.77,143.06,-
147.06,60.02,,"f40000000000000000000000000000fbf3000000c87000000400a80a000000000
007000000000000000001","1CEE"
2,3,4,9,54.84,-0.71,-0.30,-289.09,332.13,-
93.47,60.02,,"f40000000000000000000000000000fbf3000000c870000004000000000000000000
07000000000000000001","1C38"
1,1,2,5,-8.08,-1.59,-1.13,-216.98,-
142.80,109.76,60.02,,"f40000000000000000000000000000fbf3000000c87000000400000000
0000000007000000000000000001","1C61"
-2,-2,-3,-8,-58.22,0.22,0.22,288.96,-
332.25,65.27,60.02,,"f40000000000000000000000000000fbf3000000c870000004000000000
000000007000000000000000001","1C8D"
                    •
                    •
                    •
```

Trigger

Largest Current
(to Event Summary)

Event Data (Cycle 6–11)

(Continued on next page)

Figure 3.13 Sample Compressed ASCII Event Report

(Continued from previous page)

```
                    •
                    •
                    •
"SETTINGS","02E1"
"Group 1

Line Configuration

CTRW    := 400      CTRX    := 400      PTRY    := 3636     VNOMY   := 115
PTRZ    := 3636     VNOMZ   := 115      Z1MAG   := 4.72     Z1ANG   := 82.60
Z0MAG   := 14.50    Z0ANG   := 75.70    EFLOC   := Y        LL      := 100.00
```

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

```
Output

Main Board

OUT101  := 3PT
OUT102  := BK1CL
OUT103  := BK2CL
OUT104  := NA
OUT105  := NA
OUT106  := NA
OUT107  := NA
OUT108  := NA
                    •
                    •
                    •
```

Output 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 3.13 Sample Compressed ASCII Event Report

The order of the labels in the digital portion of the Column Labels field matches the order of the HEX-ASCII Relay Word. Each numeral in the HEX-ASCII Relay Word reflects the status of four Relay Word bits from the Digital Column Labels field of the Compressed ASCII event report. The HEX-ASCII Relay Word from the first sample of Cycle [7], the trigger cycle, is the following:

```
"000200c000000000000000000000000fbf3fc000000008000040000000000000000270000000000000000
    001"
```

In this HEX-ASCII Relay Word, the seventh numeral in the HEX-ASCII Relay Word is C. In binary, this is 1100. Mapping the labels to the digital Column Labels yields the following:

```
M1P M2P M3P M4P
1   1   0   0
```

M1P and M2P are elements that picked up at the first sample of Cycle [7] (see *Figure 3.9*).

Event Files Download

You can download the event file from the relay and save these files to a PC to keep as a record or examine later. Use a terminal emulation program with file transfer capability. For example, type **FILE READ EVENTS E4_10007.TXT <Enter>** at an Access Level 1 prompt or higher to download a 4-samples/cycle event report with serial number 10007. Start the terminal download routine to store the file on your computer. Use Y modem protocol.

If you want the Compressed ASCII file, type **FILE READ EVENTS C4_10007.TXT <Enter>**. In addition, you can use ACSELERATOR QuickSet to download event files. See *Retrieving Event Report Data Files: Terminal on page U.4.50* for more information on event report file download procedures.

Event Summary

You can retrieve a shortened 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 A.3.4*). See *Figure 3.14* for a sample event summary.

The SEL-421 can be configured to automatically send an event summary—see *Automatic Messages on page R.5.8*.

```
Relay 1                                     Date: 03/15/2001  Time: 23:30:49.026
Station A                                   Serial Number: 2001001234

Event: BCG T             Location:  48.17                     Time Source: OTHER
Event Number#: 10007     Shot 1P: 0    Shot 3P: 0       Freq: 60.01      Group: 1
Targets: INST TIME ZONE_1 A_PHASE B_PHASE bklrs
Breaker 1: OPEN          Trip Time: 23:30:49.026
Breaker 2: OPEN          Trip Time: 23:30:49.026
PreFault:      IA      IB      IC      IG     3I2        VA       VB       VC     V1mem
MAG(A/kV)     276     262     246      65      17   364.704  364.903  364.452  364.614
ANG(DEG)     22.1   -91.7   138.2     5.1   178.5       0.0   -119.9    120.3      0.2
Fault:
MAG(A/kV)     217    8892    8727    5586   11403   361.421  218.687  214.239  321.083
ANG(DEG)    -17.0   167.3    24.8    95.6    94.4       0.1   -129.9    126.7      0.7

                                                 L C R      L C R
                                                 B B B R    B B B R
                                                 O A A O    O A A O
                                                 K D D K    K D D K
MB:8->1       RMBA      TMBA      RMBB      TMBB     A A A A    B B B B
  TRIG     00000000  00000000  00000000  00000000    0 0 0 0    0 0 0 0
  TRIP     00000000  00000000  00000000  00000000    0 0 0 0    0 0 0 0
```

Report Header
Event Information
Circuit Breaker Status
Prefault Data
Fault Data
MIRRORED BITS Channels Status

Figure 3.14 Sample Event Summary Report

The event summary contains the following information:

- Standard report header
  - Relay and terminal identification
  - Event date and time
- Event type
- Location of fault (if applicable)
- Time source (HIRIG or OTHER)
- Event number
- Recloser shot counter at the trigger time
- System frequency
- Active group at trigger time
- Targets
- Circuit breaker trip and close times; and auxiliary contact(s) status
- Prefault and fault voltages, currents, and sequence current (from the event report row with the largest current)
- MIRRORED BITS® communications channel status (if enabled)

The relay derives the summary target information and circuit breaker trip and close times from the rising edge of relevant Relay Word bits during the event. If no trip or circuit breaker element asserted during the event, the relay uses the last row of the event.

Fault location data can be indeterminate (for example, when there is no fault on the power system). If this is the case, the relay displays “$$$$.$$” for the Location entry in the event summary. You will also see the “$$$$.$$” display if the fault location enable setting EFLOC is N.

The SEL-421 reports the event type according to the output of the fault location algorithm. *Table 3.6* lists event types in fault reporting priority. Fault event types (AG, BG, and BCG, for example) have reporting priority over indeterminate fault events. For example, you can trigger an event when there is no fault condition on the power system by using the **TRI** command. In this case, when there is no fault, the relay reports the event type as TRIG.

Table 3.6 Event Types

Event	Event Trigger
AG, BG, CG, ABC, AB, BC, CA, ABG, BCG, CAG	The relay reports phase involvement. If Relay Word bit TRIP asserts at any time during the event, the relay appends a T to the phase (AG T, for example).
TRIP	The event report includes the rising edge of Relay Word bit TRIP, but phase involvement is indeterminate.
ER	The relay generates the event with elements in the SELOGIC control equation ER, but phase involvement is indeterminate.
TRIG	The relay generates the event in response to the TRI command.

Viewing the Event Summary

Access the event summary from the communications ports and communications cards. View and download history reports 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 A.3.31*.)

Table 3.7 lists the **SUM** commands. See *SUMMARY on page R.9.49* for complete information on the **SUM** command.

Table 3.7 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 (see Event Numbering on page A.3.13).

You can retrieve event summaries with ACSELERATOR QuickSet. The **Event Waveform View > Summary Data** menu item gives you summary information for each event you select in the **Event History** dialog box. Access the **Relay Event History** dialog box via the **Analysis > View Event Files** menu. See *Analyze Events on page U.3.16* for information and examples.

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. A sample of the summary report appears in *Figure 3.15*; 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.

See *SEL Compressed ASCII Commands on page R.5.4* and *ASCII Command Reference on page R.9.1* for more information on the Compressed ASCII command set.

```
"RID","SID","FID","03e2"
"Relay 1","Station A","SEL-421-R101-V0-Z001001-D20010315","0dfc"
"EVENT_NUM","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","USEC","EVENT","LOCAT
ION","TIME_SOURCE","SHOT_1P","SHOT_3P","FREQUENCY","GROUP","BREAKER1","HOUR_T1",
"MIN_T1","SEC_T1","MSEC_T1","HOUR_C1","MIN_C1","SEC_C1","MSEC_C1","BREAKER2","HO
UR_T2","MIN_T2","SEC_T2","MSEC_T2","HOUR_C2","MIN_C2","SEC_C2","MSEC_C2","T_LED"
,"TARGETS","MB_TRIGGER","MB_TRIP","IA_PF","IA_DEG_PF","IB_PF","IB_DEG_PF","IC_PF
","IC_DEG_PF","IG_PF","IG_DEG_PF","3I2_PF","3I2_DEG_PF","I1_PF","I1_DEG_PF","VA_
PF","VA_DEG_PF","VB_PF","VB_DEG_PF","VC_PF","VC_DEG_PF","VS1_PF","VS1_DEG_PF","V
S2_PF","VS2_DEG_PF","V1MEM_PF","V1MEM_DEG_PF","V0_PF","V0_DEG_PF","V2_PF","V2_DE
G_PF","V1_PF","V1_DEG_PF","IA","IA_DEG","IB","IB_DEG","IC","IC_DEG","IG","IG_DEG
","3I2","3I2_DEG","I1","I1_DEG","VA","VA_DEG","VB","VB_DEG","VC","VC_DEG","VS1",
"VS1_DEG","VS2","VS2_DEG","V1MEM","V1MEM_DEG","V0","V0_DEG","V2","V2_DEG","V1","
V1_DEG","D94E"
10007,3,15,2001,23,30,49,026,900,"BCG
T",48.17,"OTHER",0,0,60.01,1,"OPEN",23,30,49,26,,,,,"OPEN",23,30,49,26,,,,,28872,"
INST TIME ZONE_1 A_PHASE B_PHASE bk1rs","0000000000","0000000000",276,22.05,262,
-91.71,246,138.23,784,68.57,17,178.47,261,22.93,365,0.00,365,-119.87,364,120.30,
361,-88.78,362,151.39,365,-0.01,0,-43.94,365,0.14,217,-
16.99,8727,24.82,17836,175.10,11403,94.44,361,0.07,219,-
129.89,214,126.73,321,0.75,31,2.67,321,0.75,31,2.67,67,2.55,263,-0.87,"49C7"
```

Report Header

Report Labels

Report Data

Figure 3.15 Sample Compressed ASCII Summary

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 3.16* for a sample event history.

The event history contains the following:

- Standard report header
  - Relay and terminal identification
  - Date and time of report
- Event number
- Event date and time
- Event type
- Location of fault (if applicable)
- Maximum phase current from summary fault data
- Active group at the trigger instant
- Targets

Figure 3.16 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

Maximum Current

Active Group

Figure 3.16 Sample Event History

Fault location data can be indeterminate (for example, when you trigger an event and there is no fault on the power system). If this is the case, the relay displays `$$$$.$$` for the Location entry in the event history. You will also see the `$$$$.$$` display if the fault location enable setting EFLOC is N.

The event types in the event history are the same as the event types in the event summary (see *Table 3.6* for event types).

The event history report indicates events stored in relay nonvolatile memory. The relay places a blank row in the history report output; items that are above the blank row are available for viewing (use the **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** and **HIS RA** commands).

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 R.9.23* for information on the **HIS** command. *Table 3.8* lists the **HIS** commands.

Table 3.8 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 ACSELERATOR QuickSet to retrieve the relay event history. Use the **Analysis > View Event History** menu to view the **Event History** dialog box. See *Analyze Events on page U.3.16* for information and examples.

```
"RID","SID","FID","03e2"
"Relay 1","Station A","FID=SEL-421-R101-V0-Z001001-D20010315","0f0c"
"EVENT_NUM","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","USEC","EVENT","LOCAT
ION","TIME_SOURCE","SHOT_1P","SHOT_3P","FREQUENCY","GROUP","BREAKER1","HOUR_T1",
"MIN_T1","SEC_T1","MSEC_T1","HOUR_C1","MIN_C1","SEC_C1","MSEC_C1","BREAKER2","HO
UR_T2","MIN_T2","SEC_T2","MSEC_T2","HOUR_C2","MIN_C2","SEC_C2","MSEC_C2","T_LED"
,"TARGETS","MB_TRIGGER","MB_TRIP","IA_PF","IA_DEG_PF","IB_PF","IB_DEG_PF","IC_PF
","IC_DEG_PF","IG_PF","IG_DEG_PF","3I2_PF","3I2_DEG_PF","I1_PF","I1_DEG_PF","VA_
PF","VA_DEG_PF","VB_PF","VB_DEG_PF","VC_PF","VC_DEG_PF","VS1_PF","VS1_DEG_PF","V
S2_PF","VS2_DEG_PF","V1MEM_PF","V1MEM_DEG_PF","V0_PF","V0_DEG_PF","V2_PF","V2_DE
G_PF","V1_PF","V1_DEG_PF","IA","IA_DEG","IB","IB_DEG","IC","IC_DEG","IG","IG_DEG
","3I2","3I2_DEG","I1","I1_DEG","VA","VA_DEG","VB","VB_DEG","VC","VC_DEG","VS1",
"VS1_DEG","VS2","VS2_DEG","V1MEM","V1MEM_DEG","V0","V0_DEG","V2","V2_DEG","V1","
V1_DEG","D94E"
10007,3,15,2001,23,30,49,26,900,"BCG
T",48.17,"OTHER",0,0,60.01,1,"OPEN",23,30,49,26,,,,,"OPEN",23,30,49,26,,,,,28872,"
INST TIME ZONE_1 B_PHASE C_PHASE GROUND
bk1rs","0000000000","0000000000",276,22.05,262,-
91.71,246,138.23,65,5.11,17,178.47,261,22.93,365,0.00,365,-
119.87,364,120.30,361,-88.78,362,151.39,365,-0.01,1,-117.90,0,-
43.94,365,0.14,217,-16.99,8892,167.27,8727,24.82,5586,95.60,11403,94.44,5789,-
83.19,361,0.07,219,-129.89,214,126.73,361,-
88.92,362,151.24,321,0.75,31,2.67,67,2.55,263,-0.87,"637E"
00006,3,15,2001,7,15,0,635,900,"ABC
T",22.82,"OTHER",0,1,59.98,1,"OPEN",7,15,0,635,,,,,"OPEN",7,15,0,635,,,,,57480,"IN
ST ZONE_1 A_PHASE
bk1rs","0000000000","0000000000",9,125.27,9,128.10,7,96.08,24,118.43,5,109.90,1,
-120.66,0,79.68,0,73.83,0,106.76,0,134.13,0,178.99,0,99.44,0,87.50,0,-
80.58,0,73.48,8203,-91.24,6617,148.12,7485,39.60,70,113.90,1757,-118.74,7404,-
87.80,32,0.00,40,-118.11,38,110.17,0,88.59,1,-79.09,26,-7.83,0,-
165.97,6,159.23,36,-2.68,"5A30"
00005,3,15,2001,6,43,53,428,900,"TRIG",$$$$.$$,"OTHER",0,0,60.00,1,"OPEN",,,,,,,,
,"NA",,,,,,,,,0,"","0000000000","0000000000",0,144.30,1,106.07,1,60.80,1,94.40,0
,176.31,0,-112.74,0,125.20,0,-67.34,0,-150.44,0,-21.16,0,80.35,0,34.89,0,-170.50
,0,138.88,0,94.55,1,0.00,0,41.08,1,-16.92,2,-1.92,2,19.32,0,-26.30,0,-174.55,0,-
58.17,0,-64.16,0,-70.49,0,131.85,0,34.89,0,-110.51,0,121.49,0,177.31,"49C7"
```

Report Header

Report Labels

Report Data

Figure 3.17 Sample Compressed ASCII History Report

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. A sample of the report appears in *Figure 3.17*; 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.

See *SEL Compressed ASCII Commands on page R.5.4* and *Section 9: ASCII Command Reference in the Reference Manual* for more information on the Compressed ASCII command set.

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 ACSELERATOR QuickSet to download history files. See *Retrieving Event Report Data Files: Terminal on page U.4.50* for file download procedures.

SER (Sequential Events Recorder)

The SEL-421 SER (Sequential Events Recorder) 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, and SER autoremoval/reinsertion. The SEL-421 stores the latest 1000 SER entries to nonvolatile memory. *Figure 3.18* is a sample SEL-421 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

```
Relay 1                                           Date: 03/16/2001  Time: 13:09:29.341
Station A                                         Serial Number: 2001001234

FID=SEL-421-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 3.18 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 (see *Table 3.9* or the *SER on page R.9.38*).

Viewing the SER Report

The relay displays the SER records in ASCII and binary formats. For more information on binary SER messaging, see *SEL Communications Protocols on page R.5.1*.

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 or ACSELERATOR 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. See *Table 3.9* or *Section 9: ASCII Command Reference in the Reference Manual* for more information on the **SER** command.

Table 3.9 SER Commands[a]

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*	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 and **SER R**	Clear SER records on the present port.
SER CA and **SER RA**	Clear SER data for all ports.
SER CV and **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 ACSELERATOR QuickSet. The **HMI > Meter and Control** menu item gives you the SER report. See *Viewing SER Records on page U.4.50* for information and examples. The latest 200 SER events are viewable on the front-panel display through the front-panel EVENTS MENU (see *Section 5: Front-Panel Operations in the User's Guide*).

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 3.19*; 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.

See *SEL Compressed ASCII Commands on page R.5.4* and *CSER on page R.9.13* for more information on the Compressed ASCII command set.

```
"RID","SID","FID","03e2"
"Relay 1","Station A","SEL-421-R101-V0-Z001001-D20010315","0dfc"
"#","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","ELEMENT","STATE","0FC8"
1,3,15,2001,00,32,00,114,"GROUND_O/C_1_LINE_1","51S1_DROPOUT","09D2"
2,3,15,2001,00,32,00,114,"GROUND_O/C_1_LINE_1","51S1_RESET","08E7"
3,3,15,2001,00,30,03,221,"GROUND_O/C_1_LINE_1","51S1_TIMEOUT","09B0"
4,3,15,2001,00,30,00,021,"GROUND_O/C_1_LINE_1","51S1_PICK_UP","097B"
5,3,15,2001,00,00,00,222,"Relay","Enabled","09BA"
6,3,15,2001,00,00,00,004,"Power-up","Group 1","0A0A"
```

Report Header

SER Data (6 records)

Figure 3.19 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>**. See *Downloading an SER Report File on page U.4.55* for SER file download procedures.

Setting SER Point and Aliases

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. You can also change the names of the elements and set aliases for the element clear and set states. Use the **SET R** command from a terminal, or use ACSELERATOR QuickSet **Report** branch of the **Settings** tree view to enter **SER Points and Aliases**.

Use the text-edit line mode settings method to enter or delete SER elements (see *Text-Edit Mode Line Editing on page U.4.18*). 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

Names or aliases can contain any printable ASCII character. See *Viewing SER Records on page U.4.50* for examples of entering SER data.

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. For a setting example, see *Viewing SER Records on page U.4.50*.

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 (see *SER on page R.9.38*).

Section 4
Time-Synchronized Measurements

The SEL-421 Relay records power system events with very high accuracy when you provide high-accuracy clock input signals, such as from a GPS receiver. SEL-421 relays placed at key substations can give you information on power system operating conditions in real time.

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 Synchrophasors for Power Systems. You can then perform detailed analysis and calculate load flow from the synchrophasors.

See *Section 7: Synchrophasors* in the *Reference Manual* for more information about phasor measurement functions in the SEL-421**.**

This section presents details on these measurements as well as suggestions for further application areas. This section covers:

Relay Configuration for High-Accuracy Timekeeping

The SEL-421 features two IRIG-B timekeeping modes, IRIG and high-accuracy IRIG, called HIRIG.

The HIRIG mode replaces the PPS mode in previous SEL-421 relays, which required a separate 1k PPS time input in firmware versions R111 and earlier. Relay Word bit TSOK asserts when the SEL-421 is in HIRIG mode (see *Table 4.9 on page U.4.71*).

The SEL-421 must be in the HIRIG mode in order for the synchrophasor features to operate (see *Section 7: Synchrophasors in the Reference Manual*).

See *Configuring High-Accuracy Timekeeping on page U.4.71* for details on the time-source connections of the SEL-421, including the changes made to the SEL-421 hardware and firmware version R112.

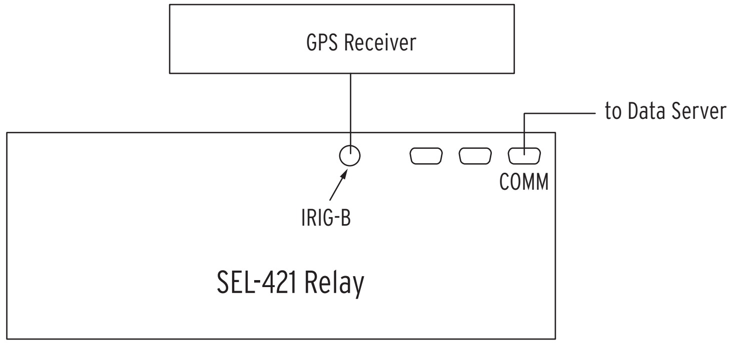

Figure 4.1 High-Accuracy Timekeeping Connections

Time-Synchronized Triggers

Program the SEL-421 to perform data captures at *specific* times. Relays that are time-locked 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 SEL-421

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. See View Synchrophasors by Using the MET PM Command on page R.7.24.

Perform the following steps to trigger an event data capture in the SEL-421 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.

You should be familiar with the ACSELERATOR® SEL-5030 Software Program. See *Section 3: PC Software in the User's Guide* and *Section 4: Basic Relay Operations in the User's Guide* for ACSELERATOR operational information.

This example assumes that you have successfully established communication with the relay (see *Establishing Communication on page U.4.4* for a step-by-step procedure). In addition, you should be familiar with relay access levels and passwords. See *Changing the Default Passwords on page U.4.6* to change the default access level passwords.

Step 1. Configure the communications port:

a. Start the ACSELERATOR QuickSet® SEL-5030 Software.

b. On the top toolbar, click **Communication** > **Parameters**.

You will see the **Communication Parameters** dialog box.

c. Select the **Data Speed**, **Data Bits**, **Stop Bits**, **Parity**, and **RTS/CTS** that match the relay settings. The defaults are **9600**, **8**, **1**, **None**, **Off**, respectively.

d. Click **OK** to update the ACSELERATOR QuickSet communications parameters.

e. Type **<Ctrl + T>** to use the serial communications terminal.

f. Type **<Enter>** to see whether the communications link is active between ACSELERATOR QuickSet and the relay.

   You will see the Access Level 0 = prompt in the terminal window.

g. Exit the terminal window.

Step 2. Confirm the correct ACSELERATOR passwords:

a. Reopen the **Communication** menu and click **Port Parameters**.

b. Enter your Access Level 1 password in the **Level One Password** text box and your Access Level 2 password in the **Level Two Password** text box.

c. Click **OK**.

Step 3. Click **Settings > Read** to read the present configuration in the SEL-421.

The relay sends all configuration and settings data to ACSELERATOR.

Step 4. Click the **+** mark next to the **Group** you want to program on the **Settings** tree view.

This example uses **Group 1**.

You will see the **Protection Free-Form Logic Settings** dialog box.

Step 5. Enter time trigger settings:

a. Click the button beside the first unused Protection SELOGIC row entry field to start the **Expression Builder**.

b. On the left side of the SELOGIC control equation, select **Math Variables** and double-click **PMV64**.

c. On the right side of the equation, select **Analog Quantities > Date and Time**.

d. Double click **THR** (Time in Hours).

e. Use the **#** character to add a comment to the line.

f. When finished, click **Accept**.

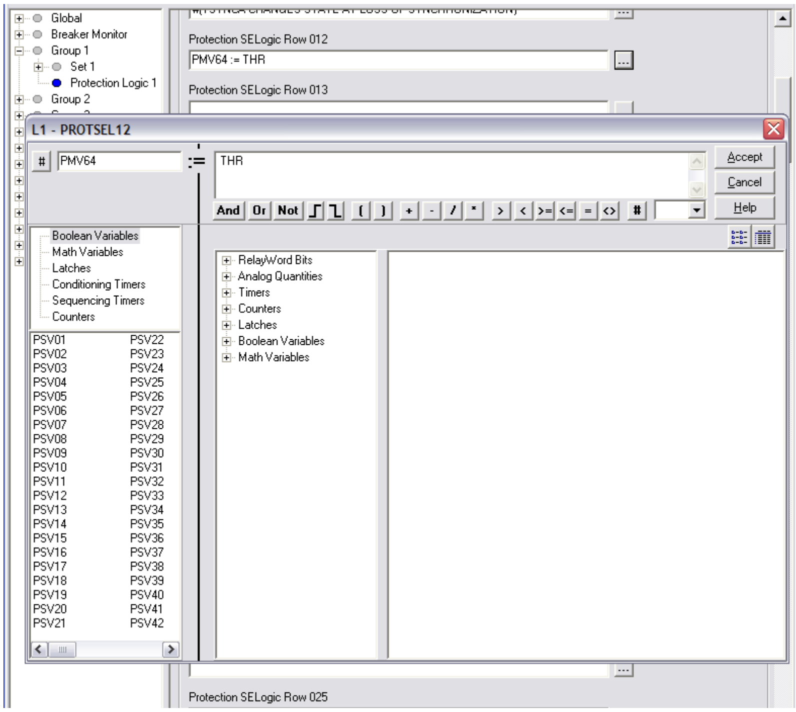

Figure 4.2 Setting PMV64 with the Expression Builder Dialog Box

Step 6. In a similar manner, build a free-form SELOGIC program in Protection Logic that causes protection free-form 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: In this example, the event report trigger will occur between 12:30:00.002 and 12:30:00.005 because of the method of SEL-421 protection logic processing.

Step 7. Select settings:

a. Click the **+** mark next to **Relay Configuration** as shown in *Figure 4.3*.

b. Click the **Trip Logic** and **ER Trigger** branch.

You will see the **Trip Logic** and **ER Trigger Settings** dialog box (see *Figure 4.3*).

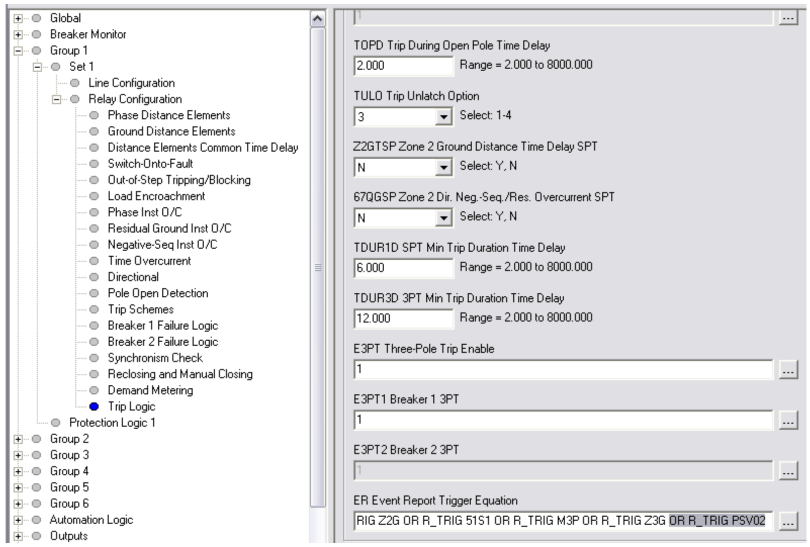

Figure 4.3 Selecting Trip Logic and ER Trigger Settings in ACSELERATOR

Step 8. Click 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.

Step 9. Click **File > Save** to save the new settings in ACSELERATOR.

Step 10. Upload the new settings to the SEL-421:

a. Click **File > Send**.

ACSELERATOR prompts you for the settings class or instance you want to send to the relay, as shown in the first dialog box in *Figure 4.4*.

b. Click the check box for **Group 1** (or the settings group that you are programming).

c. Click **OK**.

The relay responds with the second dialog box shown in *Figure 4.4*.

If you see no error message, the new settings are loaded in the relay.

NOTE: The **Relay Editor** dialog boxes shown in Figure 4.4 are for the SEL-421. The SEL-421-1 and the SEL-421-2 dialog boxes do not contain Automation 2 through Automation 10 setting instances.

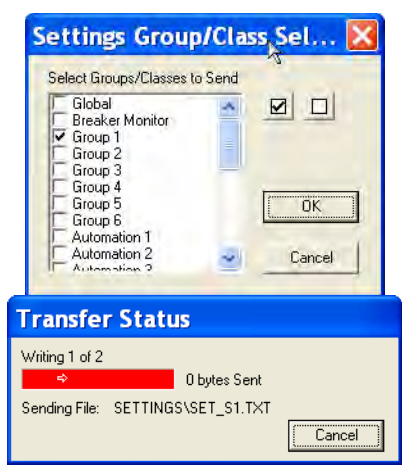

Figure 4.4 Uploading Group Settings to the SEL-421

COMTRADE File Information

Retrieve the COMTRADE files for the time-triggered data captures from each relay with the **FILE READ EVENTS** command. See *Reading Oscillograms, Event Reports, and SER on page U.4.42* for methods to retrieve these files.

Parse the binary COMTRADE data for the power system currents and voltages you need to calculate system quantities. See *Raw Data Oscillography on page A.3.8* for more information on the COMTRADE file format.

Fault Analysis

Use the SEL-421 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.

Power System Measurements

Install at least two SEL-421 relays in the power system to implement dynamic phasor determination. *Figure 4.5* shows an example of a 230 kV overhead transmission line with a SEL-421 at each terminal. Connect GPS clocks (such as the SEL-2407) at each substation to provide very high-accuracy time signal inputs for each relay. See *Configuring High-Accuracy Timekeeping on page U.4.71* for details on the IRIG-B connections required for high-accuracy IRIG (HIRIG) timekeeping in the SEL-421.

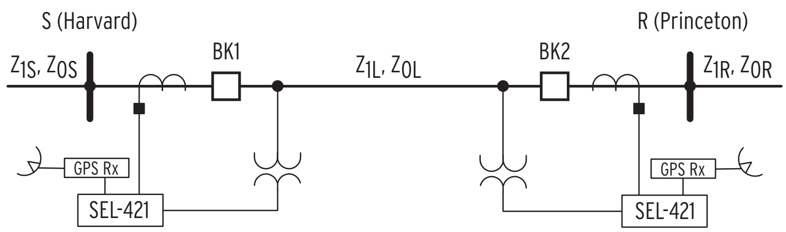

Figure 4.5 230 kV Transmission Line System

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 Analytic Assistant to select the appropriate prefault and post-fault quantities.

Power Flow Analysis

Use the SEL-421 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.

Four SEL-421 relays are installed in the power system shown in *Figure 4.6*. Substations S and R provide generation for the load at Substation T.

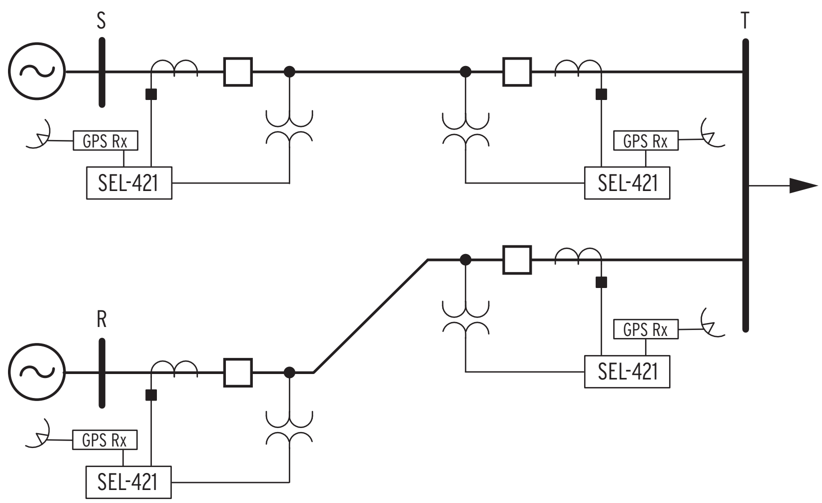

Figure 4.6 500 kV Three Bus Power System

Table 4.1 lists the voltage and current measured by the four SEL-421 relays at one particular time.

Table 4.1 SEL-421 Voltage and Current Measurement (Sheet 1 of 2)

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 Towards 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°

Table 4.1 SEL-421 Voltage and Current Measurement (Sheet 2 of 2)

Voltage		Current	
SEL-421 at Substation T Looking Towards 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 4.1* to calculate the generation supplied from Substation S and Substation R, plus the load at Substation T.

$$\begin{aligned} S_{3\varnothing} &= P_{3\varnothing} + jQ_{3\varnothing} \\ &= \sqrt{3} \bullet V_{pp} \bullet I^*{}_L \\ &= 3 \bullet V_p \bullet I^*{}_L \end{aligned}$$

Equation 4.1

where:

$S_{3\phi}$ = Three-phase complex power (MVA)
$P_{3\phi}$ = Three-phase real power (MW)
$Q_{3\phi}$ = Three-phase imaginary power (MVAR)
V_{pp} = Phase-to-phase voltage
V_p = Phase-to-neutral voltage
I^*_L = Complex conjugate of the line current

The complex power generation supplied by Substation S is:

$$\begin{aligned} S_S &= (3 \bullet 288.675\ \text{kV}\angle 0°) \bullet (238.995\ \text{A}\angle{-41.9°}) \\ &= 154.1\ \text{MW} - j138.2\ \text{MVAR} \end{aligned}$$

The complex power generation supplied by Substation R is:

$$\begin{aligned} S_R &= (3 \bullet 303.109\ \text{kV}\angle{-0.2°}) \bullet (234.036\ \text{A}\angle 44.2°) \\ &= 152.6\ \text{MW} + j148.3\ \text{MVAR} \end{aligned}$$

The load at Substation T supplied by Substation S is:

$$\begin{aligned} S_{T-S} &= (3 \bullet 295.603\ \text{kV}\angle{-1.6°}) \bullet (238.995\ \text{A}\angle 138.1°) \\ &= -153.7\ \text{MW} + j145.9\ \text{MVAR} \end{aligned}$$

The load at Substation T supplied by Substation R is:

$$\begin{aligned} S_{T-R} &= (3 \bullet 295.603\ \text{kV}\angle{-1.6°}) \bullet (234.036\ \text{A}\angle{-135.8°}) \\ &= -152.8\ \text{MW} - j140.5\ \text{MVAR} \end{aligned}$$

The total load at Substation T is:

$$\begin{aligned} S_T &= S_{T-S} + S_{T-R} \\ &= -306.5\ \text{MW} + j5.4\ \text{MVAR} \end{aligned}$$

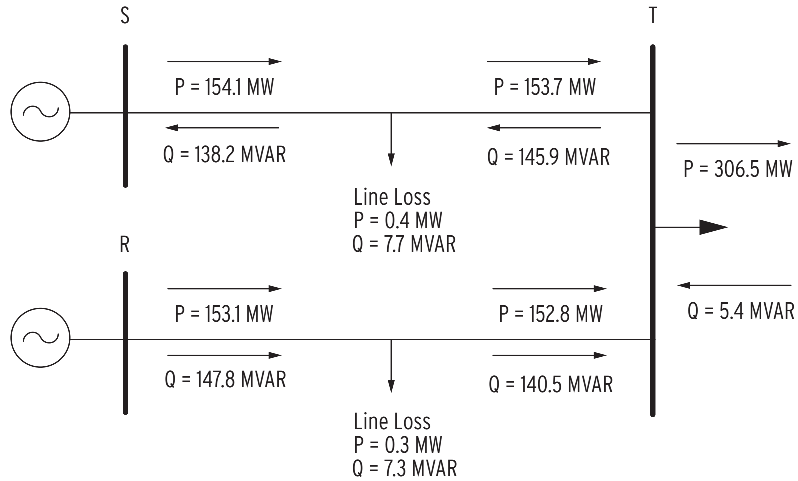

Figure 4.7 Power Flow Solution

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 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 SEL-421 Fast Messages to a central database to determine the power system state.

Use Synchrophasors for State Measurement, Not Estimation

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.

With Phasor Measurement Units (PMUs) such as the SEL-421 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 7: Synchrophasors in the Reference Manual* for information on the PMU settings and the communications protocols available for synchrophasor data collection.

Section 5
Substation Automatic Restoration

Many electric utilities tap overhead transmission lines with bulk power transformers. A tapped line with three terminals presents more operating constraints and line protection complications than does a two-terminal line. Use an automatic restoration scheme to reduce the decision-making burden on operations and dispatch personnel during equipment failures, system events, and lightning-induced line operations.

This section contains the following:

with subsections:

This section assumes that you are familiar with line protection. Find supporting material for the information in this section in *Section 2: Auto-Reclosing and Synchronism Check in the Reference Manual*, *Section 3: SELOGIC Control Equation Programming in the Reference Manual*, and *Section 5: SEL Communications Protocols in the Reference Manual*.

230 kV Tapped Transmission Line Application Example

This example shows you how to automate the complete restoration sequence, including auto-reclose and synchronism check, **for the tapped 230/115 kV autotransformer located at Substation T**. *Figure 5.1* shows a one-line diagram of the tapped 230 kV overhead transmission line.

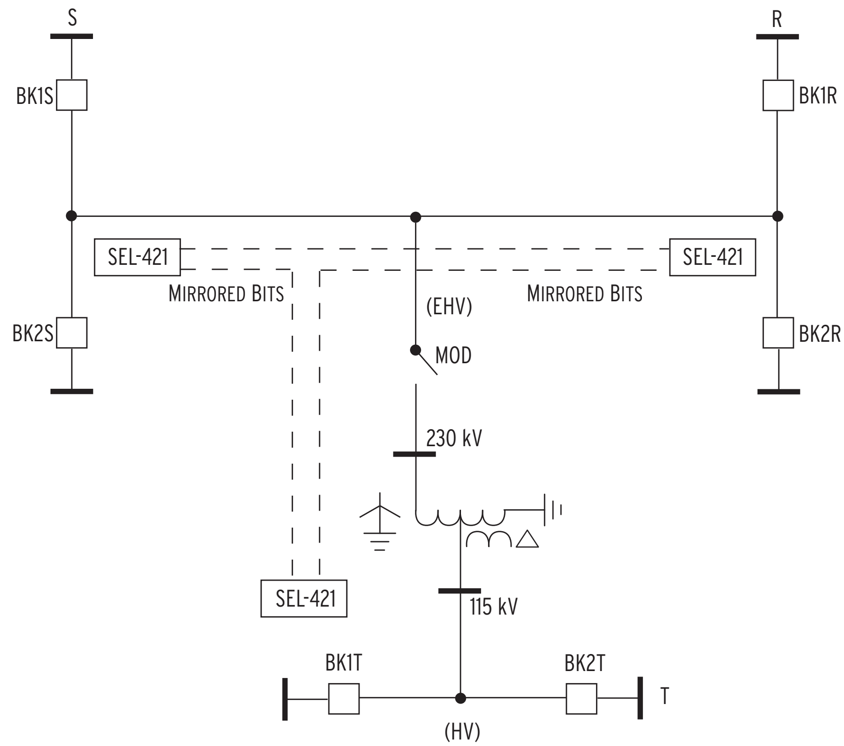

Figure 5.1 230 kV Tapped Overhead Transmission Line

The tapped autotransformer at Substation T has a high-side MOD (motor-operated disconnect) and two low-side circuit breakers. Whenever an internal fault occurs on the 230 kV overhead transmission line, the SEL-421 relays at each of the three terminals open all of the circuit breakers, followed by the high-side MOD at Substation T. The SEL-421 relays replace separate line relays, discrete reclosing and synchronism check relays, timers, latching relays, and extensive wiring for this particular example.

Use the SEL-421 protection free-form SELOGIC control equations in *Table 5.4* to automate the following actions at Substation T:

- Restore tapped Substation T to service after a successful 230 kV overhead transmission line auto-reclose operation.
- Restore the 230 kV overhead transmission line to service after an autotransformer failure or a low-side circuit breaker failure operation.
- Restore Substation T station service and 115 kV bus continuity after an unsuccessful automatic line reclose operation or a remote 230 kV circuit breaker failure trip.

Philosophy

System Protection Philosophy

SEL-421 relays located at each of the three 230 kV terminals protect the tapped 230 kV transmission line; the relays operate in the DCB (directional comparison blocking) trip scheme. Zone 1 distance protection also operates in the DUTT (direct underreaching transfer trip) scheme. When the high-side MOD is closed, the SEL-421 at Substation T direct transfer trips the other two terminals if a 115 kV circuit breaker fails to operate or an autotransformer failure occurs; the SEL-421 at Substation T also receives direct transfer trip commands from Substations S and R.

Auto-Reclose Philosophy

Refer to *Figure 5.2* for a timing diagram of the complete auto-reclose cycle.

Use the SEL-421 to provide auto-reclose at Substation T as follows.

Circuit Breaker BK1T

- If the high-side MOD is closed and the synchronism check across Circuit Breaker BK1T with respect to the 230 kV potential is successful for at least four seconds, the SEL-421 recloses Circuit Breaker BK1T in five seconds total.
- If the high-side MOD is open and the 115 kV system has been energized for at least four seconds, the relay recloses Circuit Breaker BK1T in five seconds total.

Circuit Breaker BK2T

- If Circuit Breaker BK1T recloses and the synchronism check is successful across Circuit Breaker BK2T with respect to the 230 kV potential for at least four seconds, the SEL-421 recloses Circuit Breaker BK2T in five seconds total.
- If the high-side MOD is open, Circuit Breaker BK1T recloses, and the 115 kV system has been energized for at least four seconds, the relay recloses Circuit Breaker BK2T in five seconds total.

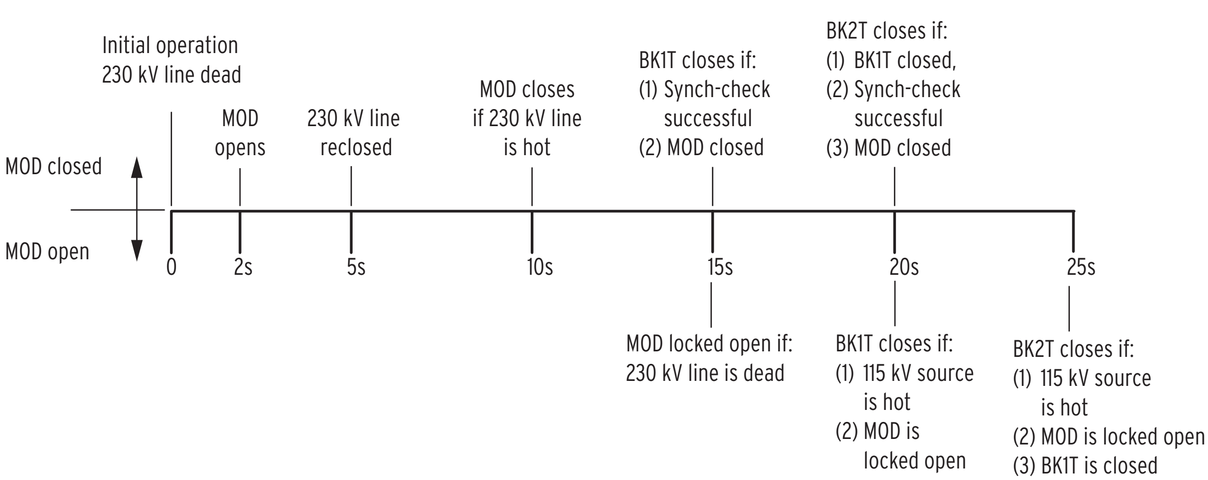

Figure 5.2 Automatic Restoration Timing Diagram

Automatic Restoration Philosophy

Refer to *Figure 5.2* for a timing diagram of the complete automatic restoration cycle. The SEL-421 at Substation T automatically restores service in response to the following system conditions:

- ➤ Low-side circuit breaker or autotransformer failure at Substation T
- ➤ Successful 230 kV line reclose
- ➤ Permanent 230 kV line fault or circuit breaker failure at Substations S or R

Transmission Line Faults or Circuit Breaker/Autotransformer Failure

The SEL-421 at Substation T responds to a 230 kV transmission line fault, low-side circuit breaker failure or autotransformer failure at the local substation, and any circuit breaker failure at Substations S and R. For these situations, the relay does the following:

- ➤ Sends a pulsed open command to the high-side MOD. The 230 kV transmission line must be dead for two seconds, and the relay must have successfully opened the 115 kV circuit breakers.
- ➤ Disables DTT (direct transfer trip) via MIRRORED BITS® communications (issued at Substation T) when the high-side MOD is open
- ➤ Inhibits reception of any DTT via MIRRORED BITS communications from any of the two remote 230 kV terminals when the high-side MOD is open

Low-Side Circuit Breaker or Autotransformer Failure. The following actions occur if a low-side circuit breaker or autotransformer failure occurs at Substation T:

- ➤ Substation S and R reclose five seconds later.
- ➤ Lockout relays at Substation T locks out the high-side MOD and low-side circuit breakers. The relay uses an external lockout relay (86 a and 86 b contacts in the breaker trip and close circuits, and an 86 b contact in the MOD close circuit); Substation T remains locked out pending further action from operations or field personnel.

Successful 230 kV Line Reclose. The SEL-421 at Substation T issues the following actions if the 230 kV transmission line auto-reclose is successful at Substations S and R:

- ➤ Sends a pulsed close command to the high-side MOD at Substation T to energize the autotransformer if the relay measures balanced nominal voltage from the high-side PTs for five seconds and the low-side circuit breakers are open; the tertiary windings of the autotransformer restore station service.
- ➤ Recloses Circuit Breaker BK1T five seconds after the high-side MOD closes, if the voltage is nominal and synchronized.
- ➤ Recloses Circuit Breaker BK2T five seconds later if the voltage is still nominal and synchronized.

Thus, the local SEL-421 restores the 115 kV system at Substation T.

Permanent 230 kV Line Fault Or Circuit Breaker Failure. If a permanent 230 kV line fault or circuit breaker failure operation occurs at Substations S or R, the SEL-421 at Substation T executes the following actions:

- Locks open the high-side MOD if there is no voltage on the 230 kV side for 13 seconds. (You can implement this logically via a timer and latch bit combination.) The latch resets if the 230 kV system is hot for 60 seconds and both low-side circuit breakers (BK1T and BK2T) are open.
- Recloses Circuit Breaker BK1T after five seconds if there is nominal voltage on the 115 kV side and the high-side MOD is locked open.
- Recloses Circuit Breaker BK2T five seconds later if there is nominal voltage on the 115 kV side, the high-side MOD is locked open, and Circuit Breaker BK1T reclosed successfully.

These actions restore station service and low-side continuity at Substation T. Substation T operates in this configuration until operations or field personnel take further action.

SEL-421 Configuration

In this example, the SEL-421 at Substation T measures a single set of three-phase potentials (input VY) and a single set of three-phase currents (input IW) on the 230 kV side of the autotransformer. The relay uses single-phase potential inputs VAZ and VBZ to provide synchronism check across the low-side circuit breakers. *Figure 5.3* shows the connection diagram.

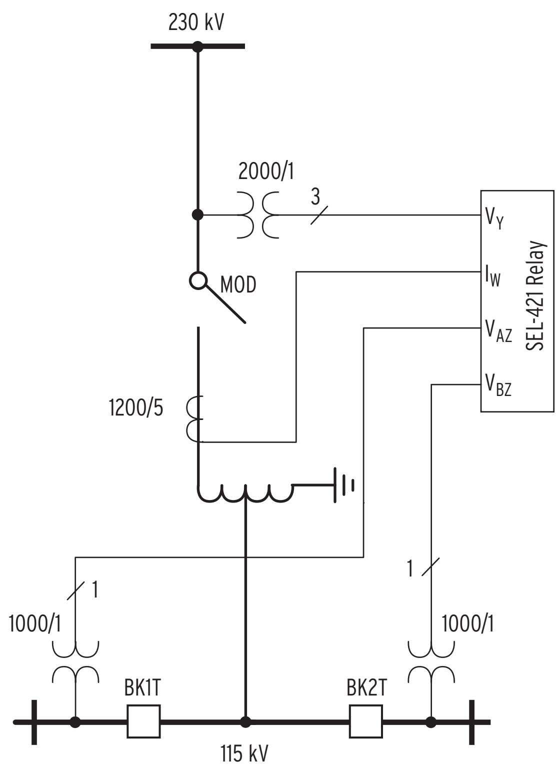

Figure 5.3 SEL-421 Inputs

SEL-421 Settings at Substation T

The settings in *Table 5.1* through *Table 5.6* provide 230 kV transmission line protection, auto-reclose, and substation restoration at Substation T as described in this application example.

Protection free-form SELOGIC control equations appear in tabular form (see *Table 5.4*). These equations, which are the free-form settings extracted from a SEL-421, are also shown in *Figure 5.4*.

Global Settings

Table 5.1 Global Settings[a]

Setting	Description	Entry
General Global Settings		
SID	Station Identifier	Station T
RID	Relay Identifier	SEL-421
NUMBK	Number of Breakers in Scheme	2
BID1	Breaker 1 Identifier	Circuit Breaker 1–115 kV
BID2	Breaker 2 Identifier	Circuit Breaker 2–115 kV
NFREQ	Nominal System Frequency (Hz)	60
PHROT	System Phase Rotation	ABC
Current and Voltage Source Selection		
ESS	Current and Voltage Source Selection	Y
LINEI	Line Current Source	IW
BK1I	Breaker 1 Current Source	NA
BK2I	Breaker 2 Current Source	NA

[a] This table shows only the global settings relevant to this particular application example.

Breaker Monitor

Table 5.2 Breaker Monitor Settings[a]

Setting	Description	Entry
Breaker Configuration		
BK1TYP	Breaker 1 Trip Type (Single-Pole = 1, Three-Pole = 3)	3
BK2TYP	Breaker 2 Trip Type (Single-Pole = 1, Three-Pole = 3)	3
Breaker 1 Inputs		
52AA1	N/O Contact Input—BK1 (SELOGIC)	NOT IN101
Breaker 2 Inputs		
52AA2	N/O Contact Input—BK2 (SELOGIC)	NOT IN102

[a] This table shows only the breaker monitor settings relevant to this particular application example.

Group Settings

Table 5.3 Group Settings (Sheet 1 of 3)

Setting	Description	Entry
Line Configuration		
CTRW	CT Ratio—Input W	240
CTRX	CT Ratio—Input X	240

Table 5.3 Group Settings (Sheet 2 of 3)

Setting	Description	Entry
PTRY	PT Ratio—Input Y	2000
VNOMY	PT Nominal Voltage (L-L)—Input Y	115
PTRZ	PT Ratio—Input Z	1000
VNOMZ	PT Nominal Voltage (L-L)—Input Z	115
DCB Trip Scheme[a]		
BT	Block Trip	RMB1A OR RMB1B
Synchronism-Check Element Reference (Group)		
SYNCP	Synch Reference	VAY
25VL	Voltage Window Low Threshold (volts)	60.0
25VH	Voltage Window High Threshold (volts)	70.0
Breaker 1 Synchronism Check (Group)		
SYNCS1	Synch Source 1	VAZ
KS1M	Synch Source 1 Ratio Factor	1.00
KS1A	Synch Source 1 Angle Shift (degrees)	0.00
25SFBK1	Maximum Slip Frequency—BK1	OFF
ANG1BK1	Maximum Angle Difference 1—BK1(degrees)	20.00
ANG2BK1	Maximum Angle Difference 2—BK1 (degrees)	20.00
BSYNBK1	Block Synch Check—BK1 (SELOGIC)	NA
Breaker 2 Synchronism Check (Group)		
SYNCS2	Synch Source 2	VBZ
KS2M	Synch Source 2 Ratio Factor	1.00
KS2A	Synch Source 2 Angle Shift (degrees)	0.00
ALTS2	Alternative Synch Source 2 (SELOGIC)	NA
25SFBK2	Maximum Slip Frequency—BK2	OFF
ANG1BK2	Maximum Angle Difference 1—BK2 (degrees)	20.00
ANG2BK2	Maximum Angle Difference 2—BK2 (degrees)	20.00
BSYNBK2	Block Synch Check—BK2 (SELOGIC)	NA
Recloser and Manual Closing		
NSPSHOT	Number of Single-Pole Reclosures	N
N3PSHOT	Number of Three-Pole Reclosures	1
E3PRI1	Three-Pole Reclose Enable—BK1 (SELOGIC)	1
E3PRI2	Three-Pole Reclose Enable—BK2 (SELOGIC)	NOT LEADBK2
TBBKD	Time Between Breakers for ARC (cycles)	300
BKCFD	Breaker Close Failure Delay (cycles)	300
SLBK1	Leader = Circuit Breaker 1 (SELOGIC)	1
SLBK2	Leader = Circuit Breaker 2 (SELOGIC)	0
FBKCEN	Follower Breaker Closing Enable (SELOGIC)	52AA1
ULCL1	Unlatch Closing for Breaker 1 (SELOGIC)	52AA1
ULCL2	Unlatch Closing for Breaker 2 (SELOGIC)	52AA2
79DTL	Recloser Drive to Lockout (SELOGIC)	NA
79BRCT	Block Reclaim Timer (SELOGIC)	NA

Table 5.3 Group Settings (Sheet 3 of 3)

Setting	Description	Entry
BK1CLSD	BK1 Reclose Supervision Delay (cycles)	1200
BK2CLSD	BK2 Reclose Supervision Delay (cycles)	1200
Three-Pole Reclose Settings (Group)		
3POID1	Three-Pole Open Interval 1 Delay (cycles)	300
3PFARC	Three-Pole Fast ARC Enable (SELOGIC)	NA
3PRCD	Three-Pole Reclaim Time Delay (cycles)	1200
3PRI	Three-Pole Reclose Initiation (SELOGIC)	M1P OR Z1G OR RXPRM
79SKP	Skip Reclosing Shot (SELOGIC)	NA
3P1CLS	Three-Pole BK1 Reclose Supervision (SELOGIC)	PCT01Q
3P2CLS	Three-Pole BK2 Reclose Supervision (SELOGIC)	PCT02Q
Trip Logic[a]		
TR	Zone 1 direct transfer trip	RMB2A OR RMB2B OR
	Step-distance or time-overcurrent protection	Z1T OR Z2T OR 51S1T OR
	Direct transfer trip if MOD closed	(RMB3A OR RMB3B) AND NOT IN103…

[a] This portion of the table shows all of the receive MIRRORED BITS (RMBn) communications assignments.

Protection Free-Form SELOGIC Control Equations

Table 5.4 Protection Free-Form SELOGIC Control Equations (Sheet 1 of 3)

Setting	Description	Entry	Comments
PSV01	Protection Comparison 1	PSV01: = V1M >= 119.500	Logical 1 if V_1 greater than or equal to 90% nominal voltage
PSV02	Protection Comparison 2	PSV02 := V1M < 26.500	Logical 1 if V_1 is less than 20% nominal voltage
PLT01S	Protection Latch 1 set	PLT01S := R_TRIG PST02Q AND NOT PLT01	MOD latch set
PLT01R	Protection Latch 1 reset	PLT01R := R_TRIG PST03Q AND PLT01	MOD latch reset
PST01PT	Protection Sequence Timer 1 preset	PST01PT := 150.00	Pulse open the MOD if:
PST01R	Protection Sequence Timer 1 reset	PST01R := NOT PSV02 OR NOT IN101 OR NOT IN102 OR PST01Q OR IN103	230 kV bus is not dead OR BK1T OR BK2T is closed OR PST01 output equals logical 1 OR MOD is open
PST01IN	Protection Sequence Timer 1 enable	PSTO1IN := PSV02 AND IN101 AND IN102 AND NOT IN103	230 kV bus is dead AND BK1T AND BK2T are open AND MOD is closed

Table 5.4 Protection Free-Form SELogic Control Equations (Sheet 2 of 3)

Setting	Description	Entry	Comments
OUT103[a]	Output 103	PST01ET > 120.00 AND NOT PCN01Q	MOD open command
PST02PT	Protection Sequence Timer 2 preset	PST02PT := 780.00	MOD latch is set if:
PST02R	Protection Sequence Timer 2 reset	PST02R := PLT01	
PST02IN	Protection Sequence Timer 2 enable	PST02IN := PSV02 AND IN103	230 kV bus is dead AND MOD is open
PST03PT	Protection Sequence Timer 3 preset	PST03PT := 3600.00	MOD latch reset if:
PST03R	Protection Sequence Timer 3 reset	PST03R := NOT PLT01	
PST03IN	Protection Sequence Timer 3 enable	PST03IN := PSV01 AND IN101 AND IN102	230 kV bus is hot AND BK1T AND BK2T are open for 60 s
PST04PT	Protection Sequence Timer 4 preset	PST04PT := 330.00	Pulse close the MOD if:
PST04R	Protection Sequence Timer 4 reset	PST04R := NOT PSV01 OR NOT IN101 OR NOT IN102 OR NOT IN103 OR PLT01 OR PST04Q	230 kV bus is not hot OR BK1T OR BK2T is closed OR MOD is closed OR PST04 output equals logical 1
PST04IN	Protection Sequence Timer 4 enable	PST04IN := PSV01 AND IN101 AND IN102 AND IN103 AND NOT PLT01	230 kV bus is hot AND BK1T AND BK2T are open AND MOD is open AND MOD latch reset
OUT106*	Output 106 AND NOT PCN02Q	PST04ET > 300.00 AND NOT PCN02Q	MOD close command
PCN01PV	Protection Counter 1 preset	PCN01PV := 2	MOD block trip if:
PCN01R	Protection Counter 1 reset	PCN01R := IN103	
PCN01IN	Protection Counter 1 enable	PCN01IN := OUT103	Two trips without MOD open
PCN02PV	Protection Counter 2 preset	PCN02PV := 2	MOD block close if:
PCN02R	Protection Counter 2 reset	PCN02R := NOT IN103	
PCN02IN	Protection Counter 2 enable	PCN02IN := OUT106	Two closes without MOD closed
PCT01PU	Protection Conditioning Timer 1 Pickup	240.00	
PCT01DO	Protection Conditioning Timer 1 Dropout	0.00	
PCT01IN	Protection Conditioning Timer 1 Enable	NOT IN103 AND 25A1BK1 OR PLT01 AND IN103 AND 59VS1	MOD is closed AND synchronized OR MOD latch set AND MOD is open AND BK1T bus is hot for 4 s

Table 5.4 Protection Free-Form SELOGIC Control Equations (Sheet 3 of 3)

Setting	Description	Entry	Comments
PCT02PU	Protection Conditioning Timer 2 Pickup	240.00	
PCT02DO	Protection Conditioning Timer 2 Dropout	0.00	
PCT02IN	Protection Conditioning Timer 2 Enable	NOT IN103 AND 25A1BK2 AND NOT IN101 OR PLT01 AND IN103 AND 59VS2 AND NOT IN101	MOD is closed AND synchronized AND BK1T is closed OR MOD latch set AND MOD is open AND BK2T bus is hot AND BK11T is closed for 4 s

[a] This control output assignment is not a protection free-form SELOGIC control equation, but appears in this table for continuity of the overall logic.

```
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Protection 1

Free-Form Protection SELogic
1:  ###  PROTECTION FREE-FORM AUTOMATION EXAMPLE
2:  ###
3:  ###  SET CONTROL VARIABLE 1
4:  ###  ASSERTS WHEN PRIMARY POSITIVE SEQUENCE VOLTAGE IS
5:  ###  GREATER THAN 90% OF NOMINAL
6:  PSV01 := V1M >= 119.500 # 90% OF 230 KV DIVIDED BY SQRT 3
7:  ###
8:  ###  SET CONTROL VARIABLE 2
9:  ###  ASSERTS WHEN PRIMARY POSITIVE SEQUENCE VOLTAGE IS
10: ###  LESS THAN 20% OF NOMINAL
11: PSV02 := V1M < 26.500 # 20% OF 230 KV DIVIDED BY SQRT 3
12: ###
13: ###  SET LATCH 1
14: PLT01S := R_TRIG PST02Q AND NOT PLT01 # SET LATCH WITH TIMER 2 OUTPUT
15: PLT01R := R_TRIG PST03Q AND PLT01 # RESET LATCH WITH TIMER 3 OUTPUT
16: ###
17: ###  SET SEQUENCING TIMER 1
18: ###  TIMES IF PSV02 IS ASSERTED, BREAKER 1 AND 2 ARE OPEN, AND
19: ###  THE MOD IS CLOSED. RESETS IF PSV02 IS NOT ASSERTED, OR BREAKER
20: ###  1 OR 2 IS CLOSED, OR MOD IS OPEN, OR TIMER 1 OUTPUT ASSERTED
21: PST01PT := 150.00 # TIMER 1 PICKUP 150 CYCLES
22: PST01R := NOT PSV02 OR NOT IN101 OR NOT IN102 OR IN103 OR PST01Q
23: PST01IN := PSV02 AND IN101 AND IN102 AND NOT IN103
24: ###
25: ###  SET SEQUENCING TIMER 2
26: ###  TIMES IF PSV02 IS ASSERTED AND THE MOD IS OPEN. RESETS IF
27: ###  LATCH 1 IS SET
28: PST02PT := 780.00 # TIMER 2 PICKUP 780 CYCLES
29: PST02R := PLT01
30: PST02IN := PSV02 AND IN103
31: ###
32: ###  SET SEQUENCING TIMER 3
33: ###  TIMES IF PSV01 IS ASSERTED AND BREAKER 1 AND 2 ARE OPEN
34: ###  RESETS WHEN LATCH 1 IS RESET
35: PST03PT := 3600.00 # TIMER 3 PICKPUP 3600 CYCLES
36: PST03R := NOT PLT01
37: PST03IN := PSV01 AND IN101 AND IN102
38: ###
39: ###  SET SEQUENCING TIMER 4
40: ###  TIMES IF PSV01 IS ASSERTED AND BREAKER 1 AND 2 ARE OPEN
41: ###  THE MOD IS OPEN, AND LATCH 1 IS NOT SET. RESET IF PSV01 NOT
42: ###  ASSERTED, OR BREAKER 1 OR 2 NOT OPEN, OR MOD NOT OPEN
43: ###  OR LATCH 1 SET, OR TIMER 4 OUTPUT ASSERTED
44: PST04PT := 330.00 # TIMER 4 PICKUP 330 CYCLES
45: PST04R := NOT PSV01 OR NOT IN101 OR NOT IN102 OR NOT IN103 OR PLT01 OR \
    PST04Q
46: PST04IN := PSV01 AND IN101 AND IN102 AND NOT PLT01 AND IN103
47: ###
48: ###  SET COUNTER 1
49: ###  MOD TRIP ANTI-PUMP, TWO TRIPS WITHOUT AN OPEN LOCKS OUT TRIP
50: PCN01PV := 2.00 # A TWO COUNT COUNTER
51: PCN01R := IN103 # AN OPEN MOD RESETS COUNTER
52: PCN01IN := OUT103 # COUNTS ON THE RISING EDGE OF AN MOD TRIP
53: ###
54: ###  SET COUNTER 2
55: ###  MOD CLOSE ANTI-PUMP, TWO CLOSES WITHOUT A CLOSE LOCKS OUT CLOSE
56: PCN02PV := 2.00 # A TWO COUNT COUNTER
57: PCN02R := NOT IN103 # A CLOSED MOD RESETS THE COUNTER
58: PCN02IN := OUT106 # COUNTS ON THE RISING EDGE OF AN MOD CLOSE
59: ###
60: ###  SET CONDITIONING TIMER 1
61: ###  SUPERVISES BK1 RECLOSING, ASSERTS IF MOD IS CLOSED AND IN SYNC. OR
62: ###  MOD LATCH SET AND MOD OPEN AND BK1 BUS HOT FOR FOUR SECONDS
63: PCT01PU := 240.00 # FOUR SECOND PICKUP TIME
64: PCT01DO := 0.0 # NO DELAY ON DROPOUT
65: PCT01IN := NOT IN103 AND 25A1BK1 OR PLT01 AND IN103 AND 59VS1
66: ###
67: ###  SET CONDITIONING TIMER 2
68: ###  SUPERVISES BK2 RECLOSING, ASSERTS IF MOD IS CLOSED AND IN SYNC. AND BK1
69: ###  CLOSED OR MOD LATCH SET AND MOD OPEN AND BK2 BUS HOT AND BK1 CLOSED
70: ###  FOR FOUR SECONDS
71: PCT02PU := 240.00 # FOUR SECOND PICKUP TIME
72: PCT02DO := 0.0 # NO DELAY ON DROPOUT
73: PCT02IN := NOT IN103 AND 25A1BK2 AND NOT IN101 OR PLT01 AND IN103 AND \
               59VS2 AND NOT IN101
```

Figure 5.4 Protection Free-Form SELogic Control Equations

Control Inputs

Connect the relay control inputs as specified in *Table 5.5*. This table shows the substation equipment that each control input monitors.

Table 5.5 Control Inputs

Input	Monitor Condition
IN101	115 kV BK1T 52 b contact
IN102	115 kV BK2T 52 b contact
IN103	230 kV MOD b contact
IN104	Circuit breaker and autotransformer failure lockouts (86)

Control Outputs

Table 5.6 Control Outputs (SELOGIC Control Equations)

Setting	Function	Entry
Main Board		
OUT101	Trip BK1T	TRIP
OUT102	Trip BK2T	TRIP
OUT103	Trip MOD	PST01ET > 120.00 AND NOT PCN01Q
OUT104	Close BK1T	BK1CL
OUT105	Close BK2T	BK2CL
OUT106	Close MOD	PST04ET > 300.00 AND NOT PCN02Q
OUT107	General alarm	NOT HALARM OR NOT SALARM OR NOT ILOP
MIRRORED BITS Transmit Equations (SELOGIC Control Equations)		
TMB1A	Blocking signal	M3P OR Z3G OR DSTRT
TMB2A	Zone 1 direct underreaching transfer trip	M1P OR Z1G
TMB3A	Direct transfer trip: 86BF or 86T and MOD closed	NOT IN103 AND IN104
TMB1B	Blocking signal	M3P OR Z3G OR DSTRT
TMB2B	Zone 1 direct underreaching transfer trip	M1P OR Z1G
TMB3B	Direct transfer trip: 86BF or 86T and MOD closed	NOT IN103 AND IN104

Figure 5.5 and *Figure 5.6* are logical representations of the free-form protection SELOGIC control equations.

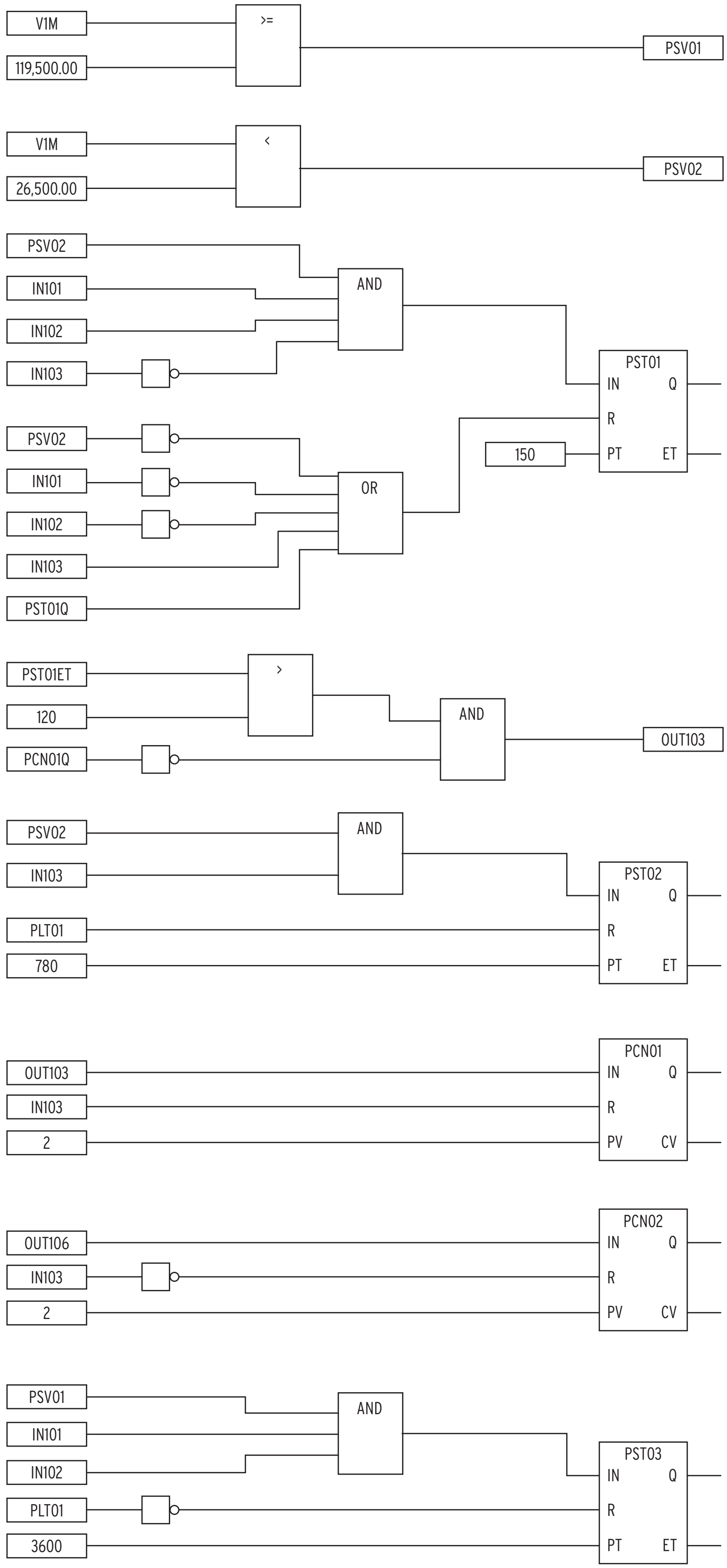

Figure 5.5 Protection Free-Form SELogic Control Equations

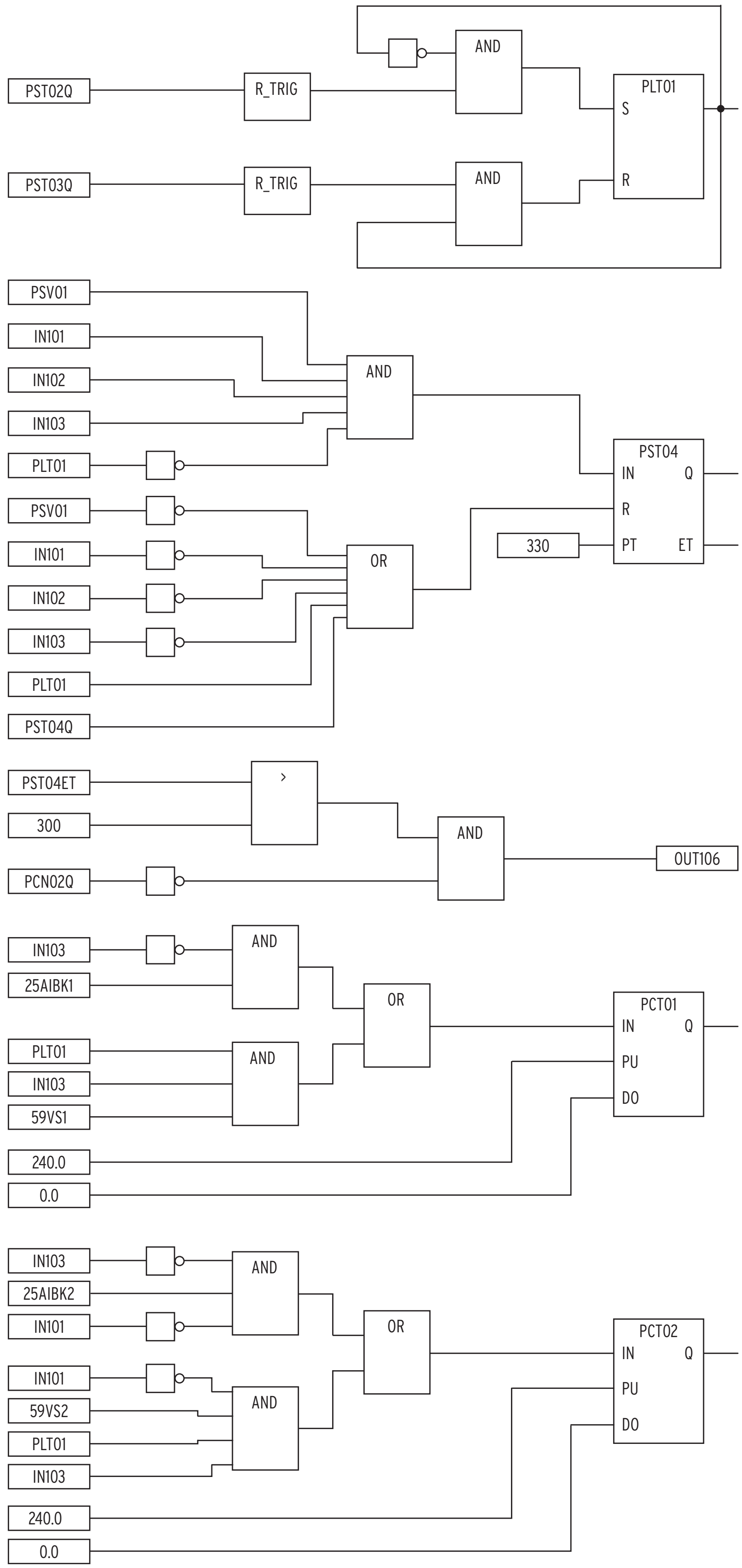

Figure 5.5 Protection Free-Form SELogic Control Equations (continued)

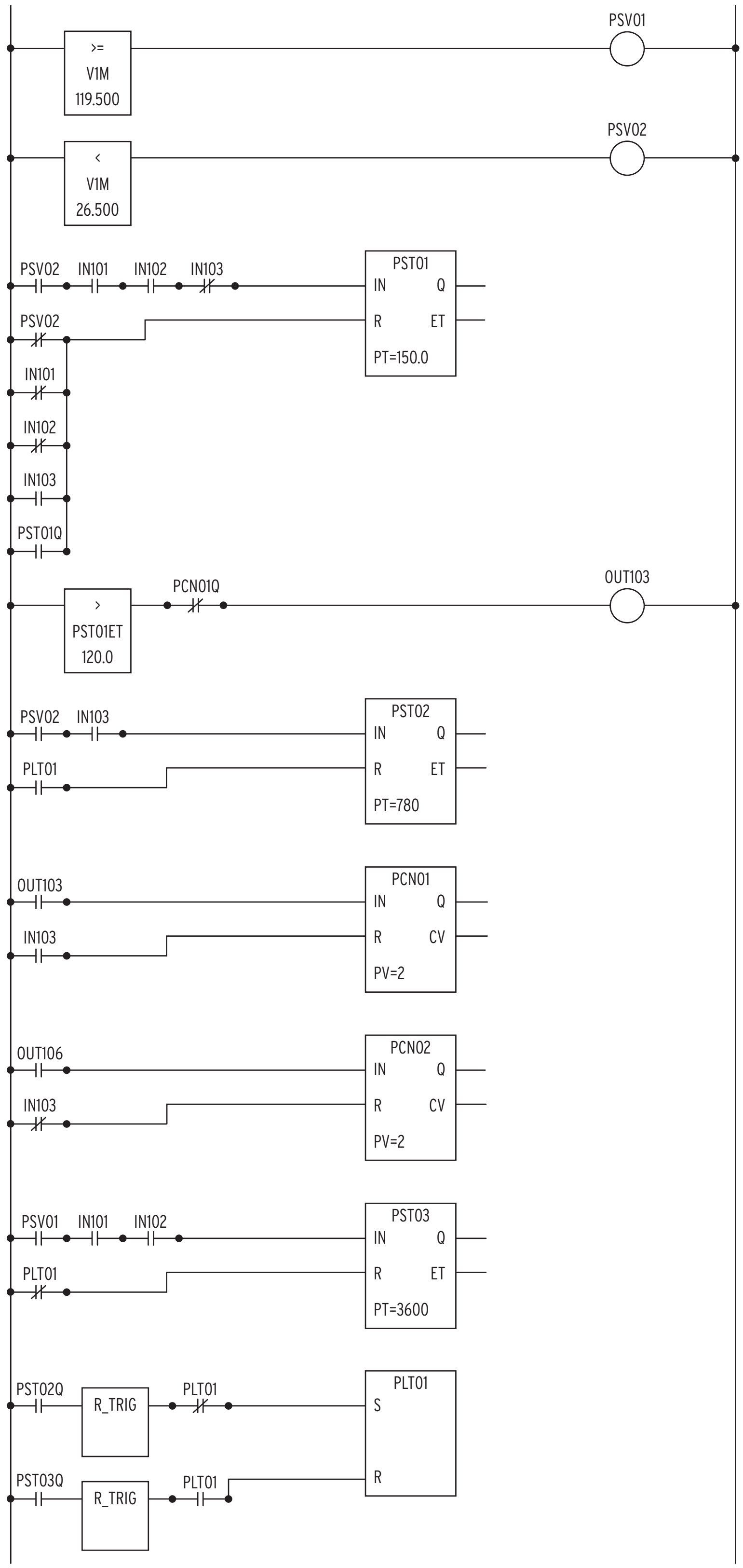

Figure 5.6 Ladder Logic Representation, Protection Free-Form SELOGIC Control Equations

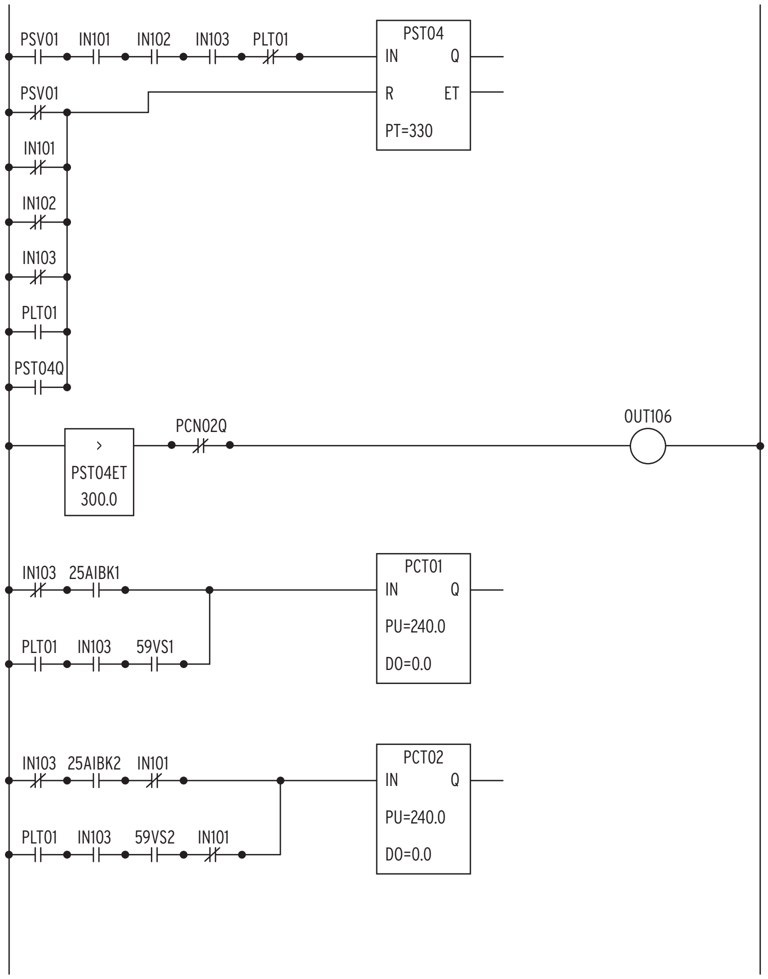

Figure 5.6 Ladder Logic Representation, Protection Free-Form SELOGIC Control Equations (continued)

Section 6

SEL Communications Processor Applications

This section describes applications where the SEL-421 Relay is applied in a system integration architecture that includes SEL Communications Processors, the SEL-2032, SEL-2030, and SEL-2020. This section addresses the following topics:

For detailed application examples using the SEL-2032, SEL-2030, and SEL-2020 Communications Processors, see the SEL library of Application Guides on our website at www.selinc.com.

SEL Communications Processors

NOTE: The IRIG-B time signal available from SEL communications processors is not suitable for high-accuracy IRIG (HIRIG) timekeeping mode, which is required for synchrophasor functions. See Configuring High-Accuracy Timekeeping on page U.4.71 for details.

SEL offers Communications Processors, the SEL-2032, SEL-2030, and SEL-2020, powerful tools for system integration and automation. These devices provide a single point of contact for integration networks with a star topology as shown in *Figure 6.1*.

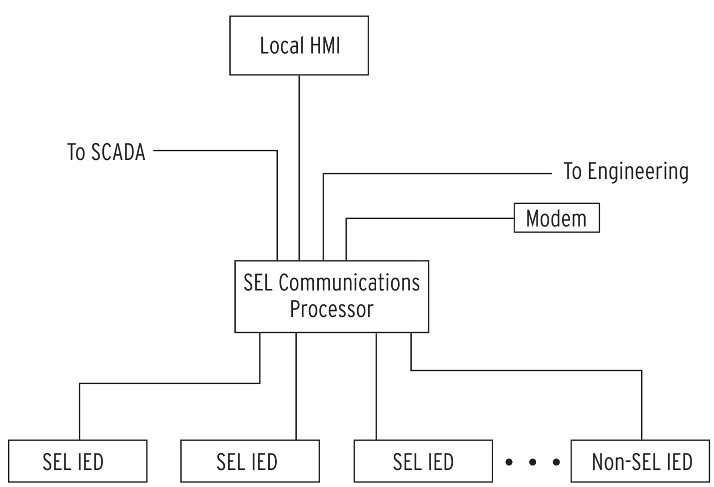

Figure 6.1 SEL Communications Processor Star Integration Network

In the star topology network in *Figure 6.1* the SEL Communications Processor offers the following substation integration functions:

- ➤ Collection of real-time data from SEL and non-SEL IEDs
- ➤ Calculation, concentration, and aggregation of real-time IED data into databases for SCADA, HMI, and other data consumers
- ➤ Access to the IEDs for engineering functions including configuration, report data retrieval, and control through local serial, remote dial-in, and Ethernet network connections
- ➤ Simultaneous collection of SCADA data and engineering connection to SEL IEDs over a single cable
- ➤ Distribution of IRIG-B time synchronization signal to IEDs based on external IRIG-B input, internal clock, or protocol interface
- ➤ Automated dial-out on alarms

The SEL Communications Processors have 16 serial ports plus a front port. This port configuration does not limit the size of a substation integration project, because you can create a multitiered solution as shown in *Figure 6.2*. In this multitiered system, the lower-tier SEL Communications Processors forward data to the upper-tier SEL Communications Processor that serves as the central point of access to substation data and station IEDs.

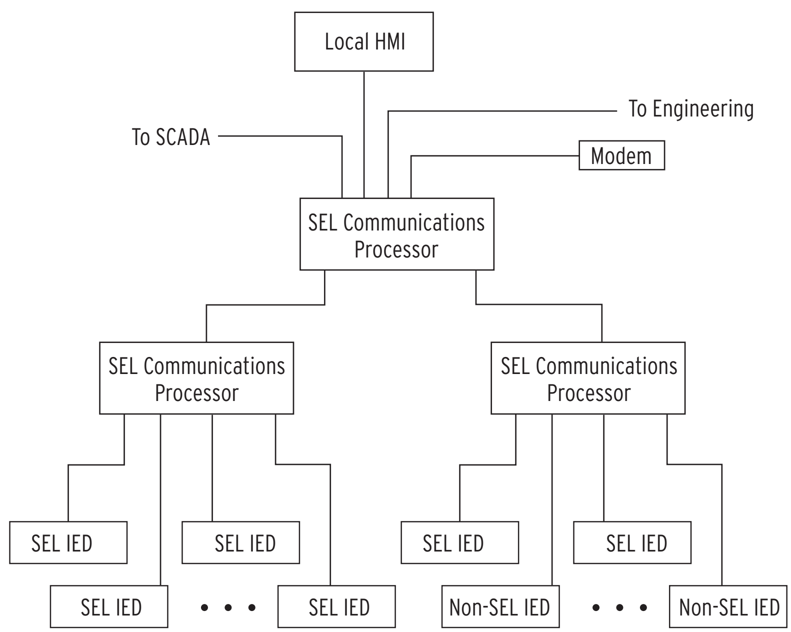

Figure 6.2 Multitiered SEL Communications Processor Architecture

You can add additional communications processors to provide redundancy and eliminate possible single points of failure. The SEL Communications Processors provide an integration solution with a reliability comparable to that of SEL relays. In terms of MTBF (mean time between failures), the SEL Communications Processors are 100 to 1000 times more reliable than computer-based and industrial technology-based solutions.

Configuration of an SEL communications processor is different from other general-purpose integration platforms. You can configure the SEL Communications Processors with a system of communication-specific keywords and data movement commands rather than programming in C or another general-purpose computer language. The SEL Communications Processors offer the protocol interfaces listed in *Table 6.1*.

Table 6.1 SEL Communications Processors Protocol Interfaces

Protocol	Connect to
DNP3 Level 2 Slave	DNP3 masters (serial)
Modbus® RTU	Modbus masters
SEL ASCII/Fast Message Slave	SEL protocol masters
SEL ASCII/Fast Message Master	SEL protocol slaves including other communications processors and SEL relays
ASCII and Binary auto messaging	SEL and non-SEL IED master and slave devices
Modbus Plus[a]	Modbus Plus peers with global data and Modbus Plus masters
FTP (File Transfer Protocol)[b]	FTP clients
Telnet[b]	Telnet servers and clients
UCA2 GOMSFE[b]	UCA2 protocol masters
UCA2 GOOSE[b]	UCA2 protocol and peers
DNP3 Level 2 Slave (Ethernet)[b]	DNP3 masters (Ethernet)

[a] Requires SEL-2711 Modbus Plus protocol card.
[b] Requires Ethernet card.

SEL Communications Processor and Relay Architecture

You can apply the SEL communications processors and SEL relays in a limitless variety of applications that integrate, automate, and improve station operation. Most of the system integration architectures using SEL communications processors involve either developing a star network or enhancing a multidrop network.

Developing Star Networks

The simplest architecture using both the SEL-421 and an SEL communications processor is shown in *Figure 6.1*. In this architecture, the SEL communications processor collects data from the SEL-421 and other station IEDs. The SEL communications processor acts as a single point of access for local and remote data consumers (local HMI, SCADA, engineers). The communications processor also provides a single point of access for engineering operations including configuration and the collection of report-based information.

By configuring a data set optimized to each data consumer, you can significantly increase the utilization efficiency on each link. A system that uses the SEL communications processors to provide a protocol interface to an RTU will have a shorter lag time (data latency); communication overhead is much less for a single data exchange conversation to collect all substation data (from a communications processor) than for many conversations required to collect data directly from each individual IED. You can further reduce data latency by connecting the SEL communications processor directly to the SCADA master and eliminating redundant communication processing in the RTU.

The SEL communications processor is responsible for the protocol interface, so you can install, test, and even upgrade the system in the future without disturbing protective relays and other station IEDs. This insulation of the protective devices from the communications interface assists greatly in situations where different departments are responsible for SCADA operation, communication, and protection.

NOTE: The communications processor Ethernet card supports components of UCA2 as a subset of IEC 61850.

You can equip SEL communications processors with an Ethernet card to provide a UCA2 interface to serial IEDs, including the standard SEL-421. The communications processor presents the SEL-421 data as models in a virtual device domain similar to the way they would appear if the SEL-421 was connected directly to the UCA2 network. The SEL communications processor and the Ethernet card offer a significant cost savings to customers who wish to continue using serial IEDs. For full details on applying the SEL communications processor with an optional Ethernet card, see the *SEL-2032* or *SEL-2030 Communications Processor Instruction Manual*.

The engineering connection can use either an Ethernet network connection through the communications processor Ethernet card or a serial port connection. This versatility will accommodate the channel that is available between the station and the engineering center. SEL software, including the ACSELERATOR QuickSet® SEL-5030 software program, can use either a serial port connection or an Ethernet network connection from an engineering workstation to the relays in the field.

Enhancing Multidrop Networks

You can also use the SEL communications processor to enhance a multidrop architecture similar to the one shown in *Figure 6.3*. In this example, the SEL communications processor enhances a system that uses the SEL-2701 with an Ethernet HMI multidrop network. In the example, there are two Ethernet networks, the SCADA LAN and the Engineering LAN. The SCADA LAN provides real-time data directly to the SCADA Control Center via a protocol gateway and to the HMI (Human Machine Interface).

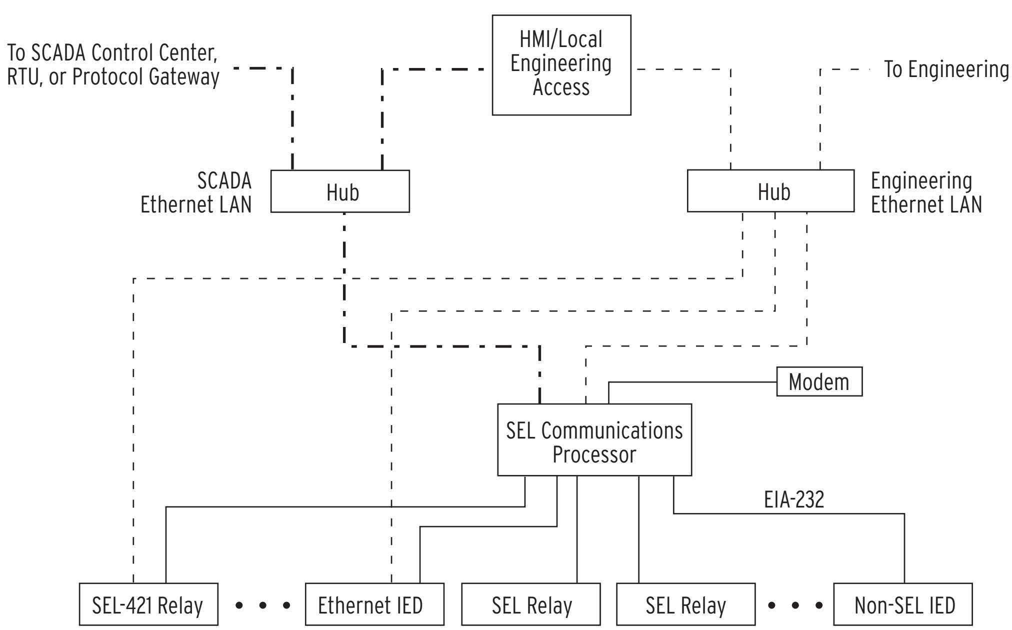

Figure 6.3 Enhancing Multidrop Networks With the SEL Communications Processors

In this example, the SEL communications processor provides the following enhancements when compared to a system that employs only the multidrop network:

- ➤ Ethernet access for IEDs with serial ports
- ➤ Backup engineering access through the dial-in modem
- ➤ IRIG-B time signal distribution to all station IEDs
- ➤ Integration of IEDs without Ethernet
- ➤ Single point of access for real-time data for SCADA, HMI, and other uses
- ➤ Significant cost savings by use of existing IEDs with serial ports

SEL Communications Processor Example

This example demonstrates the data and control points available in the SEL communications processor when you connect an SEL-421. The physical configuration used in this example is shown in *Figure 6.4*.

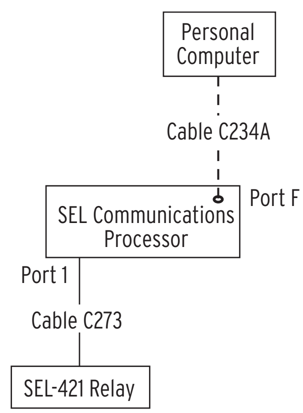

Figure 6.4 Example SEL Relay and SEL Communications Processors Configuration

Table 6.2 shows the PORT 1 settings for the SEL communications processor.

Table 6.2 SEL Communications Processors Port 1 Settings

Setting Name	Setting	Description
DEVICE	S	Connected device is an SEL device
CONFIG	Y	Allow autoconfiguration for this device
PORTID	"Relay 1"	Name of connected relay[a]
BAUD	19200	Channel speed of 19200 bits per second[a]
DATABIT	8	Eight data bits[a]
STOPBIT	1	One stop bit
PARITY	N	No parity
RTS_CTS	Y	Hardware flow control enabled
TIMEOUT	5	Idle timeout that terminates transparent connections of 5 minutes

[a] Automatically collected by the SEL communications processor during autoconfiguration.

Data Collection

Table 6.3 lists the automatic messages that are available in the SEL-421.

Table 6.3 SEL Communications Processor Data Collection Automessages

Message	Collection Mode	Data Collected
20METER	Binary	Power system metering data
20METER2	Binary	METER database region
20TARGET	Binary	Selected Relay Word bit elements
20TARGET2	Binary	TARGET database region
20DEMAND	Binary	Demand metering data
20DEMAND2	Binary	DEMAND database region
20STATUS	ASCII	Relay diagnostics
20STATUS2	Binary	STATUS database region
20HISTORY	ASCII	Relay event history
20HISTORY2	Binary	HISTORY database region
20BREAKER	ASCII	Circuit breaker monitor data
20BREAKER2	Binary	BREAKER database region
20EVENTL	ASCII	Long (16 samples/cycle) event report stored in a literal format (see the *SEL-2030 Instruction Manual)*
20LOCAL2	Binary	LOCAL database region
20ANALOGS2	Binary	ANALOGS database region
20D12	Binary	D1 270x DNP database region

Table 6.4 shows the automessage (Set A) settings for the SEL communications processor. In this example, the SEL communications processor is configured to collect metering and target data from the SEL-421 via the three automatic messages: 20TARGET, 20METER, and 20DEMAND.

Table 6.4 SEL Communications Processor Port 1 Automatic Messaging Settings (Sheet 1 of 2)

Setting Name	Setting	Description
AUTOBUF	Y	Save unsolicited messages
STARTUP	"ACC\nOTTER\n"	Automatically log-in at Access Level 1
SEND_OPER	Y	Send Fast Operate messages for remote bit and breaker bit control
REC_SER	N	Automatic sequential event recorder data collection disabled
NOCONN	NA	No SELOGIC control equation entered to selectively block connections to this port
MSG_CNT	3	Three automessages
ISSUE1	P00:00:01.0	Issue Message 1 every second
MESG1	20METER	Collect metering data
ISSUE2	P00:00:01.0	Issue Message 2 every second
MESG2	20TARGET	Collect Relay Word bit data
ISSUE3	P00:01:00.0	Issue Message 3 every minute
MESG3	20DEMAND	Collect demand metering data

Table 6.4 SEL Communications Processor Port 1 Automatic Messaging Settings (Sheet 2 of 2)

Setting Name	Setting	Description
ARCH_EN	N	Archive memory disabled
USER	0	No USER region registers reserved

Table 6.5 shows the map of regions in the SEL communications processor for data collected from the SEL-421 in the example.

Table 6.5 SEL Communications Processor Port 1 Region Map

Region	Data Collection Message Type	Region Name	Description
D1	Binary	METER	Relay metering data
D2	Binary	TARGET	Relay Word bit data
D3	Binary	DEMAND	Demand metering data
D4–D8	n/a	n/a	Unused
A1–A3	n/a	n/a	Unused
USER	n/a	n/a	Unused

Table 6.6 shows the list of meter data available in the SEL communications processor and the location and data type for the memory areas within D1 (Data Region 1). The type field indicates the data type and size. The type “int” is a 16-bit integer. The type “float” is a 32-bit IEEE floating point number.

NOTE: Communications processors using 20METER may misinterpret any analog quantities, AMV001 through AMV004, that contain a negative number. Use the math functions in your communications processor to handle these instances, or restrict AMV001 – AMV004 to positive values within the SEL-421 free-form automation logic.

The first four automation math variables (AMV001–AMV004) are reported to the communications processor as part of relay meter data. The communications processor treats these as vector quantities. Consequently, if one of these has a negative value, the communications processor will report the value as its magnitude (its absolute value) at an angle of 180 degrees.

See *Application Guide 2002-14: SEL-421 Relay Fast Messages* for more information on using the SEL Fast Meter and Fast Message protocols with the SEL-421.

Table 6.6 SEL Communications Processor METER Region Map (Sheet 1 of 2)

Item	Starting Address	Type
_YEAR	2000h	int
DAY_OF_YEAR	2001h	int
TIME(ms)	2002h	int[2]
MONTH	2004h	char
DATE	2005h	char
YEAR	2006h	char
HOUR	2007h	char
MIN	2008h	char
SECONDS	2009h	char
MSEC	200Ah	int
IA1	200Bh	float[2][a]
IB1	200Fh	float[2][a]
IC1	2013h	float[2][a]

Table 6.6 SEL Communications Processor METER Region Map (Sheet 2 of 2)

Item	Starting Address	Type
IA2	2017h	float[2][a]
IB2	201Bh	float[2][a]
IC2	201Fh	float[2][a]
IA3	2023h	float[2][a]
IB3	2027h	float[2][a]
IC3	202Bh	float[2][a]
VA	202Fh	float[2][a]
VB	2033h	float[2][a]
VC	2037h	float[2][a]
FREQ	203Bh	float[2][b]
AMV001	203Fh	float[2][b]
AMV002	2043h	float[2][b]
AMV003	2047h	float[2][b]
AMV004	204Bh	float[2][b]
IAB(A)	204Fh	float[2][a]
IBC(A)	2053h	float[2][a]
ICA(A)	2057h	float[2][a]
VAB(V)	205Bh	float[2][a]
VBC(V)	205Fh	float[2][a]
VCA(V)	2063h	float[2][a]
PA(MW)	2067h	float
QA(MVAR)	2069h	float
PB(MW)	206Bh	float
QB(MVAR)	206Dh	float
PC(MW)	206Fh	float
QC(MVAR)	2071h	float
P(MW)	2073h	float
Q(MVAR)	2075h	float
I0(A)	2077h	float[2][a]
I1(A)	207Bh	float[2][a]
I2(A)	207Fh	float[2][a]
V0(V)	2083h	float[2][a]
V1(V)	2087h	float[2][a]
V2(V)	208Bh	float[2][a]

[a] The first two addresses contain quantity; the second two addresses contain angle in degrees. Both values in IEEE 32-bit floating point format.
[b] The first two addresses contain the quantity in IEEE 32-bit floating point format; the second two addresses always contain 0.

Table 6.7 lists the Relay Word bit data available in the SEL communications processor for the memory area within D2 (Data Region 2).

Table 6.7 SEL Communications Processor TARGET Region (Sheet 1 of 3)

Address	Relay Word Bits (in Bits 7–0)							
	7	6	5	4	3	2	1	0
2804h	TEST	FMTEST	STSET	STCSET	STFAIL	STWARN	STRSET	STGSET
2805h	EN	TRIPLED	*	*	*	*	*	*
2806h	TLED_1	TLED_2	TLED_3	TLED_4	TLED_5	TLED_6	TLED_7	TLED_8
2807h	TLED_9	TLED_10	TLED_11	TLED_12	TLED_13	TLED_14	TLED_15	TLED_16
2808h	3POBK2	3POLINE	3PLSHT	BK1RS	BK2RS	79CY1	79CY3	BK1LO
2809h	BK2LO	BK1CL	BK2CL	LEADBK0	LEADBK1	LEADBK2	FOLBK0	FOLBK1
280Ah	B1OPHA	B1OPHB	B1OPHC	B2OPHA	B2OPHB	B2OPHC	LOPHA	LOPHB
280Bh	LOPHC	SPOA	SPOB	SPOC	SPO	3PO	27APO	27BPO
280Ch	27CPO	*	*	*	*	*	*	*
280Dh	52ACL1	52BCL1	52CCL1	52AAL1	52BAL1	52CAL1	52AA1	52AB1
280Eh	52AC1	*	52ACL2	52BCL2	52CCL2	52AAL2	52BAL2	52CAL2
280Fh	52AA2	52AB2	52AC2	*	*	*	*	*
2810h	*	*	*	*	*	*	*	*
2811h	*	*	*	*	*	*	*	*
2812h	*	*	*	*	*	*	*	*
2813h	*	*	*	*	*	*	*	*
2814h	BM1TRPA	BM1TRPB	BM1TRPC	BM1CLSA	BM1CLSB	BM1CLSC	B1BCWAL	B1MRTIN
2815h	*	B1MSOAL	B1ESOAL	B1PSAL	B1PDAL	B1BITAL	B1MRTAL	B1KAIAL
2816h	BM2TRPA	BM2TRPB	BM2TRPC	BM2CLSA	BM2CLSB	BM2CLSC	B2BCWAL	B2MRTIN
2817h	*	B2MSOAL	B2ESOAL	B2PSAL	B2PDAL	B2BITAL	B2MRTAL	B2KAIAL
2818h	RTD08ST	RTD07ST	RTD06ST	RTD05ST	RTD04ST	RTD03ST	RTD02ST	RTD01ST
2819h	RTDIN	RTDCOMF	RTDFL	*	RTD12ST	RTD11ST	RTD10ST	RTD09ST
281Ah	DC1F	DC1W	DC1G	DC1R	DC2F	DC2W	DC2G	DC2R
281Bh	PDEM	QDEM	GDEM	*	*	*	*	*
281Ch	RB25	RB26	RB27	RB28	RB29	RB30	RB31	RB32
281Dh	RB17	RB18	RB19	RB20	RB21	RB22	RB23	RB24
281Eh	RB09	RB10	RB11	RB12	RB13	RB14	RB15	RB16
281Fh	RB01	RB02	RB03	RB04	RB05	RB06	RB07	RB08
2820h	SG6	SG5	SG4	SG3	SG2	SG1	CHSG	*
2821h	*	IN107	IN106	IN105	IN104	IN103	IN102	IN101
2822h	IN208	IN207	IN206	IN205	IN204	IN203	IN202	IN201
2823h	IN216	IN215	IN214	IN213	IN212	IN211	IN210	IN209
2824h	IN224	IN223	IN222	IN221	IN220	IN219	IN218	IN217
2825h	IN308	IN307	IN306	IN305	IN304	IN303	IN302	IN301
2826h	IN316	IN315	IN314	IN313	IN312	IN311	IN310	IN309
2827h	IN324	IN323	IN322	IN321	IN320	IN319	IN318	IN317
2828h	PSV08	PSV07	PSV06	PSV05	PSV04	PSV03	PSV02	PSV01
2829h	PSV16	PSV15	PSV14	PSV13	PSV12	PSV11	PSV10	PSV09
282Ah	PSV24	PSV23	PSV22	PSV21	PSV20	PSV19	PSV18	PSV17
282Bh	PSV32	PSV31	PSV30	PSV29	PSV28	PSV27	PSV26	PSV25

Table 6.7 SEL Communications Processor TARGET Region (Sheet 2 of 3)

Address	Relay Word Bits (in Bits 7–0)							
	7	6	5	4	3	2	1	0
282Ch	PLT08	PLT07	PLT06	PLT05	PLT04	PLT03	PLT02	PLT01
282Dh	PLT16	PLT15	PLT14	PLT13	PLT12	PLT11	PLT10	PLT09
282Eh	PCT08Q	PCT07Q	PCT06Q	PCT05Q	PCT04Q	PCT03Q	PCT02Q	PCT01Q
282Fh	PCT16Q	PCT15Q	PCT14Q	PCT13Q	PCT12Q	PCT11Q	PCT10Q	PCT09Q
2830h	PST08Q	PST07Q	PST06Q	PST05Q	PST04Q	PST03Q	PST02Q	PST01Q
2831h	PST16Q	PST15Q	PST14Q	PST13Q	PST12Q	PST11Q	PST10Q	PST09Q
2832h	PCN08Q	PCN07Q	PCN06Q	PCN05Q	PCN04Q	PCN03Q	PCN02Q	PCN01Q
2833h	PCN16Q	PCN15Q	PCN14Q	PCN13Q	PCN12Q	PCN11Q	PCN10Q	PCN09Q
2834h	ASV008	ASV007	ASV006	ASV005	ASV004	ASV003	ASV002	ASV001
2835h	ASV016	ASV015	ASV014	ASV013	ASV012	ASV011	ASV010	ASV009
2836h	ASV024	ASV023	ASV022	ASV021	ASV020	ASV019	ASV018	ASV017
2837h	ASV032	ASV031	ASV030	ASV029	ASV028	ASV027	ASV026	ASV025
2838h	ALT08	ALT07	ALT06	ALT05	ALT04	ALT03	ALT02	ALT01
2839h	ALT16	ALT15	ALT14	ALT13	ALT12	ALT11	ALT10	ALT09
283Ah	AST08Q	AST07Q	AST06Q	AST05Q	AST04Q	AST03Q	AST02Q	AST01Q
283Bh	AST16Q	AST15Q	AST14Q	AST13Q	AST12Q	AST11Q	AST10Q	AST09Q
283Ch	ACN08Q	ACN07Q	ACN06Q	ACN05Q	ACN04Q	ACN03Q	ACN02Q	ACN01Q
283Dh	ACN16Q	ACN15Q	ACN14Q	ACN13Q	ACN12Q	ACN11Q	ACN10Q	ACN09Q
283Eh	PUNRLBL	PFRTEX	MATHERR	*	*	*	*	*
283Fh	AUNRLBL	AFRTEXP	AFRTEXA	*	*	*	*	*
2840h	SALARM	HALARM	BADPASS	CCALARM	*	*	*	*
2841h	*	*	*	*	*	*	*	*
2842h	*	*	*	*	*	*	*	*
2843h	*	*	TIRIG	TUPDH	TSYNCA	TSOK	PMDOK	FREQOK
2844h	OUT108	OUT107	OUT106	OUT105	OUT104	OUT103	OUT102	OUT101
2845h	OUT208	OUT207	OUT206	OUT205	OUT204	OUT203	OUT202	OUT201
2846h	*	OUT215	OUT214	OUT213	OUT212	OUT211	OUT210	OUT209
2847h	OUT308	OUT307	OUT306	OUT305	OUT304	OUT303	OUT302	OUT301
2848h	*	OUT315	OUT314	OUT313	OUT312	OUT311	OUT310	OUT309
2849h	PB1_LED	PB2_LED	PB3_LED	PB4_LED	PB5_LED	PB6_LED	PB7_LED	PB8_LED
284Ah	RMB8A	RMB7A	RMB6A	RMB5A	RMB4A	RMB3A	RMB2A	RMB1A
284Bh	TMB8A	TMB7A	TMB6A	TMB5A	TMB4A	TMB3A	TMB2A	TMB1A
284Ch	RMB8B	RMB7B	RMB6B	RMB5B	RMB4B	RMB3B	RMB2B	RMB1B
284Dh	TMB8B	TMB7B	TMB6B	TMB5B	TMB4B	TMB3B	TMB2B	TMB1B
284Eh	ROKA	RBADA	CBADA	LBOKA	ANOKA	DOKA	*	*
284Fh	ROKB	RBADB	CBADB	LBOKB	ANOKB	DOKB	*	*
2850h	TESTDNP	TESTDB	TESTFM	TESTPUL	*	*	*	*
2851h	CCIN25	CCIN26	CCIN27	CCIN28	CCIN29	CCIN30	CCIN31	CCIN32
2852h	CCIN17	CCIN18	CCIN19	CCIN20	CCIN21	CCIN22	CCIN23	CCIN24
2853h	CCIN09	CCIN10	CCIN11	CCIN12	CCIN13	CCIN14	CCIN15	CCIN16

Table 6.7 SEL Communications Processor TARGET Region (Sheet 3 of 3)

Address	Relay Word Bits (in Bits 7–0)							
	7	6	5	4	3	2	1	0
2854h	CCIN01	CCIN02	CCIN03	CCIN04	CCIN05	CCIN06	CCIN07	CCIN08
2855h	CCOUT25	CCOUT26	CCOUT27	CCOUT28	CCOUT29	CCOUT30	CCOUT31	CCOUT32
2856h	CCOUT17	CCOUT18	CCOUT19	CCOUT20	CCOUT21	CCOUT22	CCOUT23	CCOUT24
2857h	CCOUT09	CCOUT10	CCOUT11	CCOUT12	CCOUT13	CCOUT14	CCOUT15	CCOUT16
2858h	CCOUT01	CCOUT02	CCOUT03	CCOUT04	CCOUT05	CCOUT06	CCOUT07	CCOUT08
2859h	CCSTA01	CCSTA02	CCSTA03	CCSTA04	CCSTA05	CCSTA06	CCSTA07	CCSTA08
285Ah	CCSTA09	CCSTA10	CCSTA11	CCSTA12	CCSTA13	CCSTA14	CCSTA15	CCSTA16
285Bh	CCSTA17	CCSTA18	CCSTA19	CCSTA20	CCSTA21	CCSTA22	CCSTA23	CCSTA24
285Ch	CCSTA25	CCSTA26	CCSTA27	CCSTA28	CCSTA29	CCSTA30	CCSTA31	CCSTA32
285Dh	FSERP1	FSERP2	FSERP3	FSERPF	*	*	*	*
285Eh	ALTI	ALTV	ALTS2	DELAY	*	*	*	*
285Fh	TLED_17	TLED_18	TLED_19	TLED_20	TLED_21	TLED_22	TLED_23	TLED_24
2860h	PB9_LED	PB10LED	PB11LED	PB12LED	*	*	*	*

Control Points

The SEL communications processor can automatically pass control messages, called Fast Operate messages, to the SEL-421. You must enable Fast Operate messages using the FASTOP setting in the SEL-421 port settings for the port connected to the communications processor. You must also enable Fast Operate messages in the SEL communications processor by setting the automessage setting SEND_OPER equal to Y.

When you enable Fast Operate functions, the SEL communications processor automatically sends messages to the relay for changes in remote bits RB1–RB16 or breaker bits BR1 and BR2 on the corresponding communications processor port. In this example, if you set RB1 on Port 1 in the SEL communications processor, it automatically sets RB01 in the SEL-421.

Breaker bits BR1 and BR2 operate differently than remote bits. There are no breaker bits in the SEL-421. For Circuit Breaker 1, when you set BR1, the SEL communications processor sends a message to the SEL-421 that asserts the manual open command bit OC1 for one processing interval. If you clear BR1, the SEL communications processor sends a message to the SEL-421 that asserts the close command bit CC1 for one processing interval. If you are using the default settings, OC1 will open the circuit breaker and CC1 will close the circuit breaker. You can control and condition the effect of OC1 and CC1 by changing the manual trip and close settings (BK1MTR, BK2MTR, BK1MCL, BK2MCL) in the SEL-421. Operation for Circuit Breaker 2 with BR2, OC2, and CC2 is similar.

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Section 7

Direct Network Communication

This section describes applications in which the SEL-421 Relay connects directly to a communications network via an Ethernet card or a serial port connection. This section includes the following topics:

Direct Network Communication

You can establish direct network communication with the SEL-421 either by serial port or through an optional protocol card. The protocols available on the serial ports are DNP3 and the SEL suite of ASCII and binary protocols. The protocol card presently available for the SEL-421 is an Ethernet card with FTP, Telnet, DNP3, IEC 61850, and synchrophasor protocols. This is a factory-installed option available at the time of purchase of a new SEL-421 or as a factory-installed conversion to an existing relay.

The SEL-421 includes a protocol card slot. This slot supports an SEL standard interface for network protocol cards. Communication between the SEL-421 and an installed protocol card is automatic; you do not need any configuration or driver software. You can access any configuration settings you need for protocol parameters or network operation through the SEL-421. Each protocol card contains a processor responsible for network interface operation.

Unlike a protocol card installed in a computer, a protocol card installed in the SEL-421 is responsible for all network message and protocol processing. This means that network traffic volumes and network failures do not affect protection processing.

Because SEL relays have more than one port, you can establish direct networking and a communications processor star network simultaneously. Combine an SEL-2032 or SEL-2030 Communications Processor with a direct networking application to add the following system capabilities:

NOTE: The IRIG-B time signal available from SEL communications processors is not suitable for high-accuracy IRIG (HIRIG) timekeeping mode, which is required for synchrophasor functions. See Configuring High-Accuracy Timekeeping on page U.4.71 for details.

➤ Distribution of IRIG-B time synchronization signal

➤ Single point of access for IEDs through an Ethernet network or serial connection

➤ Nonvolatile logging of data collected from several IEDs

➤ Single point for central substation database access

➤ Single point of access for Fast SER (Sequential Events Recorder) data

Please see *Section 6: SEL Communications Processor Applications* for more information regarding use of the SEL-2032, SEL-2030, or SEL-2020 Communications Processor with the SEL-421.

Serial Networking

The protocols available on the SEL-421 serial ports are either SEL protocols or standard protocols. While the standard protocols offer connectivity without a specific SEL support in other integration products, the SEL protocols offer features not included in standard protocols. These features provide additional capabilities that can significantly enhance your application.

SEL Protocols

SEL protocols are described in detail in *Section 5: SEL Communications Protocols in the Reference Manual*. SEL protocols include Fast Meter, Fast Operate, Fast SER, MIRRORED BITS® communications, and SEL ASCII.

DNP3

DNP3 is a protocol that provides an interface for retrieving SCADA data. The DNP User's Group is responsible for maintaining and distributing the DNP3 specifications.

This section describes the serial networking features of DNP3. The DNP3 Ethernet interface is discussed briefly in *Ethernet Card on page A.7.4*.

NOTE: In order to use DNP3 features, including virtual terminal connections, your DNP3 master device must support the required standard DNP3 objects and operations.

The DNP3 settings and operation are described in *Section 6: DNP3 Communications in the Reference Manual*. The DNP3 interface has the capabilities summarized in *Table 7.1*.

Table 7.1 DNP3 Serial Feature Summary

Feature	Application
DNP 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 through remote bits
Write analog setpoint	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 communication 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
Virtual terminal	Establish an engineering connection across a DNP3 network
TEST DNP command	Test DNP3 interface without disturbing protection

You can build a DNP3 network using either a multidrop or star topology. Each DNP3 network has a DNP3 master and DNP3 remotes or slaves. *Figure 7.1* shows the DNP3 multidrop network topology while *Figure 7.2* shows the DNP3 star network topology.

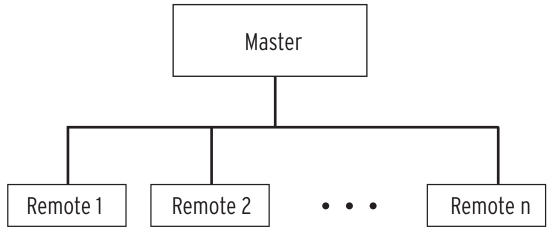


Figure 7.1 DNP3 Multidrop Network Topology

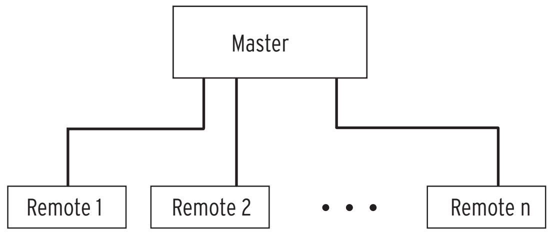


Figure 7.2 DNP3 Star Network Topology

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 network topology, you should consider the benefits of including an SEL communications processor in your design. A network with a communications processor is shown in *Figure 7.3*. 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.

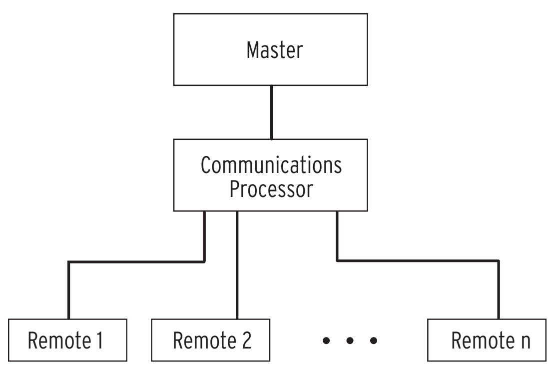


Figure 7.3 DNP3 Network with Communications Processor

In the communications processor DNP3 network you can also collect data from devices that do not have DNP3 protocol. The communications processor can collect data and present it to the master as DNP3 data regardless of the protocol between the communications processor and the remote device.

Ethernet Card

The SEL-421 Ethernet card is an optional protocol card that you can purchase as a factory-installed option. In order to exchange data over this interface, you must choose a data exchange protocol that operates over the Ethernet network link. The Ethernet card supports Telnet, DNP3, FTP, and IEC 61850 data exchange protocols.

You should carefully design your Ethernet network to maximize reliability, minimize system administration effort, and provide adequate security. Work with a networking professional to design your substation Ethernet network.

Ethernet

The SEL-421 Ethernet card provides Ethernet networking support with the popular physical and data-link standards listed in *Table 7.2*.

Table 7.2 Ethernet Connection Options

Name	Connector	Media
10BASE-T/100BASE-TX selectable	RJ45	CAT 5 (Category 5 twisted pair) cable
100BASE-FX	Standard ST	Multimode fiber-optic cable

FTP

Use FTP (File Transfer Protocol) to access data stored in files in the SEL-421. FTP is a standard TCP/IP protocol for exchanging files. A free FTP application is included with most web browser software. You can also obtain a free or inexpensive FTP application from the Internet.

When you connect to the SEL-421 Ethernet card, you will find files stored in directories. At the root or top level, you will find three directories, one for the Ethernet card and two for the SEL-421. One SEL-421 directory contains snapshots of data regions within the SEL-421 database. The other SEL-421 directory contains the files and subdirectories included in the virtual file interface described in *Section 5: SEL Communications Protocols in the Reference Manual*.

Files associated with the Ethernet card are in the SEL-2702 directory. This directory contains the file DIAGNOSTICS.TXT, which contains a log of Ethernet card system failures. The time and date of the diagnostics file correspond to the time and date of the last system failure event. The SEL-2702 directory may also contain custom mapping files for the DNP3 LAN/WAN protocol.

If the IEC 61850 protocol is installed and enabled, the following files will be found in the root directory:

- CID (Configured IED Description) file—contains the IEC 61850 SCL configuration for the SEL-421
- ERR.TXT file—contains any errors encountered during the CID file download
- CFG.XML file—contains the Ethernet card and SEL-421 configuration information

Telnet

Use Telnet to connect to the SEL-421 ASCII interface and work with the relay. Telnet is a terminal connection across a TCP/IP network that operates in a manner very similar to a direct serial port connection to one of the relay ports. As with FTP, Telnet is a part of TCP/IP. A free Telnet application is included with most computer operating systems, or you can obtain low-cost or free Telnet applications on the Internet.

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 9: ASCII Command Reference in the Reference Manual* to configure and interact with the relay. You can also use the SEL binary Fast Meter and Fast Operate commands described in *Section 5: SEL Communications Protocols in the Reference Manual*.

IEC 61850

The IEC 61850 standard is a superset of UCA2 and 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.

UCA2 utilized GOMSFE to present data from station IEDs as a series of objects called models or bricks. The IEC working group incorporated GOMSFE concepts into the standard, with some modifications to terminology; one change was the renaming of bricks to logical nodes. Each 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 measurement data and other points associated with three-phase metering including voltages and currents. Each IED may contain many functions such as protection, metering, and control. Multiple logical nodes represent the functions in multifunction devices.

The GOOSE object within IEC 61850 is for high-speed control messaging. IEC 61850 GOOSE objects can quickly and conveniently transfer status, controls, and measured values between peers on an IEC 61850 network.

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. MMS supports complex named objects and flexible services that enable the mapping to IEC 61850 in a straightforward manner. It was for this reason that the UCA users group utilized MMS for UCA from the start, and why the IEC chose to keep it for IEC 61850.

See *Section 8: IEC 61850 Communications in the Reference Manual* for important information regarding IEC 61850.

DNP3

Installation of the Ethernet card in an SEL-421 relay provides a high performance DNP3 Level 2 slave network interface designed for operation in a substation environment.

The DNP3 Ethernet interface has the capabilities summarized in *Table 7.3*.

Table 7.3 Ethernet DNP3 Feature Summary (Sheet 1 of 2)

Feature	Key Features
DNP3 Event data reporting	More efficient polling through event collection or unsolicited data
Time tagged events	Time-stamped SER data directly from the SEL-421, not an intermediate device
Control output relay blocks	Operator-initiated control through remote bits

Table 7.3 Ethernet DNP3 Feature Summary (Sheet 2 of 2)

Feature	Key Features
Custom mapping	Increase communication efficiency by organizing and/or reducing available data to what is needed with 5 custom data maps for up to 10 different sessions
Analog deadband settings per session	Deadbands may be set to different values per session depending on desired application

Customized DNP3 data within the SEL-421 relay is available to any of ten DNP3 master sessions configured in the Ethernet card. Configuration and implementation of DNP3 over the Ethernet interface is entirely independent of any serial DNP3 settings that might exist in the SEL-421.

See *Section 6: DNP3 Communications* in the *Reference Manual* for information on configuring and using DNP LAN/WAN for the SEL-421.

SEL Software

The SEL-421 configuration software, ACSELERATOR QuickSet® SEL-5030 Software, can connect to, configure, and control an SEL-421 with an Ethernet card. You can use ACSELERATOR QuickSet software to choose a connection type and provide the required information for a network connection. With this capability, you can configure and control SEL-421 relays from a local substation LAN (Local Area Network) or from an engineering workstation across a WAN (Wide Area Network). The ACSELERATOR Architect® SEL-5032 Software will be included with your purchase of the IEC 61850 option. The ACSELERATOR Architect software enables protection and integration engineers to design and commission IEC 61850 substations containing SEL IEDs.

Other SEL software includes Ethernet network connection capabilities, so you can use an Ethernet network for engineering connections to SEL protection and integration products. Check the documentation of your specific software for more information on Ethernet network connection capabilities.

Direct Networking Example

This direct networking example demonstrates direct networking to the SEL-421 using the Ethernet card. *Figure 7.4* shows the Ethernet network topology.

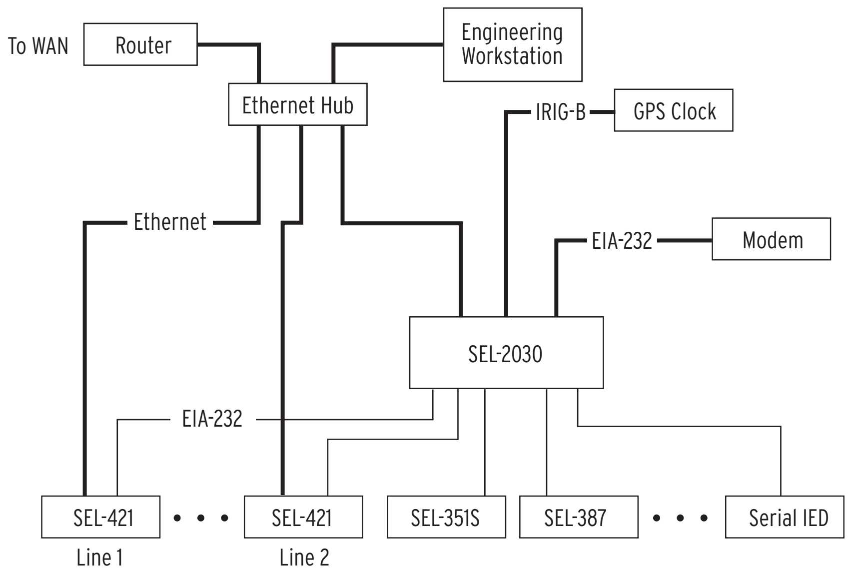


Figure 7.4 Example Direct Networking Topology

Application

In this application, all IEDs connect to the Ethernet network. The SEL-421 relays and the SEL-2030 each have an Ethernet card installed. In this example, 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-2030 to one of the serial IEDs in order to configure these devices or obtain diagnostic information.

NOTE: The IRIG-B time signal available from SEL communications processors is not suitable for high-accuracy IRIG (HIRIG) timekeeping mode, which is required for synchrophasor functions. See Configuring High-Accuracy Timekeeping on page U.4.71 for details.

There is a serial cable from the SEL-2030 to the SEL-421 relays. This cable provides IRIG-B time synchronization from the SEL-2030 that is synchronized by the GPS clock attached to the SEL-2030. The SEL-2030 provides its output synchronization signal from its internal clock, so that loss of the signal from the GPS will not result in a loss of synchronization between substation devices as they will all be synchronized to the SEL-2030 clock. During long periods of loss of synchronization, the SEL-2030 clock drift will become noticeable, but all substation devices will remain synchronized relative to each other and the SEL-2030 clock. The serial cables also allow the SEL-2030 to provide a single point for dial-in communications with the substation IEDs avoiding the high cost of high bandwidth connections (for example, ISDN or DSL) for this backup to the Ethernet network engineering connection.

Settings

This example focuses on the relay labeled Line 1 shown in *Figure 7.4*. **PORT 5** settings for the SEL-421 configure the Ethernet card. **PORT 5** settings for this example are shown in *Table 7.4*.

Table 7.4 SEL-421 PORT 5 Direct Networking Settings (Sheet 1 of 2)

Setting Name	Setting	Description
TIMEOUT	5	Port inactivity time-out in minutes (drops to Access Level 0 on Telnet connections when this expires)
AUTO	N	Automessage disabled because engineering connection will not require unsolicited messages from SEL-2030
FASTOP	N	Fast Operate messages disabled because they are not required on engineering connection
TERTIM1	1	Length of time the channel must be idle before checking for the termination string in seconds
TERSTRN	\005	Transparent communication termination string default of CTRL + E
TERTIM2	0	Length of time the channel must be idle before accepting the termination string in seconds
IPADDR	10.201.0.112	IP network address
SUBNETM	255.255.0.0	IP network subnet mask
DEFRTR	10.201.0.1	Default router
ETCPKA	N	Disable TCP keep-alive functionality (IEC 61850 only)
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	A	Primary network port selected to Port A
FAILOVR	N	Automatic fail-over disabled, forcing network operation on Port A only
FTIME	5	Fail over time-out; not used in this application
NETASPD	A	Automatically detect network speed on Port A
NETBSPD	A	Automatically detect network speed on Port B; not used in this application
FTPSERV	Y	FTP sessions enabled
FTPCBAN	FTP SERVER:	FTP connect banner
FTPIDLE	5	FTP connection time-out in minutes
FTPANMS	N	Anonymous log-in 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
T1CBAN	HOST TERMINAL SERVER:	Host Telnet connect banner
T1INIT	N	Telnet session from Ethernet card enable; not used in this application
T1RECV	Y	Telnet session to SEL-421 enable
T1PNUM	23	Host Telnet TCP/IP port

Table 7.4 SEL-421 PORT 5 Direct Networking Settings (Sheet 2 of 2)

Setting Name	Setting	Description
T2CBAN	CARD TERMINAL SERVER:	Ethernet card Telnet connect banner
T2RECV	Y	Telnet session to Ethernet card enable
T2PNUM	1024	Ethernet card Telnet TCP/IP port
TIDLE	5	Telnet connection time-out in minutes

FTP Session

Figure 7.6 is a screen capture of an FTP session with the relay. The FTP client used for this example is included with the Windows NT® 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 7.7* shows a portion of the **PORT 5** settings in the SET_P5.TXT file.

Telnet Session

This section contains screen captures of a Telnet session with the Line 1 SEL-421. The Telnet application shown is included with the Windows NT operating system. *Figure 7.5* shows the log-in dialog box and the entries required to connect to the SEL-421.

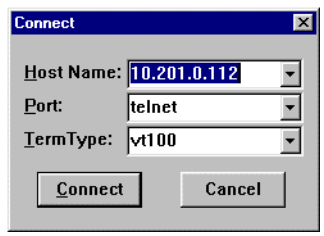


Figure 7.5 Telnet Connection Dialog Box

Figure 7.8 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.

```
C:\>ftp 10.201.0.112 <Enter>

Connected to 10.201.0.112.
220 SEL-2701 FTP SERVER:

User (10.201.0.112:(none)): 2AC
331 User name okay, need password.
Password:
230 User logged in, proceed.

ftp> ls <Enter>
200 PORT Command okay.
150 File status okay; about to open data connection.
SEL-421
SEL-2701
DD01_SEL-421
CFG.TXT
226 Closing data connection.
42 bytes received in 0.00 seconds (42000.00 Kbytes/sec)

ftp> cd SEL-421 <Enter>
250 CWD  requested file action okay, completed.

ftp> ls <Enter>
200 PORT Command okay.
150 File status okay; about to open data connection.
CFG.TXT
EVENTS
REPORTS
SETTINGS
226 Closing data connection.
36 bytes received in 0.08 seconds (0.45 Kbytes/sec)

ftp> cd SETTINGS <Enter>
250 CWD  requested file action okay, completed.

ftp> ls <Enter>
200 PORT Command okay.
150 File status okay; about to open data connection.
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_D1.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_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
226 Closing data connection.
419 bytes received in 0.73 seconds (0.57 Kbytes/sec)

ftp> get SET_P5.TXT <Enter>
200 PORT Command okay.
150 File status okay; about to open data connection.
226 Closing data connection.
2392 bytes received in 1.58 seconds (1.51 Kbytes/sec)

ftp> user entry <Enter>
221 Goodbye.
C:\>
```

Figure 7.6 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","A"
"FAILOVR","N"
"FTIME",5
"NETASPD","A"
"NETBSPD","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 7.7 Partial Contents of SET_P5.TXT

```
HOST TERMINAL SERVER:

Relay 1                                     Date: 01/19/2001  Time: 15:35:57.644
Station A                                   Serial Number: 00000000

=ACC <Enter>

Password: ?*****

Relay 1                                     Date: 01/19/2001  Time: 15:36:12.856
Station A                                   Serial Number: 00000000

Level 1

=>2AC <Enter>

Password: ?****

Relay 1                                     Date: 01/19/2001  Time: 15:36:16.887
Station A                                   Serial Number: 00000000

Level 2

=>>SHO P 5 <Enter>

Port 5

SEL Protocol Settings

TIMEOUT := 5        AUTO    := N        FASTOP  := N        TERTIM1 := 1
TERSTRN := "\005"
TERTIM2 := 0

Protocol Card Settings

IPADDR  := "10.201.0.112"
SUBNETM := "255.255.0.0"
DEFRTR  := "10.201.0.1"
NETPORT := "A"
FAILOVR := "N"
FTIME   := 5
NETASPD := "A"
NETBSPD := "A"
FTPSERV := "Y"
FTPCBAN := "FTP SERVER:"
FTPIDLE := 5
FTPANMS := "N"
FTPAUSR := ""
T1CBAN  := "HOST TERMINAL SERVER:"
T1INIT  := "N"
T1RECV  := "Y"
T1PNUM  := 23
T2CBAN  := "CARD TERMINAL SERVER:"
T2RECV  := "Y"
T2PNUM  := 1024     TIDLE   := 5
Settings HOST1-CTRLB64 Not Shown

=>>QUI <Enter>


Host connection terminated, terminating Network connection.
```

Figure 7.8 Example Telnet Session

SEL-421 Relay
Protection and Automation System

Instruction Manual

Reference Manual

20190325

SCHWEITZER ENGINEERING LABORATORIES, INC.

PM421-03

Section 1
Protection Functions

This section provides a detailed explanation for each of the many SEL-421 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.

- ➤ *Directional Comparison Unblocking Scheme Logic on page R.1.102*
- ➤ *Trip Logic on page R.1.107*
- ➤ *Circuit Breaker Failure Protection on page R.1.117*

Current and Voltage Source Selection

The SEL-421 has two sets of three-phase current inputs (IW and IX) and two sets of three-phase voltage inputs (VY and VZ), as shown in *Figure 1.1*. Currents IW and IX are also combined internally (COMB = IW + IX) on a per-phase basis and made available as the line current option for protection, metering, etc. You can select the current and voltage sources for a wide variety of applications, using the global settings in *Table 10.14 on page R.10.9*. The SEL-421 provides five default application settings (ESS := N, 1, 2, 3, or 4) that cover common applications (see *Table 1.1*). When you set ESS := Y, you can set the current and voltage sources for other applications (see *Table 1.2* and *Table 1.3*). ESS settings examples are given later in this subsection.

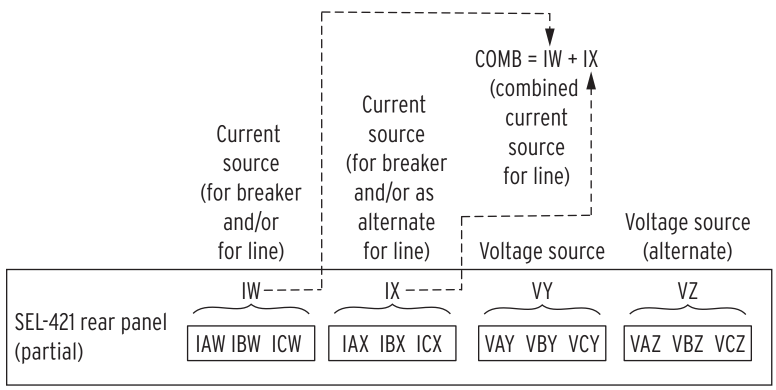


Figure 1.1 Current and Voltage Source Connections for the SEL-421 Relay

Current Source Switching

Figure 1.2 through *Figure 1.4* show the basic application of some of these settings. *Figure 1.2* shows an alternate breaker that can be substituted for the main breaker (bus switching details not shown). Normally, current IW (main breaker) is used as the line current source. But, if the alternate breaker substitutes for the main breaker, then current IX is used as the line current source, instead. SELOGIC setting ALTI controls the switching between currents IW and IX as the line current source (assert setting ALTI to switch to designated alternate line current ALINEI := IX). Alternate line current source settings ALINEI and ALTI are not used often and thus are usually set to NA. Setting ALTI is automatically hidden and set to NA if ALINEI := NA (no line current switching can occur).

NOTE: If a current source is set to "combine" (e.g., LINEI := COMB), then the current transformer ratios for the respective IW and IX secondary circuits have to be the same (i.e. group settings CTRW = CTRX).

Figure 1.3 shows combined currents IW and IX (see COMB = IW + IX in *Figure 1.1*) set for line protection, metering, etc. (LINEI := COMB). In order to combine these currents correctly inside the relay to produce the effective line current, the current transformer ratios for the respective IW and IX secondary circuits have to be the same.

Figure 1.4 shows the assignment of breaker currents for up to two circuit breakers. These assigned breaker currents are used in breaker monitoring and breaker failure functions. These same breaker currents can also be assigned as line currents (e.g., line current assignment LINE1 := IW in *Figure 1.2*).

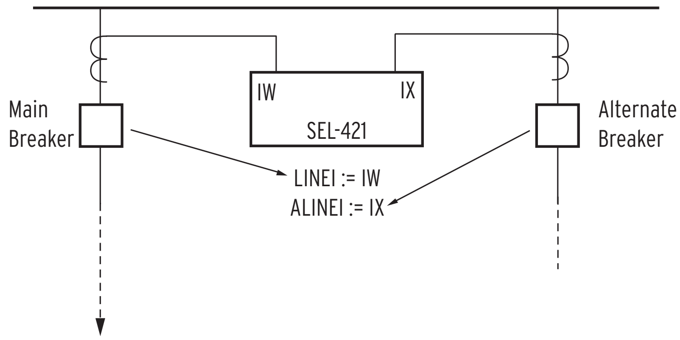


Figure 1.2 Main and Alternate Line Current Source Assignments

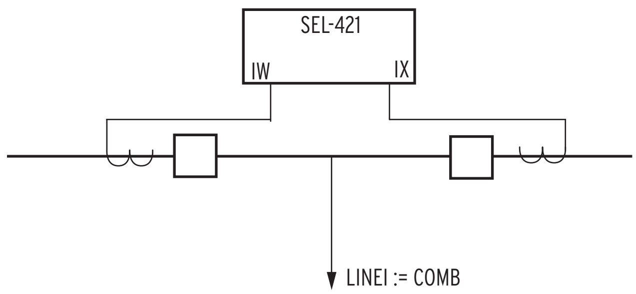


Figure 1.3 Combined Currents for Line Current Source Assignment

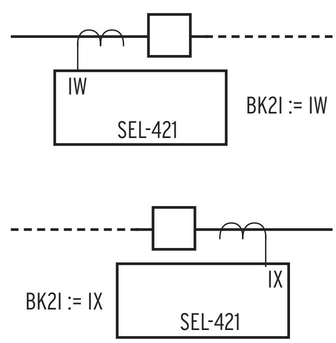


Figure 1.4 Breaker Current Source Assignments

All the available current and voltage source selection settings combinations are covered in *Table 1.1*, *Table 1.2*, and *Table 1.3*. Notice that global setting NUMBK (Number of Breakers in Scheme; see *Table 10.3 on page R.10.5*) influences available settings combinations covered in *Table 1.1*, *Table 1.2*, and *Table 1.3*. In general, if NUMBK := 1, then no settings directly involving a second circuit breaker are made (i.e., Breaker 2 current source setting BK2I is automatically set to NA and hidden, as indicated with the shaded cells in the BK2I columns in *Table 1.1* and *Table 1.2*). Also, for source-selection setting ESS := N, the settings are forced to certain values and hidden, as indicated with the shaded cells in the ESS := N rows in *Table 1.1*.

Table 1.1 Available Current Source Selection Settings Combinations

NUMBK (number of breakers)	ESS (source selection)		LINEI (line current source)	ALINEI (alternate line current source)	BK1I (Breaker 1 current source)	BK2I (Breaker 2 current source)	IPOL (polarizing current)
1	Y		see *Table 1.2*				
1	N		IW	NA	IW	NA	NA
1	1		IW	IX	IW	NA	NA
1	1		IW	NA	IW	NA	IAX, IBX, ICX, or NA
1	2		IW	IX	IX	NA	NA
1	2		IW	NA	IX	NA	NA
1	3		not allowed				
1	4		not allowed				
2	Y		see *Table 1.3*				
2	N		IW	NA	IW	NA	NA
2	1		not allowed				
2	2		not allowed				
2	3		COMB	NA	IW	IX	NA
2	4		IW	NA	IX	COMB	NA

NA = not applicable
Shaded cells indicate settings forced to given values and hidden.

Table 1.2 Available Current Source Selection Settings Combinations When ESS := Y, NUMBK := 1

NUMBK (number of breakers)	ESS (source selection)		LINEI (line current source)	ALINEI (alternate line current source)	BK1I (Breaker 1 current source)	BK2I (Breaker 2 current source)	IPOL (polarizing current)
1	Y		IW	IX	IW	NA	NA
1	Y		IW	IX	IX	NA	NA
1	Y		IW	IX	NA	NA	NA
1	Y		IW	NA	IW	NA	IAX, IBX, ICX, or NA
1	Y		IW	NA	IX	NA	NA
1	Y		IW	NA	NA	NA	IAX, IBX, ICX, or NA
1	Y		COMB	IX	IW	NA	NA
1	Y		COMB	IX	IX	NA	NA
1	Y		COMB	IX	NA	NA	NA
1	Y		COMB	NA	IW	NA	NA
1	Y		COMB	NA	IX	NA	NA
1	Y		COMB	NA	NA	NA	NA

NA = not applicable
Shaded cells indicate settings forced to given values and hidden

Table 1.3 Available Current Source Selection Settings Combinations When ESS := Y, NUMBK := 2

NUMBK (number of breakers)	ESS (source selection)		LINEI (line current source)	ALINEI (alternate line current source)	BK1I (Breaker 1 current source)	BK2I (Breaker 2 current source)	IPOL (polarizing current)
2	Y		IW	IX	IW	IX	NA
2	Y		IW	IX	IW	COMB	NA
2	Y		IW	IX	IW	NA	NA
2	Y		IW	IX	IX	COMB	NA
2	Y		IW	IX	IX	NA	NA
2	Y		IW	IX	NA	IX	NA
2	Y		IW	IX	NA	COMB	NA
2	Y		IW	IX	NA	NA	NA
2	Y		IW	NA	IW	IX	NA
2	Y		IW	NA	IW	COMB	NA
2	Y		IW	NA	IW	NA	IAX, IBX, ICX, or NA
2	Y		IW	NA	IX	COMB	NA
2	Y		IW	NA	IX	NA	NA
2	Y		IW	NA	NA	IX	NA
2	Y		IW	NA	NA	COMB	NA
2	Y		IW	NA	NA	NA	IAX, IBX, ICX, or NA
2	Y		COMB	IX	IW	IX	NA
2	Y		COMB	IX	IW	NA	NA
2	Y		COMB	IX	IX	NA	NA
2	Y		COMB	IX	NA	IX	NA
2	Y		COMB	IX	NA	NA	NA
2	Y		COMB	NA	IW	IX	NA
2	Y		COMB	NA	IW	NA	NA
2	Y		COMB	NA	IX	NA	NA
2	Y		COMB	NA	NA	IX	NA
2	Y		COMB	NA	NA	NA	NA

NA = not applicable

Current Source Uses

Refer to the global settings in *Table 10.14*. Line current source setting LINEI and alternate line current source settings ALINE1 and ALTI, if used, identify the currents used in the following elements/features described later in this section and in other sections:

- Fault location
- Open-phase detection logic
- LOP (loss-of-potential) logic
- FIDS (fault-type identification selection) logic
- Directional elements
- CVT (capacitor voltage transformer) transient detection logic
- Series-compensation line logic
- Load-encroachment logic
- OOS (out-of-step) logic
- Distance elements
- Instantaneous line overcurrent elements
- Inverse-time overcurrent elements
- DCUB (directional comparison unblocking) trip scheme logic
- *Metering on page A.2.26*, except synchrophasors

NOTE: Starting in firmware version R112, synchrophasor measurements are no longer affected by the line current source settings ALINEI and LINEI. See Synchrophasors on page R.7.1.

Breaker current-source settings (BK1I and BK2I) identify the currents used in the following elements/features described in later in this section and in other sections:

- Open-phase detection logic
- Inverse-time overcurrent elements
- Circuit breaker failure protection
- *Circuit Breaker Monitor on page A.2.1*
- *Metering on page A.2.26*

Polarizing current-source setting IPOL identifies the single current input connected to a zero-sequence current source (e.g., transformer bank neutral). This zero-sequence current is used as a reference in the zero-sequence current-polarized directional element. Such a directional element is applied to ground overcurrent elements (see *Table 1.27* and *Figure 1.23*). Setting IPOL is not used often and thus is usually set to NA. Notice that in *Table 1.1*, *Table 1.2* and *Table 1.3* there are relatively few scenarios where setting IPOL can be set to a current channel selection (only those cases where three-phase current input IX is not used for any other function). An example of using setting IPOL is found later in this subsection.

Voltage Source Switching and Uses

Refer to the global settings in *Table 10.14*. Alternate voltage source switching between VY and VZ in *Figure 1.1* is more straightforward (as shown in *Table 1.4*) than the preceding discussion on current-source selection/switching (compare to *Table 1.1* through *Table 1.3*).

Table 1.4 Available Voltage Source-Selection Setting Combinations

NUMBK (number of breakers)	ESS (source selection)		Line Voltage Source	ALINEV (alternate line voltage source)
1	Y		VY	VZ or NA
1	N		VY	NA
1	1		VY	VZ or NA
1	2		VY	VZ or NA
1	3		not allowed	
1	4		not allowed	
2	Y		VY	VZ or NA
2	N		VY	NA
2	1		not allowed	
2	2		not allowed	
2	3		VY	VZ or NA
2	4		VY	VZ or NA

NA = not applicable
Shaded cells indicate settings forced to given values and hidden

SELOGIC setting ALTV controls the switching between voltages VY and VZ for line voltage (assert setting ALTV to switch to designated alternate line voltage ALINEV := VZ). Setting ALTV is automatically hidden and set to NA if ALINEV := NA (no voltage switching can occur). Reasons for switching from one three-phase voltage to another may be for loss-of-potential or bus switching/rearrangement.

Default line voltage source VY and alternate line voltage source settings (ALINEV and ALTV) identify the voltages used in the following elements/features described later in this section and in other sections:

- Fault location
- Open-phase detection logic
- LOP (loss-of-potential) logic
- FIDS (fault-type identification selection) logic
- Directional elements
- CVT (capacitor voltage transformer) transient detection logic
- Series-compensation line logic
- Load-encroachment logic
- OOS (out-of-step) logic
- Distance elements
- SOTF (switch-onto-fault) logic
- POTT (permissive overreaching transfer tripping) scheme logic
- *Metering on page A.2.26*, including synchrophasors

Default Applications

Use setting ESS (Current and Voltage Source Selection) to easily configure the relay for your particular application. Five application settings (ESS := N, 1, 2, 3, or 4) cover both single circuit breaker and two circuit breaker configurations. If you select one of these five setting choices, the relay automatically determines the following settings:

NOTE: Setting BK2I is hidden if setting NUMBK, Number of Breakers in the Scheme, is set to 1.

- LINEI—Line Current Source (IW, COMB)
- BK1I—Breaker 1 Current Source (IW, IX, NA)
- BK2I—Breaker 2 Current Source (IX, COMB, NA)

ESS := N, Single Circuit Breaker Configuration—One Current Input

Set ESS to N for single circuit breaker applications with one current input. *Figure 1.5* illustrates this application along with the corresponding current and voltage sources. When ESS equals N, you cannot use alternate sources (ALINEI and ALINEV) and the relay hides the Global settings LINEI, ALINEI, ALTI, BK1I, BK2I, IPOL, ALINEV, and ALTV.

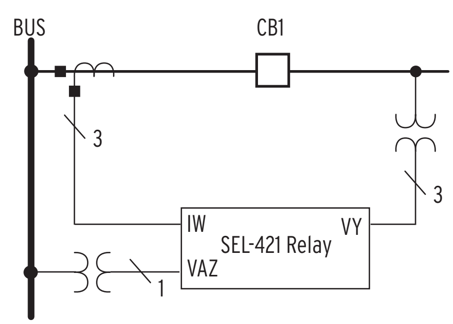
Table 1.5 ESS := N, Current and Voltage Source Selection

Setting	Description	Entry	Comments
NUMBK	Number of Breakers in Scheme (1, 2)	1	
LINEI	Line Current Source (IW, COMB)	IW	Hidden
BK1I	Breaker 1 Current Source (IW, IX, NA)	IW	Hidden
BK2I	Breaker 2 Current Source (IX, COMB, NA)	NA	Hidden

ESS := 1, Single Circuit Breaker Configuration—One Current Input

Set ESS to 1 for single circuit breaker applications with one current input. *Figure 1.5* illustrates this application along with the corresponding current and voltage sources.

With ESS := 1, the IX current channels have the option to be used as an alternate line current source (ALINEI:= IX) or as a polarizing current channel (e.g., IPOL:= IBX), but not both (see *Table 1.1*).



Analog Input	Function
IW	CB1 protection, line protection
VY	Line protection
VAZ	Synchronism check

Figure 1.5 ESS := 1, Single Circuit Breaker Configuration

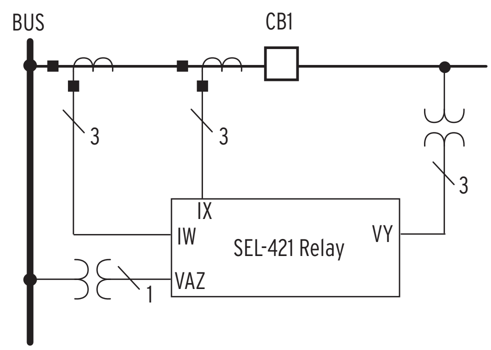
Table 1.6 ESS := 1, Current and Voltage Source Selection

Setting	Description	Entry	Comments
NUMBK	Number of Circuit Breakers in Scheme (1, 2)	1	
LINEI	Line Current Source (IW)	IW	Automatic
ALINEI	Alternate Line Current Source (IX, NA)	NA	
ALTI	Alternate Current Source (SELOGIC Equation)	NA	Hidden[a]
BK1I	Breaker 1 Current Source (IW)	IW	Automatic
BK2I	Breaker 2 Current Source (NA)	NA	Hidden
IPOL	Polarizing Current (IAX, IBX, ICX, NA)	NA	
ALINEV	Alternate Line Voltage Source (VZ, NA)	NA	
ALTV	Alternate Voltage Source (SELOGIC Equation)	NA	Hidden

[a] Hidden when preceding setting is NA.

ESS := 2, Single Circuit Breaker Configuration—Two Current Inputs

Set ESS to 2 for single circuit breaker applications using two current sources. *Figure 1.6* illustrates this application along with the corresponding current and voltage sources. The relay uses current source IW for line relaying and current source IX for Circuit Breaker 1 failure protection.



Analog Input	Function
IW	CB1 protection, line protection
IX	CB1 breaker failure
VY	Line protection
VAZ	Synchronism check

Figure 1.6 ESS := 2, Single Circuit Breaker Configuration

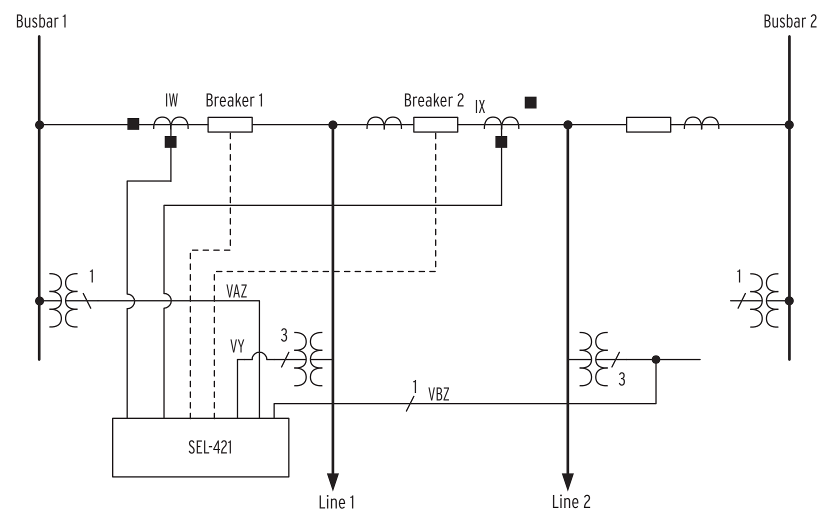
Table 1.7 ESS := 2, Current and Voltage Source Selection

Setting	Description	Entry	Comments
NUMBK	Number of Circuit Breakers in Scheme (1, 2)	1	
LINEI	Line Current Source (IW)	IW	Automatic
ALINEI	Alternate Line Current Source (IX, NA)	NA	
ALTI	Alternate Current Source (SELOGIC Equation)	NA	Hidden[a]
BK1I	Breaker 1 Current Source (IX)	IX	Automatic
BK2I	Breaker 2 Current Source (NA)	NA	Hidden
IPOL	Polarizing Current (NA)	NA	Automatic
ALINEV	Alternate Line Voltage Source (VZ, NA)	NA	
ALTV	Alternate Voltage Source (SELOGIC Equation)	NA	Hidden

[a] Hidden when preceding setting is NA.

ESS := 3, Double Circuit Breaker Configuration—Independent Current Inputs

Set ESS to 3 for circuit breaker-and-a-half applications using independent current sources. *Figure 1.7* illustrates this application along with the corresponding current and voltage sources. This selection provides independent circuit breaker failure protection for Circuit Breaker 1 and Circuit Breaker 2.



Analog Input	Function
IW+IX	Line protection
IW	CB1 protection
IX	CB2 protection
VY	Line protection
VAZ	Synchronism check Circuit Breaker 1
VBZ	Synchronism check Circuit Breaker 2

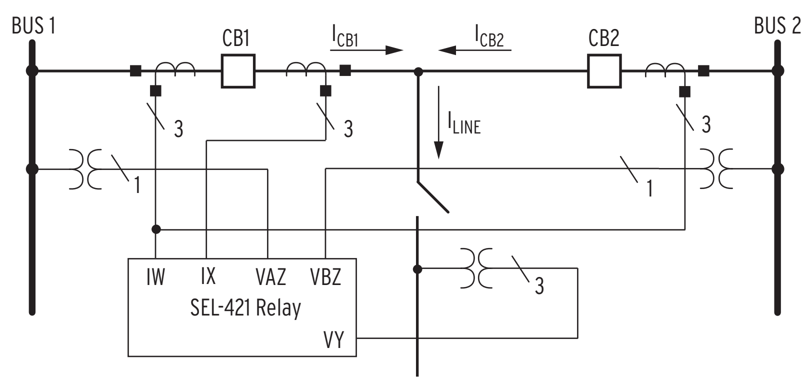
Figure 1.7 ESS := 3, Double Circuit Breaker Configuration

Table 1.8 ESS := 3, Current and Voltage Source Selection

Setting	Description	Entry	Comments
NUMBK	Number of Circuit Breakers in Scheme (1, 2)	2	
LINEI	Line Current Source (COMB)	COMB	Automatic
ALINEI	Alternate Line Current Source (NA)	NA	Automatic
ALTI	Alternate Current Source (SELOGIC Equation)	NA	Hidden
BK1I	Breaker 1 Current Source (IW)	IW	Automatic
BK2I	Breaker 2 Current Source (IX)	IX	Automatic
IPOL	Polarizing Current (NA)	NA	Automatic
ALINEV	Alternate Line Voltage Source (VZ, NA)	NA	
ALTV	Alternate Voltage Source (SELOGIC Equation)	NA	Hidden

ESS := 4, Double Circuit Breaker Configuration—Common Current Inputs

Set ESS to 4 for circuit breaker-and-a-half applications using combined current input IW. *Figure 1.8* illustrates this application along with the corresponding current and voltage sources. Current input IX provides circuit breaker failure protection for Circuit Breaker 1; the corresponding CTs are located on the line-side of Circuit Breaker 1. The relay calculates the current flowing through Circuit Breaker 2 (I_{CB2} = IW + IX= I_{CB1} + I_{CB2} + IX = I_{CB1} + I_{CB2} - I_{CB1}) to provide independent circuit breaker failure for Circuit Breaker 2.



Analog Input	Function
IW+IX	CB2 protection
IW	Line protection
IX	CB1 protection
VY	Line protection
VAZ	Synchronism check Circuit Breaker 1
VBZ	Synchronism check Circuit Breaker 2

Figure 1.8 ESS := 4, Double Circuit Breaker Configuration

Table 1.9 ESS := 4, Current and Voltage Source Selection

Setting	Description	Entry	Comments
NUMBK	Number of Circuit Breakers in Scheme (1, 2)	2	
LINEI	Line Current Source (IW)	IW	Automatic
ALINEI	Alternate Current Source (NA)	NA	Automatic
ALTI	Alternate Current Source (SELOGIC Equation)	NA	Hidden
BK1I	Breaker 1 Current Source (IX)	IX	Automatic
BK2I	Breaker 2 Current Source (COMB)	COMB	Automatic
IPOL	Polarizing Current (NA)	NA	Automatic
ALINEV	Alternate Line Voltage Source (VZ, NA)	NA	
ALTV	Alternate Voltage Source (SELOGIC Equation)	NA	Hidden

ESS := Y, Other Applications

Set ESS to Y for applications that are not covered under the five default applications.

Tapped Line

Figure 1.9 illustrates a tapped EHV transmission overhead line. A power transformer is located at Substation T along the tapped line. An SEL-421 is located at all three EHV terminals (Substations S, R, and T). The SEL-421 relays operate in a DCB (directional comparison blocking) trip scheme to provide high-speed clearance for all faults internal to the tapped EHV transmission line. For a complete explanation of this example, see *Section 5: Substation Automatic Restoration in the Applications Handbook*.

Set NUMBK (Number of Breakers in Scheme) to 2 so you can program the auto-reclosing function and synchronism-check elements to control both of the low-side circuit breakers.

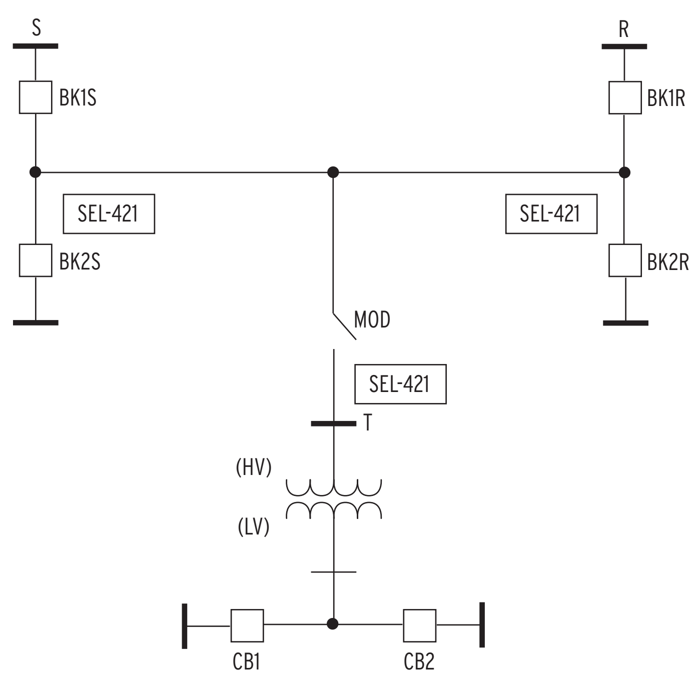
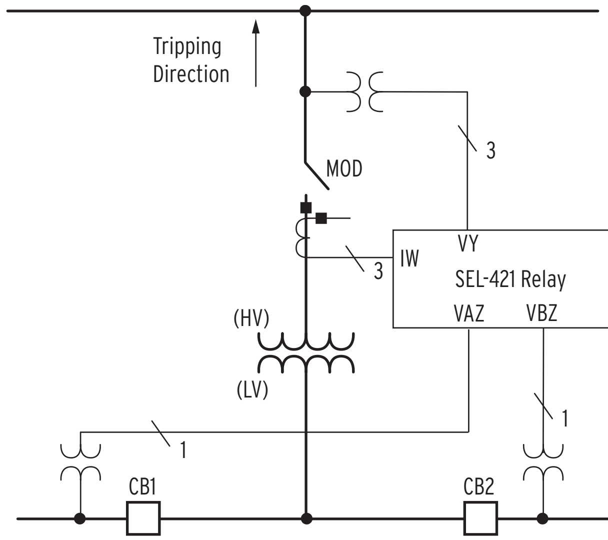


Figure 1.9 Tapped EHV Overhead Transmission Line

Figure 1.10 illustrates the tapped overhead transmission line with an MOD (motor operated disconnect) on the high side of a power transformer and two circuit breakers on the low side.



Analog Input	Function
IW	Line protection
VY	Line protection
VAZ	Synchronism check Circuit Breaker 1
VBZ	Synchronism check Circuit Breaker 2

Figure 1.10 ESS := Y, Tapped Line

Table 1.10 ESS := Y, Tapped Line

Setting	Description	Entry	Comments
NUMBK	Number of Circuit Breakers in Scheme (1, 2)	2	
LINEI	Line Current Source (IW, COMB)	IW	
ALINEI	Alternate Current Source (IX, NA)	NA	
ALTI	Alternate Current Source (SELOGIC Equation)	NA	Hidden[a]
BK1I	Breaker 1 Current Source (IW, IX, NA)	NA	
BK2I	Breaker 2 Current Source (IX, COMB, NA)	NA	
IPOL	Polarizing Current (IAX, IBX, ICX, NA)	NA	
ALINEV	Alternate Line Voltage Source (VZ, NA)	NA	Default
ALTV	Alternate Voltage Source (SELOGIC Equation)	NA	Hidden

[a] Hidden when preceding setting is NA.

Single Circuit Breaker With Current Polarizing Source

Figure 1.11 shows a single circuit breaker situated by an autotransformer. The SEL-421 uses the delta-connected tertiary as a current polarizing source for the zero-sequence current-polarized directional element 32I. For example, connect to current to input IAX (set IPOL := IAX).

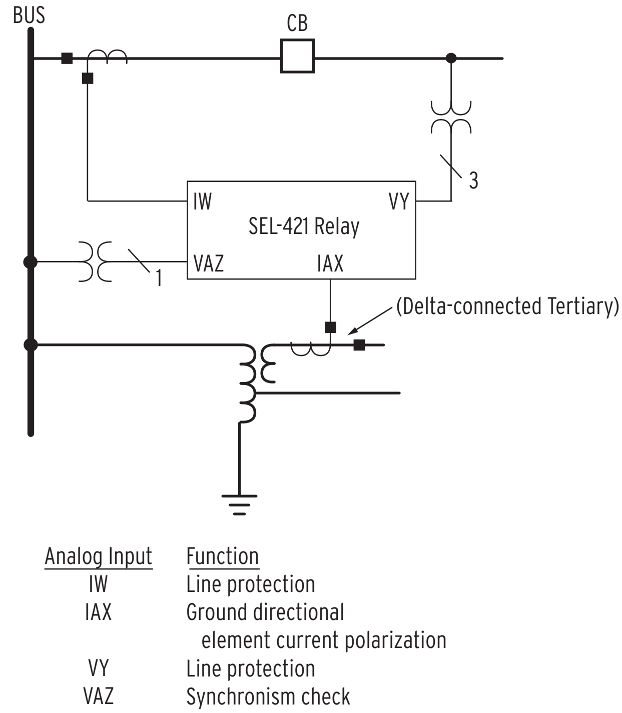


Figure 1.11 ESS := Y, Single Circuit Breaker With Current Polarizing Source Tapped Power Transformer

Table 1.11 ESS := Y, Current Polarizing Source

Setting	Description	Entry	Comments
NUMBK	Number of Circuit Breakers in Scheme (1, 2)	1	
LINEI	Line Current Source (IW, COMB)	IW	
ALINEI	Alternate Current Source (IX, NA)	NA	
ALTI	Alternate Current Source (SELOGIC Equation)	NA	Hidden
BK1I	Breaker 1 Current Source (IW, IX, NA)	IW	
BK2I	Breaker 2 Current Source (NA)	NA	Hidden
IPOL	Polarizing Current (IAX, IBX, ICX, NA)	IAX	
ALINEV	Alternate Line Voltage Source (VZ, NA)	NA	Default
ALTV	Alternate Voltage Source (SELOGIC Equation)	NA	Hidden

Using ALTI and ALTV

SELOGIC control equations ALTI and ALTV give great flexibility in choosing alternate CT and PT inputs to the SEL-421. The relay switches immediately to the alternate source when these SELOGIC control equations become true. The relay delays a subsequent ALTI or ALTV switch for 8 cycles after the initial switch to give time for the system to settle.

Test the SELOGIC control equation programming that you use to switch ALTI and ALTV alternate sources. It is possible to create a toggling condition where the relay repeatedly switches between sources. Examine each line of SELOGIC control equation programming to verify that this toggling condition does not occur in your protection/control scheme.

One method for exercising caution when implementing alternate current source and alternate voltage source switching is to use SELOGIC control equation protection latches (PLT01–PLT32) to switch alternate sources. For example, to switch to an alternate voltage, set ALINEV to VZ (enables setting ALTV) and then set ALTV to PLT31. To perform the switch use the protection latch control inputs PLT31S and PLT31R (Set and Reset, respectively).

Polarizing Quantity for Distance Element Calculations

The relay uses positive-sequence memory voltage as the polarizing quantity for distance element calculations. Memory polarization ensures proper operation during zero-voltage three-phase faults and provides expansion of the mho characteristic back to the source impedance, improving fault-resistance coverage. However, longer memory may impair distance element security when a power system disturbance causes a fast frequency excursion.

The polarization memory is adaptive. The relay normally uses positive-sequence voltage with short or medium length memory. This short or medium length memory works satisfactorily for all faults other than zero-voltage three-phase faults. When the relay measures positive-sequence voltage magnitude lower than a threshold, it automatically switches to a long memory polarizing quantity.

The VMEMC setting allows you to choose between short or medium length memory voltage for the normal polarizing quantity. To closely follow the power system frequency, set VMEMC = 0. When VMEMC is deasserted (logical 0), the relay normally uses a short memory time constant that closely follows the positive-sequence voltage, yet automatically switches to the long memory when necessary. This setting provides less expansion of the distance element characteristics, while still providing security for zero-voltage three-phase faults. SEL recommends that you use this setting.

If your application requires more expansion of the distance element characteristics, set VMEMC = 1. When VMEMC is asserted, the relay normally uses medium length memory and automatically switches to the long memory when necessary. This setting provides the same element operation as provided in firmware R130 and earlier, including greater expansion of the distance element characteristics and the same security for zero-voltage three-phase faults.

The short memory is not available for series compensated lines (ESERCMP = Y). When ESERCMP = Y, the relay uses the medium length memory and automatically switches to the long memory polarizing quantity when the relay detects voltage inversion or positive-sequence voltage magnitude lower than a threshold.

Table 1.12 VMEMC Relay Setting

Name	Description	Range	Default
VMEMC[a]	Memory Voltage Control (SELOGIC Equation)	SV	0[b]

[a] If the Advanced Settings are not enabled (setting EADVS :=N), the relay hides the setting. If the Series Compensation Line Logic Setting is enabled (setting ESERCMP := Y), the relay hides the setting.
[b] Setting VMEMC is forced to 1 if the Series Compensation Line Logic Setting is enabled (setting ESERCMP := Y).

Frequency Estimation

The SEL-421 measures power system frequency based on fixed rate sampled voltages. The relay measures the time between zero crossings, filters the time measurement, and processes the measurement with an algorithm to remove line anomalies.

The output of the frequency estimation routine is used to alter the protection algorithm sample rate which is in samples per cycle. The protection algorithms are processed at 8 samples per power system cycle.

In most applications, no settings changes are required for frequency estimation. Advanced Global settings (see *Table 1.13*) are provided for special cases, and these allow selection of the voltage input terminal(s) to be used as frequency estimation inputs. An alternate frequency source may also be enabled and selected by control from a SELOGIC control equation.

Table 1.13 Frequency Estimation[a]

Label	Prompt	Default Value
EAFSRC	Alternate Frequency Source (SELOGIC Equation)	NA
VF01	Local Frequency Source 1 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	VAY
VF02	Local Frequency Source 2 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	VBY
VF03	Local Frequency Source 3 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	VCY
VF11	Alternate Frequency Source 1 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	ZERO
VF12	Alternate Frequency Source 2 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	ZERO
VF13	Alternate Frequency Source 3 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	ZERO

[a] These settings are available only if you have enabled Global advanced settings, EGADVS := Y.

Table 1.14 Frequency Estimation Outputs

Name	Description	Type
FREQ	Measured system frequency (Hz)	Analog Quantity
FREQOK	Measured frequency valid[a]	Relay Word bit

[a] Deasserts approximately two seconds after a pole-open condition or after all frequency estimation voltages drop out.

The SEL-421 will not measure frequency using the voltage from any phase that has an open-pole condition. For example, with the factory default settings listed in *Table 1.13*, if Relay Word bit SPOB is asserted, the signal present on the VBY input is treated as zero volts and will not be a contributing factor to the frequency estimate. If all three poles are open, or all selected voltage signals dropout, the measured frequency reverts to the nominal frequency (Global setting NFREQ := 50 or 60 Hz) after approximately two seconds. In this situation, Relay Word bit FREQOK deasserts.

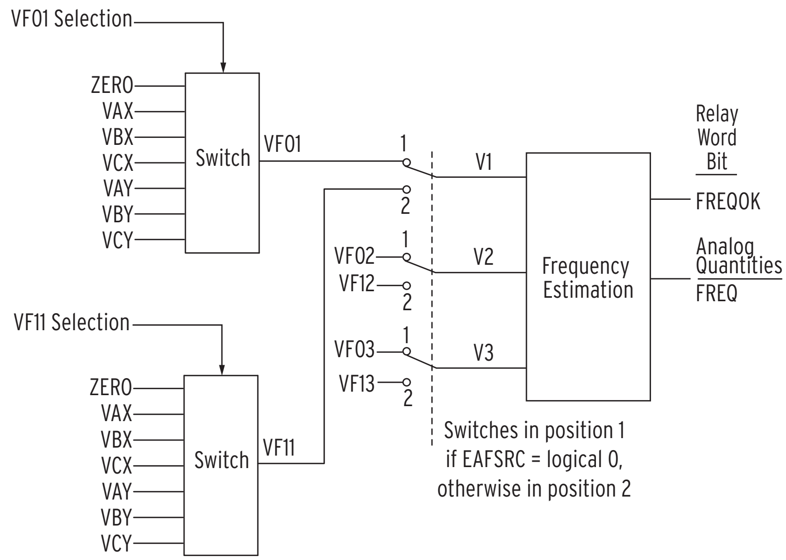


Figure 1.12 Frequency Estimation for Protection Functions

Frequency Estimation Provided by Synchrophasor

The frequency and rate of change of frequency is estimated using synchrophasors. These measurements are included in the synchrophasor data packet and can be viewed by the **MET PM** command. The rate of change of frequency (DFDT) is also included as an analog quantity that can be used in SELOGIC control equations. Note that DFDT is not available if synchrophasors are not enabled or active.

NOTE: The DFDT calculation is only performed when Global setting EPMU := Y.

Time-Error Calculation

Description and Settings

The Time-Error calculation function in the SEL-421 measures the amount of time that an ac clock running from the same line frequency measured by the relay would differ from a reference clock. The relay integrates the difference between the measured power system frequency and the nominal frequency (Global setting NFREQ) to create a time-error analog quantity, TE.

NOTE: The LOADTE SELOGIC equation is processed once per cycle. A momentary assertion must be conditioned to be at least one cycle in duration. A rising edge operator (R_TRIG) should not be used in the LOADTE setting.

A correction feature allows the present time-error estimate (TE) to be discarded, and a new value (TECORR) loaded when SELOGIC control equation LOADTE asserts. For example, if the TECORR value is set to zero, and then LOADTE is momentarily asserted, the TE analog quantity will be set to 0.000 seconds.

The TECORR analog quantity can be pre-loaded by the **TEC** Command (see *TEC on page R.9.51*), or via DNP3, object 40, 41 index 01 (see *Table 6.10*). In either case, Relay Word bit PLDTE asserts for approximately 1.5 cycles to indicate that the preload was successful.

A separate SELOGIC control equation, STALLTE, when asserted, causes time-error calculation to be suspended.

Table 1.15 lists the inputs and outputs of the time-error function.

Table 1.15 Time-Error Calculation Inputs and Outputs

INPUTS	Description
Analog Quantities	
FREQ	Measured system frequency (see *Table 1.14*).
TECORR	Time-error correction factor. This value can be preloaded via the **TEC** command, or DNP3.
Global Settings	
NFREQ	Nominal frequency (see *Table 10.3*)
LOADTE	Load Time-Error Correction Factor (SELOGIC control equation). A rising edge will cause the relay to load the TECORR analog quantity into TE. LOADTE has priority over STALLTE.
STALLTE	Stall Time-Error Calculation (SELOGIC control equation). A logical 1 will stall (freeze) the time-error function. The TE value will not change when STALLTE is asserted (unless LOADTE asserts).
Relay Word bit	
FREQOK	Frequency Measurement valid. If this Relay Word bit deasserts, the TE quantity is frozen (see *Table 1.14*).
OUTPUTS	**Description**
Analog Quantity	
TE	Time-Error estimate, in seconds. Positive numbers indicate that the ac clock would be fast (ahead of the reference clock). Negative numbers indicate that the ac clock would be slow (behind the reference clock).
Relay Word bit	
PLDTE	Preload Time-Error value updated. This element asserts for approximately 1.5 cycles after TECORR is changed by the **TEC** command or by DNP3.

Time Error Command (TEC)

The **TEC** serial port command provides easy access to the time-error function. See *TEC on page R.9.51* for command access level information.

Enter the **TEC** command to view the time-error status. A sample display is given in *Figure 1.13*.

```
=>TEC <Enter>

Relay 1                                    Date: 11/02/2004  Time: 11:25:50.460
Station A                                  Serial Number: 0000000000

Time Error Correction Preload Value
TECORR = 0.000 s

Relay Word Elements
LOADTE = 0, STALLTE = 0, FREQOK = 1

Accumulated Time Error
TE = -7.838 s

=>
```

Figure 1.13 Sample TEC Command Response

Enter the **TEC** command with a single numeric argument *n* (–30.000 ≥ *n* ≤ 30.000) to preload the TECORR value. This operation does not affect the TE analog quantity until the SELOGIC control equation LOADTE next asserts. *Figure 1.14* shows an example of the **TEC *n*** command in use.

```
==>TEC 2.25 <Enter>

Relay 1                                     Date: 11/02/2004  Time: 11:53:12.701
Station A                                   Serial Number: 0000000000

Change TECORR to 2.250 s:

Are you sure (Y/N)?Y <Enter>

Time Error Correction Preload Value
TECORR = 2.250 s

Relay Word Elements
LOADTE = 0, STALLTE = 0, FREQOK = 1

Accumulated Time Error
TE = -5.862 s

==>
```

Figure 1.14 Sample TEC n Command Response

Fault Location

The SEL-421 computes distance to fault from data stored in the event reports. The relay calculates distance to fault upon satisfaction of all four of the following conditions:

- ➤ The fault locator is enabled, setting EFLOC := Y.
- ➤ A single-pole open condition does not exist (i.e., Relay Word bit SPO equals logical 0).
- ➤ A phase distance, ground distance, residual ground overcurrent, negative-sequence, or time-overcurrent element picks up no later than 15 cycles after the event report trigger.
- ➤ The fault duration is greater than one cycle, as determined by the previously listed asserted protection element(s).

Table 1.16 Fault Location Triggering Elements

Fault Type	Protection Element
Ground Faults	Z1G–Z5G 67G1–67G4 67Q1–67Q4 51S1–51S3[a]
Phase Faults	M1P–M5P 67Q1–67Q4 51S1–51S3[b]

[a] Corresponding group setting 51SkO must be set to 3I2L or 3I0L (k = 1–3).
[b] Corresponding group setting 51SkO must be set to IAL, IBL, ICL, I1L, 3I2L, or IMAXL (k = 1–3).

The relay calculates distance to fault in per unit of the positive-sequence line impedance, Z_1. Use the relay setting LL, Line Length, to determine the units that the relay reports for the distance to a fault. For example, if a fault occurs at the midpoint of the protected line and you set LL to 126 for a line length of 126 kilometers, the result of the relay distance-to-fault calculation is 63.

Distance-to-fault calculation results range from –999.99 to 999.99. If the calculation cannot be determined (e.g., insufficient information) or if the result is outside the specified range, the relay reports the fault location as `$$$$.$$`.

The relay provides an analog fault location value from the most recent event report, labeled FLOC.

The relay specifies fault type along with the distance to fault. The fault type can be one of the types listed in *Table 1.17*.

Table 1.17 Fault Type

Label	Fault Type
AG	A-phase-to-ground
BG	B-phase-to-ground
CG	C-phase-to-ground
AB	A-phase-to-B-phase
BC	B-phase-to-C-phase
CA	C-phase-to-A-phase
ABG	A-phase-to-B-phase-to-ground
BCG	B-phase-to-C-phase-to-ground
CAG	C-phase-to-A-phase-to-ground
ABC	Three-phase

Table 1.18 Fault Location Settings

Name	Description	Range	Default (5 A)
Z1MAG	Positive-Sequence Line Impedance Magnitude (Ω)	$(0.25–1275)/I_{nom}$	7.80
Z1ANG	Positive-Sequence Line Impedance Angle (°)	5.00–90	84.00
Z0MAG	Zero-Sequence Line Impedance Magnitude (Ω)	$(0.25–1275)/I_{nom}$	24.80
Z0ANG	Zero-Sequence Line Impedance Angle (°)	5.00–90	81.50
EFLOC	Fault Location	Y, N	Y
LL	Line Length	0.10–999	100.00

Table 1.19 Fault Location Relay Word Bit

Name	Description
RSTFLOC	Fault locator analog quantity reset in progress.[a]

[a] Use global setting RSTFLOC shown in Table 10.11 to reset the stored fault location analog quantity FLOC. Relay Word bit RSTFLOC will assert momentarily while the clearing action proceeds.
When reset, the value contained in FLOC is set to a very large number (greater than 10^{37}). Resetting this value has no effect on the event reports stored in the SEL-421, nor does it have an effect on DNP3 event access.

Open Phase Detection Logic

Some line relaying applications (e.g., circuit breaker failure protection) benefit from fast open phase detection. The resetting time of the instantaneous overcurrent elements using filtered quantities can be extended after the corresponding phase(s) is open if subsidence current is present. The SEL-421 open phase detector senses an open phase in less than one cycle. This information is used for purposes such as quickly disabling instantaneous overcurrent elements in the circuit breaker failure schemes and open pole detection.

The open phase detection logic uses both the half-cycle and one-cycle cosine digital filter data shown in *Figure 3.1 on page A.3.3* to achieve the high-speed response to an open phase condition. *Table 1.20* lists the output Relay Word bits.

Table 1.20 Open Phase Detection Relay Word Bits

Name	Description
B1OPHA	Breaker 1 A-phase open
B1OPHB	Breaker 1 B-phase open
B1OPHC	Breaker 1 C-phase open
B2OPHA	Breaker 2 A-phase open
B2OPHB	Breaker 2 B-phase open
B2OPHC	Breaker 2 C-phase open
LOPHA	Line A-phase open
LOPHB	Line B-phase open
LOPHC	Line C-phase open

Pole Open Logic

The SEL-421 pole open logic detects single-, double-, and three-pole open conditions. The relay uses the same processing for single- and double-pole open conditions. Pole open logic supervises various protection elements and functions that use analog inputs from the power system (e.g., distance elements, directional elements, LOP logic).

Table 1.21 Pole Open Logic Settings

Name	Description	Range	Default
EPO	Pole Open Detection	52, V	52
27PO	Undervoltage Pole Open Threshold (V)[a]	1–200	40
SPOD	Single-Pole Open Dropout Delay (cycles)	0.000–60	0.500
3POD	Three-Pole Open Dropout Delay (cycles)	0.000–60	0.500

[a] 1 V steps

Setting EPO (Enable Pole Open) offers two options for deciding the conditions that signify an open pole. These options are listed in *Table 1.22*.

Table 1.22 EPO Setting Selections

Selection	Description
52	Phase undercurrent and circuit breaker auxiliary contact input status
V	Phase undercurrent and phase undervoltage

NOTE: The 3PO, SPOA, SPOB, SPOC, and SPO Relay Word bits shown in Figure 1.15 are used in some protective elements of the SEL-421. Separate Relay Word bits SPOBKn, 3POBKn, 2POBKn (n = 1 or 2), and 3POLINE are not affected by the EPO setting and are used in the auto-reclose logic only—see Figure 2.5 and Figure 2.6.

Set EPO to V only if you use line-side potential transformers for relaying purposes. Do not select option V if shunt reactors are applied because the voltage decays slowly after the circuit breaker(s) opens. If you select EPO := V, the relay cannot declare an open pole when LOP is asserted.

Table 1.23 Pole Open Logic Relay Word Bits

Name	Description
SPOA	A-phase open
SPOB	B- phase open
SPOC	C- phase open
SPO	One or two poles open
3PO	All three poles open
27APO	A-phase undervoltage—pole open
27BPO	B-phase undervoltage—pole open
27CPO	C-phase undervoltage—pole open

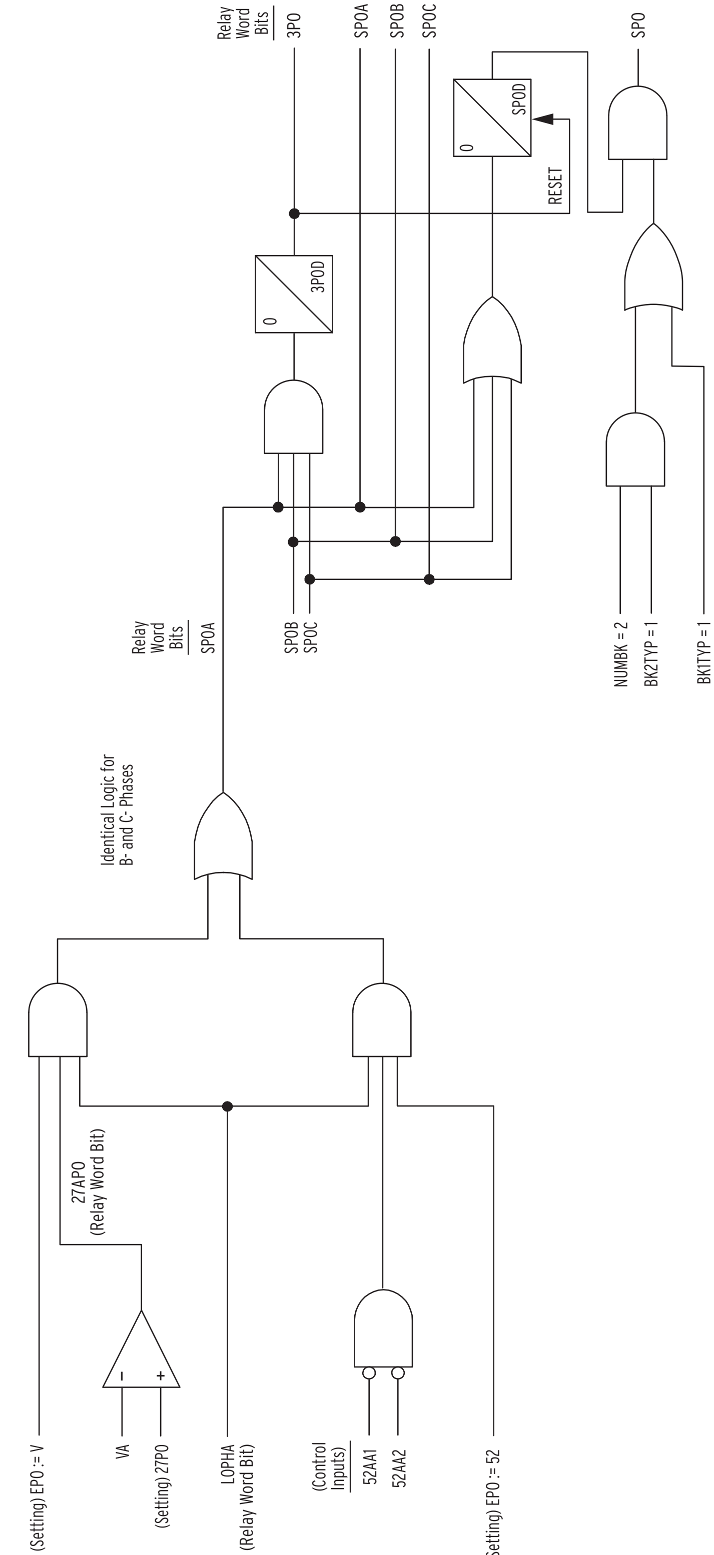


Figure 1.15 Pole Open Logic Diagram

Loss-of-Potential Logic

Fuses or molded case circuit breakers often protect the secondary windings of the power system potential transformers. Operation of one or more fuses or molded case circuit breakers results in a loss of polarizing potential inputs to the relay. Loss of one or more phase voltages prevents the relay from discriminating fault distance and direction properly.

An occasional loss-of-potential (LOP) at the secondary inputs of a distance relay is unavoidable but detectable. The relay detects a loss-of-potential condition and asserts Relay Word bits LOP (Loss-of-Potential Detected) and ILOP (Internal Loss-of-Protection From ELOP Setting). This allows you to block distance element operation, block or enable forward-looking directional overcurrent elements, and issue an alarm for any true LOP condition.

If line-side PTs are used, the circuit breaker(s) must be closed for the LOP logic to detect a three-phase LOP condition. Therefore, if three-phase potential to the relay is lost while the circuit breaker(s) is open (e.g., the PT fuses are removed while the line is de-energized), the relay cannot detect an LOP when the circuit breaker(s) closes again.

The SEL-421 also asserts LOP upon circuit breaker closing for one or two missing PTs. If the relay detects a voltage unbalance with balanced currents at circuit breaker close, then the relay declares a loss-of-potential condition.

Inputs into the LOP logic are as follows:

- 3PO—three-pole open condition
- SPO—single-pole open condition
- OOSDET—out-of-step condition detected
- OST—out-of-step tripping assertion
- V_1—positive-sequence voltage (V secondary)
- I_1—positive-sequence current (A secondary)
- V_0—zero-sequence voltage (V secondary)
- I_0—zero-sequence current (A secondary)

All three poles of the circuit breaker(s) must be closed (i.e., Relay Word bit 3PO equals logical 0) and neither Relay Word bit OSB nor OST can be asserted for the LOP logic to operate.

The relay declares an LOP condition (Relay Word bit LOP equals logical 1) if V_1 drops in magnitude by at least ten percent and there is no corresponding change in I_1 or I_0 magnitude or angle. An LOP condition persisting for 15 cycles causes the LOP logic to latch. LOP resets (Relay Word bit LOP equals logical 0) when V_1 returns to a level greater than 85 percent nominal voltage and V_0 is less than 10 percent of V_1.

The LOP logic requires no settings other than enable setting ELOP.

Setting ELOP := N

If you set ELOP to N, the LOP logic operates but does not disable any voltage-polarized elements. This option is for indication only.

Setting ELOP := Y

If you set ELOP to Y and an LOP condition occurs, the voltage-polarized directional elements and all distance elements are disabled. The forward-looking directional overcurrent elements effectively become nondirectional and provide overcurrent protection during an LOP condition.

Setting ELOP := Y1

If you set ELOP to Y1 and an LOP condition occurs, the voltage-polarized directional elements and all distance elements are disabled. This setting for ELOP also disables the overcurrent elements that these voltage-polarized directional elements control.

Table 1.24 LOP Logic Setting

Name	Description	Range	Default
ELOP	Loss-of-potential	Y, Y1, N	Y1

Table 1.25 LOP Logic Relay Word Bits

Name	Description
ILOP	Internal loss-of-potential from ELOP setting
LOP	Loss-of-potential detected

Figure 1.16 illustrates how the LOP logic processes an LOP decision. *Figure 1.17* provides a logic diagram for the LOP logic.

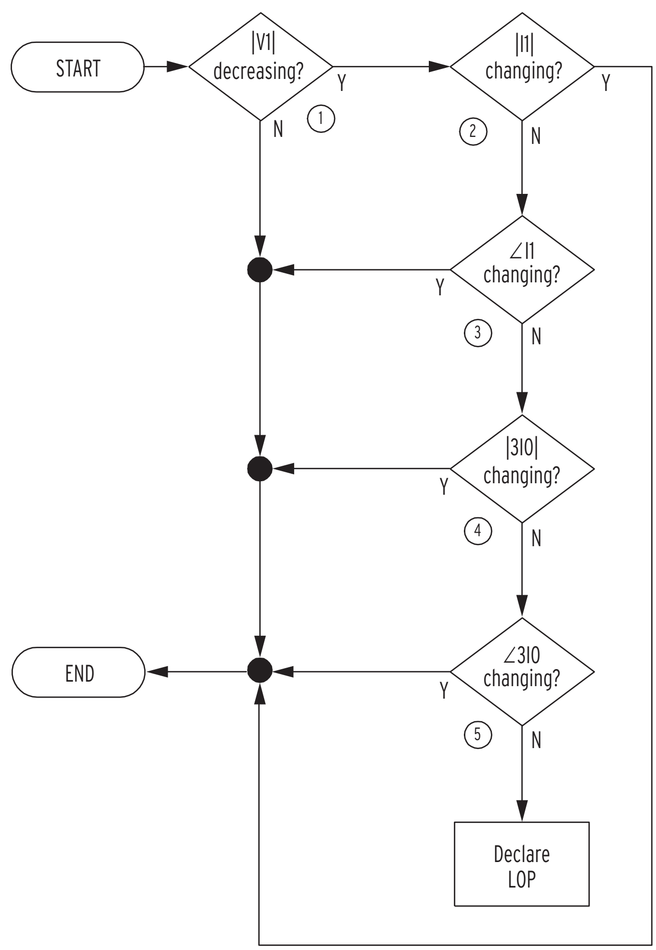


Figure 1.16 LOP Logic Process Overview

The following text gives additional description of the steps shown in *Figure 1.16*:

(1) Magnitude of positive-sequence voltage is decreasing. Measure positive-sequence voltage magnitude (called $|V_{1(k)}|$, where k represents the present processing interval result) and compare it to $|V_1|$ from one power system cycle earlier (called $|V_{1(k-1\ cycle)}|$). If $|V_{1(k)}|$ is less than or equal to 90 percent $|V_{1(k-1\ cycle)}|$, assert LOP if all of the conditions in the next four steps are satisfied. This is the decreasing delta change in V_1 ($-\Delta|V_1| > 10\%$) shown as an input in the logic diagram of *Figure 1.17*.

(2) Positive-sequence current magnitude not changing. Measure positive-sequence current magnitude ($|I_{1(k)}|$) and compare it to $|I_{1(k-1\ cycle)}|$ from one cycle earlier. If this difference is greater than two percent nominal current, the condition measured is not an LOP, even if all other conditions are met. This input is labeled as $\Delta|I_1| > 2\%$ in *Figure 1.17*.

(3) Positive-sequence current angle is not changing. Measure positive-sequence current angle ($\angle I_{1k}$) and compare it to $\angle I_{1(k-1\ cycle)}$ from one cycle earlier. If this difference is greater than 5 degrees, the condition measured is not an LOP, even if all other conditions are met. This input is labeled as $\angle I_1 > 5°$ in *Figure 1.17*. If $|I_1|$ is less than five percent nominal current (I_{nom}), this angle check does not block LOP.

(4) Zero-sequence current magnitude is not changing. Measure zero-sequence current magnitude ($|I_{0k}|$) and compare it to $|I_{0(k-1\ cycle)}|$ from one cycle earlier. If this difference is greater than six percent nominal current, the condition measured is not an LOP, even if all other conditions are met. This input is labeled as $\Delta|I_0| > 6\%$ in *Figure 1.17*.

(5) Zero-sequence current angle is not changing. Measure zero-sequence current angle ($\angle I_{0k}$) and compare it to $\angle I_{0(k-1\ cycle)}$. If this difference is greater than 5 degrees, the condition measured is not an LOP even if all other conditions are met. This input is labeled as $\angle I_0 > 5°$ in *Figure 1.17*. For security, this declaration requires that $|I_0|$ be greater than five percent of nominal current to override an LOP declaration.

If the criteria identified in all five steps listed above are met, the LOP logic declares an LOP condition.

The relay resets LOP logic when the following conditions are true for 30 cycles:

1. a decreasing delta change in V_1 is less than 10 percent (see point (1) above), and
2. the magnitude of V_1 is larger than 85 percent of Vnom, and
3. the magnitude of $|V_0|$ is not larger than 10 percent of magnitude $|V_1|$

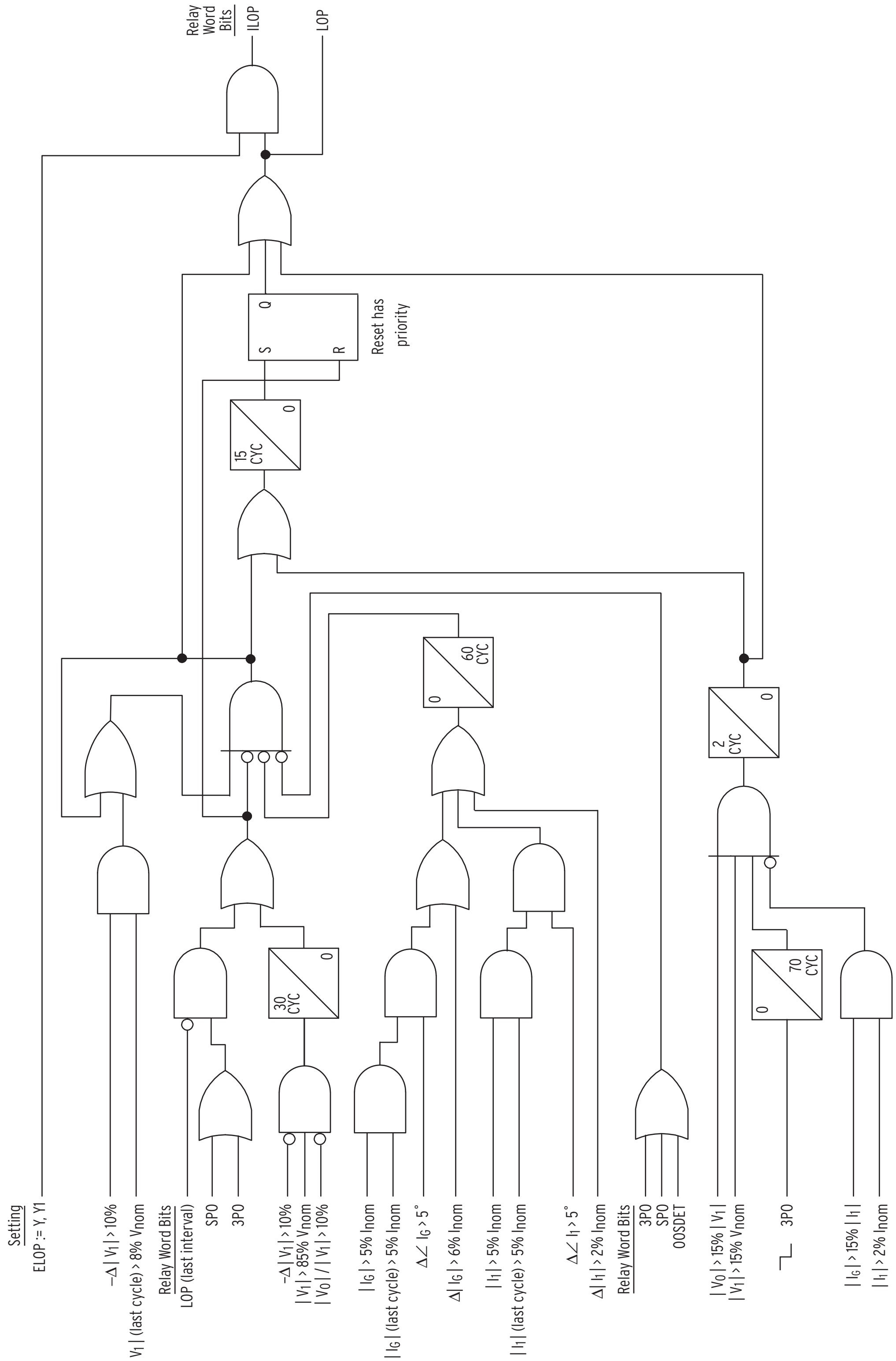


Figure 1.17 LOP Logic

Fault Type Identification Selection Logic

This logic identifies the faulted phase(s) for all faults involving ground by comparing the angle between I_0 and I_2.

For cases where only zero-sequence current flows through the relay terminal (that is, no negative-sequence current and no positive-sequence current), the Fault Type Identification Selection (FIDS) Logic uses single-phase undervoltage elements for faulted phase selection.

The FIDS logic is not active during an SPO (single pole open) condition (i.e., when SPO equals logical 1).

Table 1.26 FIDS Relay Word Bits

Name	Description
FIDEN	FIDS logic enabled
FSA	A-phase-to-ground fault or B-phase to C-phase-to-ground fault selected
FSB	B-phase-to-ground fault or C-phase to A-phase-to-ground fault selected
FSC	C-phase-to-ground fault or A-phase to B-phase-to-ground fault selected

Ground Directional Element

The SEL-421 offers a choice of three independent directional elements to supervise the ground distance elements and directional residual ground overcurrent elements (67G*n*, where *n* equals 1 through 4) during ground faults. You can also use the ground directional element for torque control. Internal logic selects the best choice automatically. *Table 1.27* lists the directional elements the relay uses to provide ground directional decisions.

Table 1.27 Directional Elements Supervising Ground Elements

Directional Elements	Description	Forward Output	Reverse Output
32QG	Negative-sequence voltage polarized for ground faults	F32QG	R32QG
32V	Zero-sequence voltage polarized	F32V	R32V
32I	Zero-sequence current polarized	F32I	R32I

The negative-sequence voltage polarized directional element 32QG listed in *Table 1.27* supervises the ground distance elements and residual ground directional overcurrent elements. The negative-sequence voltage polarized directional element 32Q illustrated in *Figure 1.26* only supervises the phase distance elements.

The relay internal logic selects the best choice for directional supervision according to prevailing power system conditions during the ground fault. The logic determines the best choice for the ground directional element (32G) from among the negative-sequence voltage-polarized directional element (32QG), zero-sequence voltage-polarized directional element (32V), or the zero-sequence current-polarized directional element (32I). The ground directional element also supervises the quadrilateral ground distance elements.

During the single-pole open condition (SPO is a logical 1), the relay supervises the ground directional element with an open pole directional element. The purpose of this directional element is to ensure secure operation of the distance elements during the single-pole open condition. The operation of the single-pole open directional element is indicated by the 32SPOF and the 32SPOR Relay Word bits.

As the single-pole open directional element may operate due to unbalance currents generated during the single-pole open condition, it is recommended that ground and negative-sequence overcurrent elements that are used for single-pole tripping be supervised by the single-pole open condition. To supervise overcurrent elements during the single-pole open condition, set the element torque control equation (67G*n*TC or 67Q*n*TC, where *n* equals 1 through 4) equal to NOT SPO.

Settings

Table 1.28 lists the relay settings corresponding to the ground directional element.

Table 1.28 Ground Directional Element Settings

Setting	Description	Range	Default (5 A)
E32	Directional Control	Y, AUTO	AUTO
ORDER	Ground Directional Element Priority	combine Q, V, I	QV
50FP	Forward Directional Overcurrent Pickup (A)	$(0.05–1) \cdot I_{nom}$	0.60
50RP	Reverse Directional Overcurrent Pickup (A)	$(0.05–1) \cdot I_{nom}$	0.40
Z2F	Forward Directional Z2 Threshold (Ω)	$\pm 320/I_{nom}$	3.90
Z2R	Reverse Directional Z2 Threshold (Ω)	$\pm 320/I_{nom}$	4.00
a2	Positive-Sequence Restraint Factor, I2/I1	0.02–0.5	0.10
k2	Zero-Sequence Restraint Factor, I2/I0	0.1–1.2	0.20
Z0F	Forward directional Z0 threshold (Ω)	$\pm 320/I_{nom}$	12.40
Z0R	Reverse directional Z2 threshold (Ω)	$\pm 320/I_{nom}$	12.50
a0	Positive-Sequence restraint factor, I0/I1	0.02–0.5	0.10
E32IV	Zero-sequence voltage current enable	SELOGIC Equation	1

If you set E32 to AUTO, the relay automatically calculates the settings shown in *Table 1.29*.

Table 1.29 Ground Directional Element Settings AUTO Calculations

Setting	Equation
50FP	$0.12 \cdot I_{nom}$
50RP	$0.08 \cdot I_{nom}$
Z2F	$0.5 \cdot$ Z1MAG
Z2R	$Z2F + 1/(2 \cdot I_{nom})$
a2	0.1
k2	0.2
Z0F	$0.5 \cdot$ Z0MAG
Z0R	$Z0F + 1/(2 \cdot I_{nom})$
a0	0.1

Detailed Settings Description

If you set E32 to Y, you can change the settings listed in *Table 1.29*.

50FP and 50RP

Setting 50FP is the threshold for the current level detector that enables forward decisions for both the negative- and zero-sequence voltage-polarized directional elements. If the magnitude of $3I_2$ or $3I_0$ is greater than 50FP, the corresponding directional element can process a forward decision.

Setting 50RP is the threshold for the current level detector that enables reverse decisions for both the negative- and zero-sequence voltage-polarized directional elements. If the magnitude of $3I_2$ or $3I_0$ is greater than 50RP, the corresponding directional element can process a reverse decision.

Z2F and Z2R

Setting Z2F is the forward threshold for the negative-sequence voltage-polarized directional element. If the relay measures the apparent negative-sequence impedance z2 less than Z2F, the relay declares the unbalanced fault to be forward.

Setting Z2R is the reverse threshold for the negative-sequence voltage-polarized directional element. If the relay measures apparent negative-sequence impedance z2 greater than Z2R, the relay declares the unbalanced fault to be reverse.

a2 and k2

Positive-sequence current restraint factor a2 compensates for highly unbalanced systems. Unbalance is typical in systems that have many untransposed lines. This factor also helps prevent misoperation during current transformer saturation. The a2 factor is the ratio of the magnitude of negative-sequence current to the magnitude of positive-sequence current, $|I_2|/|I_1|$. If the measured ratio exceeds a2, the negative-sequence voltage-polarized directional element is enabled. Typically, you can apply the default calculations in *Table 1.29*.

Zero-sequence current restraint factor k2 also compensates for highly unbalanced systems. This factor is the ratio of the magnitude of negative-sequence current to the magnitude of zero-sequence current, $|I_2|/|I_0|$. If the measured ratio exceeds k2, the negative-sequence voltage-polarized directional element is enabled. If the measured ratio is less than k2, the zero-sequence voltage polarized directional element is enabled. Typically, you can apply the default calculations that appear in *Table 1.29*.

Z0F and Z0R

Setting Z0F is the forward threshold for the zero-sequence voltage-polarized directional element. If the relay measures apparent zero-sequence impedance z0 less than Z0F, the relay declares the unbalanced fault to be forward.

Setting Z0R is the reverse threshold for the zero-sequence voltage-polarized directional element. If the relay measures apparent zero-sequence impedance z0 greater than Z0R, then the relay declares the unbalanced fault to be reverse.

Typically, you can apply the default calculations that appear in *Table 1.29* for the settings Z2F, Z2R, Z0F, and Z0R. For series-compensated lines, calculate each of these settings separately. The forward threshold setting must be less than corresponding reverse threshold setting to avoid the situation where the measured apparent impedance satisfies both forward and reverse conditions.

a0

Positive-sequence current restraint factor a0 is the ratio of the magnitude of zero-sequence current to the magnitude of positive-sequence current, $|I_0|/|I_1|$. If the relay measures a ratio greater than a0, the zero-sequence voltage-polarized directional element is enabled. Typically you can apply the default calculations that appear in *Table 1.29*.

ORDER

The SEL-421 uses Best Choice Ground Directional™ logic to determine the order in which the relay selects 32QG, 32V, or 32I to provide directional decisions for the ground distance elements and the residual ground directional overcurrent elements. Directional element classification is as follows:

- Q—Negative-sequence voltage-polarized directional element (32QG)
- V—Zero-sequence voltage-polarized directional element (32V)
- I—Zero-sequence current-polarized directional element (32I)

You can set ORDER with any combination of Q, V, and I. The listed order of these directional elements determines the priority that these elements operate to provide the ground directional element.

Set E32 := Y to edit the ground directional element settings. If you set E32 := Y the relay hides certain relay settings depending on the setting ORDER.

If ORDER does not contain Q, the relay hides the Z2F, Z2R, a2, and k2 settings. If ORDER does not contain V, the relay hides the Z0F and Z0R settings. If ORDER contains only Q, the relay hides settings a0, E32IV, Z0F, and Z0R.

E32IV

SELOGIC control equation setting E32IV must be asserted to enable the zero-sequence voltage-polarized or zero-sequence current-polarized directional elements. This provides directional control of the ground distance elements and directional residual ground overcurrent elements.

Directional Element Enables

The Relay Word bits shown in *Table 1.30* indicate when the relay has enabled the ground directional element.

Table 1.30 Ground Directional Element Enables

Name	Description
32QE	Negative-sequence voltage-polarized directional element enable—phase faults
32QGE	Negative-sequence voltage-polarized directional element enable—ground faults
32VE	Zero-sequence voltage-polarized directional element enable—ground faults
32IE	Zero-sequence current-polarized directional element enable—ground faults

Figure 1.18 and *Figure 1.19* correspond to *Table 1.30*.

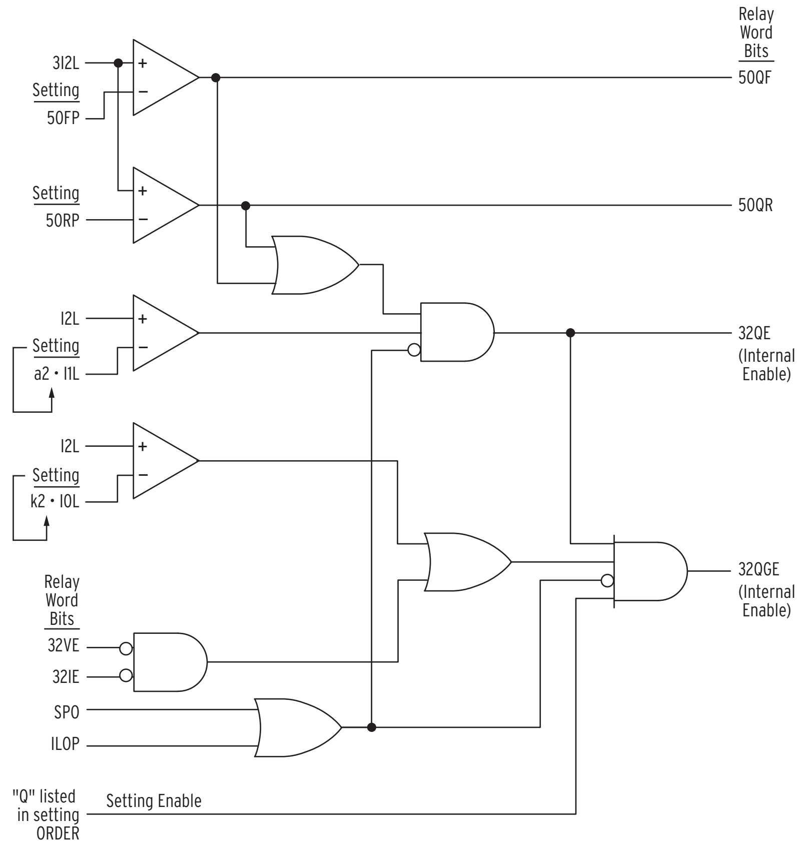


Figure 1.18 32Q and 32QG Enable Logic Diagram

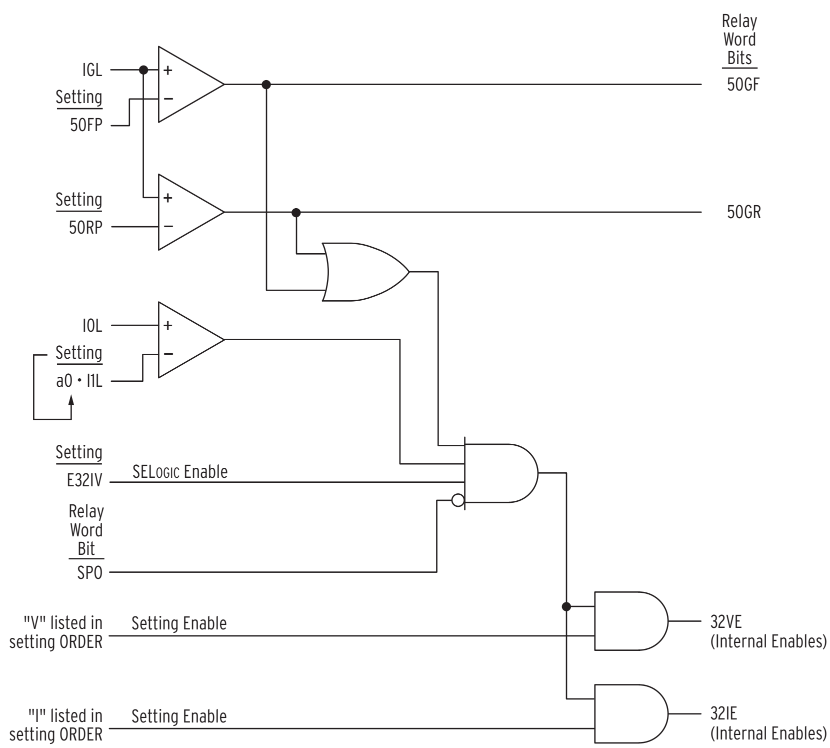


Figure 1.19 32V and 32I Enable Logic Diagram

Table 1.31 Ground Directional Element Relay Word Bits

Name	Description
32SPOF	Forward open-pole directional declaration
32SPOR	Reverse open-pole directional declaration
50QF	Forward negative-sequence supervisory current level detector
50QR	Reverse negative-sequence supervisory current level detector
32QE	32Q internal enable
32QGE	32QG internal enable
50GF	Forward zero-sequence supervisory current level detector
50GR	Reverse zero-sequence supervisory current level detector
32VE	32V internal enable
32IE	32I internal enable
32GF	Forward ground directional declaration
32GR	Reverse ground directional declaration
F32I	Forward current polarized zero-sequence directional element
R32I	Reverse current polarized zero-sequence directional element
F32V	Forward voltage polarized zero-sequence directional element
R32V	Forward voltage polarized zero-sequence directional element
F32QG	Forward negative-sequence ground directional element
R32QG	Forward negative-sequence ground directional element

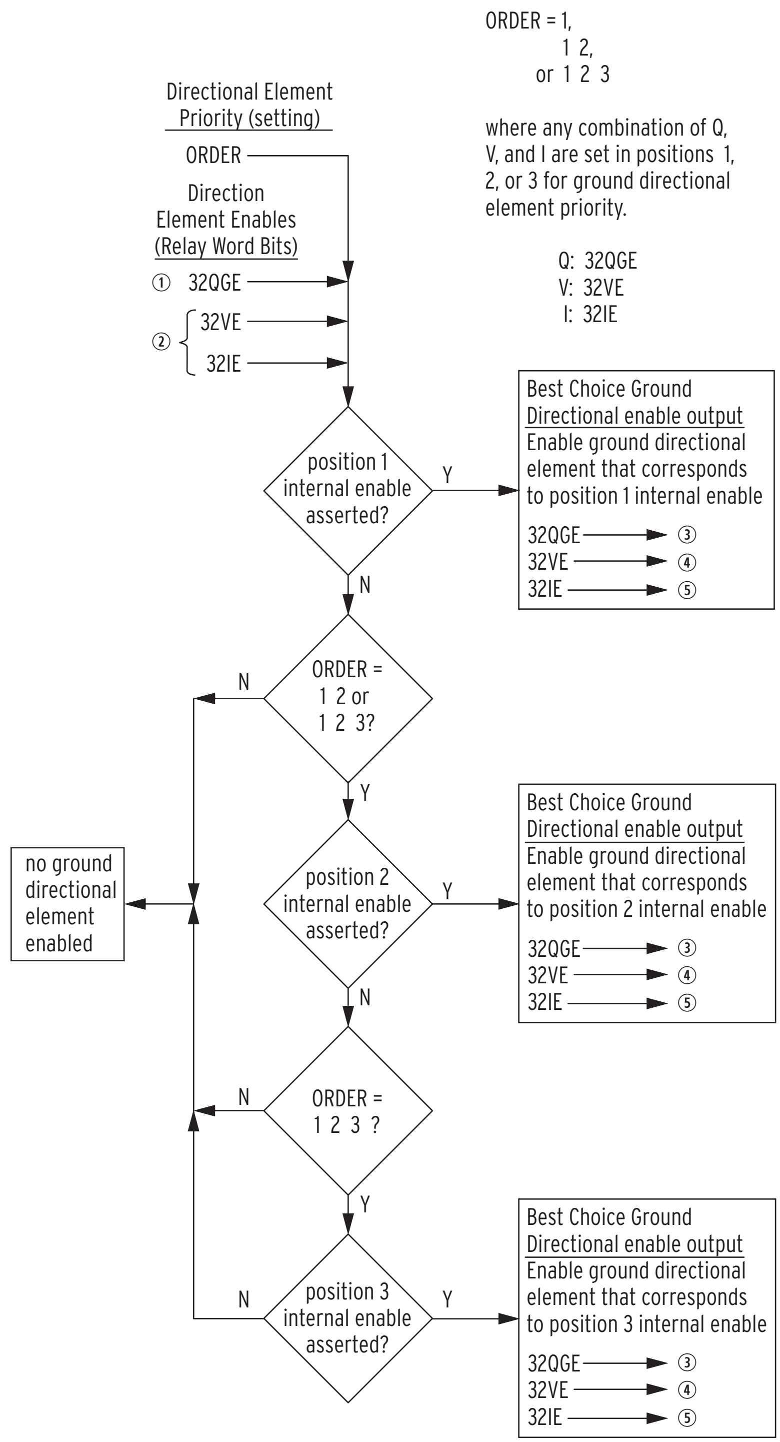


Figure 1.20 Best Choice Ground Directional Logic

① From Figure 1.19, ② From Figure 1.20, ③ To Figure 1.22, ④ To Figure 1.23, ⑤ To Figure 1.24

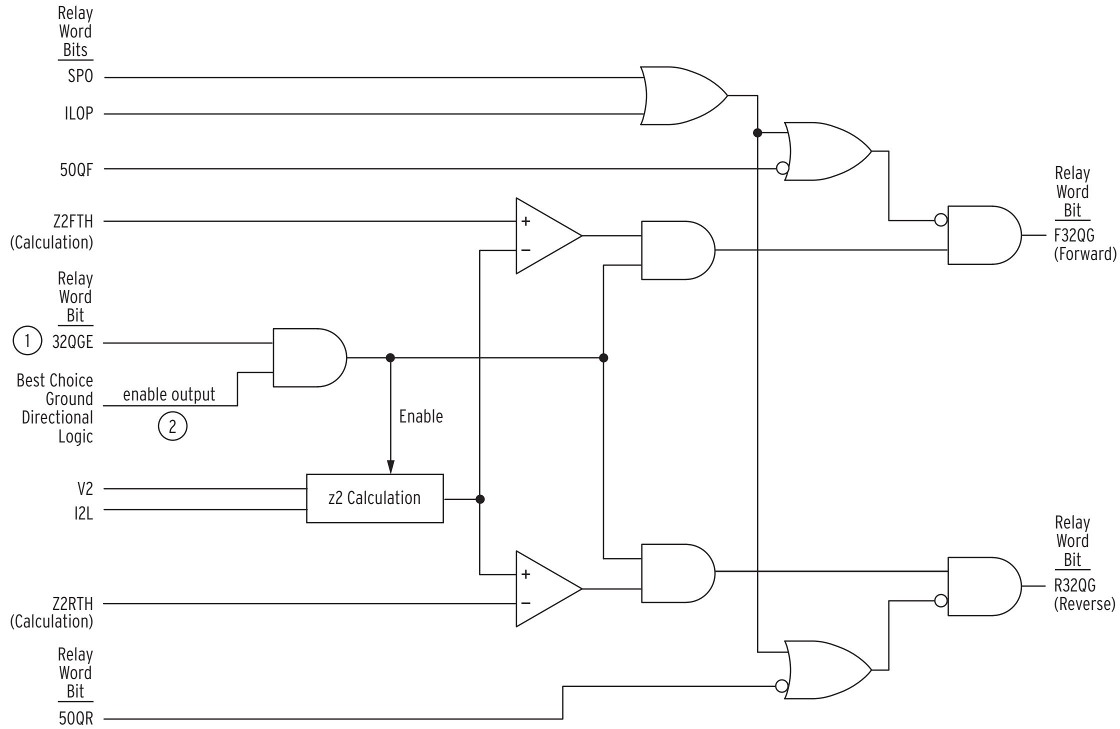


Figure 1.21 Negative-Sequence Voltage-Polarized Directional Element Logic

① From Figure 1.18; ② From Figure 1.20

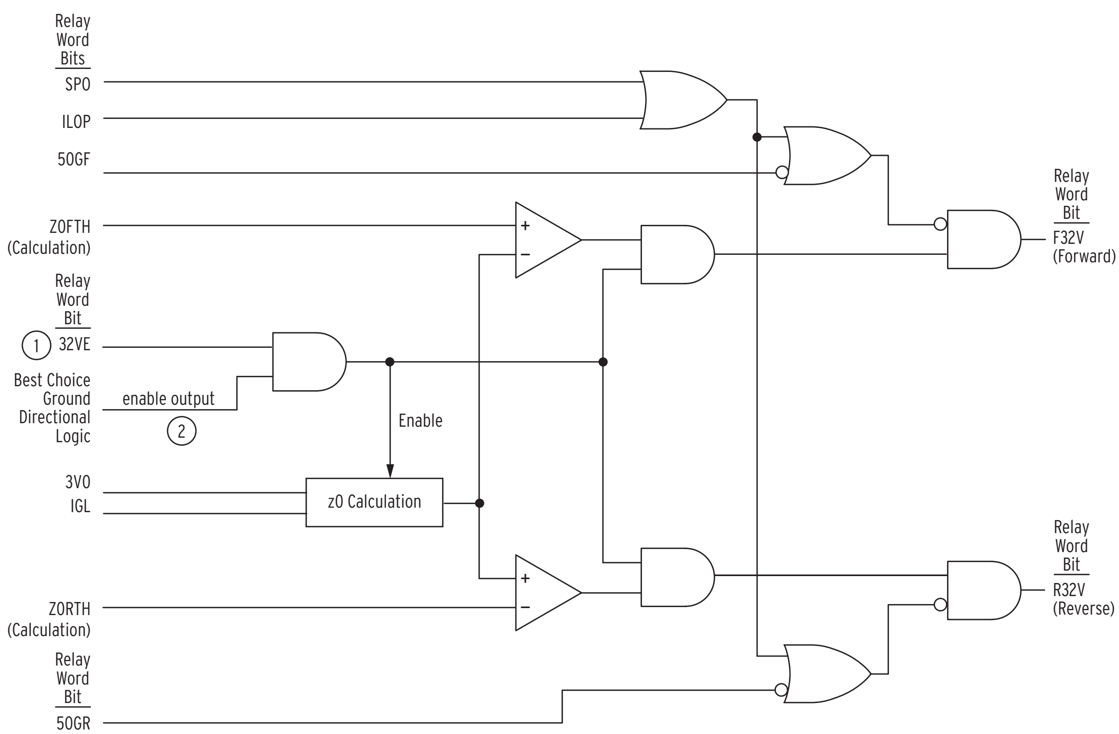


Figure 1.22 Zero-Sequence Voltage-Polarized Directional Element Logic

① From Figure 1.18; ② From Figure 1.20

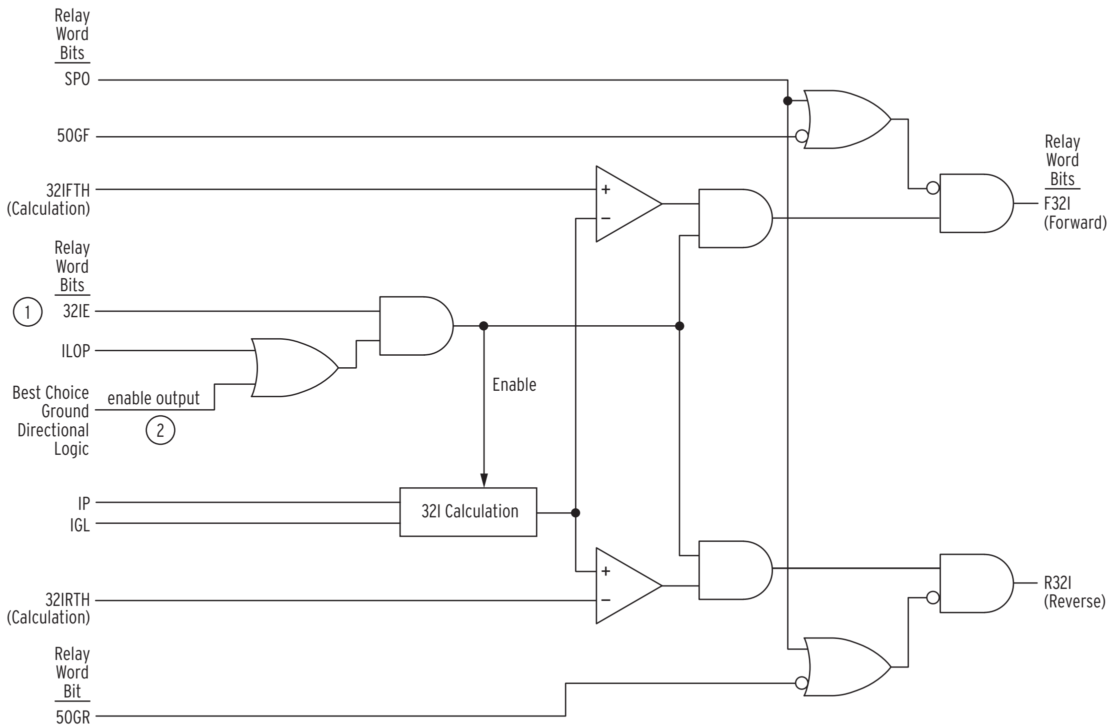


Figure 1.23 Zero-Sequence Current-Polarized Directional Element Logic

① From Figure 1.18; ② From Figure 1.20

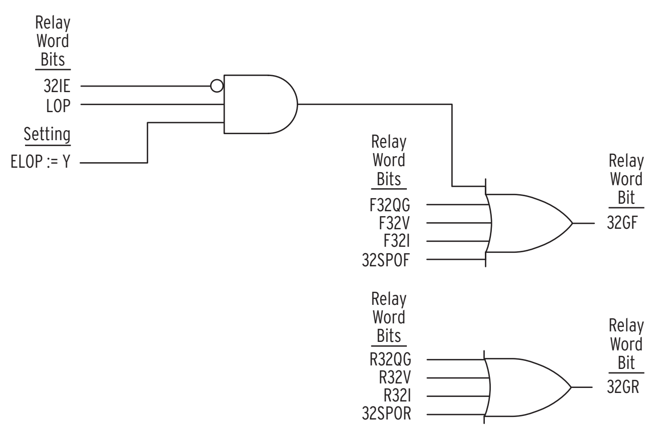


Figure 1.24 Ground Directional Element Output Logic Diagram

Table 1.32 Reference Table for Figure 1.21, Figure 1.22, and Figure 1.23

Name	Description
z2	Negative-sequence voltage-polarized directional element impedance calculation
Z2FTH	Negative-sequence voltage-polarized directional element forward threshold calculation
Z2RTH	Negative-sequence voltage-polarized directional element reverse threshold calculation
z0	Zero-sequence voltage-polarized directional element impedance calculation
Z0FTH	Zero-sequence voltage-polarized directional element forward threshold calculation
Z0RTH	Zero-sequence voltage-polarized directional element reverse threshold calculation
32I	Zero-sequence current-polarized directional element calculation
32IFTH	Zero-sequence current-polarized directional element forward threshold calculation
32IRTH	Zero-sequence current-polarized directional element reverse threshold calculation

Ground Directional Element Equations

For legibility, these equations use vector quantities, defined in *Table 1.33*. The analog quantities are listed in *Table B.2*.

Table 1.33 Vector Definitions for Equation 1.1 through Equation 1.11

Vector	Analog Quantities	Description
V_2	1/3 [3V2FIM] ∠ 3V2FIA	Negative-sequence voltage
V_0	1/3 [3V0FIM] ∠ 3V0FIA	Zero-sequence voltage
I_2	1/3 [L3I2FIM] ∠ L3I2FIA	Negative-sequence current
IG	LIGFIM ∠ LIGFIA	Zero-sequence current
IP	IPFIM ∠ IPFIA[a]	Polarizing current

[a] The polarizing current angle quantity, IPFIA, is an internal quantity only and is not available as an analog quantity.

32QG

Directional Calculation

$$z2 = \frac{\mathrm{Re}[V_2 \bullet (I_2 \bullet 1\angle Z1ANG)^*]}{|I_2|^2}$$

Equation 1.1

Forward Threshold

If Z2F is less than or equal to 0:

$$Z2FTH = 0.75 \bullet Z2F - 0.25 \bullet \left|\frac{V_2}{I_2}\right|$$

Equation 1.2

Z2F is greater than 0:

$$Z2FTH = 1.25 \bullet Z2F - 0.25 \bullet \left|\frac{V_2}{I_2}\right|$$

Equation 1.3

Reverse Threshold

If Z2R is greater than or equal to 0:

$$Z2RTH = 0.75 \bullet Z2R + 0.25 \bullet \left|\frac{V_2}{I_2}\right|$$

Equation 1.4

If Z2R is less than 0:

$$Z2RTH = 1.25 \bullet Z2R + 0.25 \bullet \left|\frac{V_2}{I_2}\right|$$

Equation 1.5

32V

Directional Calculation

$$z0 = \frac{Re[3V_0 \bullet (I_G \bullet 1\angle Z0ANG)^*]}{|I_G|^2}$$

Equation 1.6

Forward Threshold

If Z0F is less than or equal to 0:

$$Z0FTH = 0.75 \bullet Z0F - 0.25 \bullet \left|\frac{3V_0}{I_G}\right|$$

Equation 1.7

If Z0F is greater than 0:

$$Z0FTH = 1.25 \bullet Z0F - 0.25 \bullet \left|\frac{3V_0}{I_G}\right|$$

Equation 1.8

Reverse Threshold

If Z0R is greater than or equal to 0:

$$Z0RTH = 0.75 \bullet Z0R + 0.25 \bullet \left|\frac{3V_0}{I_G}\right|$$

Equation 1.9

If Z0R is less than 0:

$$Z0RTH = 1.25 \bullet Z0R + 0.25 \bullet \left|\frac{3V_0}{I_G}\right|$$

Equation 1.10

32I

Directional Calculation

$$32I = \mathrm{Re}[I_G \cdot I_P^{*}]$$ **Equation 1.11**

where:

I_P = Polarizing Current

Forward Threshold

$$32IFTH = 0.01 \cdot (\text{InX nominal rating}) \cdot (\text{nominal current rating})$$ **Equation 1.12**

Reverse Threshold

$$32IRTH = -0.01 \cdot (\text{InX nominal rating}) \cdot (\text{nominal current rating})$$ **Equation 1.13**

Phase and Negative-Sequence Directional Elements

Phase (32P) and negative-sequence voltage-polarized (32Q) directional elements supervise the phase distance elements. 32Q has priority over 32P. Relay Word bit ZLOAD (Load Impedance Detected) disables the 32P element. The 32Q element operates for all unbalanced faults.

When E32 := AUTO, you do not need to enter settings for 32Q or 32P elements. However, if you set E32 (Directional Control) to Y, the settings you enter for 50FP, 50RP, Z2F, Z2R, and a2 affect the 32Q element (see *Ground Directional Element on page R.1.28* for more details).

Table 1.34 Phase and Negative-Sequence Directional Elements Relay Word Bits

Name	Description
F32P	Forward phase directional declaration
R32P	Reverse phase directional declaration
F32Q	Forward negative-sequence directional declaration
R32Q	Reverse negative-sequence directional declaration
32QF	Forward negative-sequence overcurrent directional declaration
32QR	Reverse negative-sequence overcurrent directional declaration

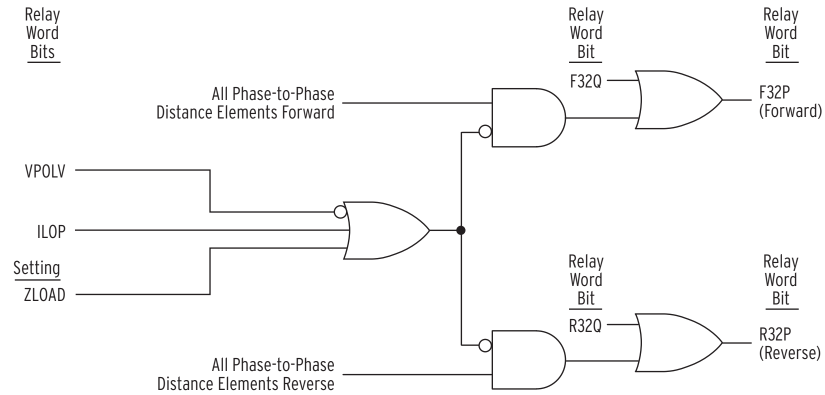


Figure 1.25 32P, Phase Directional Element Logic Diagram

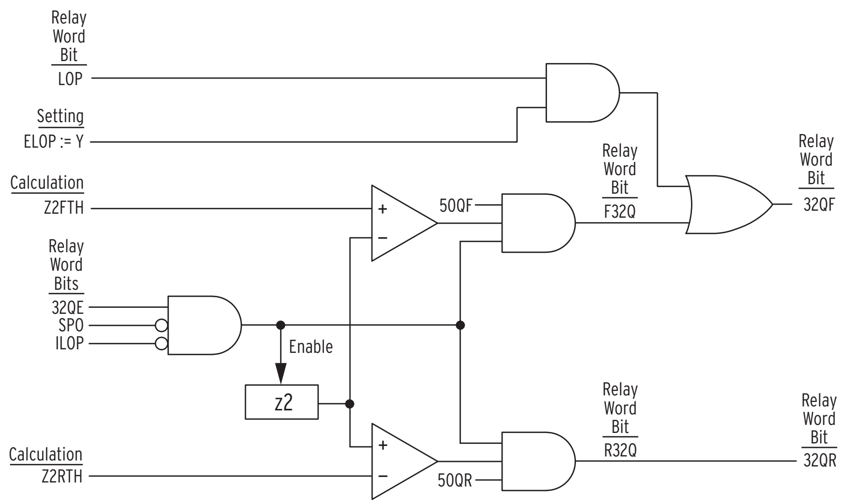


Figure 1.26 32Q, Negative-Sequence Directional Element Logic Diagram

Directionality

Zone 1 and Zone 2 distance element directions are fixed in the forward direction. You can select the other distance protection zones (Zone 3, Zone 4, and Zone 5) independently as forward-looking (F), or reverse-looking (R) with settings DIR3, DIR4, and DIR5.

Level 1 and Level 2 directional overcurrent element directions are fixed in the forward direction for residual ground and negative-sequence directional overcurrent elements. Level 3 and Level 4 residual and negative-sequence directional overcurrent elements (67Q3, 67Q4, 67G3, and 67G4) share the same direction as the corresponding zones of distance protection, also using settings DIR3 and DIR4.

This directional control option is performed in addition to the regular torque control settings for each element (the torque control setting acts as a supervisory input).

The phase directional overcurrent elements (67P1–67P4) and the selectable operating quantity time-overcurrent elements (51S1–51S3) do not have any built-in directional control. The torque control settings (67P1TC, 67P2TC,

67P3TC, 67P4TC, 51S1TC, 51S2TC, 51S3TC) can be used to achieve directional control, as shown in the *230 kV Overhead Transmission Line Example on page A.1.2*.

Table 1.35 Zone Directional Settings

Setting	Description	Range	Default
DIR3	Zone/Level 3 Directional Control	F, R	R
DIR4	Zone/Level 4 Directional Control	F, R	F
DIR5	Zone/Level 5 Directional Control	F, R	F

CVT Transient Detection

The SEL-421 detects CVT (Capacitor Voltage Transformer) transients that can cause Zone 1 distance elements to overreach during external faults. If CVT transient blocking is enabled and the relay detects a high SIR (source-to-impedance ratio) when a Zone 1 distance element is picked up, the relay delays tripping for as long as 1.5 cycles to allow the CVT transients to stabilize.

You do not need to enter settings. The relay adapts automatically to different system SIR conditions by monitoring the measured voltage and current.

If the distance calculation does not change significantly (i.e., is smooth), the SEL-421 unblocks CVT transient blocking resulting from low voltage and low current during close-in faults driven by a source with a high SIR. Therefore, Zone 1 distance elements operate without significant delay for close-in faults.

Consider using CVT transient detection logic when you have either of the following two conditions:

- ➤ SIR greater than or equal to five
- ➤ CVTs with AFSC (active ferroresonance-suppression circuits)

The following conditions can aggravate CVT transients:

- ➤ CVT secondary with a mostly inductive burden
- ➤ A low C value CVT, as defined by the manufacturer

Table 1.36 CVT Transient Detection Logic Setting

Name	Description	Range	Default
ECVT	CVT Transient Detection	Y, N	N

Table 1.37 CVT Transient Detection Logic Relay Word Bit

Name	Description
CVTBL	CVT transient blocking active

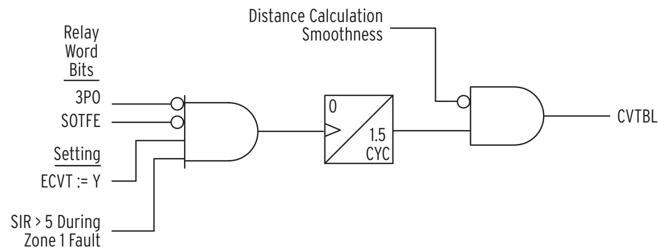


Figure 1.27 CVT Transient Detection Logic

SIR is defined as follows:

$$\mathrm{SIR} = \frac{Z_{1S}}{Z_R}$$

where:

Z_{1S} = positive-sequence source impedance
Z_R = distance element reach

Use the Zone 1 distance element reach (Z1P, Z1MG, or XG1) since the CVT transient detection logic only supervises Zone 1 distance protection.

Series-Compensation Line Logic

NOTE: The SEL-421-1 and the SEL-421-2 do not provide series-compensated line protection logic.

The SEL-421 includes logic to detect when a fault is beyond a series capacitor (a series capacitor can possibly cause Zone 1 overreach). The relay blocks the Zone 1 elements until the series-compensation logic determines that the fault is between the relay and the series capacitor (i.e., the fault is on the protected line section).

The value that you enter for setting XC depends on the position of the series-compensation capacitor(s) relative to the relay potential transformers. Capacitors can be on either end of a line, in the middle of a line, or at both ends of a line. Capacitors that are external to a protected line section can have an effect if infeed conditions are present.

In applications where there is a series capacitor on an adjacent line, for any SEL-421 relays on non-compensated lines, set ESERCMP := Y and XC := OFF. This allows the Zone 1 element to be set to the desired sensitivity, yet still be secure during the voltage reversal that will occur when a neighboring compensated line experiences a fault.

For more information on setting the relay for series-compensated lines see SEL *Application Guide 2000-11: Applying the* SEL-*321 Relay on Series-Compensated Systems*.

Table 1.38 Series-Compensation Line Logic Relay Settings

Name	Description	Range	Default (5 A)
ESERCMP	Series-Compensation Line Logic	Y, N	N
XC	Series Capacitor Reactance (Ω)	(OFF, 0.25–320 Ω)/I_{nom}	OFF

Load-Encroachment Logic

The load-encroachment logic prevents load from causing phase protection to operate. You can set the phase distance and phase overcurrent elements independent of load. Two independent positive-sequence impedance characteristics monitor the positive-sequence load impedance (Z_1) for both export and import load. The positive-sequence voltage-polarized directional element (32P) is blocked when the load-encroachment logic is enabled and load is detected. The phase distance elements cannot operate during balanced system conditions unless the logic asserts the 32P element.

Figure 1.28 illustrates the load-encroachment logic. The logic operates only if the positive-sequence current (I_1) is greater than the positive-sequence threshold (10 percent of the nominal relay current). Relay Word bit ZLOUT indicates that load is flowing out with respect to the relay (an export condition). Relay Word bit ZLIN indicates that load is flowing in with respect to the relay (an import condition). *Figure 1.29* illustrates load-encroachment settings and corresponding characteristics in the positive-sequence impedance plane. Either Relay Word bit ZLOUT or ZLIN asserts if the relay measures a positive-sequence impedance that lies within the corresponding hatched region. Relay Word bit ZLOAD is the OR combination of ZLOUT and ZLIN.

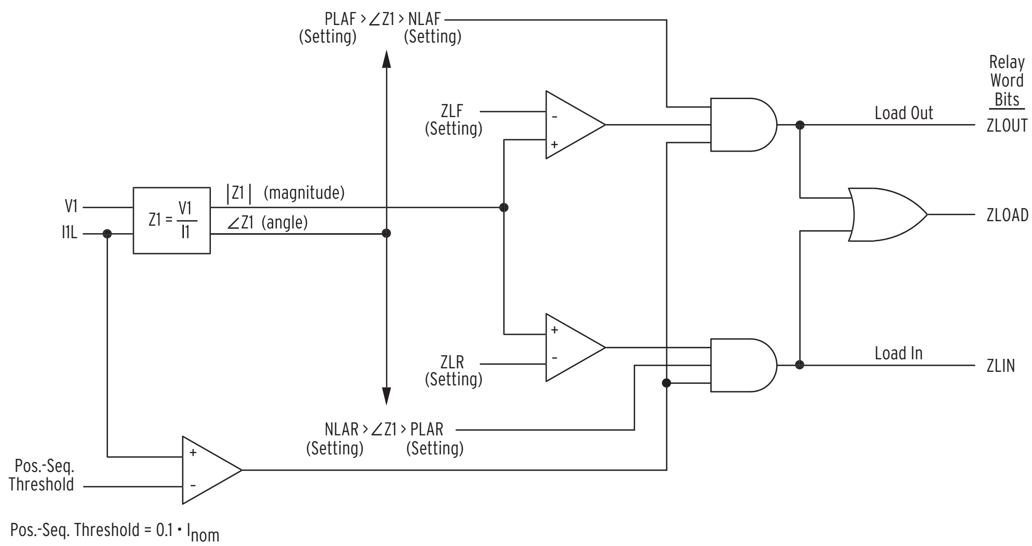


Figure 1.28 Load-Encroachment Logic Diagram

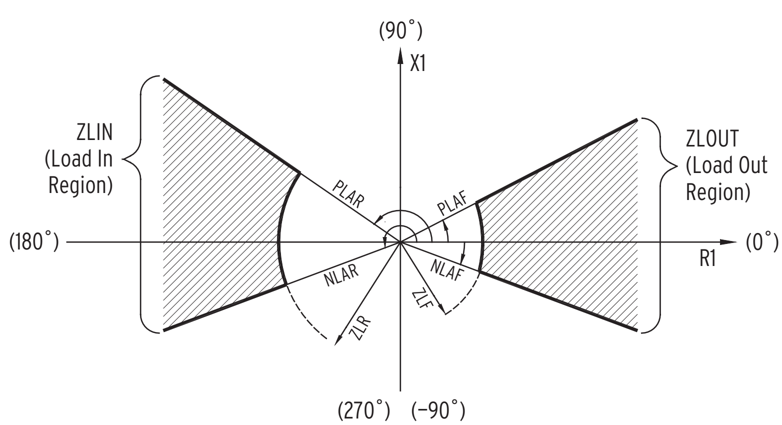


Figure 1.29 Load-Encroachment Characteristics

Table 1.39 Load-Encroachment Logic Relay Settings

Name	Description	Range	Default (5 A)
ELOAD	Load Encroachment	Y, N	Y
ZLF	Forward Load Impedance (Ω)	(0.25–320)/I_{nom}	9.22
ZLR	Reverse Load Impedance (Ω)	(0.25–320)/I_{nom}	9.22
PLAF	Forward Load Positive Angle (°)	–90.0 to +90	30.0
NLAF	Forward Load Negative Angle (°)	–90.0 to +90	–30.0
PLAR	Reverse Load Positive Angle (°)	90.0–270	150.0
NLAR	Reverse Load Negative Angle (°)	90.0–270	210.0

Table 1.40 Load-Encroachment Logic Relay Word Bits

Name	Description
ZLOAD	ZLIN OR ZLOUT
ZLIN	Import load impedance detected
ZLOUT	Export load impedance detected

Out-of-Step Logic

The out-of-step (OOS) logic determines whether a power swing is stable. This relay logic can be set to either block distance protection or allow tripping when the measured positive-sequence impedance (Z_1) remains between inner Zone 6 and outer Zone 7 longer than either the OOS blocking delay (setting OSBD) or the OOS tripping delay (setting OSTD), respectively (refer to *Figure 1.30*).

NOTE: E50Q must be set to 1 or greater for enabling 67Q1T override of OOS blocking for Zone 1 (see Figure 1.35, Figure 1.38, and Figure 1.41).

The relay offers two mutually exclusive ways to override the Zone 1 OOS blocking logic should an unbalanced Zone 1 fault occur during an OOS condition (see *Figure 1.32* for more detail). When EOOS = Y, the override logic uses Relay Word bit 67Q1T to defeat the OOS logic for Zone 1 faults. When EOOS = Y2, the override logic uses Relay Word bit 67QUBF to defeat the OOS logic for Zone 1 faults. Using the EOOS = Y2 option replaces the 67Q1T directional element in the Zone 1 mho phase distance elements and the Zone 1 mho ground and the Zone 1 quadrilateral ground distance elements with the 67QUBF directional element. Other distance elements (mho and quadrilateral) operate the same whether EOOS = Y or Y2, except that the UBD time delay is not settable, but is fixed at 1.5 cycles when EOOS = Y2.

In general, the OOS logic detects all power swings that enter the OOS characteristics; even if a single-pole open condition exists (Relay Word bit SPO equals logical 1). If negative-sequence directional element 67Q1T (EOOS = Y) or 67QUBF (EOOS = Y2) picks up during a power swing and a single-pole open condition does not exist (Relay Word bit SPO equals logical 0), the logic overrides OOS blocking (i.e., an unbalanced fault has occurred) of the Zone 1 ground and phase distance elements.

If negative-sequence directional element 67QUBF (EOOS = Y or Y2) picks up during a power swing and a single-pole open condition does not exist (Relay Word bit SPO equals logical 0), the logic overrides OOS blocking (i.e., an unbalanced fault has occurred) of the Zone 2 phase distance elements.

If negative-sequence directional element 67QUBF (for forward zones, and EOOS = Y or Y2) or 67QUBR (for reverse zones, and EOOS = Y or Y2) picks up during a power swing and a single-pole open condition does not exist (Relay Word bit SPO equals logical 0), the logic overrides OOS blocking (i.e., an unbalanced fault has occurred) of the Zone 3, 4 or 5 phase distance elements.

Table 1.41 shows the Relay Word bits that override OOS blocking during a power swing. In all cases, a single-pole open condition does not exist (Relay Word bit SPO equals logical 0).

Table 1.41 Relay Word Bits That Override OOS Blocking

	67Q1T	67QUBF	67QUBR
EOOS = Y	Zone 1	Forward-looking zones (2, 3, 4, or 5)	Reverse-looking zones (3, 4, or 5)
EOOS = Y2		Forward-looking zones (1, 2, 3, 4, or 5)	Reverse-looking zones (3, 4, or 5)

When EOOS = Y, the negative-sequence current level detector 50QUB determines the sensitivity of the 67QUBF or 67QUBR elements for all zones except Zone 1. When EOOS = Y2, positive-sequence unbalance factor a2 determines the sensitivity of the 67QUBF and 67QUBR elements.

The following describes the differences between setting EOOS = Y and Y2.

When EOOS = Y, the relay supervises the 67QUBF and 67QUBR elements with negative-sequence pickup setting 50QUBP (see *Figure 1.32* for more detail). When you set the 50QUBP pickup level to something other than OFF, the level of negative-sequence current exceeds the 50QUBP setting threshold, and the relay has made a valid directional decision (32 elements), the relay asserts either the 67QUBF or the 67QUBR directional element after time-delay setting UBD. In this manner, the relay removes out-of-step blocking for phase distance elements other than Zone 1 elements during unbalanced faults.

When EOOS = Y2, the relay does not use the 50QUBP pickup setting to supervise the 67QUBF and 67QUBR elements. Instead, the relay uses the positive-sequence current factor a2 multiplied by three times the positive-sequence current magnitude to supervise the 67QUBF and 67QUBR elements (see *Figure 1.32* for more detail). If the negative-sequence current exceeds this factor and if the relay has made a valid directional decision (32 elements), the relay asserts either the 67QUBF or the 67QUBR directional element after a fixed time delay of 1.5 cycles. In this manner, the relay removes out-of-step blocking for phase distance elements (including Zone 1 elements) during unbalanced faults.

Table 1.42 summarizes the differences between setting EOOS = Y and Y2.

Table 1.42 Differences between EOOS = Y and EOOS = Y2 Settings and Zone 1 OOS Unblocking

	EOOS = Y	EOOS = Y2
Unblock Zone 1	67Q1T	67QUBF
Settings	E50Q, 50Q1P, 67Q1D, 67Q1TC, UBD[a], 50QUBP, UBOSFB	a2

[a] When setting EOOS = Y2, the unblock delay time is fixed at 1.5 cycles.

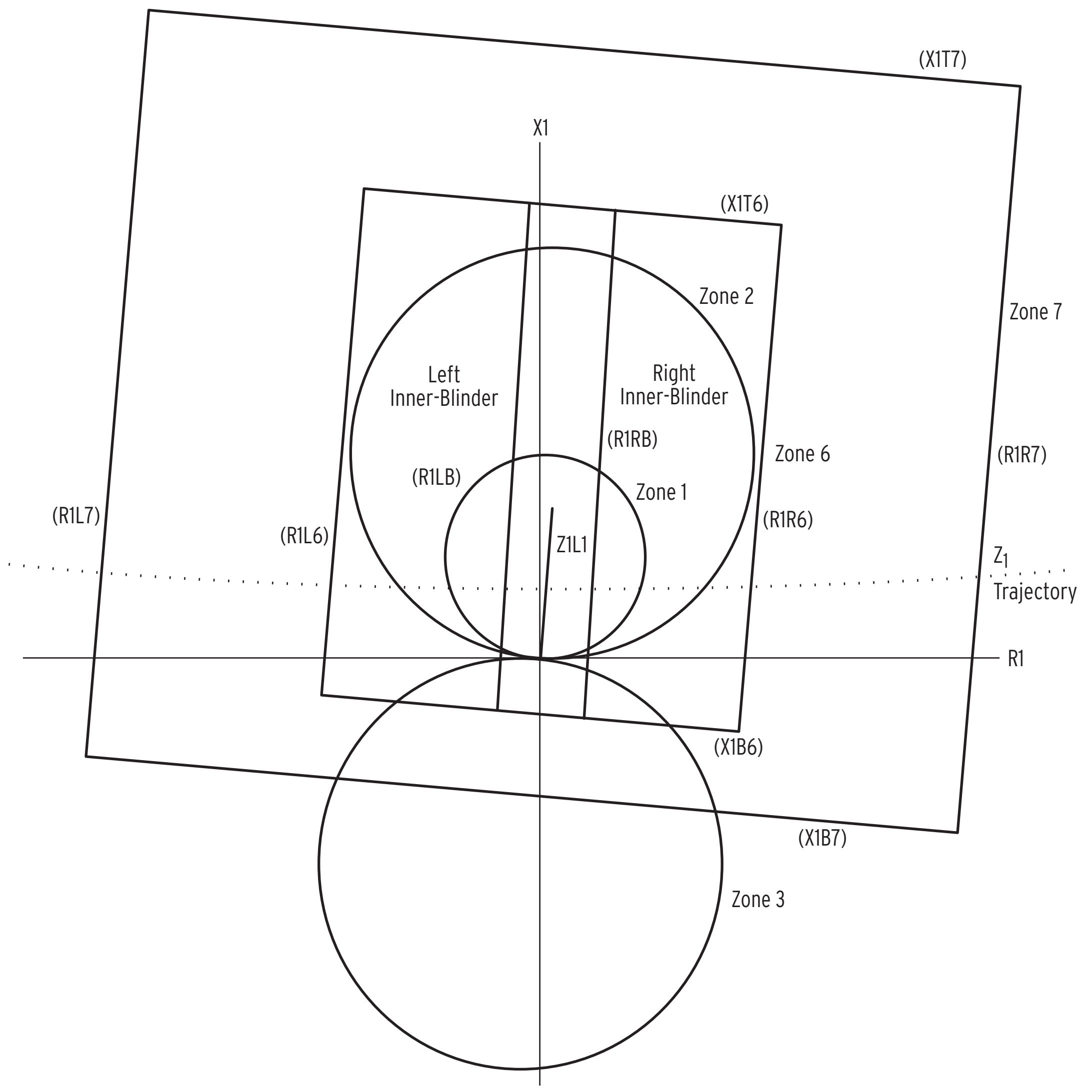


Figure 1.30 OOS Characteristics

If a three-phase fault occurs during a power swing that has operated the OOS logic, the logic also overrides OOS blocking; a set of internally derived inner blinders encompasses the protected line and detects internal three-phase faults. The OOS logic can also detect a power swing when a single-pole open condition exists; for such a case, the logic can block both phase and ground distance protection.

Refer to *Section 1: Protection Application Examples in the Applications Handbook* for detailed descriptions of the various functions utilized by the OOS logic.

The following rules apply when you set the OOS logic:

- You can enable the OOS logic when setting Z1ANG is greater than 45 degrees.
- Settings X1T6, X1T7, R1R6, and R1R7 must be set to a positive value.
- Settings X1B6, X1B7, R1L6, and R1L7 must be set to a negative value.
- Setting R1R6 must be set less than R1R7.

- ➤ Setting R1L6 must be set greater than R1L7.
- ➤ Setting X1T6 must be set less than X1T7.
- ➤ Setting X1B6 must be set greater than X1B7.
- ➤ The minimum separation between settings R1R6 and R1R7 is $0.25/I_{nom}$.
- ➤ The minimum separation between settings R1L6 and R1L7 is $0.25/I_{nom}$.
- ➤ The minimum separation between settings X1T6 and X1T7 is $0.25/I_{nom}$.
- ➤ The minimum separation between settings X1B6 and X1B7 is $0.25/I_{nom}$.
- ➤ Setting OSBD must be greater than OSTD by a minimum of 0.5 cycle.

Table 1.43 OOS Logic Relay Settings

Name	Description	Range	Default (5 A)
EOOS	Out-of-Step	Y, Y2, N	N
OOSB1	Block Zone 1	Y, N	Y
OOSB2	Block Zone 2	Y, N	Y
OOSB3	Block Zone 3	Y, N	Y
OOSB4	Block Zone 4	Y, N	N
OOSB5	Block Zone 5	Y, N	N
OSBD	Out-of-Step Block Time Delay (cycles)	0.500–8000	2.000
OSBLTCH	Latch Out-of-Step Blocking[a]	Y, N	N
EOOST	Out-of-Step Trip Delay[b]	N, I, O	N
OSTD	Out-of-Step Trip Delay (cycles)	0.500–8000	0.500
X1T7	Zone 7 Reactance—Top (Ω)	$(0.25–480)/I_{nom}$	23.00
X1T6	Zone 6 Reactance—Top (Ω)	$(0.25–480)/I_{nom}$	21.00
R1R7	Zone 7 Resistance—Right (Ω)	$(0.25–350)/I_{nom}$	23.00
R1R6	Zone 6 Resistance—Right (Ω)	$(0.25–350)/I_{nom}$	21.00
X1B7[c]	Zone 7 Reactance—Bottom (Ω)	$(–0.25–480)/I_{nom}$	–23.00
X1B6[c]	Zone 6 Reactance—Bottom (Ω)	$(–0.25–480)/I_{nom}$	–21.00
R1L7[c]	Zone 7 Resistance—Left (Ω)	$(–0.25–350)/I_{nom}$	–23.00
R1L6[c]	Zone 6 Resistance—Left (Ω)	$(–0.25–350)/I_{nom}$	–21.00
50ABCP[c]	Pos.-Seq. Current Supervision (A)	$(0.20–20) \cdot I_{nom}$	1.00
50QUBP[c,d]	Neg.-Seq. Current Supervision (A)	$(\text{OFF}, 0.10–20) \cdot I_{nom}$	OFF
UBD[c,d]	Neg.-Seq. Current Unblock Delay (cycles)	0.500–120	0.500
UBOSBF[c]	Out-of-Step Angle Unblock Rate (three-phase)	1–10	4

[a] The OSB (Out-of-Step Blocking) logic resets automatically after it asserts for more than 2 seconds. You can latch OSB if the power swing moves outside of Zone 6 before the two-second timer expires.
[b] Option I enables tripping on the way into Zone 6; option O enables tripping on the way out of Zone 6; option N disabled OST (Out-of-Step Trip).
[c] Advanced Setting if EADVS := Y. If the Advanced Settings are not enabled (setting EADVS := N), the relay hides the setting.
[d] Hidden when EOOS = Y2.

Table 1.44 OOS Logic Relay Word Bits

Name	Description
50ABC	Positive-sequence current level detector
X6ABC	Zone 6
X7ABC	Zone 7
UBOSB	Unblock out-of-step blocking
OSB	Out-of-step blocking
OSTI	Incoming out-of-step tripping
OSTO	Outgoing out-of-step tripping
OST	Out-of-step tripping
67QUBF	Negative-sequence forward directional element
67QUBR	Negative-sequence reverse directional element
OOSDET	OOS condition detected
OSB1	Block Zone 1 during out-of-step condition
OSB2	Block Zone 2 during out-of-step condition
OSB3	Block Zone 3 during out-of-step condition
OSB4	Block Zone 4 during out-of-step condition
OSB5	Block Zone 5 during out-of-step condition
OSBA	A-Phase out-of-step blocking
OSBB	B-Phase out-of-step blocking
OSBC	C-Phase out-of-step blocking

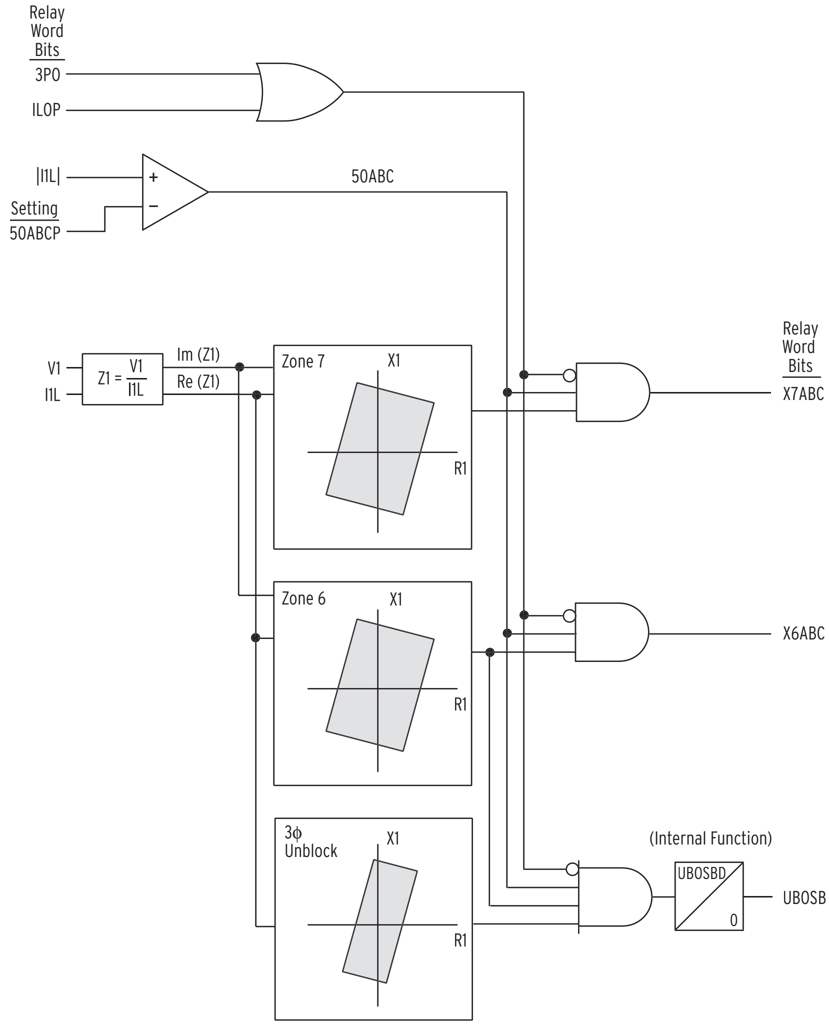


Figure 1.31 OOS Positive-Sequence Measurements

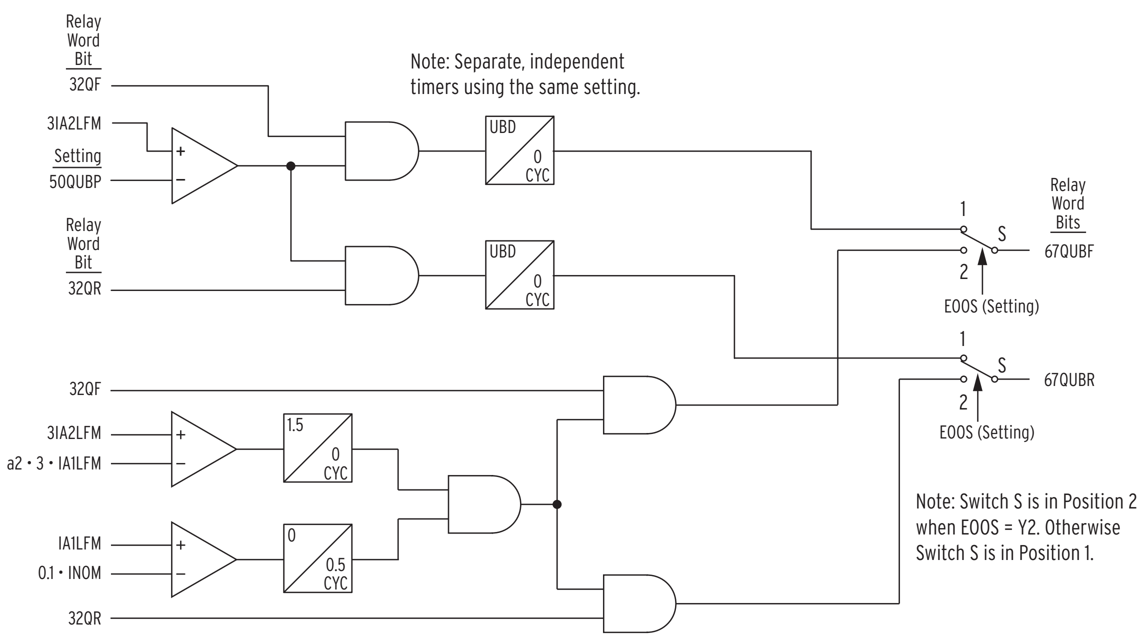


Figure 1.32 OOS Override Logic

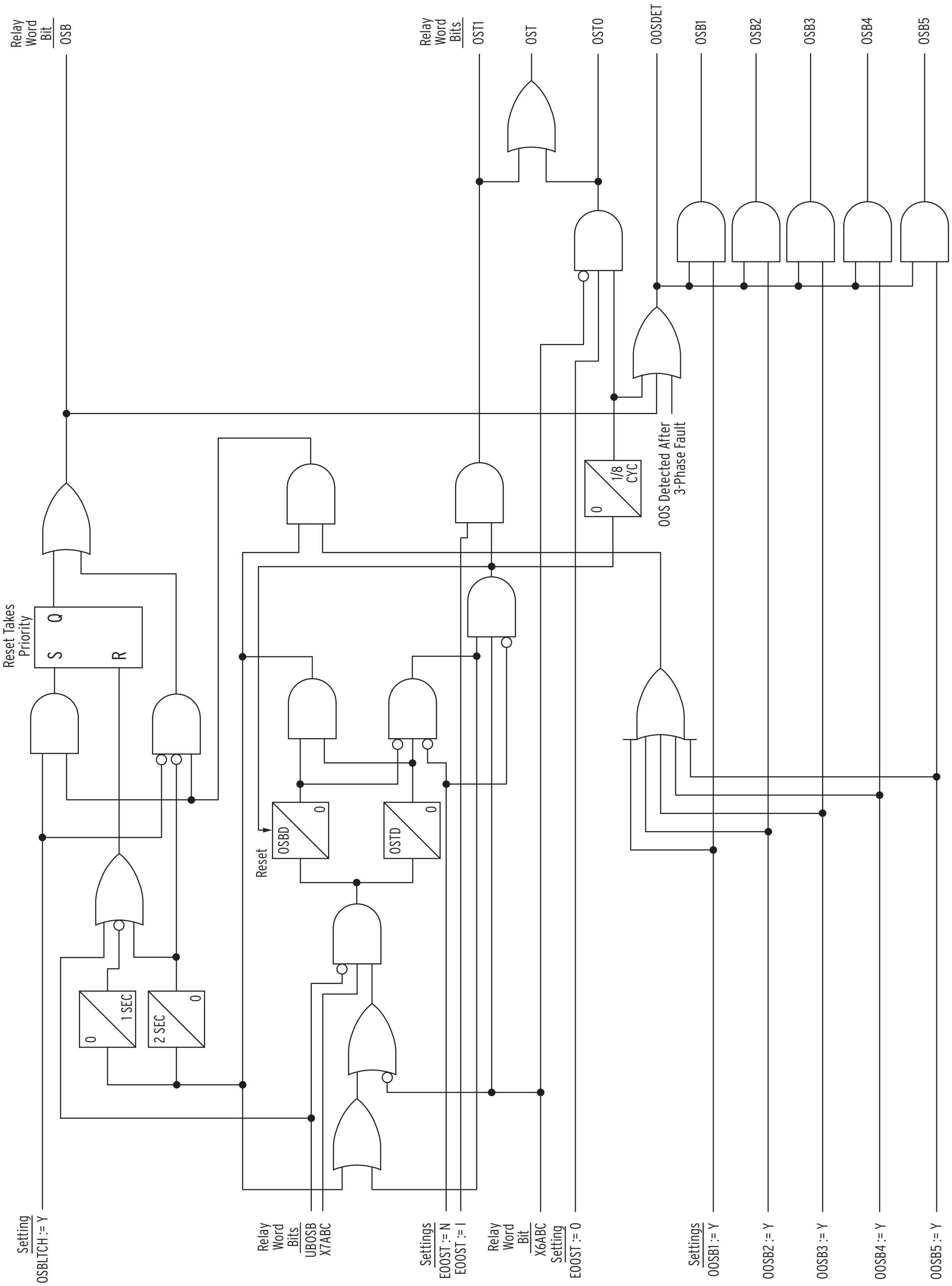


Figure 1.33 OOS Logic Diagram

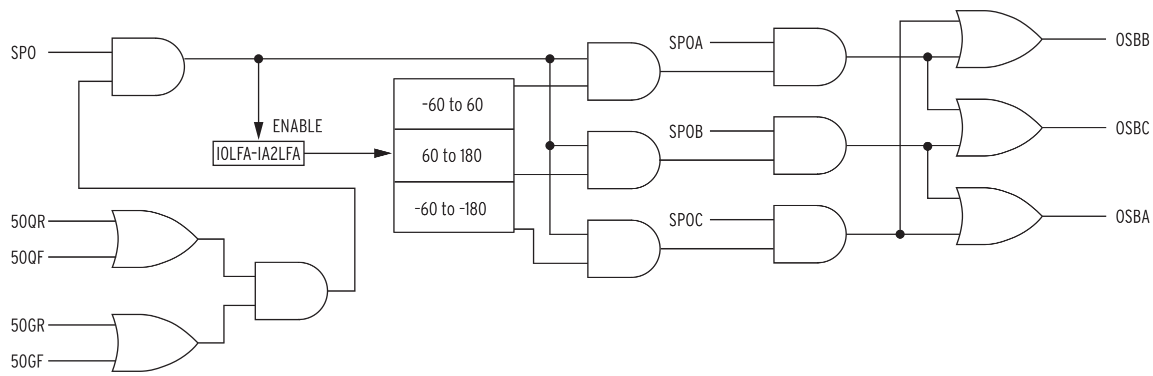


Figure 1.34 Open-Pole OSB Unblock Logic

Mho Ground Distance Elements

The SEL-421 has five independent zones of mho ground distance protection. The mho ground distance protection operates only for single phase-to-ground faults. You can set the reach for each zone independently. Zone 1 and Zone 2 distance elements are forward only; you can set Zone 3 through Zone 5 distance elements either forward or reverse. The mho ground distance elements use positive-sequence voltage polarization for security and generate a dynamic expanding mho characteristic.

NOTE: The SEL-421-1 and the SEL-421-2 provide fast and secure tripping but do not have high-speed distance elements. Typical detection time for the SEL-421-1 and for the SEL-421-2 is 1.5 cycles.

The SEL-421 has three independent zones of high-speed mho ground distance protection. The high-speed mho ground distance protection operates for single phase-to-ground faults. The first three zones of mho ground distance protection (Zones 1 through 3) are for high-speed operation; typical detection time is less than one cycle.

The Zone 1 zero-sequence compensation factor (k01) is independent from the forward and reverse compensation factors (k0 and k0R) the relay uses for the other zones.

If you set k0M1 to AUTO, the relay automatically calculates the values k01, k0, and k0R based on the following equation:

$$k0 = \frac{Z_{0L} - Z_{1L}}{3 \cdot Z_{1L}}$$

Equation 1.14

where:

Z_{1L} = positive-sequence transmission line impedance
Z_{0L} = zero-sequence transmission line impedance

Table 1.45 Mho Ground Distance Element Settings

Name	Description	Range	Default (5 A)
E21MG	Mho Phase Distance Protection	N, 1 to 5	3
Mho Ground Distance Element Reach			
Z1MG	Zone 1 (Ω)	OFF, (0.25–320)/I_{nom}	6.24
Z2MG	Zone 2 (Ω)	OFF, (0.25–320)/I_{nom}	9.36
Z3MG	Zone 3 (Ω)	OFF, (0.25–320)/I_{nom}	1.87
Z4MG	Zone 4 (Ω)	OFF, (0.25–320)/I_{nom}	OFF
Z5MG	Zone 5 (Ω)	OFF, (0.25–320)/I_{nom}	OFF
Zero-Sequence Compensation Factor			
k0M1	Zone 1 ZSC Factor Magnitude	AUTO, 0.000–10	0.726
k0A1	Zone 1 ZSC Factor Angle (°)	–180.00 to +180	–3.69
k0M[a]	Forward Zones ZSC Factor Magnitude	0.000–10	0.726
k0A[a]	Forward Zones ZSC Factor Angle (°)	–180.00 to +180	–3.69
k0MR[a]	Reverse Zones ZSC Factor Magnitude	0.000–10	0.726
k0AR[a]	Reverse Zones ZSC Factor Angle (°)	–180.00 to +180	–3.69

[a] Advanced Setting if EADVS := Y. If the Advanced Settings are not enabled (setting EADVS := N), the relay hides the settings.

Table 1.46 Mho Ground Distance Elements Relay Word Bits

Name	Description
MAG1	Zone 1 A-phase mho ground distance element
MBG1	Zone 1 B-phase mho ground distance element
MCG1	Zone 1 C-phase mho ground distance element
MAG2	Zone 2 A-phase mho ground distance element
MBG2	Zone 2 B-phase mho ground distance element
MCG2	Zone 2 C-phase mho ground distance element
MAG3	Zone 3 A-phase mho ground distance element
MBG3	Zone 3 B-phase mho ground distance element
MCG3	Zone 3 C-phase mho ground distance element
MAG4	Zone 4 A-phase mho ground distance element
MBG4	Zone 4 B-phase mho ground distance element
MCG4	Zone 4 C-phase mho ground distance element
MAG5	Zone 5 A-phase mho ground distance element
MBG5	Zone 5 B-phase mho ground distance element
MCG5	Zone 5 C-phase mho ground distance element
Z1G	Zone 1 ground distance element
Z2G	Zone 2 ground distance element
Z3G	Zone 3 ground distance element
Z4G	Zone 4 ground distance element
Z5G	Zone 5 ground distance element

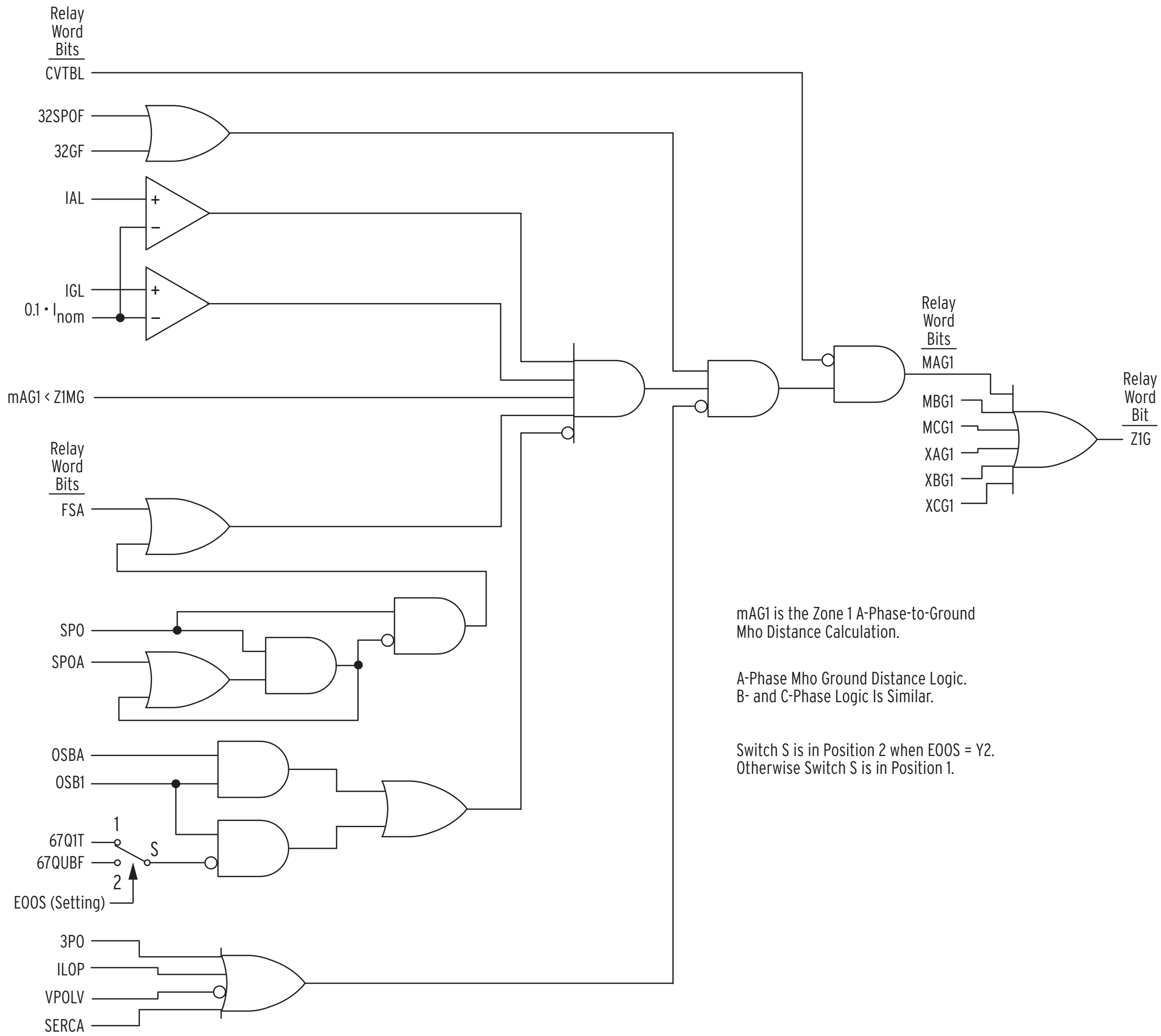


Figure 1.35 Zone 1 Mho Ground Distance Element Logic Diagram

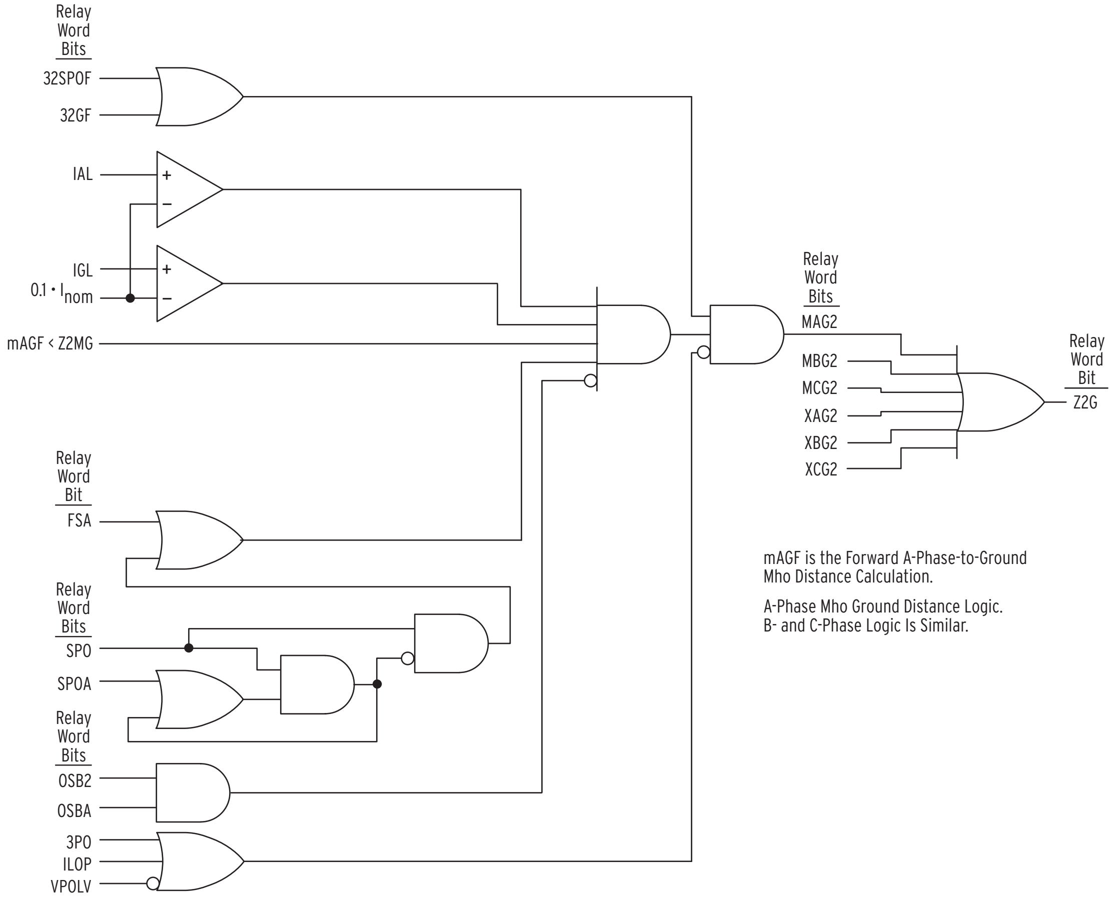


Figure 1.36 Zone 2 Mho Ground Distance Element Logic Diagram

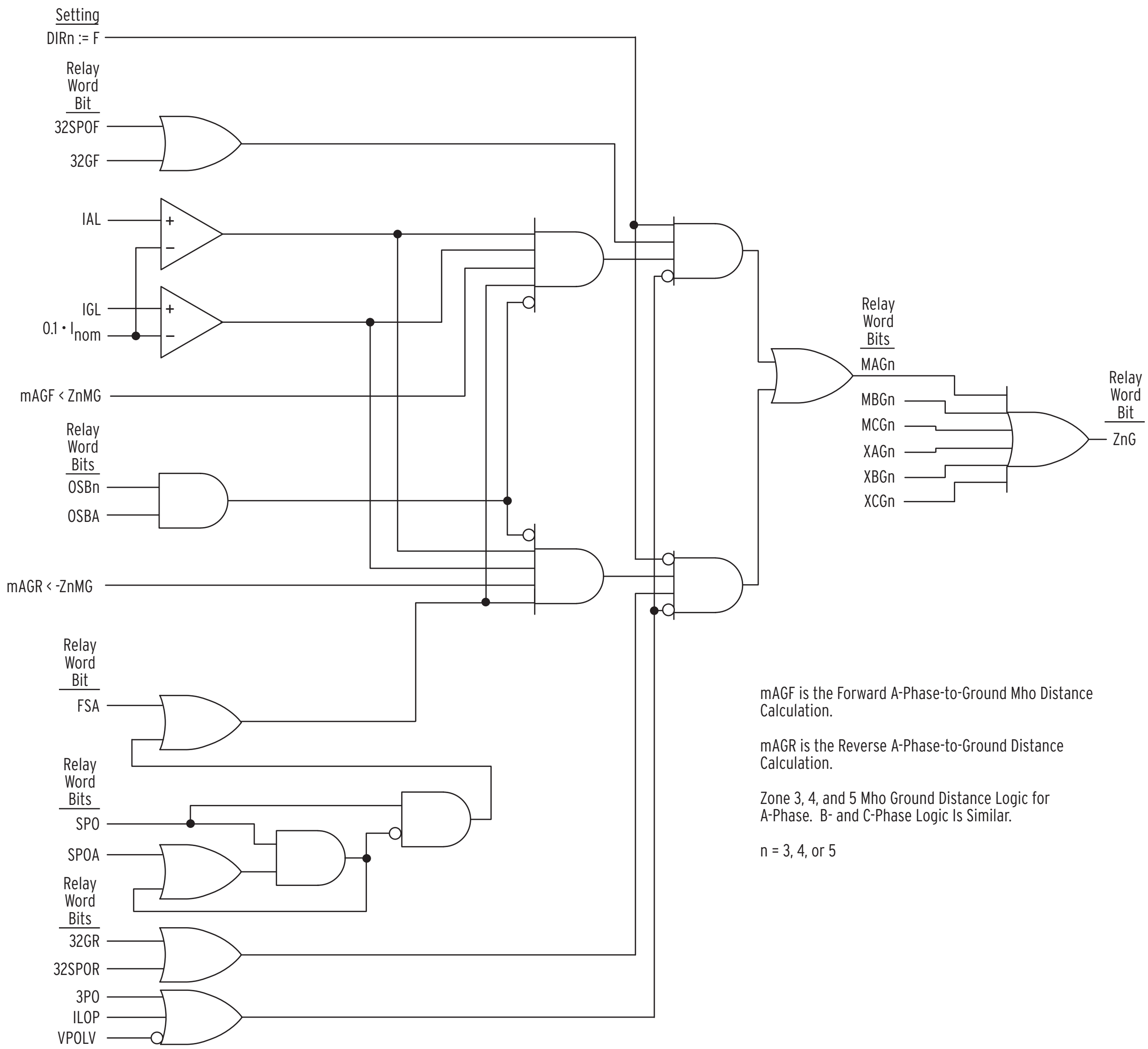


Figure 1.37 Zones 3, 4, and 5 Mho Ground Distance Element Logic Diagram

Quadrilateral Ground Distance Elements

The SEL-421 has five independent zones of quadrilateral ground distance protection. The quadrilateral ground distance protection only operates for single phase-to-ground faults.

Set the reactance (XG) and resistive (RG) reach for each zone independently. Rather than 90 degrees (purely reactive), the reactance measurement lies along the setting Z1ANG (complex).

Zone 1 and Zone 2 distance elements are forward only, while you can set Zone 3 through Zone 5 distance elements either forward or reverse.

You select whether the quadrilateral ground distance elements use negative- or zero-sequence current to polarize the reactance line when the Advanced Settings are enabled (setting EADVS := Y); otherwise, negative-sequence current is the default setting.

The Zone 1 zero-sequence compensation factor (k01) is independent from the forward and reverse compensation factors (k0 and k0R) that the relay uses for quadrilateral ground distance protection for the other zones.

When setting E21XG (Quadrilateral Ground Distance Zones) is 1 or more, there are two selections for setting XGPOL (Quadrilateral Ground Polarizing Quantity): I2 or IG. When the setting XGPOL is I2, set the first selection in the setting ORDER (Ground Directional Element Priority) to Q. When the setting XGPOL is IG, the first selection in the setting ORDER must be Q or V.

Table 1.47 Quadrilateral Ground Distance Element Settings

Name	Description	Range	Default (5 A)
E21XG	Quadrilateral Ground Distance Zones	N, 1 to 5	N
XG1	Zone 1 Reactance (Ω)	OFF, (0.25–320)/I_{nom}	OFF
RG1	Zone 1 Resistance (Ω)	(0.25–250)/I_{nom}	12.48
XG2	Zone 2 Reactance (Ω)	OFF, (0.25–320)/I_{nom}	OFF
RG2	Zone 2 Resistance (Ω)	(0.25–250)/I_{nom}	18.72
XG3	Zone 3 Reactance (Ω)	OFF, (0.25–320)/I_{nom}	OFF
RG3	Zone 3 Resistance (Ω)	(0.25–250)/I_{nom}	3.64
XG4	Zone 4 Reactance (Ω)	OFF, (0.25–320)/I_{nom}	OFF
RG4	Zone 4 Resistance (Ω)	(0.25–250)/I_{nom}	31.20
XG5	Zone 5 Reactance (Ω)	OFF, (0.25–320)/I_{nom}	OFF
RG5	Zone 5 Resistance (Ω)	(0.25–250)/I_{nom}	50.00
XGPOL[a]	Quadrilateral Ground Polarizing Quantity	I2, IG	I2
TANG[a]	Nonhomogeneous Correction Angle (°)	–40.0 to +40.0	–3.0

[a] Advanced Setting if EADVS := Y. If the Advanced Settings are not enabled (setting EADVS := N), the relay hides the settings.

Table 1.48 Quadrilateral Ground Distance Elements Relay Word Bits

Name	Description
XAG1	Zone 1 A-phase quadrilateral ground distance element
XBG1	Zone 1 B-phase quadrilateral ground distance element
XCG1	Zone 1 C-phase quadrilateral ground distance element
XAG2	Zone 2 A-phase quadrilateral ground distance element
XBG2	Zone 2 B-phase quadrilateral ground distance element
XCG2	Zone 2 C-phase quadrilateral ground distance element
XAG3	Zone 3 A-phase quadrilateral ground distance element
XBG3	Zone 3 B-phase quadrilateral ground distance element
XCG3	Zone 3 C-phase quadrilateral ground distance element
XAG4	Zone 4 A-phase quadrilateral ground distance element
XBG4	Zone 4 B-phase quadrilateral ground distance element
XCG4	Zone 4 C-phase quadrilateral ground distance element
XAG5	Zone 5 A-phase quadrilateral ground distance element
XBG5	Zone 5 B-phase quadrilateral ground distance element
XCG5	Zone 5 C-phase quadrilateral ground distance element

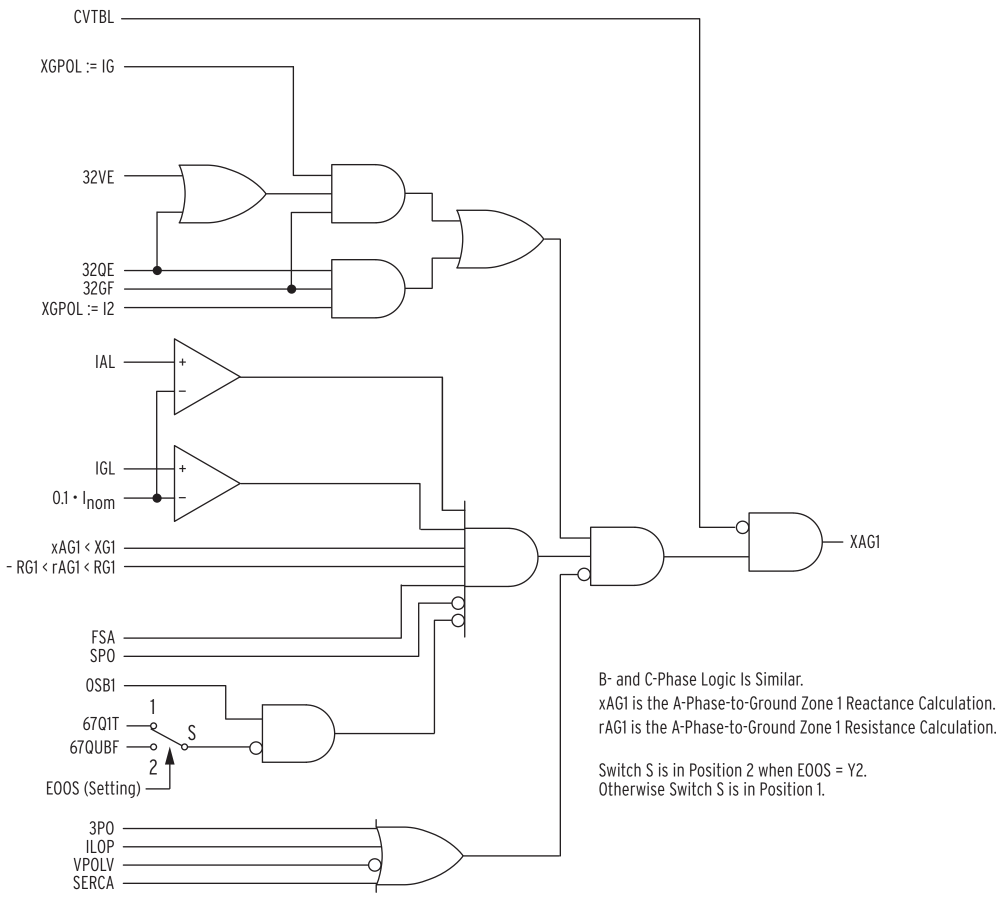


Figure 1.38 Zone 1 Quadrilateral Ground Distance Element Logic Diagram

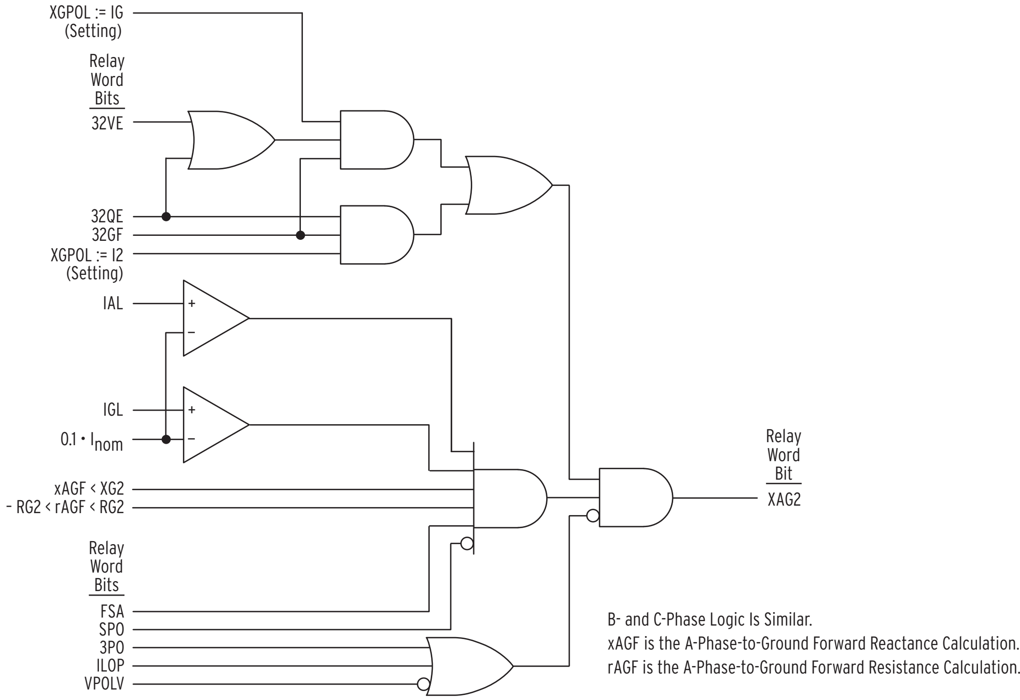


Figure 1.39 Zone 2 Quadrilateral Distance Element Logic Diagram

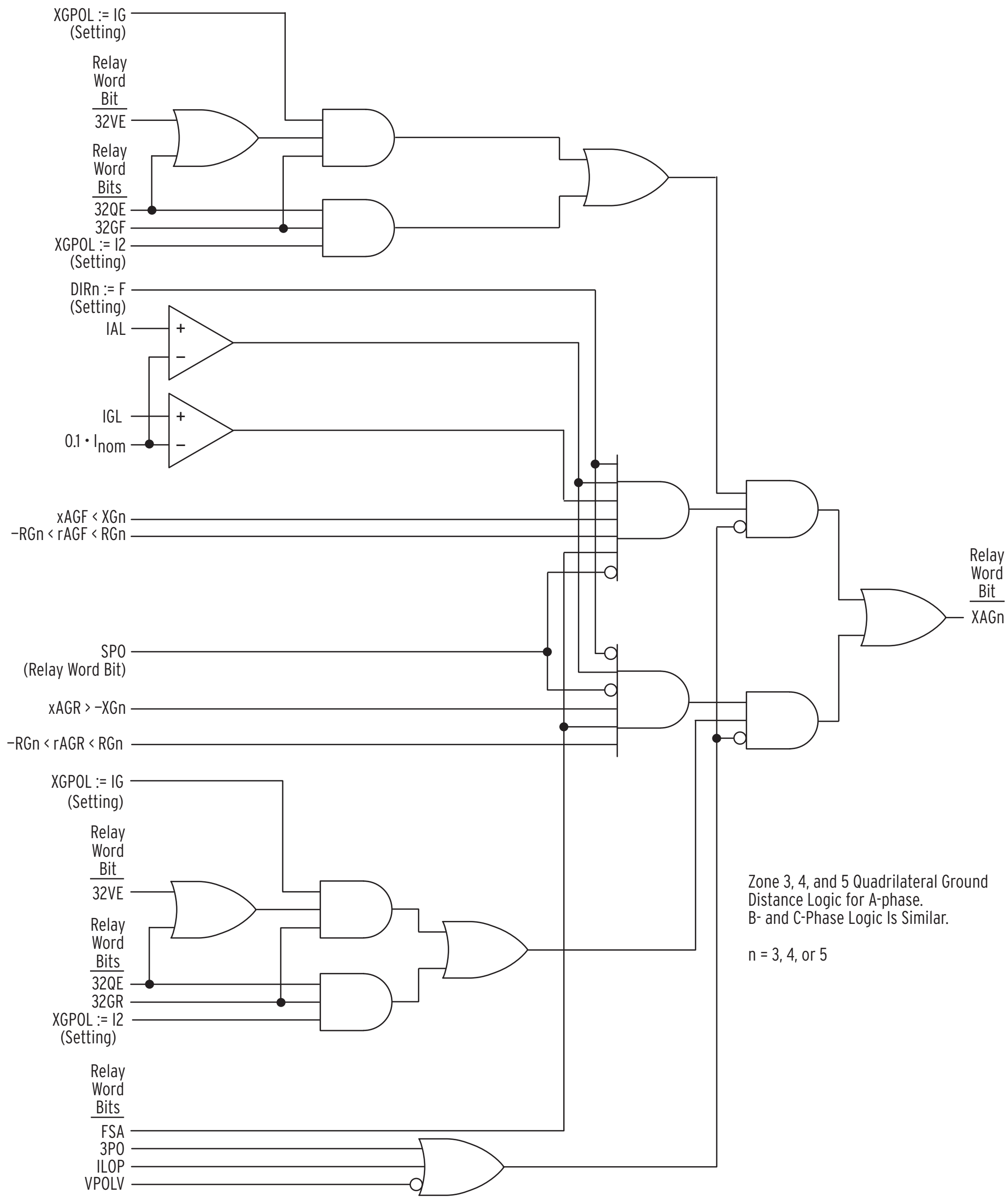


Figure 1.40 Zones 3, 4, and 5 Quadrilateral Ground Distance Element Logic

Mho Phase Distance Elements

The SEL-421 has five independent zones of mho phase distance protection. The mho phase distance protection operates for phase-to-phase, phase-to-phase-to-ground, and three-phase faults. Set the reach for each zone independently. Zone 1 and Zone 2 distance elements are forward only, while you can set Zone 3 through Zone 5 distance elements either forward or reverse. The mho phase distance elements use positive-sequence voltage polarization for security, and also generate a dynamic expanding mho characteristic that provides additional fault resistance coverage.

NOTE: The SEL-421-1 and the SEL-421-2 provide fast and secure tripping but do not have high-speed distance elements. Typical detection time for the SEL-421-1 and for the SEL-421-2 is 1.5 cycles.

The SEL-421 has three independent zones of high-speed mho phase distance protection. The high-speed mho phase distance protection operates for phase-to-phase, phase-to-phase-to-ground, and three-phase faults. The first three zones of mho phase ground distance protection (Zone 1, Zone 2, and Zone 3) are for high-speed operation; typical detection time is less than one cycle.

Table 1.49 Mho Phase Distance Element Settings

Name	Description	Range	Default (5 A)
E21P	Mho Phase Distance Zones	N, 1–5	3
Z1P	Zone 1 Reach (Ω)	OFF (0.25–320)/I_{nom}	6.24
Z2P	Zone 2 Reach (Ω)	OFF, (0.25–320)/I_{nom}	9.36
Z3P	Zone 3 Reach (Ω)	OFF, (0.25–320)/I_{nom}	1.87
Z4P	Zone 4 Reach (Ω)	OFF, (0.25–320)/I_{nom}	OFF
Z5P	Zone 5 Reach (Ω)	OFF, (0.25–320)/I_{nom}	OFF

Table 1.50 Mho Phase Distance Elements Relay Word Bits (Sheet 1 of 2)

Name	Description
MAB1	Zone 1 A-phase-to-B-phase mho distance elements
MBC1	Zone 1 B-phase-to-C-phase mho distance elements
MCA1	Zone 1 C-phase-to-A-phase mho distance element
MAB2	Zone 2 A-phase-to-B-phase mho distance element
MBC2	Zone 2 B-phase-to-C-phase mho distance element
MCA2	Zone 2 C-phase-to-A-phase mho distance element
MAB3	Zone 3 A-phase-to-B-phase mho distance element
MBC3	Zone 3 B-phase-to-C-phase mho distance element
MCA3	Zone 3 C-phase-to-A-phase mho distance element
MAB4	Zone 4 A-phase-to-B-phase mho distance element
MBC4	Zone 4 B-phase-to-C-phase mho distance element
MCA4	Zone 4 C-phase-to-A-phase mho distance element
MAB5	Zone 5 A-phase-to-B-phase mho distance element
MBC5	Zone 5 B-phase-to-C-phase mho distance element
MCA5	Zone 5 C-phase-to-A-phase mho distance element

Table 1.50 Mho Phase Distance Elements Relay Word Bits (Sheet 2 of 2)

Name	Description
M1P	Zone 1 mho phase distance elements
M2P	Zone 2 mho phase distance elements
M3P	Zone 3 mho phase distance elements
M4P	Zone 4 mho phase distance elements
M5P	Zone 5 mho phase distance elements

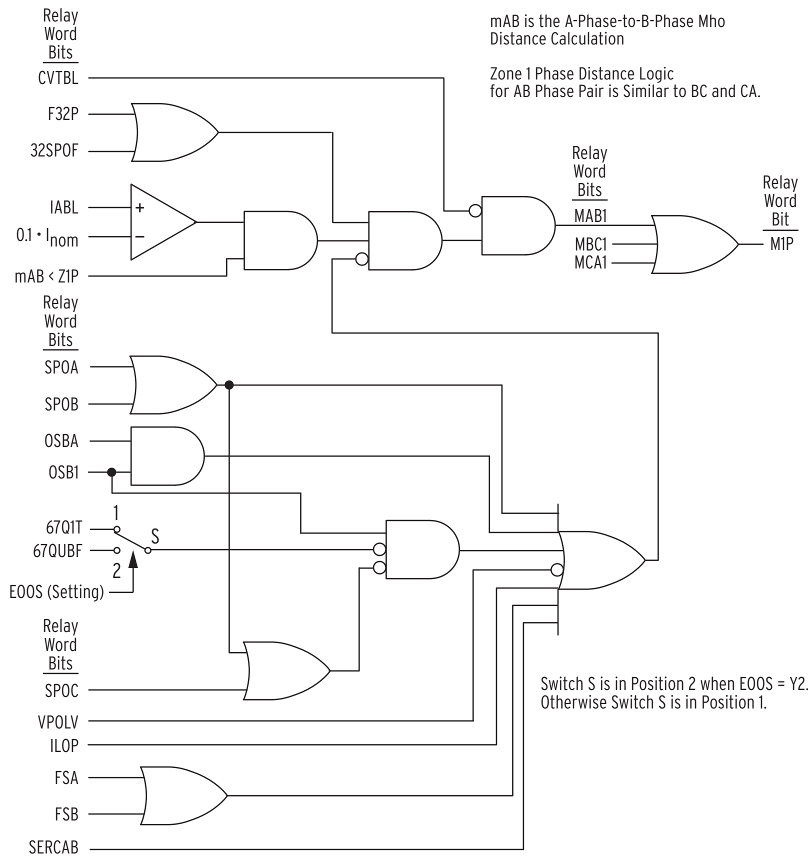


Figure 1.41 Zone 1 Mho Phase Distance Element Logic Diagram

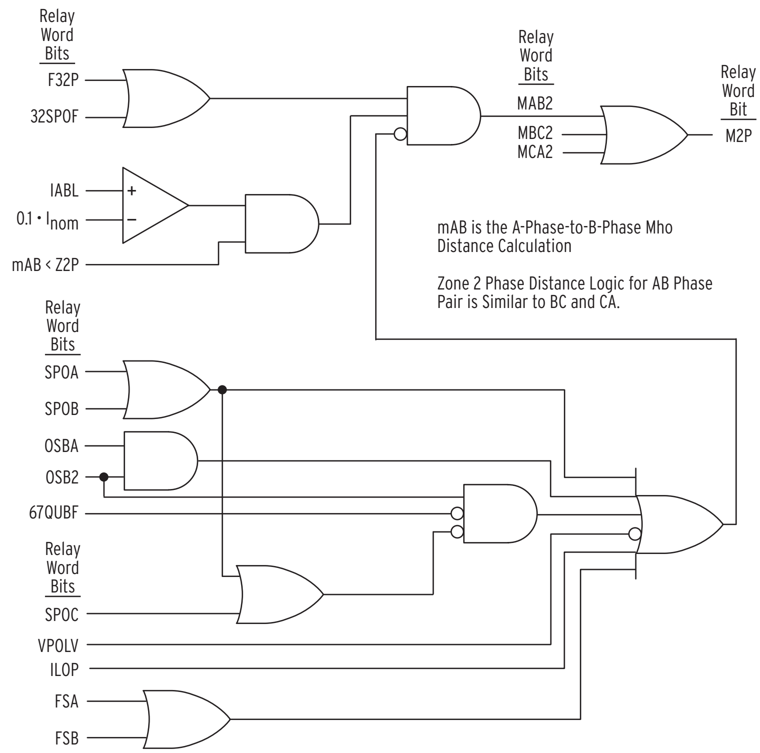


Figure 1.42 Zone 2 Mho Phase Distance Element Logic Diagram

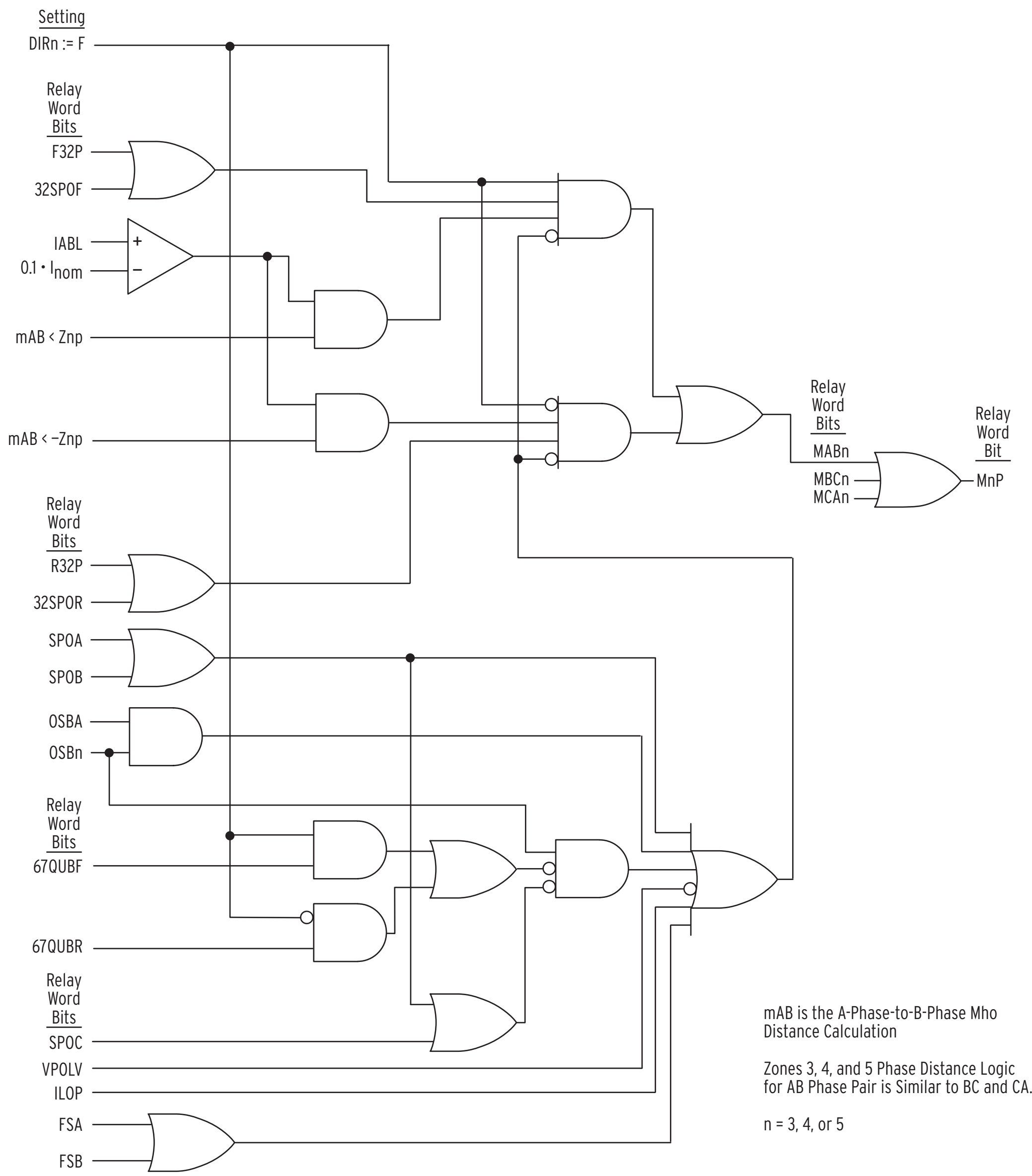


Figure 1.43 Zones 3, 4, and 5 Mho Phase Distance Element Logic Diagram

Zone Time Delay

The SEL-421 supports two philosophies of zone timing:

➤ Independent timing—the phase and ground distance elements drive separate timers for each zone

➤ Common timing—the phase and ground distance elements both drive a common timer

Independent Zone Timing

Use Relay Word bits M*n*PT (Time-Delayed Zone Phase Distance Protection) and Z*n*GT (Time-Delayed Zone Ground Distance Protection) to select independent zone timing in SELOGIC control equation TR (Trip) (*n* = 1–5).

The example below uses independent timing for Zone 2 phase and ground distance protection:

TR := M1P OR Z1G OR M2PT OR Z2GT

Common Zone Timing

Use Relay Word bits Z*n*T (Zone *n* Distance Protection) to select common zone timing in SELOGIC control equation TR (Trip) (*n* = 1–5).

The next example uses common timing for Zone 2 distance protection:

TR := M1P OR Z1G OR Z2T

If the timer input drops out while timing, the relay suspends the common zone timer for one cycle. This feature prevents resetting the timer when a fault evolves (e.g., the fault changes from a single phase-to-ground to phase-to-phase-to-ground). If the timer expires, the relay blocks the suspend-timing logic.

Table 1.51 Zone Delay Settings

Name	Description	Selection	Default (5 A)
Phase Distance[a]			
Z1PD	Zone 1 Time Delay (cycles)	OFF, (0.000–16000)	0.000
Z2PD	Zone 2 Time Delay (cycles)	OFF, (0.000–16000)	20.000
Z3PD	Zone 3 Time Delay (cycles)	OFF, (0.000–16000)	60.000
Z4PD	Zone 4 Time Delay (cycles)	OFF, (0.000–16000)	OFF
Z5PD	Zone 5 Time Delay (cycles)	OFF, (0.000–16000)	OFF
Ground Distance[a]			
Z1GD	Zone 1 Time Delay (cycles)	OFF, (0.000–16000)	0.000
Z2GD	Zone 2 Time Delay (cycles)	OFF, (0.000–16000)	20.000
Z3GD	Zone 3 Time Delay (cycles)	OFF, (0.000–16000)	60.000
Z4GD	Zone 4 Time Delay (cycles)	OFF, (0.000–16000)	OFF
Z5GD	Zone 5 Time Delay (cycles)	OFF, (0.000–16000)	OFF
Distance Elements[b]			
ECDTD	Distance Element Common Time Delay	Y, N	N
Z1D	Zone 1 Time Delay (cycles)	OFF, (0.000–16000)	0.000
Z2D	Zone 2 Time Delay (cycles)	OFF, (0.000–16000)	20.000
Z3D	Zone 3 Time Delay (cycles)	OFF, (0.000–16000)	60.000
Z4D	Zone 4 Time Delay (cycles)	OFF, (0.000–16000)	OFF
Z5D	Zone 5 Time Delay (cycles)	OFF, (0.000–16000)	OFF

[a] Independent.
[b] Common.

Table 1.52 Zone Time Delay Relay Word Bits (Sheet 1 of 2)

Name	Description
M1PT	Zone 1 phase distance, time delayed
M2PT	Zone 2 phase distance, time delayed
M3PT	Zone 3 phase distance, time delayed
M4PT	Zone 4 phase distance, time delayed
M5PT	Zone 5 phase distance, time delayed

Table 1.52 Zone Time Delay Relay Word Bits (Sheet 2 of 2)

Name	Description
Z1GT	Zone 1 ground distance, time delayed
Z2GT	Zone 2 ground distance, time delayed
Z3GT	Zone 3 ground distance, time delayed
Z4GT	Zone 4 ground distance, time delayed
Z5GT	Zone 5 ground distance, time delayed
Z1T	Zone 1 phase or ground distance, common time delayed
Z2T	Zone 2 phase or ground distance, common time delayed
Z3T	Zone 3 phase or ground distance, common time delayed
Z4T	Zone 4 phase or ground distance, common time delayed
Z5T	Zone 5 phase or ground distance, common time delayed

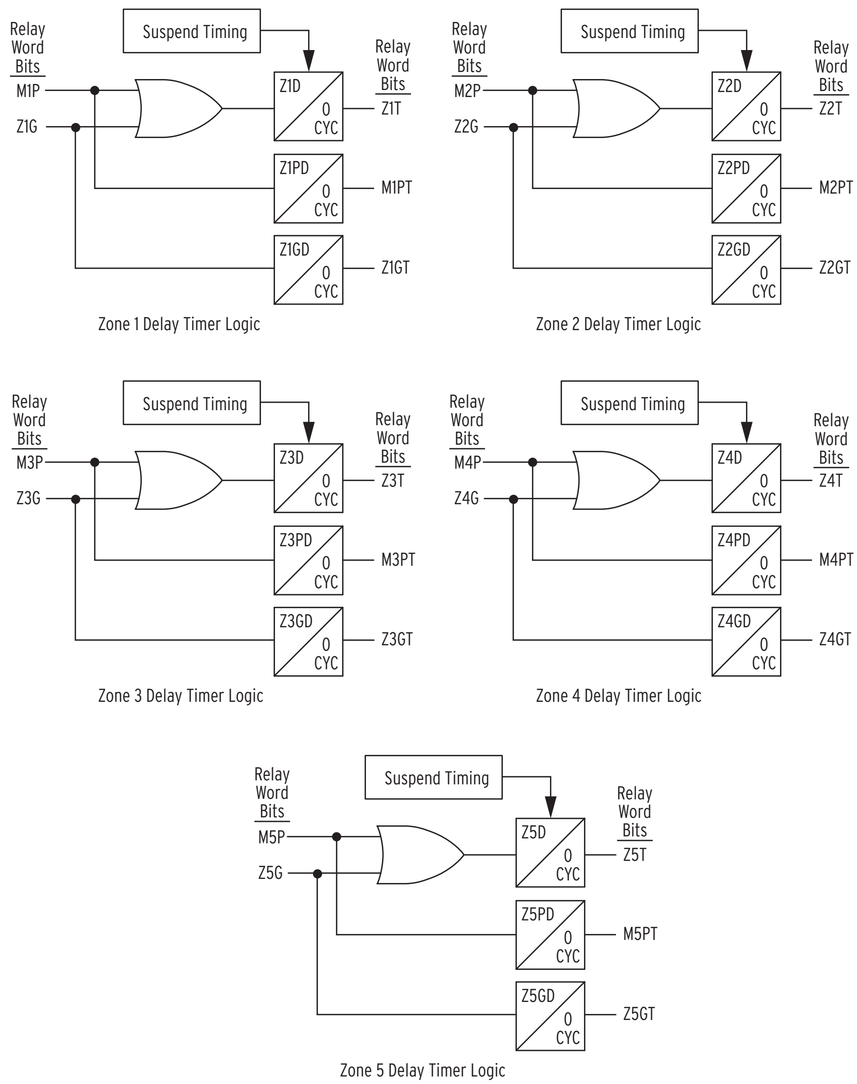


Figure 1.44 Zone Timers

Instantaneous Line Overcurrent Elements

The SEL-421 calculates instantaneous overcurrent elements for phase (P), residual ground (G, vector sum of I_A, I_B, and I_C), and negative-sequence (Q) quantities. Four levels of instantaneous elements are available named 50P1–50P4, 50Q1–50Q4, and 50G1–50G4, as shown in *Table 1.56* through *Table 1.58*, with settings shown in *Table 1.53* through *Table 1.55*.

These overcurrent elements always operate on the line current (IW-terminal current or the sum of the IW and IX terminal currents) according to the global setting LINEI (Line Current Source). The instantaneous overcurrent elements are inputs to the instantaneous directional (67P*n*, 67Q*n*, 67G*n*, where *n* = 1–4) and definite-time directional overcurrent elements (67P*n*T, 67Q*n*T, 67G*n*T, where *n* = 1–4). See *Directionality on page R.1.40* for details on the directional control option. Note that the 67P*n* and 67P*n*T elements are not directionally controlled by the built-in logic; they can be made directional through the use of the torque control settings 67P1TC – 67P4TC.

Each of the instantaneous directional elements includes a torque control setting (67P*n*TC, 67Q*n*TC, 67G*n*TC, where *n* = 1–4) to supervise the element operation.

The enable settings (E50P, E50Q, E50G) control how many of each type of instantaneous/definite-time overcurrent elements are available. For example, if E50P := 2, only 50P1, 67P1, 67P1T, 50P2, 67P2, and 67P2T are processed. The remaining phase instantaneous/definite-time overcurrent elements (*n* = 3–4) are defeated, and the output Relay Word bits are forced to logical 0.

Table 1.53 Phase Overcurrent Element Settings

Setting	Description	Range	Default (5 A)
Phase Instantaneous Overcurrent Elements			
E50P	Phase Inst./Def.-Time O/C Elements	N, 1–4	1
50P1P	Level 1 Pickup (A)	OFF, (0.05–20) • I_{nom}	10.00
50P2P	Level 2 Pickup (A)	OFF, (0.05–20) • I_{nom}	OFF
50P3P	Level 3 Pickup (A)	OFF, (0.05–20) • I_{nom}	OFF
50P4P	Level 4 Pickup (A)	OFF, (0.05–20) • I_{nom}	OFF
Phase Definite-Time Overcurrent Elements			
67P1D	Level 1 Time Delay (cycles)	0.000–16000	0.000
67P2D	Level 2 Time Delay (cycles)	0.000–16000	0.000
67P3D	Level 3 Time Delay (cycles)	0.000–16000	0.000
67P4D	Level 4 Time Delay (cycles)	0.000–16000	0.000
67P1TC	Level 1 Torque Control	SELOGIC Equation	1
67P2TC	Level 2 Torque Control	SELOGIC Equation	1
67P3TC	Level 3 Torque Control	SELOGIC Equation	1
67P4TC	Level 4 Torque Control	SELOGIC Equation	1

Table 1.54 Negative-Sequence Overcurrent Element Settings

Setting	Description	Range	Default (5 A)
Negative-Sequence Instantaneous Overcurrent Elements			
E50Q	Neg.-Seq. Inst./Def.-Time O/C Elements	N, 1–4	N
50Q1P	Level 1 Pickup (A)	OFF, (0.05–20) • I_{nom}	OFF
50Q2P	Level 2 Pickup (A)	OFF, (0.05–20) • I_{nom}	OFF
50Q3P	Level 3 Pickup (A)	OFF, (0.05–20) • I_{nom}	OFF
50Q4P	Level 4 Pickup (A)	OFF, (0.05–20) • I_{nom}	OFF
Negative-Sequence Definite-Time Overcurrent Elements			
67Q1D	Level 1 Time Delay (cycles)	0.000–16000	0.000
67Q2D	Level 2 Time Delay (cycles)	0.000–16000	0.000
67Q3D	Level 3 Time Delay (cycles)	0.000–16000	0.000
67Q4D	Level 4 Time Delay (cycles)	0.000–16000	0.000
67Q1TC	Level 1 Torque Control	SELOGIC Equation	1
67Q2TC	Level 2 Torque Control	SELOGIC Equation	1
67Q3TC	Level 3 Torque Control	SELOGIC Equation	1
67Q4TC	Level 4 Torque Control	SELOGIC Equation	1

Table 1.55 Residual Ground Overcurrent Element Settings

Setting	Description	Range	Default (5 A)
Residual Ground Instantaneous Overcurrent Elements			
E50G	Residual Ground Inst./Def.-Time O/C Elements	N, 1–4	N
50G1P	Level 1 Pickup (A)	OFF, (0.05–20) • I_{nom}	OFF
50G2P	Level 2 Pickup (A)	OFF, (0.05–20) • I_{nom}	OFF
50G3P	Level 3 Pickup (A)	OFF, (0.05–20) • I_{nom}	OFF
50G4P	Level 4 Pickup (A)	OFF, (0.05–20) • I_{nom}	OFF
Residual Ground Definite-Time Overcurrent Elements			
67G1D	Level 1 Time Delay (cycles)	0.000–16000	0.000
67G2D	Level 2 Time Delay (cycles)	0.000–16000	0.000
67G3D	Level 3 Time Delay (cycles)	0.000–16000	0.000
67G4D	Level 4 Time Delay (cycles)	0.000–16000	0.000
67G1TC	Level 1 Torque Control	SELOGIC Equation	1
67G2TC	Level 2 Torque Control	SELOGIC Equation	1
67G3TC	Level 3 Torque Control	SELOGIC Equation	1
67G4TC	Level 4 Torque Control	SELOGIC Equation	1

Table 1.56 Phase Instantaneous/Definite-Time Line Overcurrent Relay Word Bits

Name	Description
50P1	Level 1 instantaneous phase overcurrent element
50P2	Level 2 instantaneous phase overcurrent element
50P3	Level 3 instantaneous phase overcurrent element
50P4	Level 4 instantaneous phase overcurrent element
67P1	Level 1 definite-time phase directional overcurrent element
67P2	Level 2 definite-time phase directional overcurrent element
67P3	Level 3 definite-time phase directional overcurrent element
67P4	Level 4 definite-time phase directional overcurrent element
67P1T	Level 1 time-delayed definite-time phase directional overcurrent element
67P2T	Level 2 time-delayed definite-time phase directional overcurrent element
67P3T	Level 3 time-delayed definite-time phase directional overcurrent element
67P4T	Level 4 time-delayed definite-time phase directional overcurrent element

Table 1.57 Negative-Sequence Instantaneous/Definite-Time Line Overcurrent Relay Word Bits

Name	Description
50Q1	Level 1 instantaneous negative-sequence overcurrent element
50Q2	Level 2 instantaneous negative-sequence overcurrent element
50Q3	Level 3 instantaneous negative-sequence overcurrent element
50Q4	Level 4 instantaneous negative-sequence overcurrent element
67Q1	Level 1 definite-time negative-sequence directional overcurrent element
67Q2	Level 2 definite-time negative-sequence directional overcurrent element
67Q3	Level 3 definite-time negative-sequence directional overcurrent element
67Q4	Level 4 definite-time negative-sequence directional overcurrent element
67Q1T	L.evel 1 time-delayed definite-time negative-sequence directional overcurrent element
67Q2T	Level 2 time-delayed definite-time negative-sequence directional overcurrent element
67Q3T	Level 3 time-delayed definite-time negative-sequence directional overcurrent element
67Q4T	Level 4 time-delayed definite-time negative-sequence directional overcurrent element

Table 1.58 Residual Ground Instantaneous/Definite-Time Line Overcurrent Relay Word Bits (Sheet 1 of 2)

Name	Description
50G1	Level 1 instantaneous residual ground overcurrent element
50G2	Level 2 instantaneous residual ground overcurrent element
50G3	Level 3 instantaneous residual ground overcurrent element
50G4	Level 4 instantaneous residual ground overcurrent element
67G1	Level 1 definite-time residual ground directional overcurrent element
67G2	Level 2 definite-time residual ground directional overcurrent element
67G3	Level 3 definite-time residual ground directional overcurrent element

Table 1.58 Residual Ground Instantaneous/Definite-Time Line Overcurrent Relay Word Bits (Sheet 2 of 2)

Name	Description
67G4	Level 4 definite-time residual ground directional overcurrent element
67G1T	Level 1 time-delayed definite-time residual ground directional overcurrent element
67G2T	Level 2 time-delayed definite-time residual ground directional overcurrent element
67G3T	Level 3 time-delayed definite-time residual ground directional overcurrent element
67G4T	Level 4 time-delayed definite-time residual ground directional overcurrent element

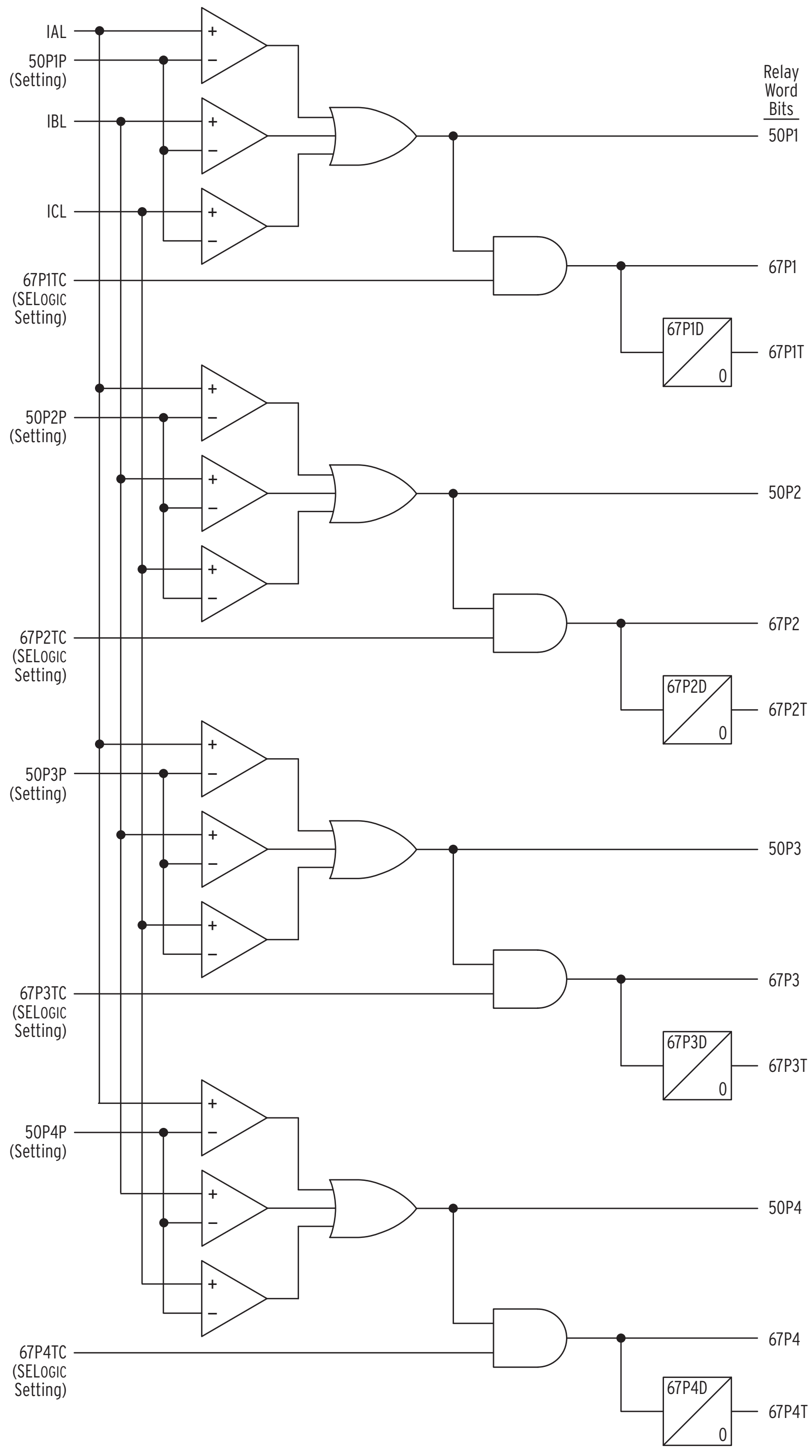


Figure 1.45 Phase Instantaneous/Definite-Time Overcurrent Elements

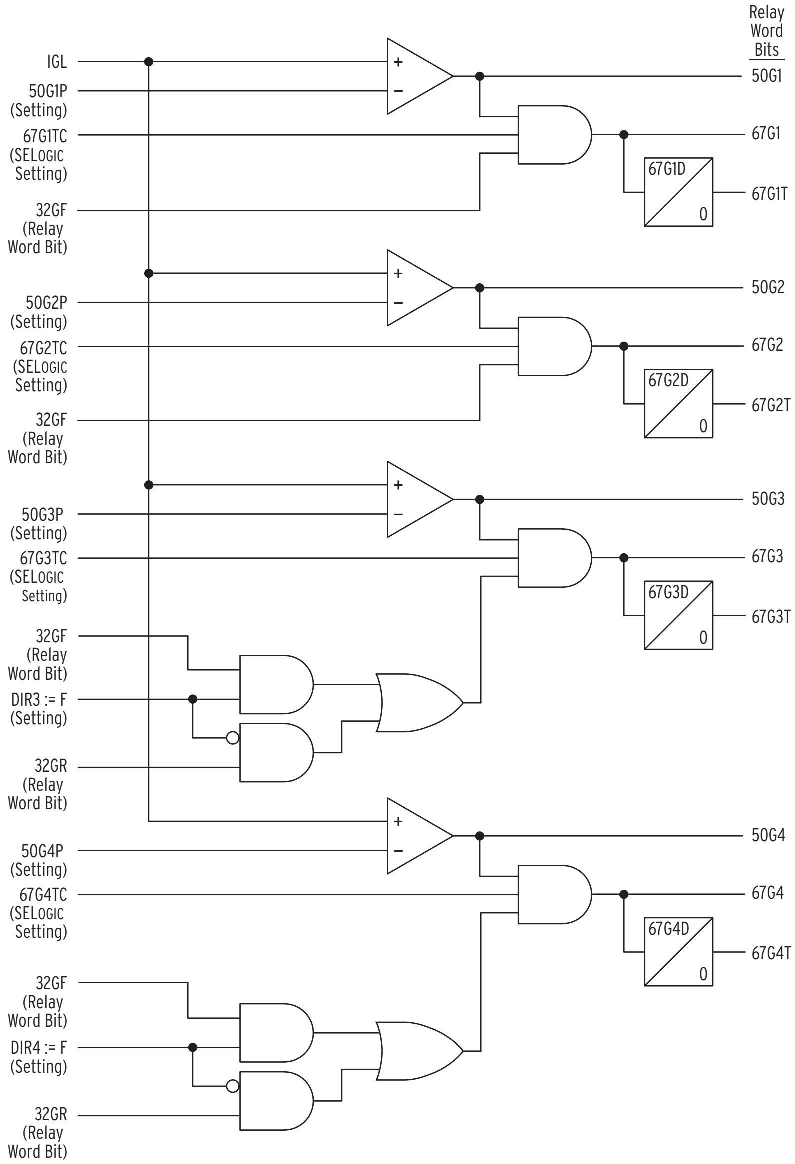


Figure 1.46 Residual Ground Instantaneous/Directional Overcurrent Elements

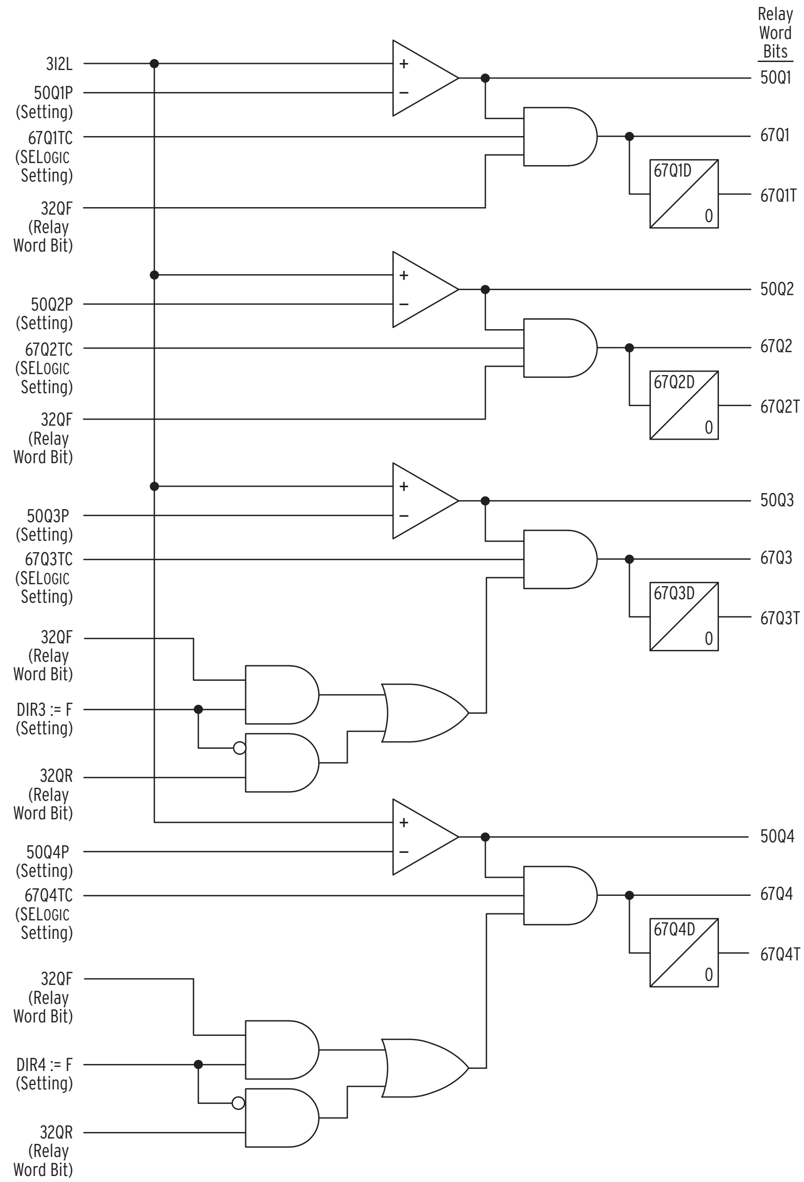


Figure 1.47 Negative-Sequence Instantaneous/Directional Overcurrent Elements

Inverse-Time Overcurrent Elements

The SEL-421 provides three selectable operating quantity inverse-time overcurrent elements. Ten different time-overcurrent characteristics (5 U.S. and 5 IEC curves) are available.

Each time-overcurrent element can be configured to operate on the line current (i.e., IW-terminal current or the sum of the IW and IX terminal currents) depending upon setting LINEI (line Current Source); or circuit breaker operating quantities, with the terminal source depending upon settings BK1I and BK2I.

Symmetrical component current quantities are available only for the line current source. *Table 1.59* defines the available setting choices for operating quantities and the corresponding analog quantity name as found in *Table B.2*.

Each time-overcurrent element has a torque control SELOGIC equation 51SkTC (k = 1–3) that enables the element when the equation evaluates to logical 1, and disables the element when the equation evaluates to logical 0. See *Figure 1.61* for a logic diagram of the time-overcurrent elements, including the torque control input.

The enable setting (E51S) controls how many time-overcurrent elements are available. For example, if E51S := 1, only 51S1 is processed. The remaining time-overcurrent elements 51S*k* (*k* = 2–3) are defeated, and the output Relay Word bits are forced to logical 0.

NOTE: In the SEL-421, the time-overcurrent elements are not directionally controlled in the internal logic. Directional control may be achieved through the use of the torque control settings, as shown in Section 1: Protection Application Examples in the Applications Handbook. Also refer to Directionality on page R.1.40.

Table 1.59 Selectable Current Quantities[a]

Quantity	Description	Analog Quantities
IA*n*	A-Phase	LIAFIM, B1IAFIM, B2IAFIM
IB*n*	B-Phase	LIBFIM, B1IBFIM, B2IBFIM
IC*n*	C-Phase	LICFIM, B1ICFIM, B2ICFIM
IMAX*n*	Maximum Phase	
I1L	Line positive-sequence current	LI1FIM
3I2L	Line negative-sequence current	L3I2FIM
3I0*n*	Zero-sequence current	LIGFIM, B1IGFIM, B2IGFIM

[a] Parameter n is L for Line, 1 for Breaker 1, and 2 for Breaker 2.

Table 1.60 Selectable Inverse-Time Overcurrent Settings[a] (Sheet 1 of 2)

Setting	Description	Range	Default (5 A)
E51S	Selectable Inverse-Time Overcurrent Element	N, 1–3	1
51S1O	Operating Quantity Element 1	IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0*n*	3I0L
51S1P	51S1 O/C Pickup Element 1 (A)	(0.05–3.2) • I_{nom}	0.75
51S1C	51S1 Inverse Time O/C Curve Element 1	U1–U5 C1–C5	U3
51S1TD	51S1 Inverse Time O/C Time Dial Element 1	0.50–15.00 (U*x*)[b] 0.05–1.00 (C*x*)[b]	1.0
51S1RS	51S1 Inverse Time O/C Electromechanical Reset Element 1	Y, N	N
51S1TC	51S1 Inverse Time O/C Torque Control Element 1	SELOGIC Equation	32GF
51S2O	Operating Quantity Element 2	IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0*n*	3I2L
51S2P	51S2 O/C Pickup Element 2 (A)	(0.05–3.2) • I_{nom}	5.00
51S2C	51S2 Inverse Time O/C Curve Element 2	U1–U5 C1–C5	U3
51S2TD	51S2 Inverse Time O/C Time Dial Element 2	0.50–15.00 (U*x*)[b] 0.05–1.00 (C*x*)[b]	1
51S2RS	51S2 Inverse Time O/C Electromechanical Reset Element 2	Y, N	N

Table 1.60 Selectable Inverse-Time Overcurrent Settings[a] (Sheet 2 of 2)

Setting	Description	Range	Default (5 A)
51S2TC	51S2 Inverse Time O/C Torque Control Element 2	SELOGIC Equation	32QF
51S3O	Operating Quantity Element 3	IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0*n*	IMAXL
51S3P	51S3 O/C Pickup Element 3 (A)	OFF, (0.05–3.2) • I_{nom}	5.00
51S3C	51S3 Inverse Time O/C Curve Element 3	U1–U5 C1–C5	U3
51S3TD	51S3 Inverse Time O/C Time Dial Element 3	0.50–15.00 (U*x*)[b] 0.05–1.00 (C*x*)[b]	1
51S3RS	51S3 Inverse Time O/C Electromechanical Reset Element 3	Y, N	N
51S3TC	51S3 Inverse Time O/C Torque Control Element 3	SELOGIC Equation	M2P

[a] Parameter n is L for Line, 1 for BK1, and 2 for BK2.
[b] Parameter x is a number from 1–5 indicating the operating curve (see Figure 1.48 through Figure 1.57).

Table 1.61 Selectable Inverse-Time Overcurrent Relay Word Bits

Name	Description
51S1	Inverse-Time Overcurrent Element 1 pick-up
51S1T	Inverse-Time Overcurrent Element 1 timed out
51S1R	Inverse-Time Overcurrent Element 1 reset
51S2	Inverse-Time Overcurrent Element 2 pick-up
51S2T	Inverse-Time Overcurrent Element 2 timed out
51S2R	Inverse-Time Overcurrent Element 2 reset
51S3	Inverse-Time Overcurrent Element 3 pick-up
51S3T	Inverse-Time Overcurrent Element 3 timed out
51S3R	Inverse-Time Overcurrent Element 3 reset

Time-Current Operating Characteristics

The following information describes curve timing for time-overcurrent element curve and time-dial settings. The time-overcurrent relay curves in *Figure 1.48* through *Figure 1.57* conform to *IEEE C37.112–1996 IEEE Standard Inverse-Time Characteristic Equations for Overcurrent Relays*.

T_p = operating time in seconds
T_r = electromechanical induction-disk emulation reset time in seconds (if you select electromechanical reset setting)
TD = time-dial setting
M = applied multiples of pickup current [for operating time (T_p), $M > 1$; for reset time (T_r), $M \le 1$]

Table 1.62 Equations Associated With U.S. Curves

Curve Type	Operating Time	Reset Time	Figure
U1 (Moderately Inverse)	$T_p = TD \cdot \left(0.0226 + \frac{0.0104}{M^{0.02} - 1}\right)$	$T_r = TD \cdot \left(\frac{1.08}{1 - M^2}\right)$	*Figure 1.48*
U2 (Inverse)	$T_p = TD \cdot \left(0.180 + \frac{5.95}{M^2 - 1}\right)$	$T_r = TD \cdot \left(\frac{5.95}{1 - M^2}\right)$	*Figure 1.49*
U3 (Very Inverse)	$T_p = TD \cdot \left(0.0963 + \frac{3.88}{M^2 - 1}\right)$	$T_r = TD \cdot \left(\frac{3.88}{1 - M^2}\right)$	*Figure 1.50*
U4 (Extremely Inverse)	$T_p = TD \cdot \left(0.02434 + \frac{5.64}{M^2 - 1}\right)$	$T_r = TD \cdot \left(\frac{5.64}{1 - M^2}\right)$	*Figure 1.51*
U5 (Short-Time Inverse)	$T_p = TD \cdot \left(0.00262 + \frac{0.00342}{M^{0.02} - 1}\right)$	$T_r = TD \cdot \left(\frac{0.323}{1 - M^2}\right)$	*Figure 1.52*

Table 1.63 Equations Associated With IEC Curves

Curve Type	Operating Time	Reset Time	Figure
C1 (Standard Inverse)	$T_p = TD \cdot \left(\frac{0.14}{M^{0.02} - 1}\right)$	$T_r = TD \cdot \left(\frac{13.5}{1 - M^2}\right)$	*Figure 1.53*
C2 (Very Inverse)	$T_p = TD \cdot \left(\frac{13.5}{M - 1}\right)$	$T_r = TD \cdot \left(\frac{47.3}{1 - M^2}\right)$	*Figure 1.54*
C3 (Extremely Inverse)	$T_p = TD \cdot \left(\frac{80}{M^2 - 1}\right)$	$T_r = TD \cdot \left(\frac{80}{1 - M^2}\right)$	*Figure 1.55*
C4 (Long-Time Inverse)	$T_p = TD \cdot \left(\frac{120}{M - 1}\right)$	$T_r = TD \cdot \left(\frac{120}{1 - M}\right)$	*Figure 1.56*
C5 (Short-Time Inverse)	$T_p = TD \cdot \left(\frac{0.05}{M^{0.04} - 1}\right)$	$T_r = TD \cdot \left(\frac{4.85}{1 - M^2}\right)$	*Figure 1.57*

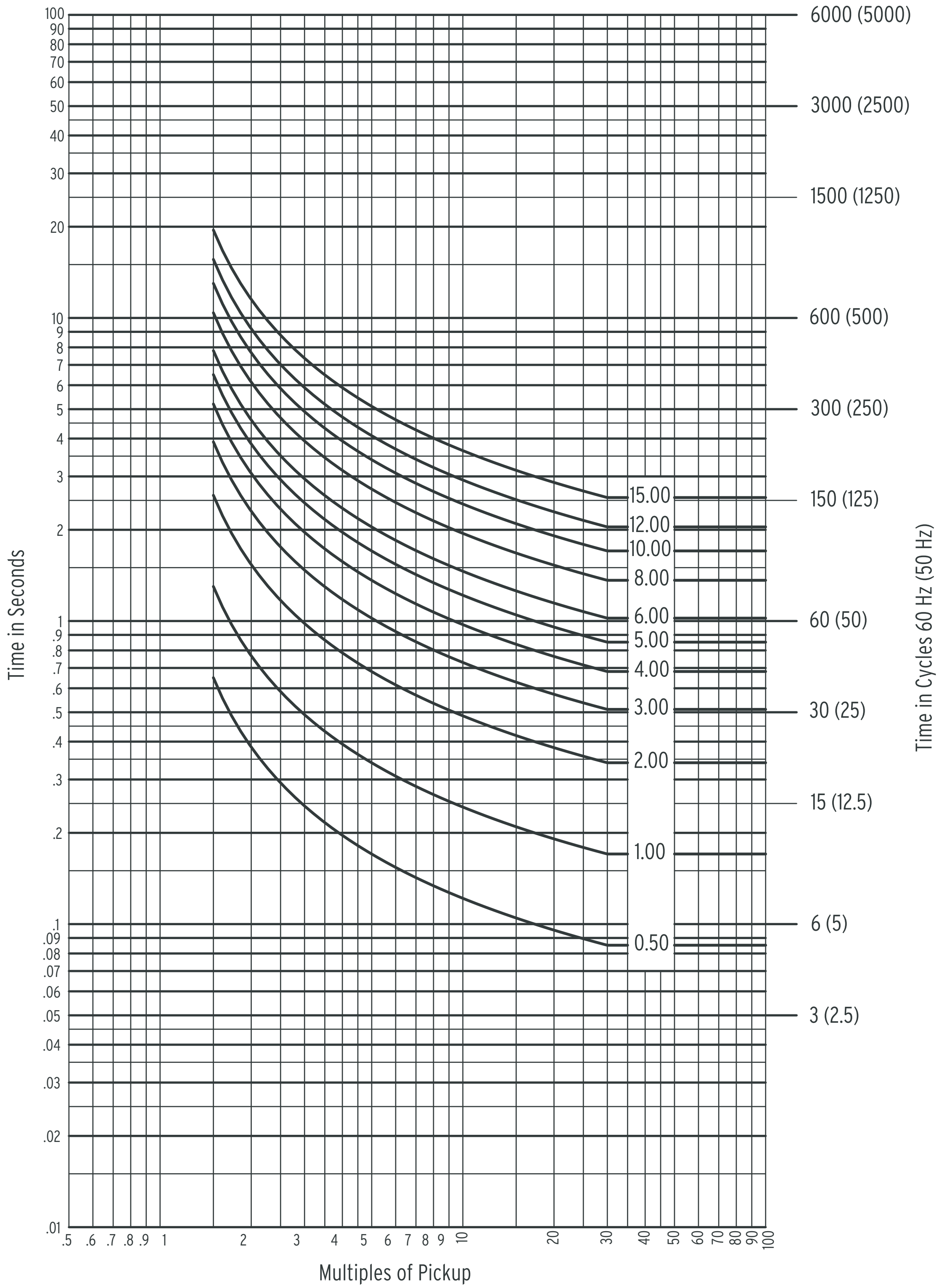


Figure 1.48 U.S. Moderately Inverse—U1

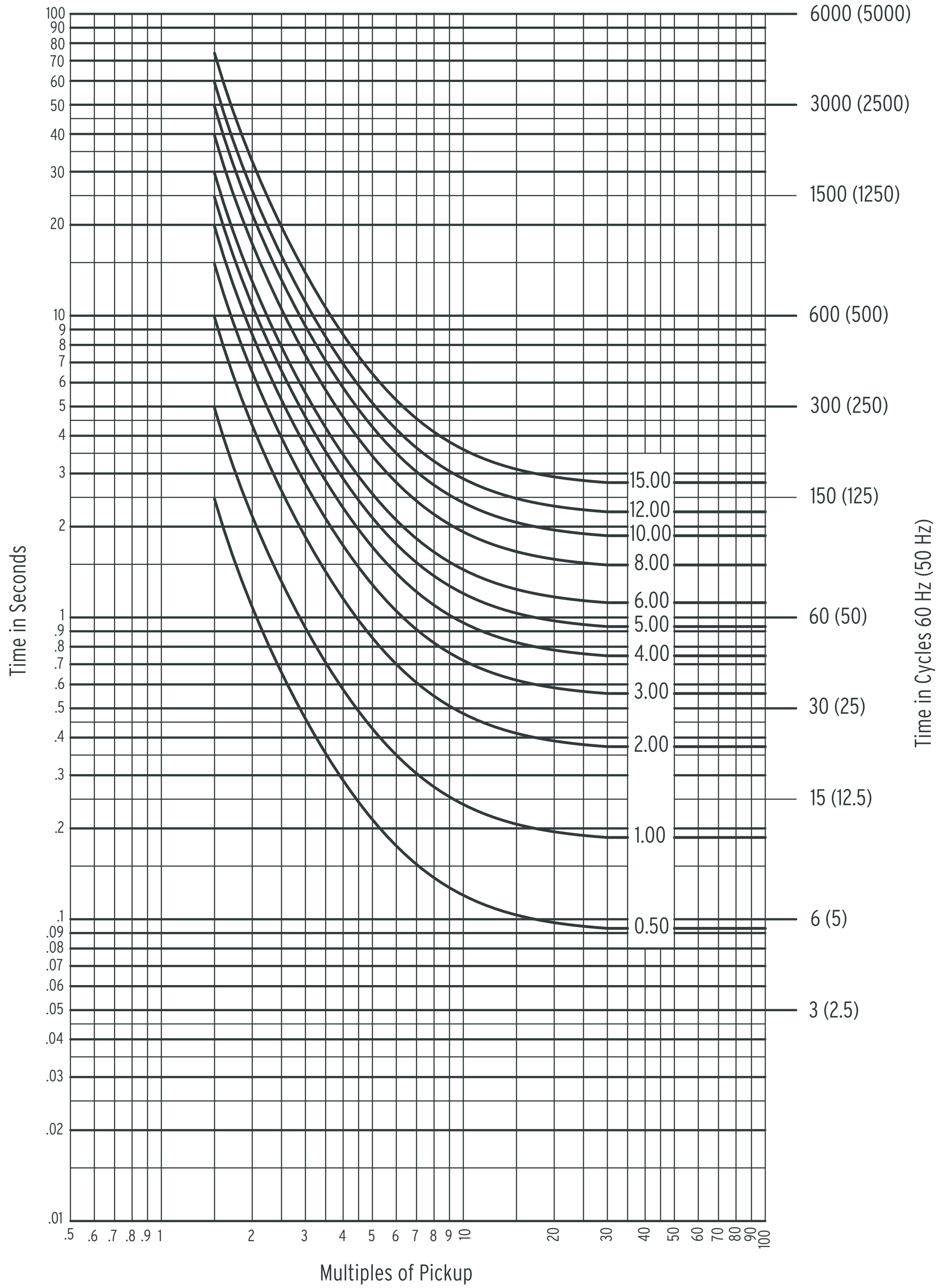


Figure 1.49 U.S. Inverse—U2

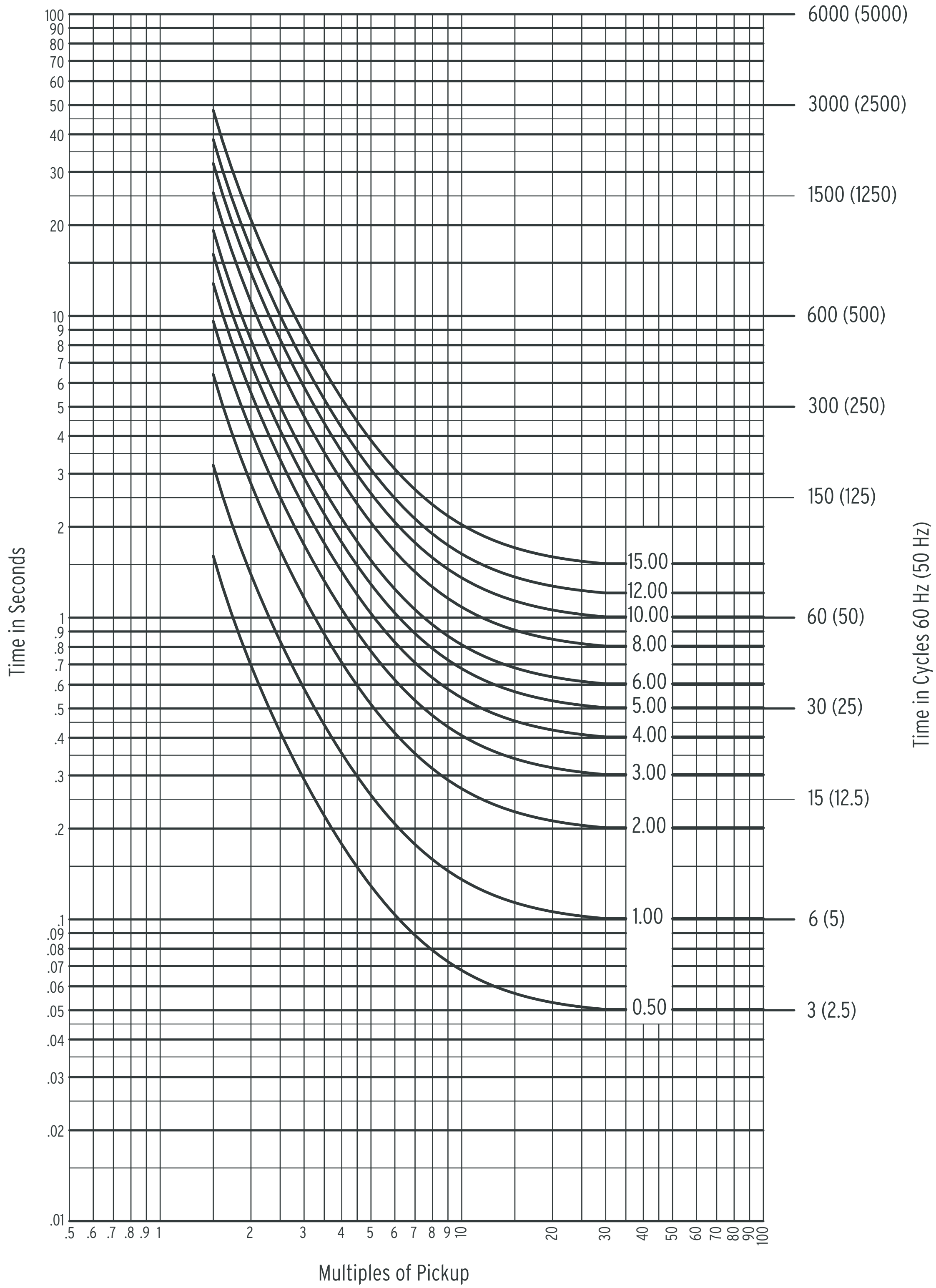


Figure 1.50 U.S. Very Inverse—U3

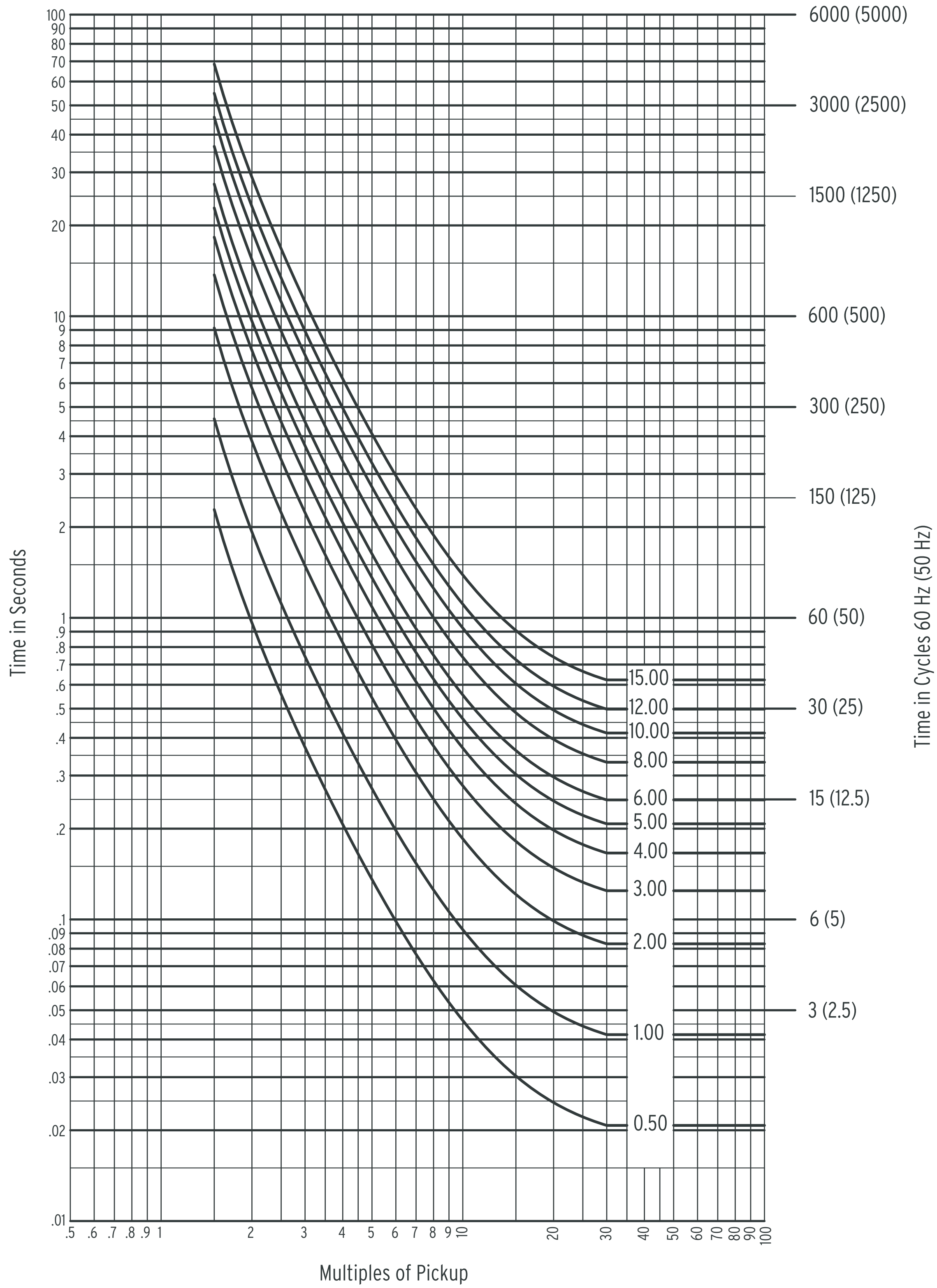


Figure 1.51 U.S. Extremely Inverse—U4

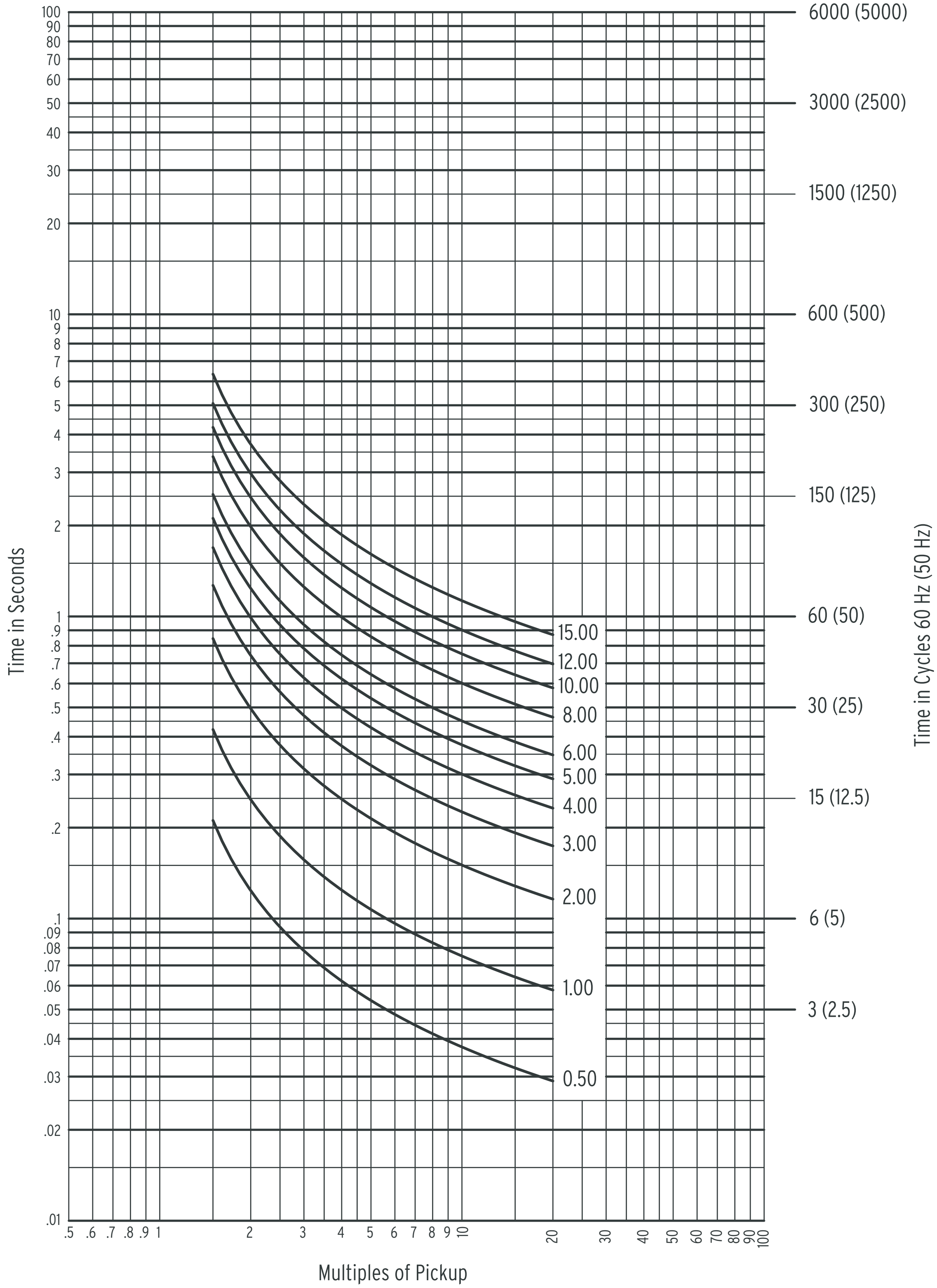


Figure 1.52 U.S. Short-Time Inverse—U5

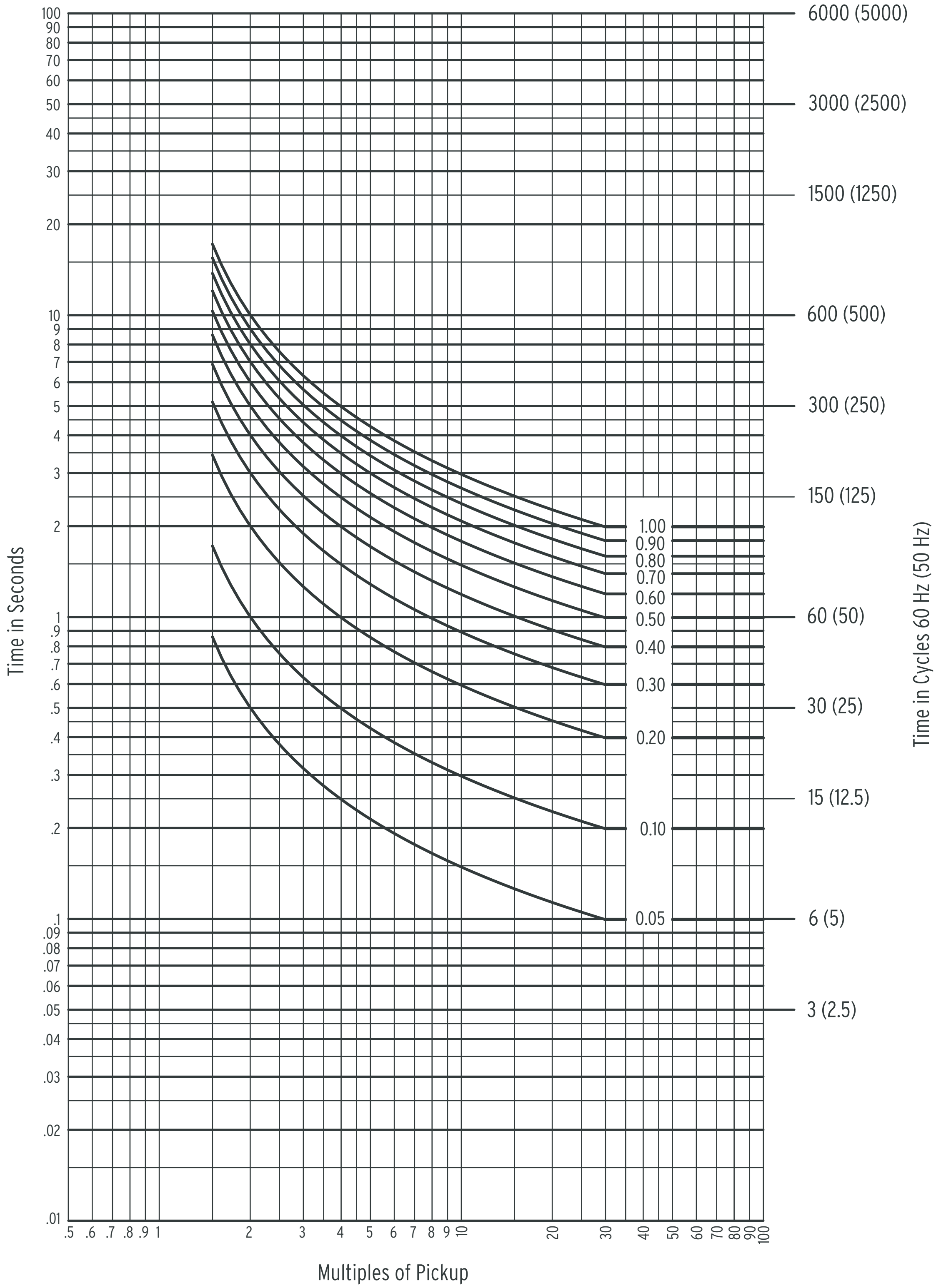


Figure 1.53 IEC Standard Inverse—C1

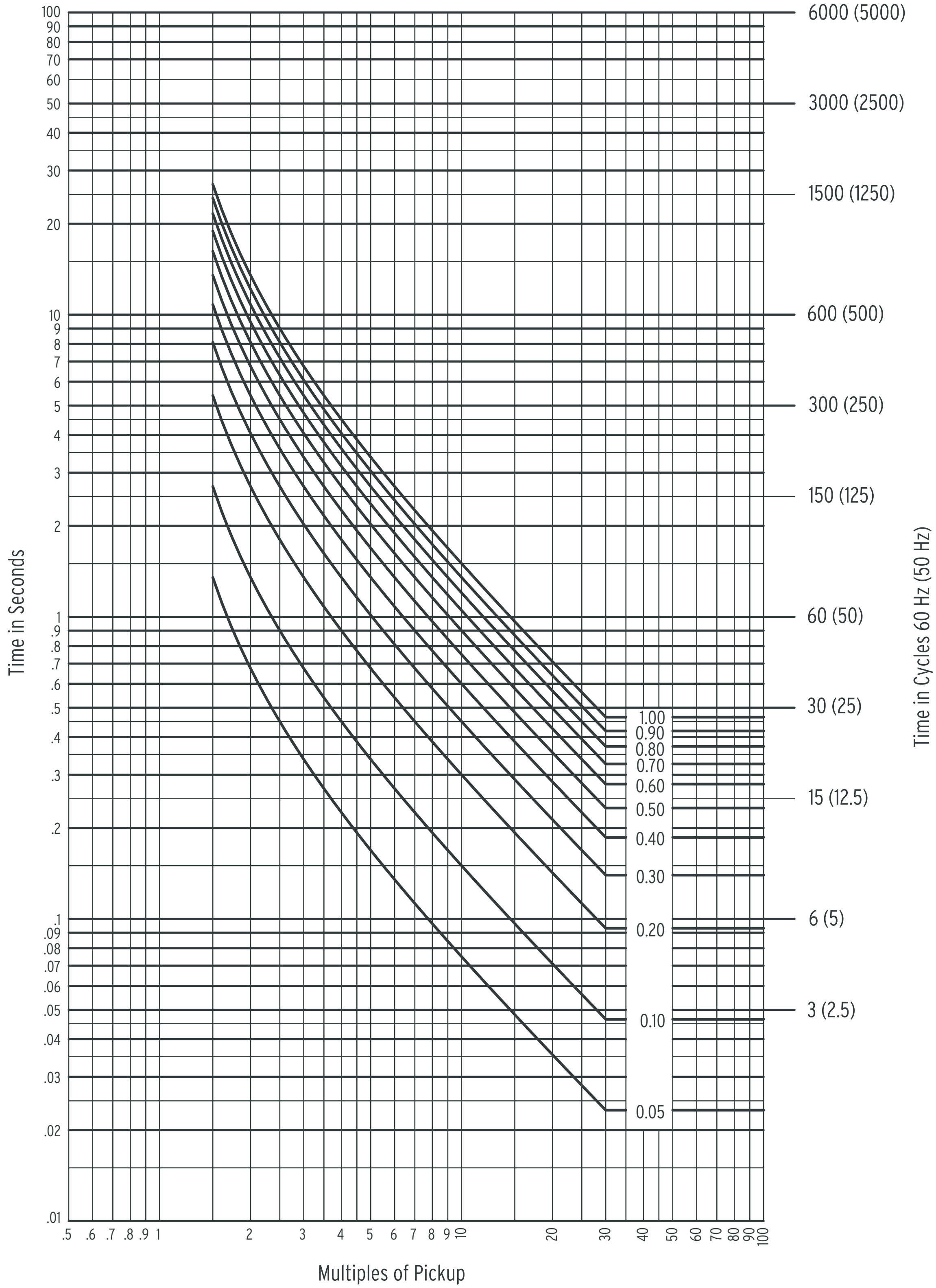


Figure 1.54 IEC Very Inverse—C2

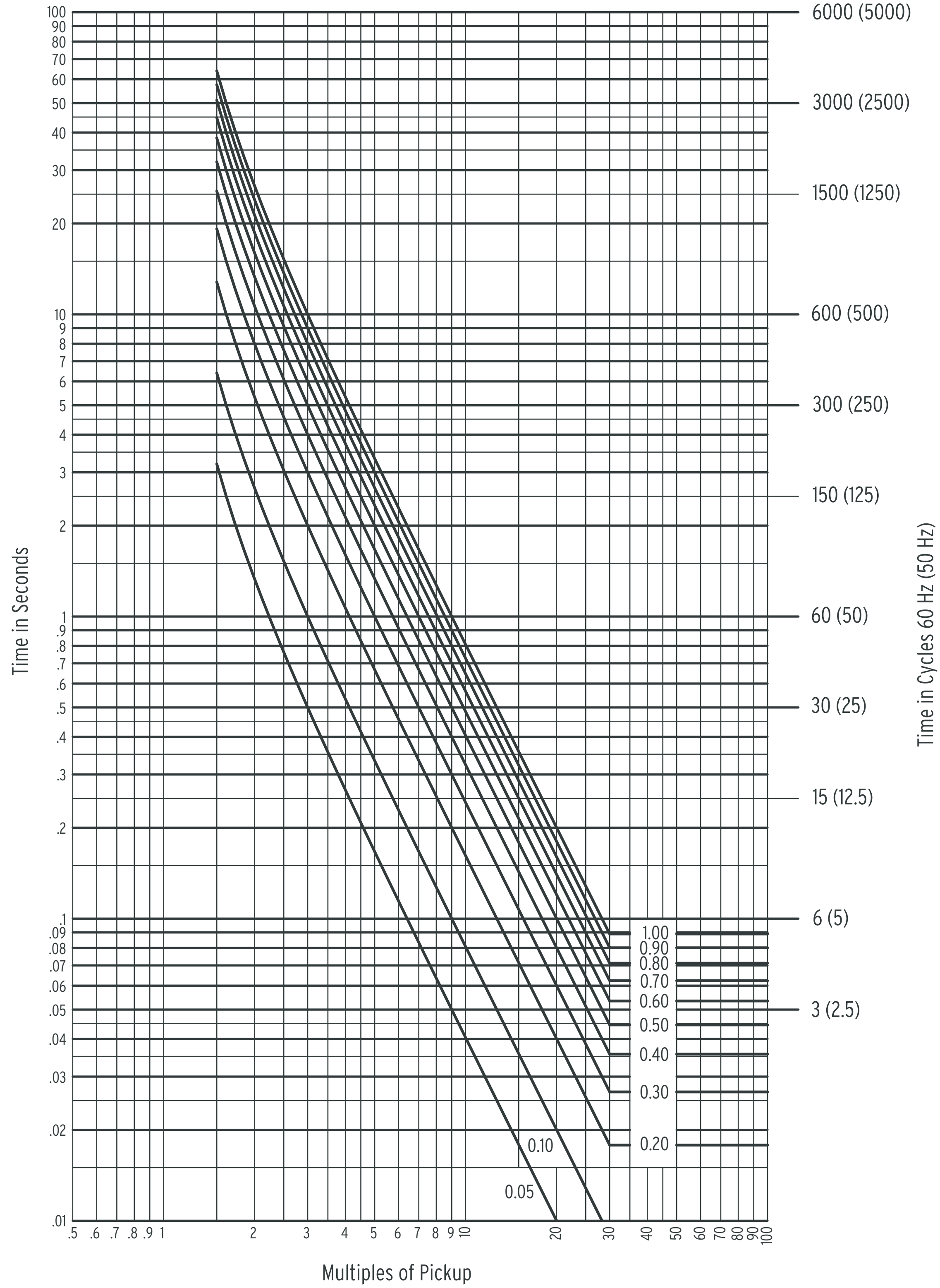


Figure 1.55 IEC Extremely Inverse—C3

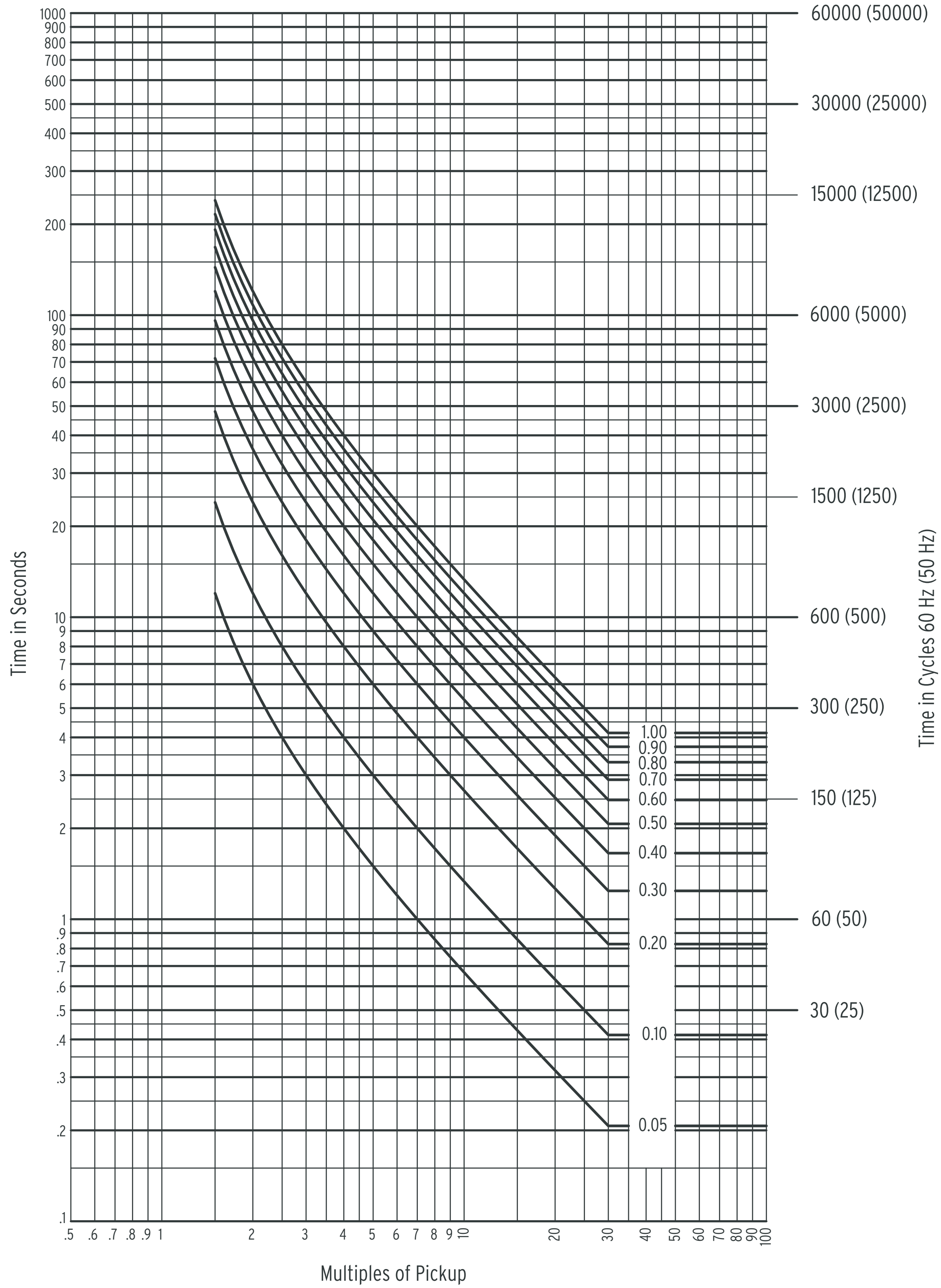


Figure 1.56 IEC Long-Time Inverse—C4

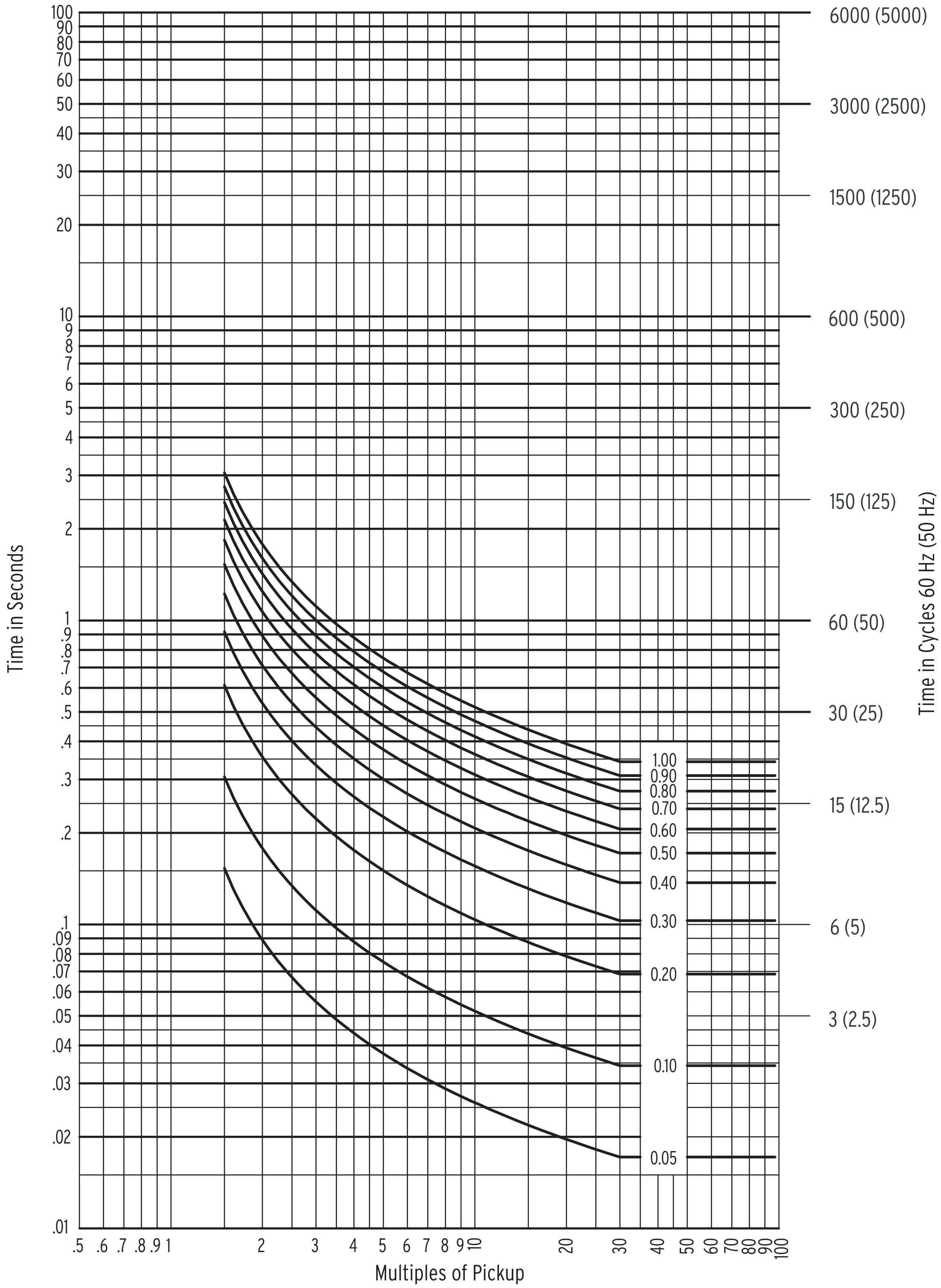


Figure 1.57 IEC Short-Time Inverse—C5

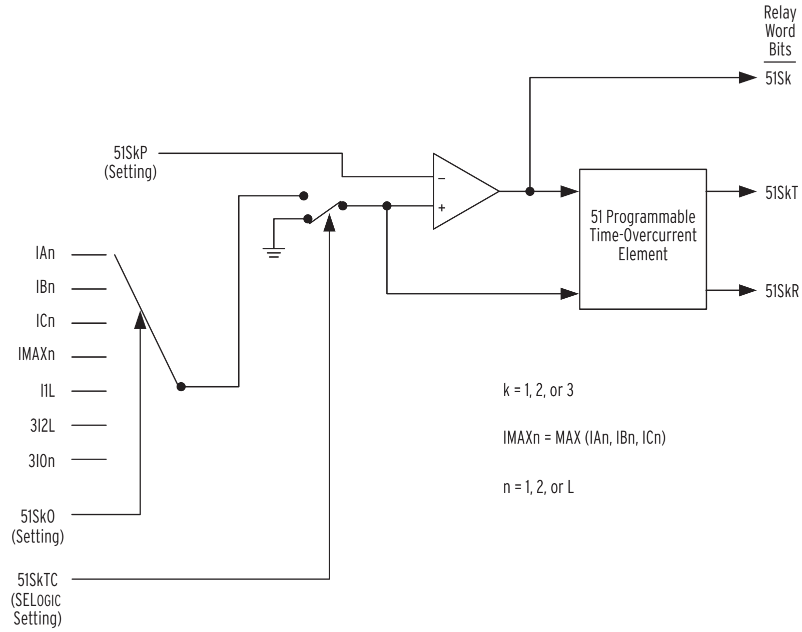


Figure 1.58 Selectable Inverse-Time Overcurrent Element Logic Diagram

Switch-Onto-Fault Logic

The switch-onto-fault (SOTF) logic permits specified protection elements to trip for a settable time after the circuit breaker closes. Specify these elements in the SELOGIC control equation TRSOTF (switch-onto-fault trip). The SOTF logic works in two stages: validating a possible SOTF condition and initiating (enabling) the SOTF protection duration.

The relay validates an SOTF condition by sensing the following:

- *Upon circuit breaker opening*: detection of a pole open condition (3PO or SPO) when setting 52AEND (52A Pole Open Qualifying Time Delay) is other than OFF
- *Upon circuit breaker closing*: detection of a pole open condition (3PO or SPO) when setting CLOEND (CLSMON or Single-Pole Open Delay) is other than OFF

Select either or both methods for the validating procedure.

The relay initiates SOTF protection at these corresponding instances:

- *Circuit breaker opening*: 52AEND timer timeout
- *Circuit breaker closing*: CLOEND time timeout and SELOGIC control equation CLSMON assertion

Circuit Breaker Opened SOTF Logic

Set ESOTF to Y and set 52AEND to other than OFF to enable the circuit breaker-opened SOTF logic. When the circuit breaker opens, the 52AEND timer operates when one or three poles open (SPO or 3PO assert). The logic includes the SPO condition if setting ESPSTF := Y (see *SOTF Options*). When the 3PO or SPO condition lasts longer than the 52AEND timer, the relay asserts Relay Word bit SOTFE (SOTF Enable).

When the circuit breaker closes, either Relay Word bit 3PO deasserts after the 3POD dropout time or Relay Word bit SPO deasserts after the SPOD dropout time. When 3PO or SPO deasserts, the relay continues to assert Relay Word bit SOTFE for dropout time SOTFD or until the logic detects a healthy voltage condition (if EVRST := Y, see *SOTF Options*).

Circuit Breaker Closed SOTF Logic

You can detect circuit breaker close bus assertion by monitoring the dc close bus. Connect a control input on the SEL-421 to the dc close bus. The control input energizes whenever a manual close or automatic reclosure occurs. Set SELOGIC control equation CLSMON (Close Signal Monitor) to monitor the control input (e.g., CLSMON := IN102) and consequently detect close bus assertion.

Set ESOTF to Y and set CLOEND to other than OFF to enable the circuit breaker-closed SOTF logic. The CLOEND timer operates when one or three poles open (SPO or 3PO asserts). If the 3PO or SPO condition continues longer than the CLOEND time and the close bus asserts (SELOGIC control equation CLSMON equals logical 1), Relay Word bit SOTFE asserts and remains asserted for dropout time setting SOTFD or until the logic detects a healthy voltage condition (if EVRST := Y, see *SOTF Options*).

SOTF Options

If the setting EVRST (Voltage Reset Enable) is enabled (EVRST := Y), Relay Word bit SOTFE resets automatically when the relay measures healthy balanced positive-sequence voltage at greater than 85 percent nominal voltage.

If setting ESPSTF (Single-Pole SOTF Enable) is enabled (ESPSTF := Y), the relay provides SOTF protection for a single-pole open (SPO) condition.

Table 1.64 SOTF Settings

Setting	Description	Range	Default (5 A)
ESOTF	Switch-Onto-Fault	Y, N	Y
ESPSTF	Single-Pole Switch-Onto-Fault	Y, N	N
EVRST	Switch-Onto-Fault Voltage Reset	Y, N	N
52AEND	52A Pole Open Time Delay (cycles)	OFF, 0.000–16000	10.000
CLOEND	CLSMON or Single Pole Open Delay (cycles)	OFF, 0.000–16000	OFF
SOTFD	Switch-Onto-Fault Enable Duration (cycles)	0.500–16000	10.000
CLSMON	Close Signal Monitor	SELOGIC Equation	NA

Table 1.65 SOTF Relay Word Bits

Name	Description
SOTFE	Switch-onto-fault trip logic enabled

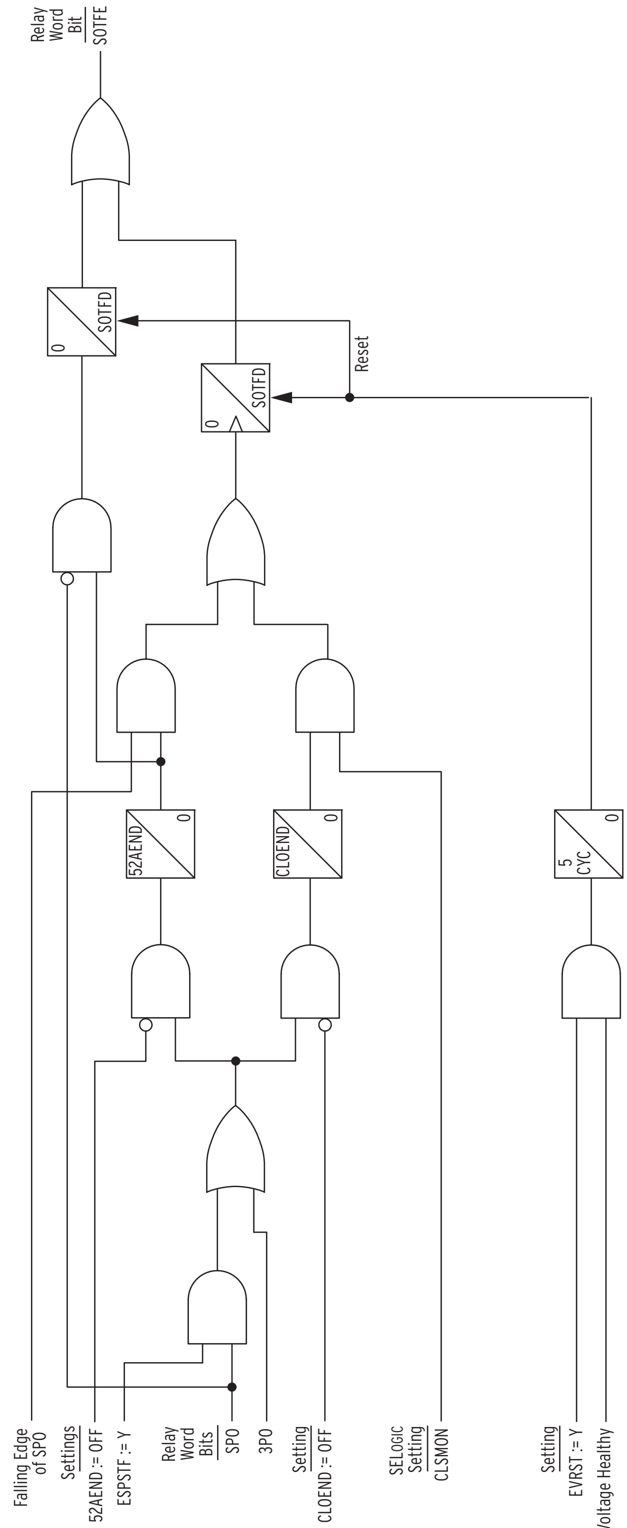


Figure 1.59 SOTF Logic Diagram

Communications-Assisted Tripping Logic

Communications-assisted tripping schemes provide unit protection for transmission lines without any need for external coordination devices. The relay includes the following five schemes.

- POTT—Permissive-Overreaching Transfer Trip
- POTT2—Two-Channel Permissive Overreaching Transfer Trip
- POTT3—Phase-Segregated Permissive Overreaching Transfer Trip
- DCUB—Directional Comparison Unblocking
- DCB—Directional Comparison Blocking

All of these schemes work in both two-terminal and three-terminal line applications. For the DCUB scheme, you have separate settings choices for these applications (ECOMM equals DCUB1 or DCUB2) because of unique DCUB logic considerations.

You must set Zone 3 reverse-looking (DIR3 equals R) for all three schemes.

Table 1.66 ECOMM Setting

Setting	Description	Range	Default (5 A)
ECOMM	Communications-Assisted Tripping	N, DCB, POTT, POTT2, POTT3, DCUB1, DCUB2	POTT

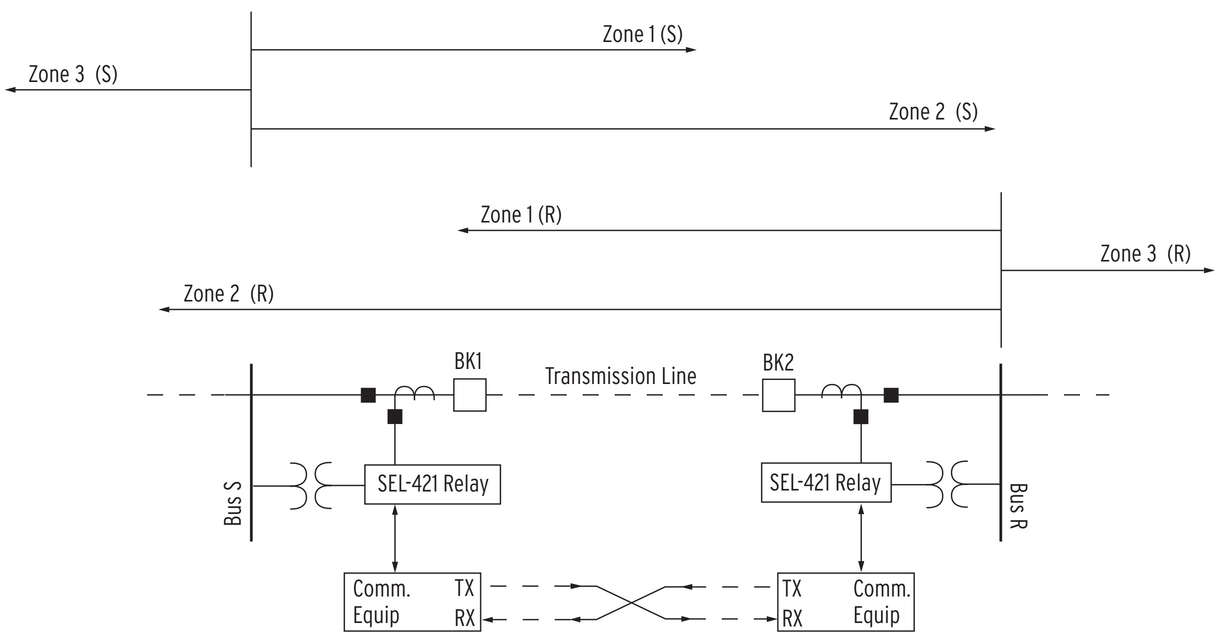


Figure 1.60 Required Zone Directional Settings

Directional Comparison Blocking Scheme

The Directional Comparison Blocking (DCB) trip scheme performs the following tasks:

- Provides carrier coordination timers that allow time for the block trip signal to arrive from the remote terminal. The 21SD timer is for the Zone 2 distance elements M2P and Z2G. The 67SD timer is for the Level 2 overcurrent elements 67Q2 and 67G2.
- Instantaneously keys the communications equipment to transmit block trip for reverse faults and extends this signal for a settable time (Z3XD) following the dropout of all Zone 3 distance and Level 3 directional overcurrent elements.
- Latches block trip send condition by the phase distance elements following a close-in zero voltage three-phase fault when the polarizing memory expires; return of polarizing memory voltage or interruption of fault current removes the latch.
- Extends the received block trip signal by a settable time (BTXD).

The DCB scheme consists of four sections:

- Coordination timers
- Starting elements
- Extension of the blocking signal
- Stopping elements

Coordination Timers

Momentarily delaying the forward-looking Zone 2 and Level 2 elements that provide high-speed tripping at the local terminal ensures that the local circuit breaker does not trip for external faults behind the remote terminal. This delay provides time for the nondirectional and reverse-looking elements at the remote terminal to send a blocking signal to the local terminal during out-of-section faults. This particular time delay is the coordination time for the DCB scheme. There are separate coordination timers for Zone 2 distance elements (21SD) and Level 2 residual directional overcurrent elements (67SD).

The recommended setting for the 21SD timer is the sum of the following three times:

- Control input recognition time (including debounce timer)
- Remote Zone 3 distance protection maximum operating time
- Maximum communications channel time

The output of Zone 2 delay timer 21SD is Relay Word bit Z2PGS (Zone 2 Phase and Ground Short Delay).

The recommended setting for the 67SD timer is the sum of the following three times:

- Control input recognition time (including debounce timer)
- Remote Level 3 nondirectional low-set overcurrent element maximum operating time
- Maximum communications channel time

The output of Level 2 delay timer 67SD is Relay Word bit 67QG2S (Negative-Sequence and Residual Directional Overcurrent Short Delay).

If the control input time delay on pickup debounce timer is zero, the maximum recognition time for the control input is 0.125 cycles.

Starting Elements

You can select nondirectional elements, directional elements, or both to detect external faults behind the local terminal. These elements send a blocking signal to the remote station to prevent unwanted high-speed tripping during out-of-section faults. Nondirectional elements do not process a directional decision, so nondirectional elements are always faster than directional elements.

Nondirectional Start

Relay Word bit NSTRT (Nondirectional Start) is assigned to a contact output to start transmitting the blocking signal. NSTRT asserts if either 50Q3 or 50G3 pickup.

Directional Start

Relay Word bit DSTRT (Directional Start) asserts if any of the following elements pick up:

- Zone 3 phase distance elements
- Zone 3 ground distance elements
- Level 3 negative-sequence directional overcurrent element
- Level 3 zero-sequence directional overcurrent element

Relay Word bit DSTRT is useful when a bolted close-in three-phase fault occurs behind the relay. Zone 3 phase distance characteristics do not need a reverse offset. Should the polarizing voltage for the distance elements collapse to zero, the corresponding Zone 3 supervisory phase-to-phase current level detectors will cause the Zone 3 phase distance elements to latch.

Use timer Z3XD (Zone 3 Reverse Time Delay on Dropout) to extend the blocking signal during current reversals. Use timer Z3XPU (Zone 3 Reverse Time Delay on Pickup) to prevent extension of the blocking signal resulting from Z3XD if a reverse-looking element picks up during a transient. This pickup delay ensures high-speed tripping for internal faults.

Extension of the Blocking Signal

The directional comparison blocking scheme typically uses an on/off carrier signal to block high-speed tripping at the remote terminal for out-of-section faults. Connect the carrier receive block signal output contact from the teleprotection equipment to a control input assigned to Relay Word bit BT (Block Trip Received). This input must remain asserted to block the forward-looking elements after the coordination timers expire. If the blocking signal drops out momentarily, the distance relay can trip for out-of-section faults.

Timer BTXD (Block Trip Extension) delays dropout of the control input assigned to Relay Word bit BT so that unwanted tripping does not occur during momentary lapses of the blocking signal (carrier holes). This timer maintains the blocking signal at the receiving relay by delaying the dropout of Relay Word bit BT.

Three-Terminal Line

If you apply the DCB scheme to a three-terminal line, program SELOGIC control equation BT as follows:

BT := **IN105 OR IN106** Block Trip Received (SELOGIC Equation)

Relay inputs IN105 or IN106 assert when the relay receives a blocking signal from either of the two other terminals. The relay cannot high-speed trip if either control input asserts. These two control inputs were chosen for this particular example. Use appropriate control inputs for your application.

Stopping Elements

Zone 2 distance and Level 2 directional overcurrent elements detect that the fault is in the tripping direction and stop the starting elements from transmitting the blocking signal to the remote terminal. Program an output contact to stop carrier by energizing an input of the communications equipment transmitter.

The stopping elements must have priority over the nondirectional starting elements; however, directional starting elements must have priority over the stopping elements. *Figure 1.61* shows that the directional starting elements have internal priority over the stopping elements. Use SELOGIC control equations to make sure that the stopping elements have priority over the nondirectional starting elements:

OUT101 := **NSTRT AND NOT STOP OR DSTRT** Output (SELOGIC Equation)

Table 1.67 DCB Settings

Setting	Description	Range	Default (5 A)
Z3XPU	Zone 3 Reverse Pickup Delay (cycles)	0.000–16000	1.000
Z3XD	Zone 3 Reverse Dropout Time Delay (cycles)	0.000–16000	6.000
BTXD	Block Trip Receive Extension Time (cycles)	0.000–16000	1.000
21SD	Zone 2 Distance Short Delay (cycles)	0.000–16000	2.000
67SD	Level 2 Overcurrent Short Delay (cycles)	0.000–16000	2.000
BT	Block Trip Received	SELOGIC Equation	NA

Table 1.68 DCB Relay Word Bits

Name	Description
Z3XT	Current reversal guard timer
Z2PGS	Zone 2 phase and ground short delay element
67QG2S	Negative-sequence and residual directional overcurrent short delay element
DSTRT	Directional start element
NSTRT	Nondirectional start element
STOP	Stop element
BTX	Blocking signal extended

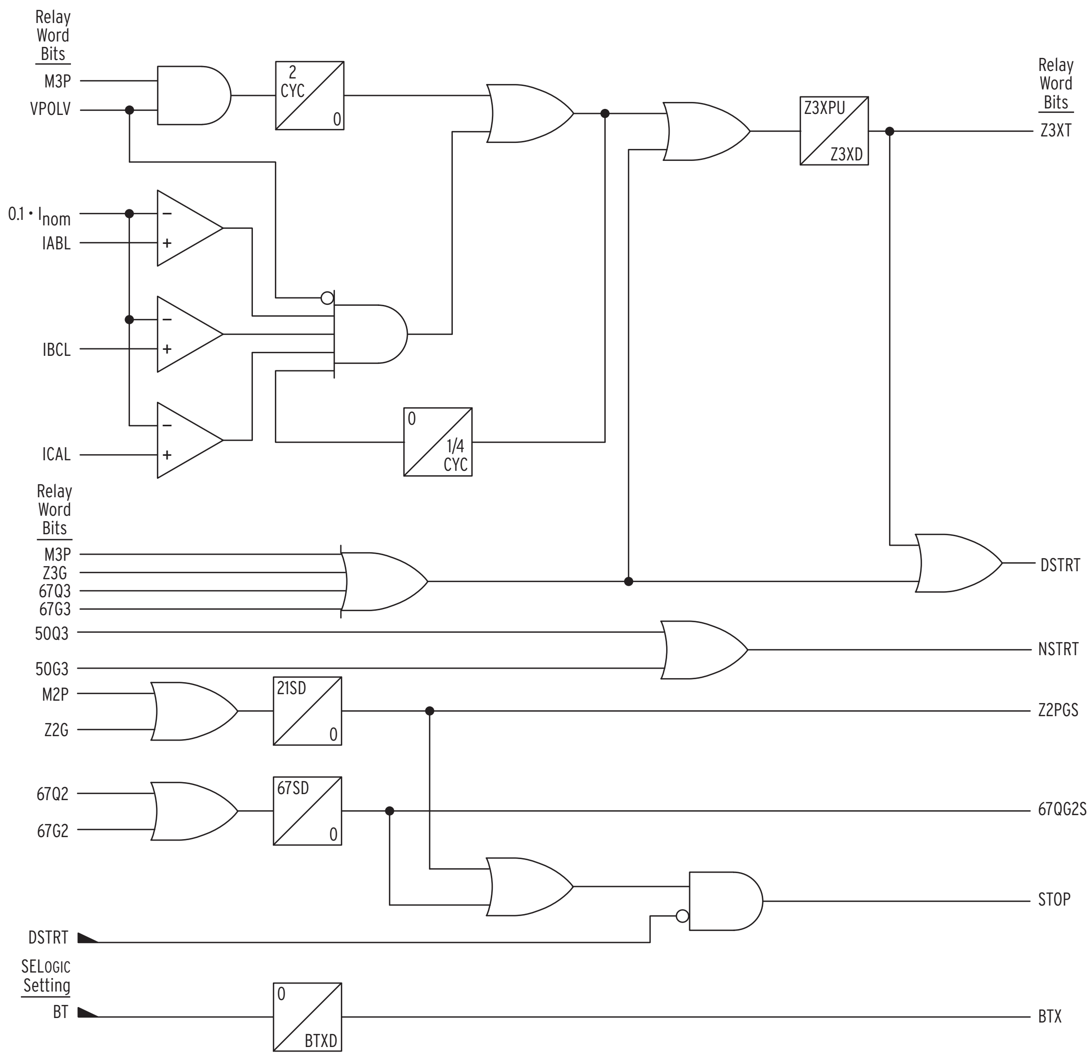


Figure 1.61 DCB Logic Diagram

Permissive Overreaching Transfer Tripping Scheme

Use MIRRORED BITS® communications to implement a Permissive Overreaching Transfer Tripping (POTT) scheme efficiently and economically. MIRRORED BITS communications technology improves security and improves the overall operating speed. If the communications channel is reliable and noise-free (as with fiber-optic channels), then POTT provides both security and reliability. You can also implement a POTT scheme with other conventional communications channels such as leased telephone lines and microwave. The DCUB trip scheme is a better choice if the communications channel is less than perfect, but communications channel failures are unlikely to occur during external faults.

POTT Scheme Selection

The SEL-421 offers three POTT schemes: POTT, POTT2, and POTT3. The type of communications channel(s) in your application best determines which scheme to implement.

POTT

Use the conventional POTT scheme for an application with a single communications channel.

For details about implementing a conventional POTT scheme, see *POTT Trip Scheme on page A.1.36*.

POTT2

Use the POTT2 scheme for applications with two communications channels, one for single-phase fault identification and one for multi-phase fault identification. This scheme is useful in applications where there is a high likelihood of cross-country faults.

For details about implementing a POTT2 scheme, see *Cross-Country Fault Identification on page A.1.41*.

POTT3

Use the POTT3 scheme for phase-segregated applications with three communications channels. In this scheme, each channel indicates permissive trip for single-phase. Multi-phase fault detection results in all three channels transmitting a permissive trip.

For details about implementing a POTT3 scheme, see *Three-Channel POTT Scheme, POTT3 on page A.1.44*.

POTT Scheme Logic

The POTT scheme logic performs the following tasks:

- ➤ Keys the communications equipment to send permissive trip (PT) when any element you include in the TRCOMM SELOGIC control equation asserts and the current reversal logic is not asserted
- ➤ Prevents keying and tripping by the POTT logic following a current reversal
- ➤ Echoes the received permissive signal to the remote terminal
- ➤ Prevents channel lockup during echo and test
- ➤ Provides a secure means of tripping for weak- and/or zero-infeed terminals
- ➤ Ensures proper tripping at both terminals during cross-country faults (via special logic implemented with SELOGIC control equations)

The POTT scheme logic consists of the following:

- ➤ Current reversal guard logic
- ➤ Echo
- ➤ Weak infeed logic

Current Reversal Guard Logic

Use current reversal guard for parallel line applications if the Zone 2 reach extends beyond the midpoint of the parallel transmission line. With current reversal guard, the relay does not key the transmitter and ignores reception of a permissive signal from the remote terminal when the reverse-looking protection sees an external fault. The Zone 3 Reverse Block Delay (Z3RBD) timer extends these two actions after a current reversal ceases and the reverse-looking elements drop out.

Echo

If the local circuit breaker is open, or a weak infeed condition exists, the remote relay permissive signal can echo back to itself and issue a high-speed trip for faults beyond the remote relay Zone 1 reach. The SEL-421 includes logic that echoes the received permissive signal back to the remote terminal after specific conditions are satisfied. This echo logic includes timers for qualifying the permissive signal and timers to block the echo logic during specific conditions.

Use the Echo Block Time Delay (EBLKD) to block the echo logic after dropout of local permissive elements. The recommended time setting for the EBLKD timer is the sum of the following:

- Remote terminal circuit breaker opening time
- Communications channel round-trip time
- Safety margin

An echo delay ensures that the reverse-looking elements at the receiving end have sufficient time to operate and block the received echo signal for external faults behind the remote terminal. This delay also guards the echo and weak infeed logic against noise bursts that can occur on the communications channel during close-in external faults. Typically, these noise bursts coincide with faults external to the line section.

Because of the brief duration of noise bursts and the pickup for the reverse-looking elements, a received signal must be present for a short time to allow the POTT scheme to echo the permissive signal back to the remote terminal. The Echo Time Delay Pickup (ETDPU) timer specifies the time a permissive trip signal must be present.

The Echo Duration Time Delay (EDURD) limits the duration of the echoed permissive signal. Once the echo signal begins, it should remain for a minimum period of time and then stop, even if a terminal receives a continuous permissive signal. This cessation of the echo signal prevents the permissive trip signal from latching between the two terminals.

Weak-Infeed Logic

The SEL-421 provides weak-infeed logic to high-speed trip both line terminals for internal faults near the weak terminal. The weak terminal echoes the permissive signal back to the strong terminal and allows the strong terminal to trip. After satisfaction of specific conditions, the weak terminal trips by converting the echoed permissive signal to a trip signal.

In some applications, one terminal might not contribute enough fault current to operate the protective elements, even with all sources in. It is important to trip the weak-infeed terminal to prevent low-level fault current from maintaining the fault arc (i.e., the fault will restrike following auto-reclose at the strong terminal). Because the strong terminal is beyond the Zone 1 reach, it cannot trip for end-zone faults.

The faulted phase voltage(s) is depressed at the weak-infeed terminal, a condition that generates significant residual voltage during ground faults. The SEL-421 uses phase-to-phase undervoltage level detectors and a residual overvoltage level detector to qualify a weak-infeed condition. If setting EWFC equals Y, the relay enables the weak-infeed logic and settings 27PPW and 59NW are active. For single-pole tripping applications, set EWFC to SP and setting 27PWI is active.

The weak-infeed logic sets the ECTT (Echo Conversion to Trip) element upon satisfaction of the following:

- No reverse-looking elements have picked up (the reverse-looking elements override operation of the weak-infeed and echo logic for faults behind the relay location)
- LOP is deasserted when the setting ELOP equals Y1
- At least one phase-to-phase undervoltage element or the residual overvoltage element operates
- The local circuit breaker(s) is closed
- A permissive trip signal is received for ETDPU time period

The EWFC setting enables the weak-infeed feature of the relay. When the EWFC setting is Y, the ECTT (Echo Conversion to Trip) logic is enabled. When the setting EWFC is SP, the relay can convert echo to a single-pole trip at the local terminal. ECTT logic is disabled when the setting is N.

Three-Terminal Lines

If you apply the POTT scheme to a three-terminal line, program SELOGIC control equation PT1 as follows:

PT1 := **IN105 AND IN106** General Permissive Trip Received (SELOGIC Equation)

Relay control inputs IN105 and IN106 assert when the relay receives a permissive signal from each of the two other terminals. The relay cannot high-speed trip until both inputs assert. These two control inputs were chosen for this particular example. Use control inputs that are appropriate for your application.

Cross-Country Faults

Refer to *500 kV Parallel Transmission Lines With Mutual Coupling Example on page A.1.18* for a complete description of how to apply the SEL-421 using MIRRORED BITS communications. The SEL-421 POTT scheme logic (ECOMM = POTT2 or POTT3) includes additional logic that ensures proper single-pole tripping at both stations during cross-country faults. A cross-country fault consists of simultaneous single phase-to-ground faults on both of the parallel lines. If the simultaneous ground faults are beyond Zone 1 reach with respect to the local station, unwanted three-pole tripping could occur.

Table 1.69 POTT Settings (Sheet 1 of 2)

Setting	Description	Range	Default (5 A)
Z3RBD	Zone 3 Reverse Block Time Delay (cycles)	0.000–16000	5.000
EBLKD	Echo Block Time Delay (cycles)	0.000–16000	10.000
ETDPU	Echo Time Delay Pickup (cycles)	0.000–16000	2.000
EDURD	Echo Duration Time Delay (cycles)	0.000–16000	4.000
EWFC	Weak Infeed Trip	Y, N, SP	N
27PWI[a]	Weak Infeed Phase Undervoltage Pickup (V)	1.0–200	47.0
27PPW[b]	Weak Infeed Undervoltage Pickup ($V_{\phi\phi}$)	0.1–300	80.0
59NW[b]	Weak Infeed Zero-Sequence Overvoltage Pickup (V)	0.1–200	5.0

Table 1.69 POTT Settings (Sheet 2 of 2)

Setting	Description	Range	Default (5 A)
PT1	General Permissive Trip Received (when ECOMM = POTT or POTT2)	SELOGIC Equation	IN102 AND PLT02
PT3	Three-Pole Permissive Trip Received (when ECOMM = POTT2)	SELOGIC Equation	NA
PTA	A-Phase Permissive Trip Received (when ECOMM = POTT3)	SELOGIC Equation	NA
PTB	B-Phase Permissive Trip Received (when ECOMM = POTT3)	SELOGIC Equation	NA
PTC	C-Phase Permissive Trip Received (when ECOMM = POTT3)	SELOGIC Equation	NA

[a] Make setting when EWFC := SP
[b] Make setting when EWFC := Y or SP

Table 1.70 POTT Relay Word Bits

Name	Description
PT	Permission to trip received (ECOMM = POTT or POTT2)
PTA	A-phase permissive trip received (ECOMM = POTT3)
PTB	B-phase permissive trip received (ECOMM = POTT3)
PTC	C-phase permissive trip received (ECOMM = POTT3)
Z3RB	Current reversal guard asserted (ECOMM = POTT or POTT2)
Z3RBA	A-phase current reversal guard asserted (ECOMM = POTT3)
Z3RBB	B-phase current reversal guard asserted (ECOMM = POTT3)
Z3RBC	C-phase current reversal guard asserted (ECOMM = POTT3)
KEY	Transmit permission to trip (ECOMM = POTT or POTT2)
KEYA	Transmit A-phase permissive trip (ECOMM = POTT3)
KEYB	Transmit B-phase permissive trip (ECOMM = POTT3)
KEYC	Transmit C-phase permissive trip (ECOMM = POTT3)
EKEY	Echo received permission to trip (ECOMM = POTT or POTT2)
EKEYA	A-phase echo received permissive trip signal (ECOMM = POTT3)
EKEYB	B-phase echo received permissive trip signal (ECOMM = POTT3)
EKEYC	C-phase echo received permissive trip signal (ECOMM = POTT3)
ECTT	Echo conversion to trip (ECOMM = POTT or POTT2)
27AWI	A-phase undervoltage condition
27BWI	B-phase undervoltage condition
27CWI	C-phase undervoltage condition
WFC	Weak-infeed detected
KEY1	Transmit permission to single-pole trip
KEY3	Transmit permission to three-pole trip

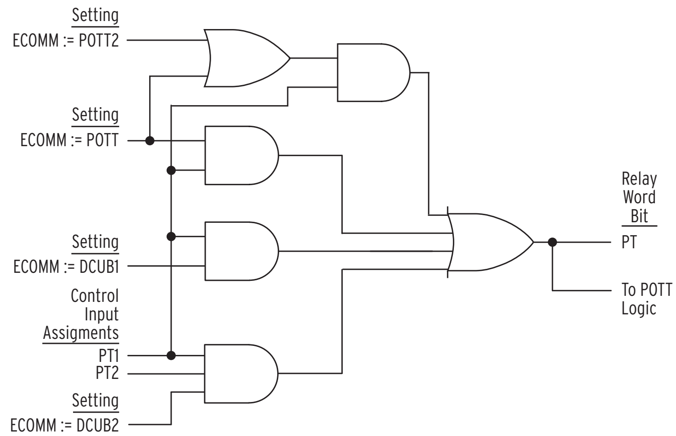


Figure 1.62 Permissive Trip Receiver Logic Diagram

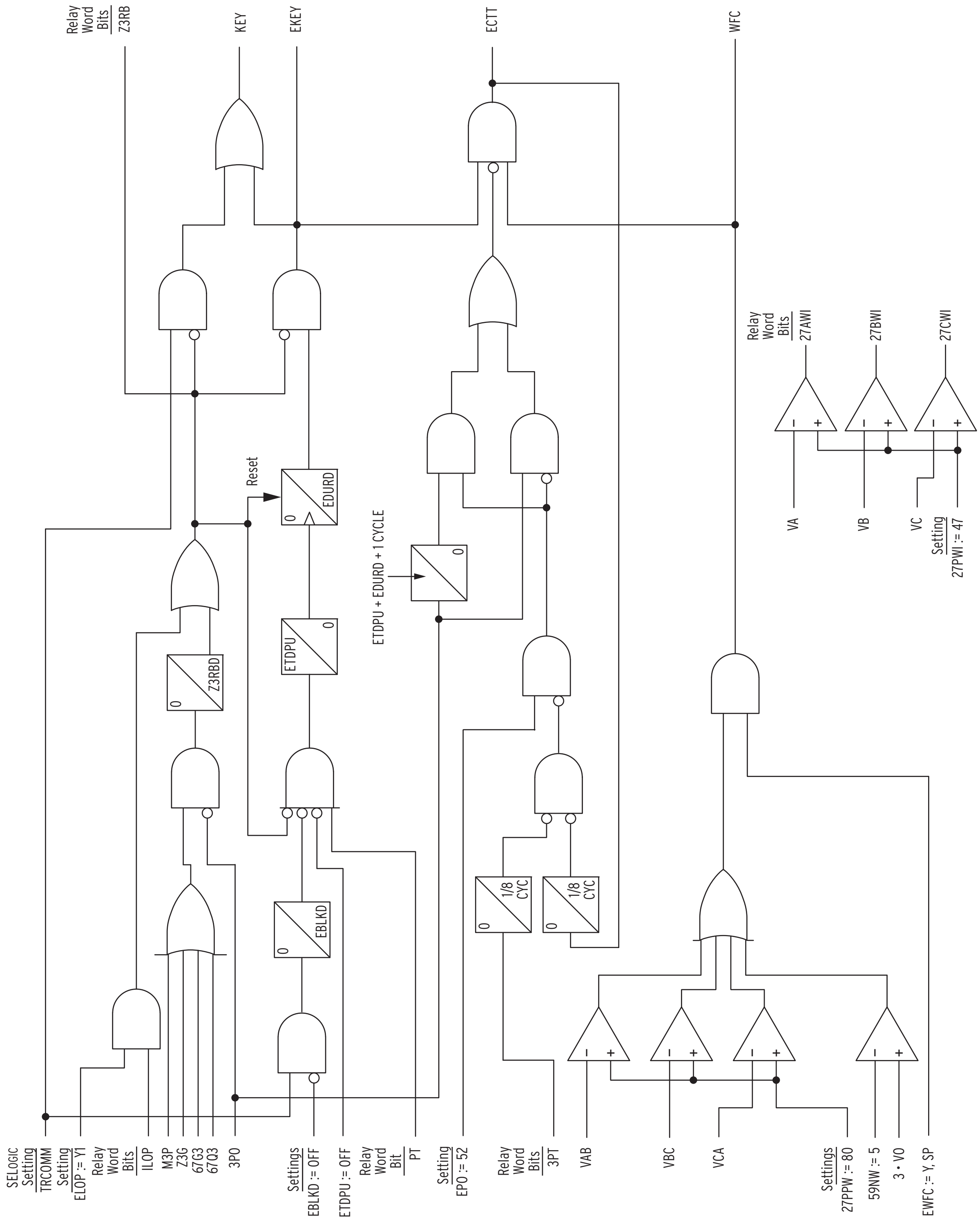


Figure 1.63 POTT Logic Diagram

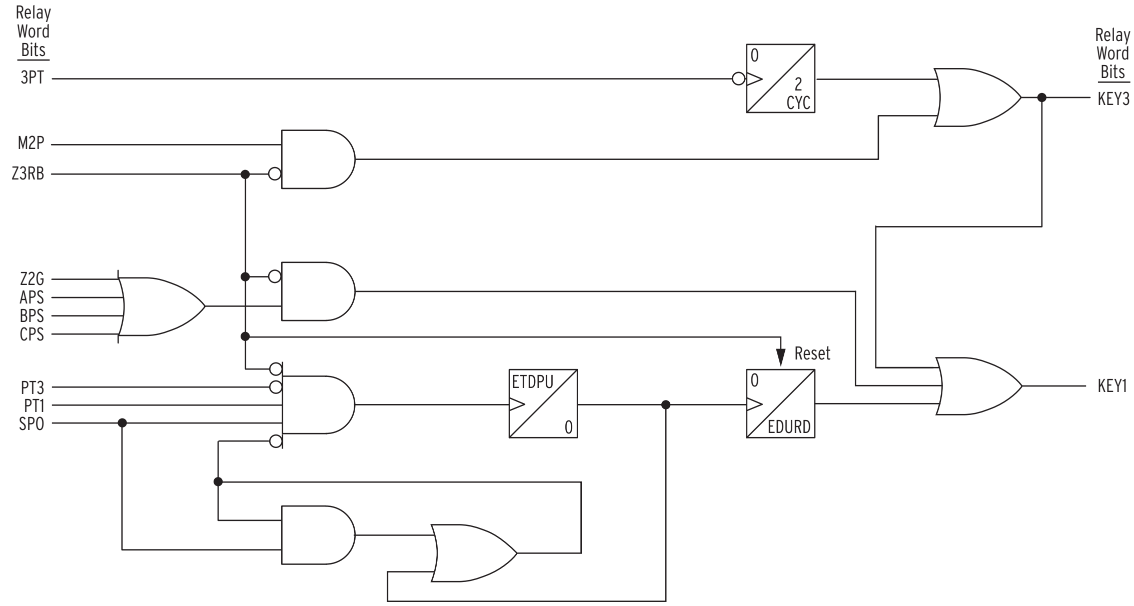


Figure 1.64 POTT Cross-Country Logic Diagram

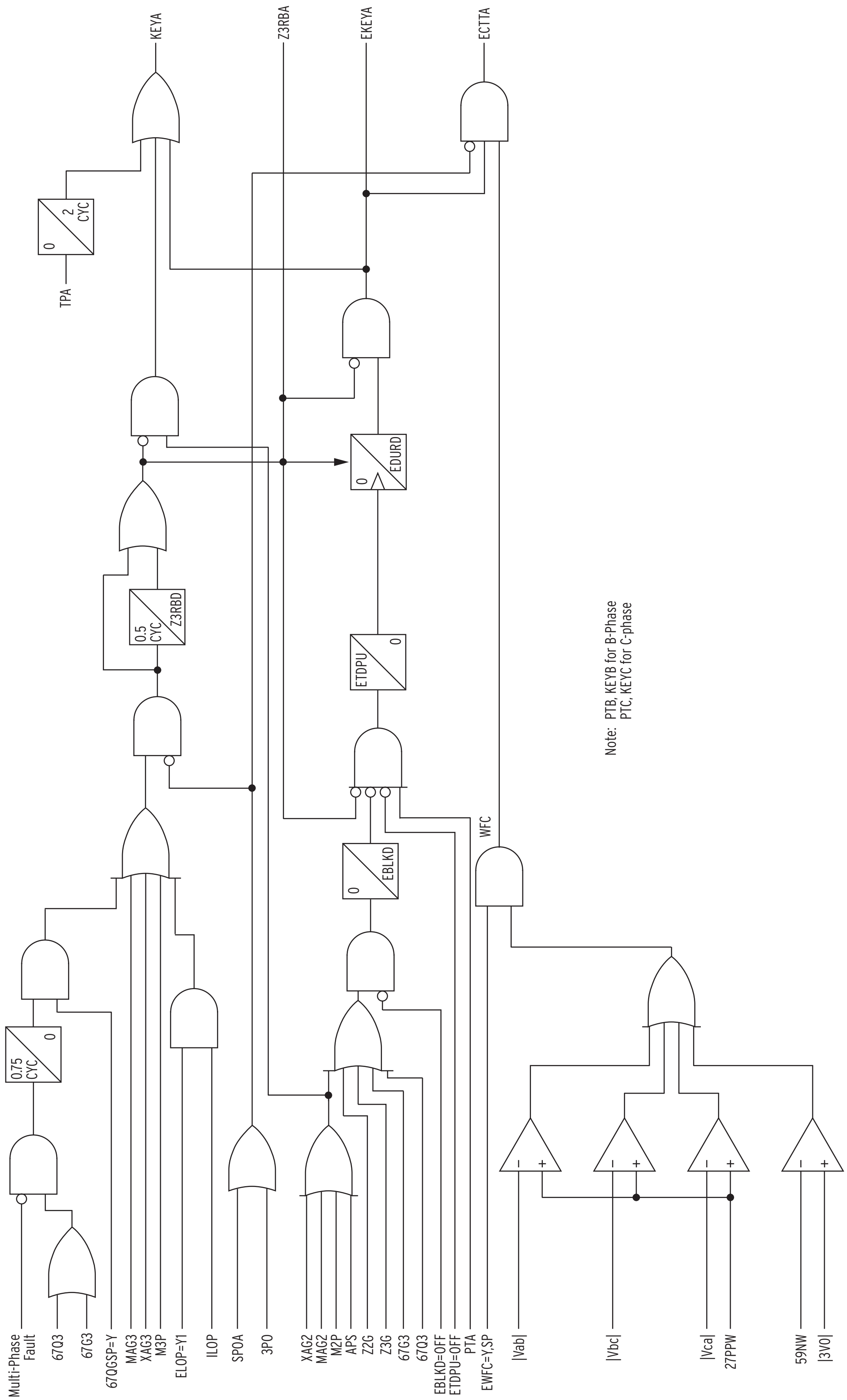


Figure 1.65 POTT Scheme Logic (ECOMM := POTT3) With Echo and Weak Infeed

Directional Comparison Unblocking Scheme Logic

The directional comparison unblocking (DCUB) tripping scheme in the SEL-421 provides a good combination of security and reliability, even when a communications channel is less than perfect. Communications channel failures are unlikely to occur during external faults. You can use the DCUB trip scheme with conventional communications channels such as PLC (power line carrier). Use improved methods such as MIRRORED BITS communications to implement the DCUB tripping scheme efficiently and economically. MIRRORED BITS communications and the DCUB tripping scheme give secure, high-speed operation.

Through a control input programmed to the LOG (loss-of-guard) function, the relay monitors the LOG output from the communications receiver. If LOG asserts, and no trip permission is received, the relay can high-speed trip during a short window using selected overreaching elements. The relay then asserts permissive trip blocking signal UBB and locks out permissive trip Relay Word bit PTRX. The typical DCUB application is a POTT scheme with the addition of a frequency shift-keying (FSK) carrier as the communications medium.

Enable the DCUB logic by setting ECOMM to DCUB1 or DCUB2. You must provide the relay all POTT settings plus the settings exclusive to the DCUB scheme. The following is an explanation of the differences between setting choices DCUB1 and DCUB2:

- DCUB1—directional comparison unblocking scheme for two-terminal lines (i.e., communication from **one** remote terminal)
- DCUB2—directional comparison unblocking scheme for three-terminal lines (i.e., communication from **two** remote terminals)

The DCUB logic takes the loss-of-guard and permissive trip outputs from the communications receivers and makes permissive trip (PTRX1 and PTRX2) outputs and permissive trip (unblock) blocking (UBB1 and UBB2) outputs.

PTRX1 asserts for loss of channel or for an actual received permissive trip in two-terminal line applications (e.g., setting ECOMM to DCUB1).

PTRX1 or PTRX2 assert for loss of channel or for an actual received permissive trip (for the respective Channel 1 or 2) in three-terminal line applications (e.g., setting ECOMM to DCUB2).

Enable setting ECOMM (when set to DCUB1 and DCUB2) determines the routing of Relay Word bits PTRX1 and PTRX2 to control Relay Word bit PTRX. Relay Word bit PTRX is the permissive trip receive input into the trip logic.

Three-Terminal Lines

If you apply the DCUB scheme to a three-terminal line, program SELOGIC control equation PT1 and PT2 as follows:

PT1 := **IN105** General Permissive Trip Received (SELOGIC Equation)

PT2 := **IN106** Channel 2 Permissive Trip Received (SELOGIC Equation)

Relay control inputs IN105 or IN106 assert when the relay receives a permissive signal from one of the two other terminals. The relay cannot high-speed trip until both inputs assert. These two control inputs were chosen for this example. Use control inputs that are appropriate for your application.

In addition, for a three-terminal line, program SELOGIC control equations LOG1 and LOG2 as follows:

LOG1 := **IN205** Channel 1 Loss-of-Guard

LOG2 := **IN206** Channel 2 Loss-of-Guard

Relay control inputs IN205 or IN206 assert when the relay receives a loss-of-guard signal from either of the two other terminals. When SELOGIC control equation LOG1 (Channel 1 Loss-of-Guard) asserts, the relay asserts Relay Word bit UBB1 (Block Permissive Trip on Receiver 1) and removes the possibility that Relay Word bit PTRX1 (Permissive Trip on Receiver 1) will assert. These two control inputs were chosen for this particular example. Use control inputs that are appropriate for your application.

See *Table 1.71* for the DCUB settings. The first portion of the settings (from Z3RBD to PT1) are identical to the settings for the ECOMM := POTT scheme; (see *POTT Scheme Logic on page R.1.94*).

Table 1.71 DCUB Settings

Setting	Description	Range	Default (5 A)
Z3RBD	Zone 3 Reverse Block Time Delay (cycles)	0.000–16000	5.000
EBLKD	Echo Block Time Delay (cycles)	0.000–16000	10.000
ETDPU	Echo Time Delay Pickup (cycles)	0.000–16000	2.000
EDURD	Echo Duration Time Delay (cycles)	0.000–16000	4.000
EWFC	Weak Infeed Trip	Y, N, SP	N
27PWI[a]	Weak Infeed Phase Undervoltage Pickup (V)	1.0–200	47.0
27PPW[b]	Weak Infeed Undervoltage Pickup ($V_{\phi\phi}$)	0.1–300	80.0
59NW[b]	Weak Infeed Zero-Sequence Overvoltage Pickup (V)	0.1–200	5.0
PT1	General Permissive Trip Received	SELOGIC Equation	IN101 AND PLT02
GARD1D	Guard Present Security Delay (cycles)	0.000–16000	120.000
UBDURD	DCUB Disabling Time Delay (cycles)	0.000–16000	180.000
UBEND	DCUB Duration Time Delay (cycles)	0.000–16000	20.000
PT2[c]	Channel 2 Permissive Trip Received	SELOGIC Equation	NA
LOG1	Channel 1 Loss-of-Guard	SELOGIC Equation	NA
LOG2[c]	Channel 2 Loss-of-Guard	SELOGIC Equation	NA

[a] Make setting when EWFC := SP
[b] Make setting when EWFC := Y or SP
[c] Make setting when ECOMM := DCUB2

Timer Setting Recommendations

GARD1D: Guard-Present Delay

This timer determines the minimum time before the relay reinstates permissive tripping following a loss-of-channel condition. Channel 1 and Channel 2 logic use separate timers but have this same delay setting.

UBDURD: DCUB Disable Delay

This timer prevents high-speed tripping via the POTT scheme logic after a settable time following a loss-of-channel condition; a typical setting is nine cycles. Channel 1 and Channel 2 logic use separate timers but have this same delay setting.

UBEND: DCUB Duration Delay

This timer determines the minimum time before the relay declares a loss-of-channel condition; a typical setting is 0.5 cycles. Channel 1 and Channel 2 logic use separate timers but have this same delay setting.

Table 1.72 DCUB Relay Word Bits

Name	Description
UBB1	Block permissive trip on Receiver 1
PTRX1	Permissive trip received on Channel 1
UBB2	Block permissive trip on Receiver 2
PTXR2	Permissive trip received on Channel 2
UBB	Block permissive trip received on Channel 1 or Channel 2
PTRX	Permissive trip received on Channel 1 and Channel 2

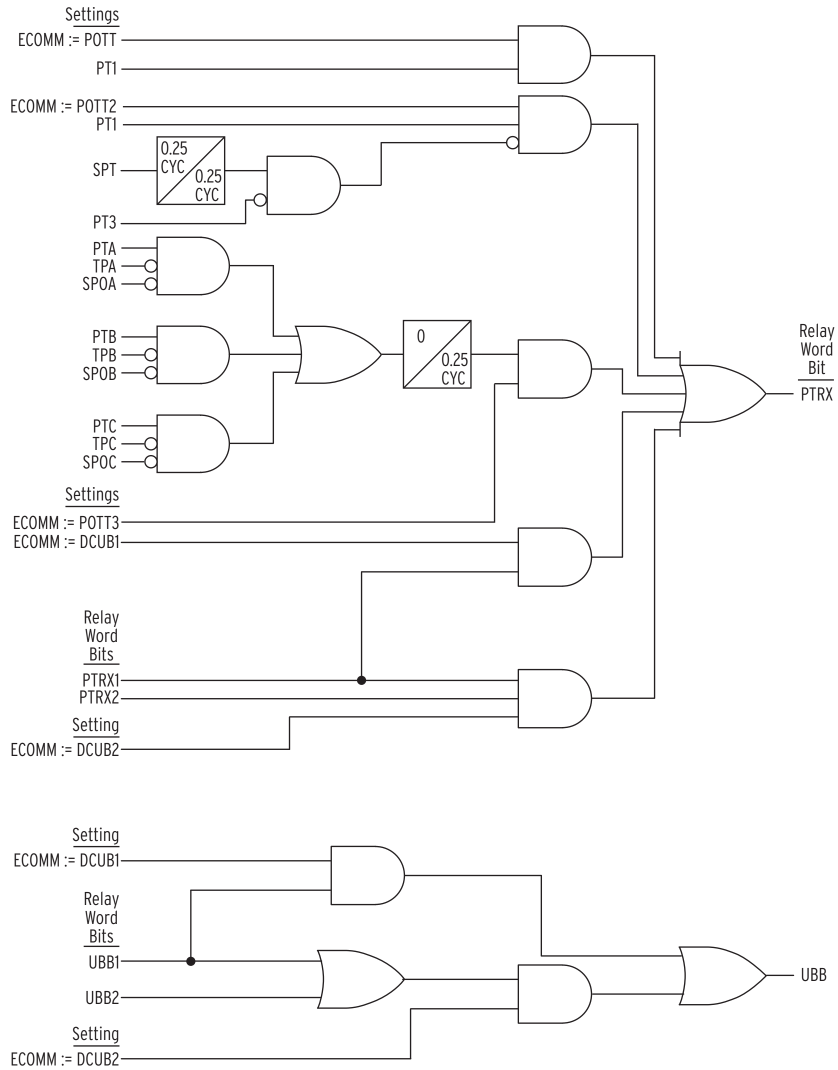


Figure 1.66 Permissive Trip Received Logic Diagram

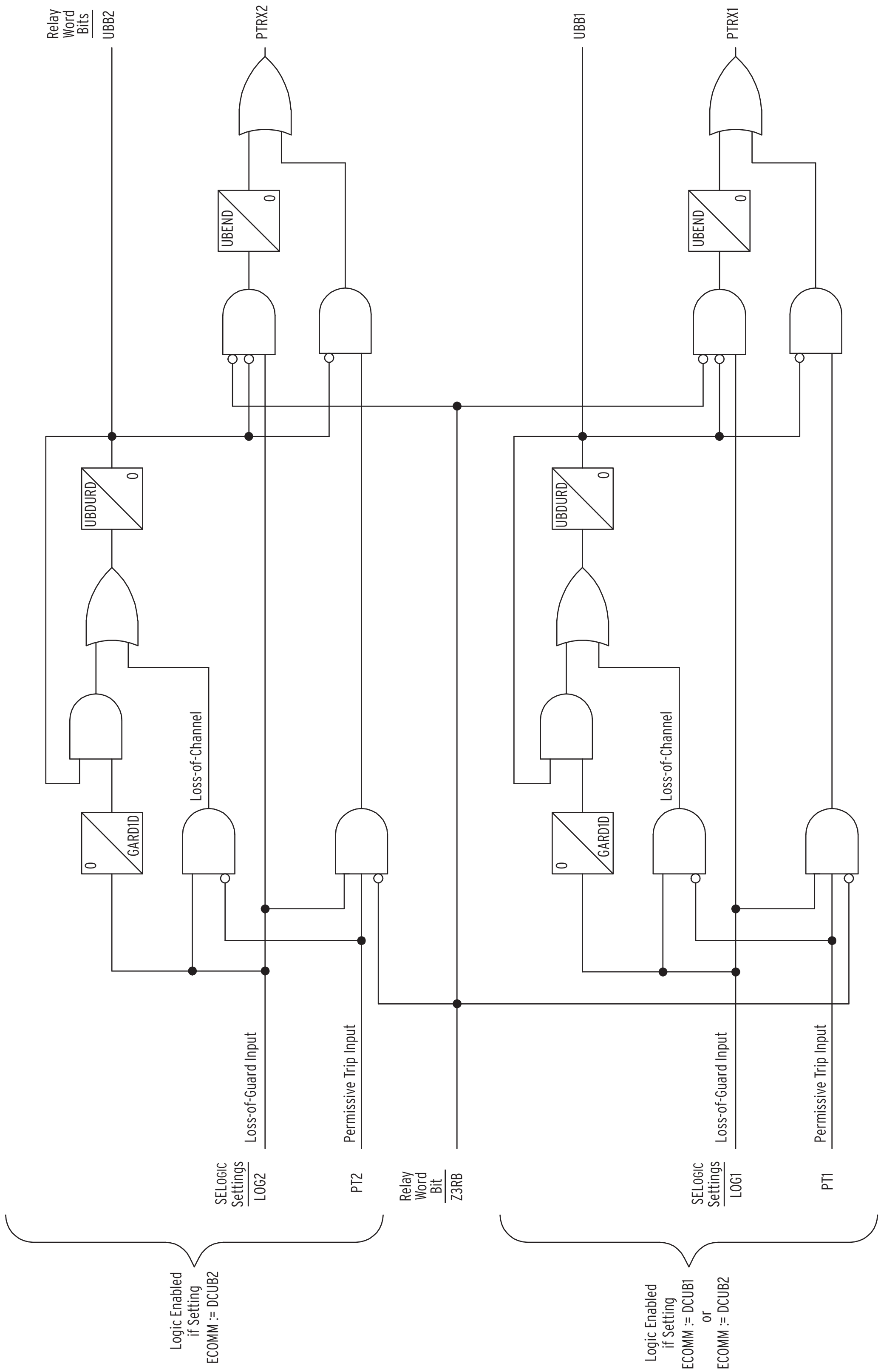


Figure 1.67 DCUB Logic Diagram

Trip Logic

Use the SEL-421 trip logic to configure the relay for tripping one or two circuit breakers. You can apply the SEL-421 in single-pole tripping applications, three-pole tripping applications, or both. Set the SEL-421 to trip unconditionally (as with step distance) or with the aid of a communications channel (as with the POTT, DCUB, DCB, and DTT schemes).

Three-Pole Tripping

The relay uses three-pole tripping logic if Relay Word bit E3PT (three-pole trip enable SELOGIC control equation) equals logical 1. You can set E3PT to 1 or assign a control input so that an external condition changes the state of this Relay Word bit.

There are separate three-pole tripping SELOGIC control equations for two circuit breakers, E3PT1 and E3PT2, respectively. When you set E3PT1 or E3PT2 to 1, the corresponding circuit breaker trips three pole only. For details on setting E3PT, E3PT1, and E3PT2, see *Trip Logic and Reclose Sources on page R.2.26*.

Single-Pole Tripping

The relay uses single-pole tripping logic if Relay Word bit E3PT, three-pole trip enable SELOGIC control equation, equals logical 0. You can either set E3PT to 0 or assign a control input so that an external condition changes the state of this Relay Word bit.

The SEL-421 automatically single-pole trips for the following conditions when the single-pole tripping logic is active:

- ➤ Zone 1 ground distance protection asserts for a single phase-to-ground fault
- ➤ Zone 2 ground distance protection asserts for a single phase-to-ground fault and is permitted to trip via the communications-assisted tripping logic
- ➤ Any one of three SELOGIC control equations, DTA, DTB, or DTC, is assigned to an input and asserts (per-phase direct transfer trip)

You can also set the SEL-421 to single-pole trip through the following three options:

Table 1.73 Additional Settings for Single Pole Tripping (SPT)

Setting	Description	Selection
Z2GTSP	Zone 2 Ground Distance Time Delay Single-Pole Trip	Y
67QGSP	Zone 2 Directional Negative-Sequence/Residual Ground Overcurrent Single Pole Trip	Y
EWFC[a]	Weak-Infeed Trip	SP[b]

[a] In POTT and DCUB settings
[b] SP = single pole

Trip SELOGIC Control Equations

You select the appropriate relay elements for unconditional, direct transfer tripping, switch-onto-fault, and communications-assisted tripping. Set these SELOGIC control equations for tripping:

- TR—Unconditional tripping
- DTA, DTB, DTC—Direct transfer tripping
- TRSOTF—SOTF tripping
- TRCOMM—Communications-assisted tripping

Include the instantaneous and time-delayed tripping elements in the TR SELOGIC control equation. You would typically set instantaneous high-set current level detectors and Zone 2 distance protection in the TRSOTF SELOGIC control equation. You would also set instantaneous Zone 2 distance protection in the TRCOMM SELOGIC control equation.

TR

The TR SELOGIC control equation determines which elements trip unconditionally. You would typically set all instantaneous and time-delayed tripping elements (step-distance protection plus instantaneous and time-overcurrent protection) in the TR SELOGIC control equation.

DTA, DTB, and DTC

The DTA, DTB, and DTC SELOGIC control equations determine which elements directly trip the remote terminal. Each equation is phase selective. If you are applying three-pole tripping only, set DTA, DTB, and DTC to the same Relay Word bit expression.

TRSOTF

The TRSOTF control equation defines which elements trip while SOTF protection is active. These elements trip instantaneously if they assert during the SOTFD time.

TRCOMM

The TRCOMM SELOGIC control equation determines which elements trip via the communications-based scheme logic. You would typically set the overreaching Zone 2 distance elements or Level 2 directional overcurrent elements in the TRCOMM SELOGIC control equation.

Trip Unlatch Options

Unlatch the trip contact output after the trip to remove dc voltage from the trip coil. The SEL-421 provides two settings to unlatch trip contact outputs after a protection trip has occurred:

- TULO—following a protection trip, phase selective
- ULTR—following a protection trip, all three poles

TULO

Table 1.74 shows the four trip unlatch options for setting TULO.

Table 1.74 Setting TULO Unlatch Trip Options

Option	Description
1	Unlatch the trip when the relay detects that one or more poles of the line terminal are open and the Relay Word bit 3PT has deasserted.
2	Unlatch the trip when the relay detects that the corresponding 52A contact(s) from both circuit breakers (e.g., 52AA1 and 52AA2) are deasserted.
3	Unlatch the trip when the relay detects that the conditions for Options 1 and 2 are satisfied.
4	Do not run this logic.

ULTR

Use ULTR, the unlatch trip SELOGIC control equation, to define the conditions that unlatch the trip contact outputs. This method always unlatches all three poles.

Timers

The SEL-421 provides dedicated timers (minimum trip duration, trip during open pole, etc.) for the trip logic.

Minimum Trip Duration

The minimum trip duration timer settings, TDUR1D and TDUR3D, determine the minimum length of time that Relay Word bits TPA1, TPA2, TPB1, TPB2, TPC1, TPC2, and 3PT assert. Use these timers for the designated trip control outputs. The trip output occurs for the TDURD time or the duration of the trip condition, whichever is greater.

TDUR1D is the minimum trip duration time following a single-pole trip. TDUR3D is the minimum trip duration time following a three-pole trip. If another trip occurs during the single-pole open dead time following a single-pole trip, TDUR3D replaces TDUR1D.

Trip During Open-Pole Time Delay

If another fault occurs, it is common to trip the two remaining phases for the following two periods:

- During the single-pole-open interval following the original single-pole trip.
- During the reclosing relay reclaim (reset) time state following a single-pole reclose.

To use the reclosing relay in the SEL-421 to reclose the breaker(s), see *Internal Recloser on page R.2.26*. This section describes the E3PT, E3PT1, and E3PT2 settings necessary for auto-reclose logic control of the single-pole and three-pole tripping sequence. The TOPD (Trip during Open-Pole Time Delay) setting has no relevance in this situation.

If an external reclosing relay is being used, control signals from the reclosing relay will typically be used to control the SEL-421 single- and three-pole tripping sequence. Another method is to use the TOP (Trip during Open-Pole) Relay Word bit to select a three-pole trip after a single-pole trip in the

SEL-421 by making an appropriate setting for TOPD (Trip during Open-Pole Time Delay), and then including the TOP Relay Word bit in the E3PT setting—see *Figure 1.71*. See *External Recloser on page R.2.27* for additional information. See *TOPD on page A.1.39* for an application example using the TOP Relay Word bit.

Timer setting TOPD (Trip During Open Pole Time Delay) determines the period during which any subsequent single-pole trips are converted to a three-pole trip following the original single-pole trip. To use this feature, include the Relay Word bit TOP in the E3PT setting.

Trip Output Signals

There are seven Relay Word bits (TPA1, TPA2, TPB1, TPB2, TPC1, TPC2, and 3PT) that you can program to drive contact outputs to trip circuit breakers. Relay Word bits TPA*n*, TPB*n*, and TPC*n* are phase-selective tripping signals for controlling the individual poles of the circuit breakers for single-pole tripping schemes. Use Relay Word bit 3PT (Three-Pole Trip) to trip all three poles of both circuit breakers.

Manual Trip Logic

The SEL-421 also has additional logic for manually tripping the circuit breakers. Use SELOGIC control equations BK1MTR and BK2MTR to trip the circuit breakers manually. Use SELOGIC control equations ULMTR1 and ULMTR2 to unlatch manual trips for Circuit Breaker 1 and Circuit Breaker 2, respectively.

Trip Logic Settings and Relay Word Bits

The trip logic settings are shown in *Table 1.75*, and the Relay Word bits are shown in *Table 1.76*. Some of the settings are only required in certain situations, as noted.

Table 1.75 Trip Logic Settings (Sheet 1 of 2)

Setting	Description	Range	Default (5 A)
TR	Trip	SELOGIC Equation	M1P OR Z1G OR M2PT OR Z2GT
TRCOMM[a]	Communications-Assisted Trip	SELOGIC Equation	(M2P OR Z2G) AND PLT02
TRSOTF[b]	Switch-Onto-Fault Trip	SELOGIC Equation	50P1 OR M2P OR Z2G
DTA	Direct Transfer Trip A-phase	SELOGIC Equation	NA
DTB	Direct Transfer Trip B-phase	SELOGIC Equation	NA
DTC	Direct Transfer Trip C-phase	SELOGIC Equation	NA
BK1MTR	Breaker 1 Manual Trip—BK1	SELOGIC Equation	OC1 OR PB8_PUL
BK2MTR[c]	Breaker 2 Manual Trip—BK2	SELOGIC Equation	NA
ULTR	Unlatch Trip	SELOGIC Equation	TRGTR
ULMTR1	Unlatch Manual Trip—BK1	SELOGIC Equation	NOT (52AA1 AND 52AB1 AND 52AC1)
ULMTR2[c]	Unlatch Manual Trip—BK2	SELOGIC Equation	1
TOPD	Trip During Open Pole Time Delay (cycles)	2.000-8000	2.000
TULO	Trip Unlatch Option	1, 2, 3, 4	3
Z2GTSP	Zone 2 Ground Distance Time Delay	Y, N	N

Table 1.75 Trip Logic Settings (Sheet 2 of 2)

Setting	Description	Range	Default (5 A)
67QGSP	Zone 2 Direct Negative Sequence /Residual Overcurrent SPT	Y, N	N
TDUR1D	Single-Pole Trip Minimum Trip Duration Time Delay (cycles)	2.000–8000	6.000
TDUR3D	Three-Pole Trip Minimum Trip Duration Time Delay (cycles)	2.000–8000	12.000
E3PT	Three-Pole Trip Enable	SELOGIC Equation	1
E3PT1	Breaker 1 Three-Pole Trip	SELOGIC Equation	1
E3PT2	Breaker 2 Three-Pole Trip	SELOGIC Equation	1
ER	Event Report Trigger Equation	SELOGIC Equation	R_TRIG M2P OR R_TRIG Z2G OR R_TRIG 51S1 OR R_TRIG M3P OR R_TRIG Z3G

[a] Make setting when ECOMM ≠ N.
[b] Make setting when ESOTF := Y.
[c] Make setting when NUMBK := 2.

Table 1.76 Trip Logic Relay Word Bits (Sheet 1 of 2)

Name	Description
RXPRM	Receiver trip permission
COMPRM	Communications-assisted trip permission
TRPRM	Trip permission
DTR	Direct transfer trip
SOTFT	Switch-onto-fault trip
E3PT	Three-pole trip enable
E3PT1	Circuit Breaker 1 three-pole trip enable
E3PT2	Circuit Breaker 1 three-pole trip enable
APS	A-phase selected
BPS	B-phase selected
CPS	C-phase selected
3PS	Three-phase selected
27AWI	Weak infeed A-phase undervoltage
27BWI	Weak infeed B-phase undervoltage
27CWI	Weak infeed C-phase undervoltage
ULTRA	Unlatch A-phase trip
ULTRB	Unlatch B-phase trip
ULTRC	Unlatch C-phase trip
ULTR	Unlatch all protection trips
ATPA	Assert A-phase trip
ATPB	Assert B-phase trip
ATPC	Assert C-phase trip
A3PT	Assert three-pole trip

Table 1.76 Trip Logic Relay Word Bits (Sheet 2 of 2)

Name	Description
TPA	Trip A-phase
TPB	Trip B-phase
TPC	Trip C-phase
TRIP	Trip A-phase or B-phase or C-phase
3PT	Three-pole trip
SPT	Single-pole trip
TPA1	Circuit Breaker 1 trip A-phase
TPB1	Circuit Breaker 1 trip B-phase
TPC1	Circuit Breaker 1 trip C-phase
TPA2	Circuit Breaker 2 trip A-phase
TPB2	Circuit Breaker 2 trip B-phase
TPC2	Circuit Breaker 2 trip C-phase
TOP	Trip during open pole timer is asserted
ULMTR1	Circuit Breaker 1 unlatch manual trip
ULMTR2	Circuit Breaker 2 unlatch manual trip

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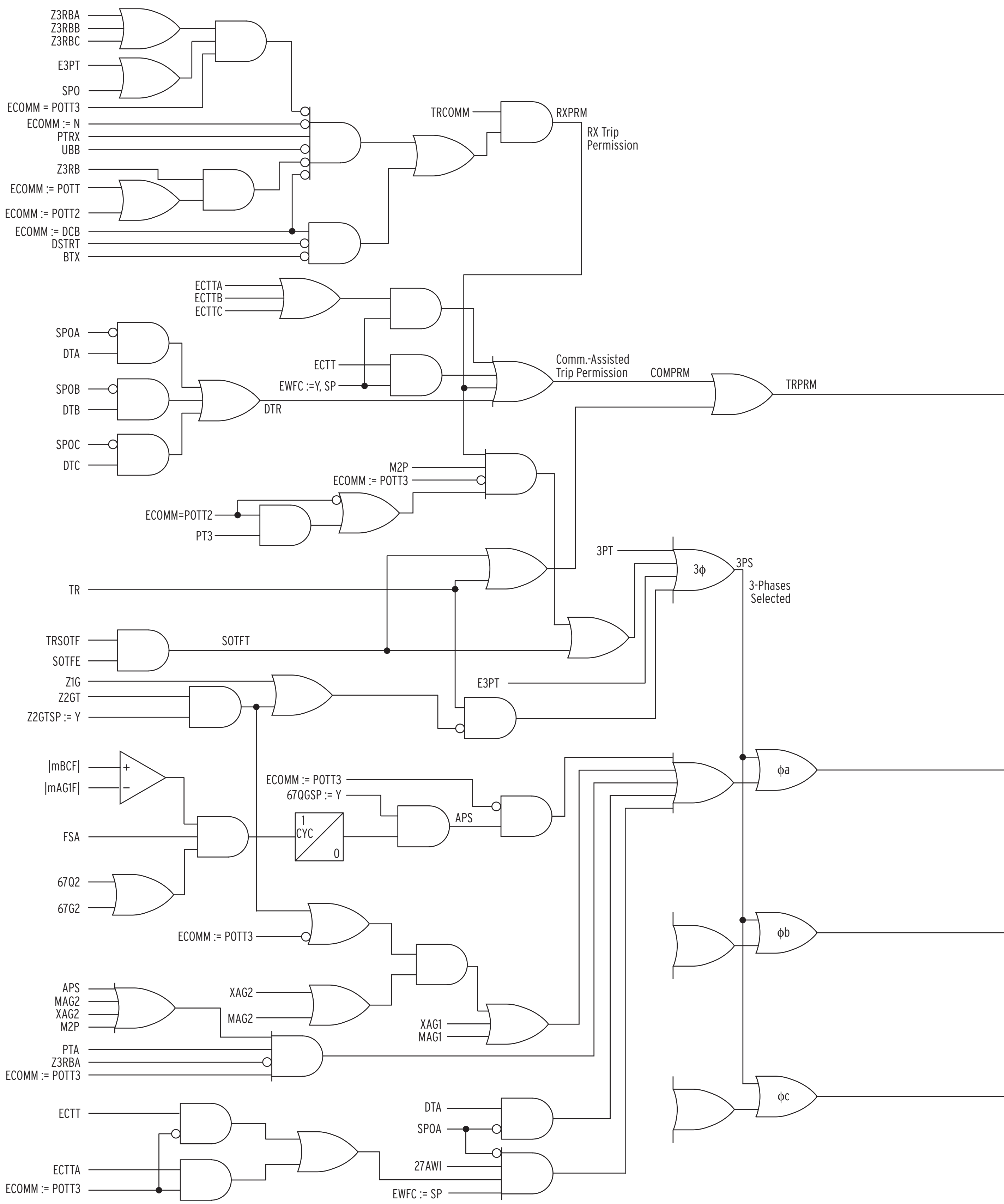

Figure 1.68 Trip Logic Diagram

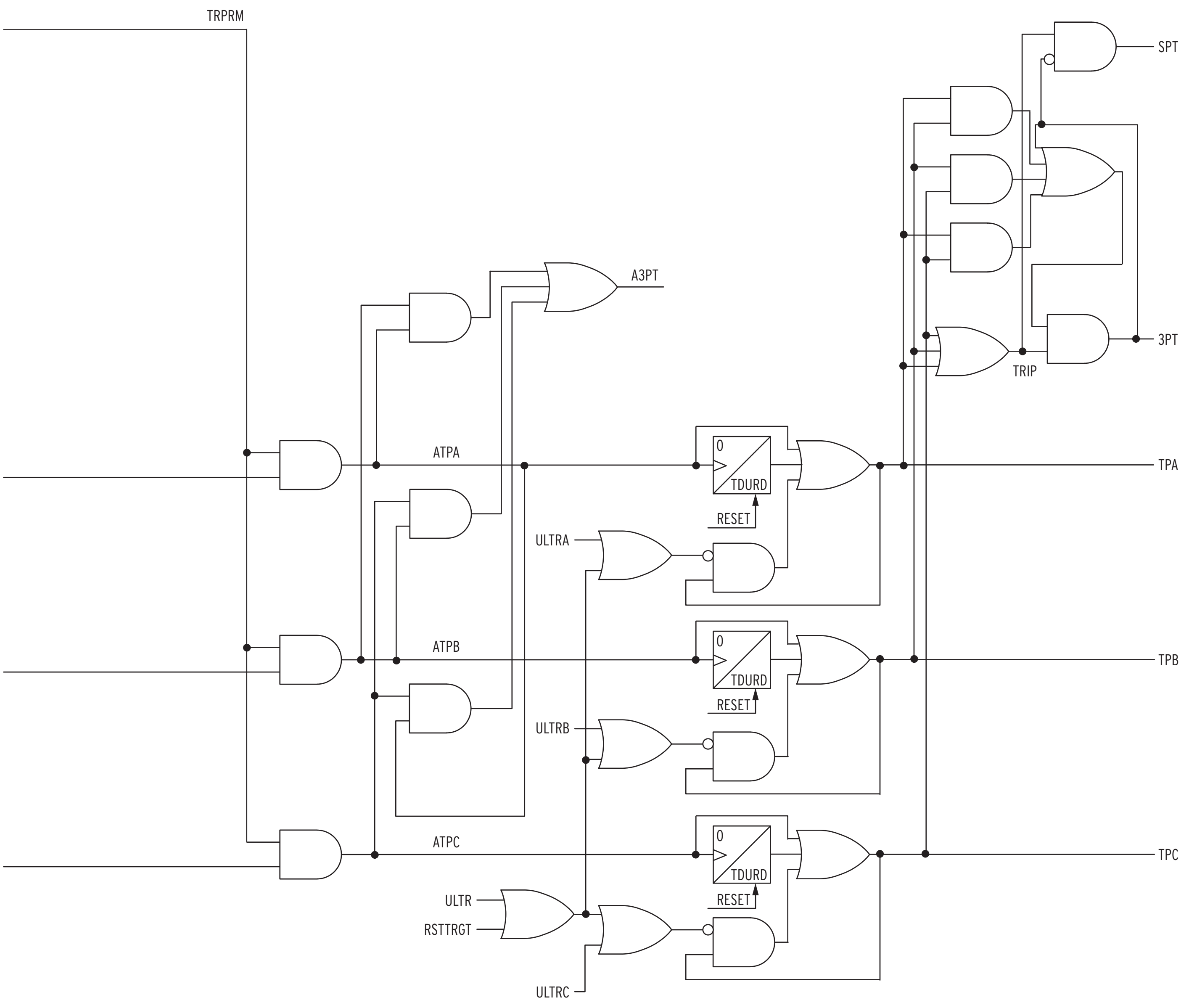

Figure 1.68 **Trip Logic Diagram (**continued)

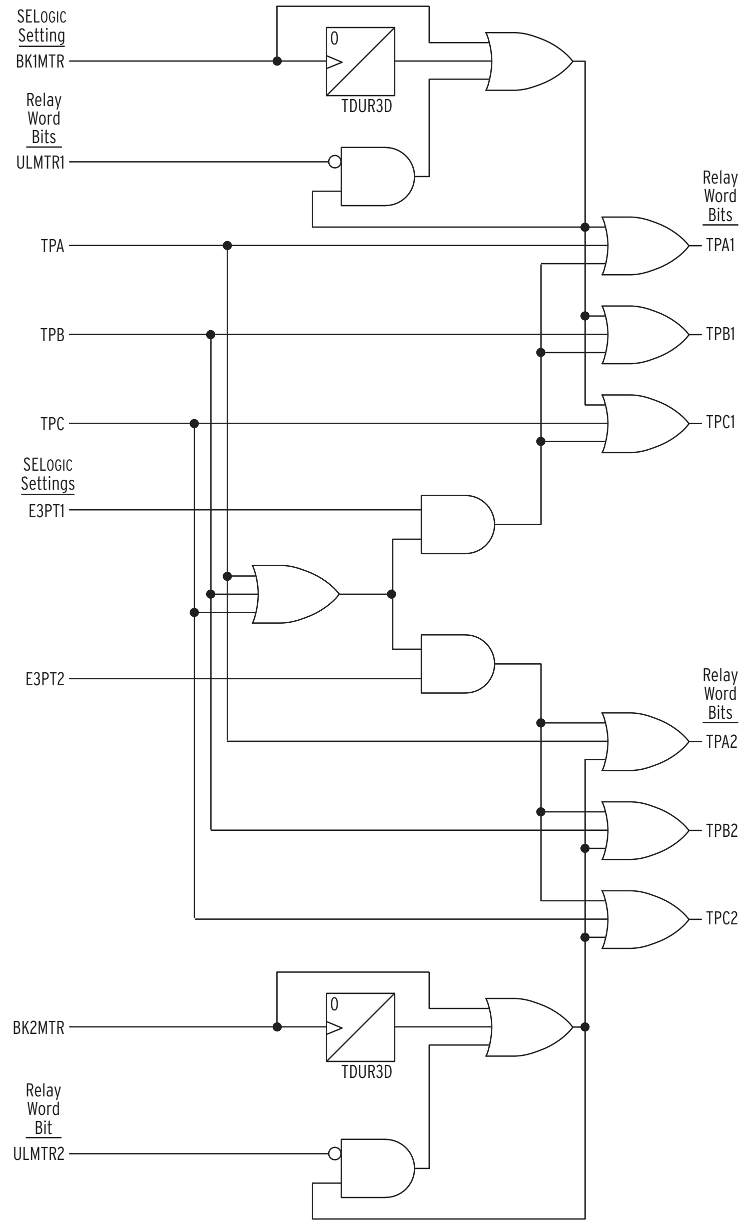

Figure 1.69 Two Circuit Breakers Trip Logic Diagram

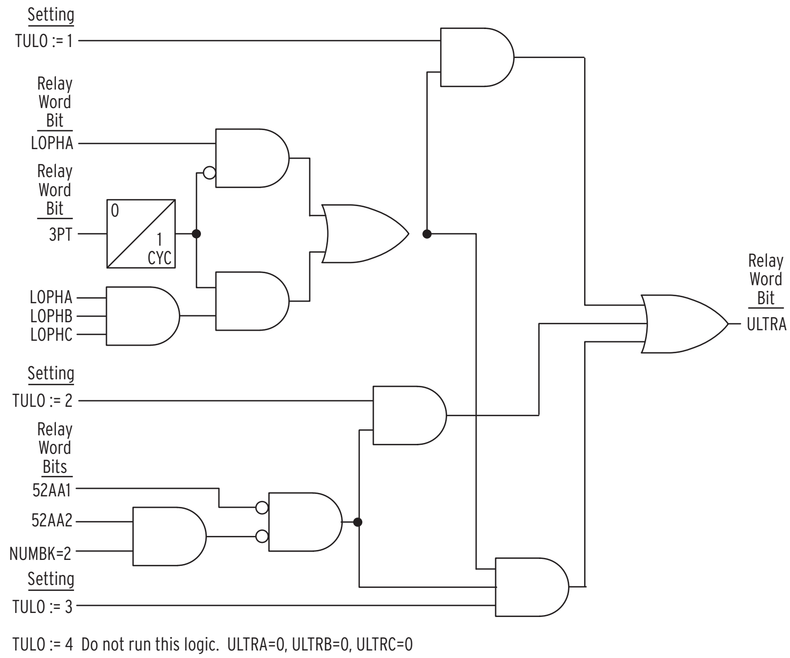

Figure 1.70 Trip A Unlatch Logic

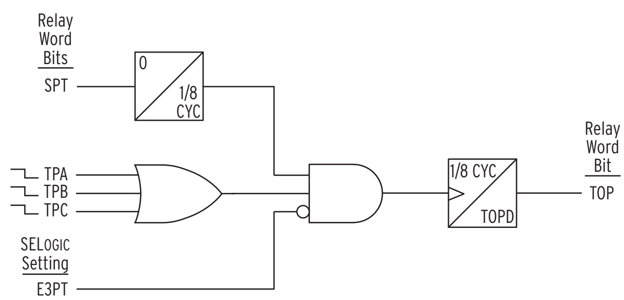

Figure 1.71 Trip During Open Pole

Circuit Breaker Failure Protection

Use the SEL-421 to provide circuit breaker failure protection for as many as two circuit breakers. The circuit breaker failure protection logic includes the following schemes:

- ➤ Failure to interrupt fault current for phase currents
- ➤ Failure to interrupt load current
- ➤ No current/residual current circuit breaker failure protection
- ➤ Flashover protection while the circuit breaker is open

All schemes can incorporate single-pole and three-pole retrip. Single-pole and three-pole initiations are available for circuit breaker failure, including extended breaker failure initiation. The circuit breaker failure logic also includes breaker failure trip latching logic.

The failure-to-interrupt-fault-current logic includes two schemes; both are suitable for three-pole or single-pole tripping applications. Scheme 1 is basic circuit breaker failure that is useful for most applications. Scheme 2 allows you to have different breaker failure times to differentiate between single-pole and three-pole tripping conditions. The failure-to-trip-load-current logic uses the circuit breaker failure initiation input for three-pole trips only. The flashover protection logic does not need voltage information.

Subsidence current results from the energy trapped in the CT magnetizing branch after the circuit breaker opens to clear a fault or interrupt load. Subsidence current exponentially decays and delays resetting of instantaneous overcurrent elements. However, the open phase detection logic causes the SEL-421 50Fϕ*n* elements to reset in less that one cycle during subsidence current conditions (see *Figure 1.78*, and *Figure 1.79* and *Figure 1.80*). The open phase detection logic output is B*n*OPHϕ (see *Table 1.20*).

Failure to Interrupt Fault Current: Scheme 1

Circuit Breaker Failure Protection Logic

The logic shown in *Figure 1.72* applies to single circuit breaker configurations. Fault current causes 50FA1 (Breaker 1 A-Phase Instantaneous Overcurrent Element) to assert immediately following fault inception and just prior to the assertion of Relay Word bit BFI3P1 (Breaker 1 Three-Pole Circuit Breaker Failure Initiation). At circuit breaker failure initiation, timer BFPU1 (Breaker 1 Circuit Breaker Failure Time Delay on Pickup Timer) starts timing. If 50FA1 remains asserted when the BFPU1 timer expires, Relay Word bit FBF1 asserts. Use this Relay Word bit in the circuit breaker failure tripping logic to cause a circuit breaker failure trip (see *Circuit Breaker Failure Trip Logic on page R.1.123*). If the protected circuit breaker opens successfully, 50FA1 drops out before the BFPU1 timer expires and FBF1 does not assert.

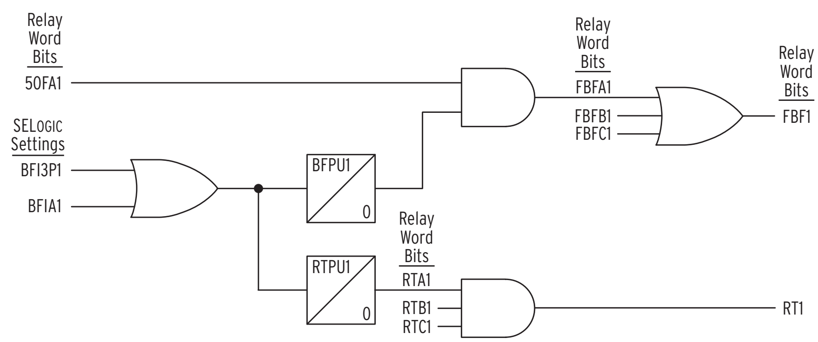

Figure 1.72 Scheme 1 Logic Diagram

Retrip Logic

Some three-pole circuit breakers have two separate trip coils. If one trip coil fails, the local protection can attempt to energize the second trip coil 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 time delay timer expires.

RTPU1 (Retrip Time Delay on Pickup Timer) begins timing when BFI3P1 asserts. Relay Word bit RT1 (Breaker 1 Retrip) asserts immediately after RTPU1 times out. Assign a control output to trip the circuit breaker when Relay Word bit RT1 asserts.

Failure to Interrupt Fault Current: Scheme 2

Scheme 2 actually consists of two discrete circuit breaker failure protection schemes. The first scheme is applied for multiphase faults; apply a short time delay on pickup prior to asserting the circuit breaker failure trip since three-phase faults are the greatest threat to transient power system stability. The second scheme is applied for single phase-to-ground faults; an additional timer is provided so you can coordinate retripping and circuit breaker failure tripping for the different fault types.

Circuit Breaker Failure Protection Logic: MultiPhase Faults

The logic diagram shown in *Figure 1.73* applies to three-pole tripping for one or two circuit breakers. Use this logic when the protected circuit breaker fails following a three-pole trip from the line-relaying scheme.

Fault current causes 50FA1 (Breaker 1 A-Phase Instantaneous Overcurrent Element) to assert immediately following fault inception and just prior to the assertion of Relay Word bit BFIA1 (Breaker 1 A-Phase Circuit Breaker Failure Initiation). At circuit breaker failure initiation, timer BFPU1 (Breaker 1 Circuit Breaker Failure Time Delay on Pickup Timer) starts timing. If 50FA1 remains asserted when timer BFPU1 expires and at least two of the three initiation Relay Word bits BFIA1, BFIB1, or BFIC1 are asserted, Relay Word bit FBF1 (Breaker 1 Circuit Breaker Failure) asserts. (Two of three asserted initiation Relay Word bits indicate a multi-phase fault.) Use FBF1 in the circuit breaker failure tripping logic to cause a circuit breaker failure trip (see *Circuit Breaker Failure Trip Logic on page R.1.123*). If the protected circuit breaker opens successfully, 50FA1 drops out before timer BFPU1 expires and Relay Word bit FBF1 does not assert.

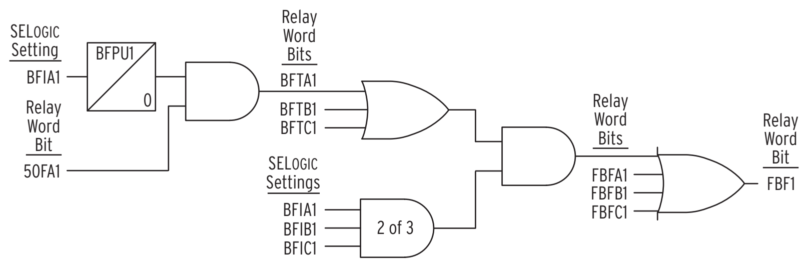

Figure 1.73 Scheme 2 Three-Pole Circuit Breaker Failure Protection Logic

Circuit Breaker Failure Protection Logic: Single-Phase Faults

The logic diagram shown in *Figure 1.74* applies to single-pole tripping for one or two circuit breakers. A-phase is discussed; B-phase and C-phase logic is similar. Use this logic when one pole of the circuit breaker fails following a single-pole trip from the line-relaying scheme.

Fault current causes 50FA1 (Breaker 1 A-Phase Instantaneous Overcurrent Element) to assert immediately following ground fault inception and just prior to the assertion of Relay Word bit BFIA1 (Breaker 1 A-Phase Circuit Breaker Failure Initiation). At circuit breaker failure initiation timer BFPU1 (Breaker 1 Circuit Breaker Failure Time Delay on Pickup Timer) starts timing. Timer BFPU1 cascades into timer SPBFPU1 (Breaker 1 Single-Pole Trip Breaker Failure Time Delay on Pickup Timer). Therefore, use this second timer, SPBFPU1, to coordinate circuit breaker failure operations for single-pole and three-pole trips.

If 50FA1 remains asserted when timer SPBFPU1 expires and neither of the two Relay Word bits BFIB1 and BFIC1 are asserted, Relay Word bit FBFA1 (A-Phase Breaker 1 Circuit Breaker Failure) asserts. Use FBFA1 in the circuit breaker failure tripping logic to cause a circuit breaker failure trip (see *Circuit Breaker Failure Trip Logic on page R.1.123*). If the protected circuit breaker successfully opens, 50FA1 drops out before timer SPBFPU1 expires and Relay Word bit FBFA1 does not assert.

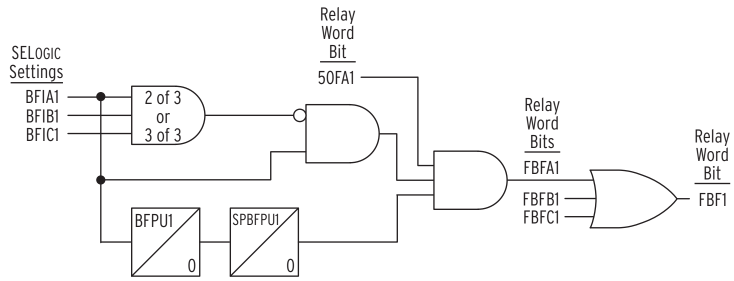

Figure 1.74 Scheme 2 Single-Pole Circuit Breaker Failure Protection Logic

Retrip Logic

Some single-pole circuit breakers have two separate trip coils per pole. All three primary trip coils are energized if the line-relaying scheme asserts a three-pole trip. If one or more of the primary trip coils fail, the local protection should attempt a three-pole retrip.

Only one of the primary trip coils is energized if the line-relaying scheme asserts a single-pole trip. The corresponding primary trip coil can fail following the single-pole trip. You can decide whether to single-pole or three-pole retrip following the unsuccessful single-pole trip. Attempt all local retrips before the corresponding circuit breaker failure time delay (BFPU*n* and SPBFPU*n*) on pickup timer expires.

Figure 1.75 illustrates the current-supervised three-pole retrip logic. Timer RT3PPU1 (Breaker 1 Three-Pole Retrip Time Delay on Pickup Timer) begins timing when at least two of the initiation Relay Word bits BFIA1, BFIB1, or BFIC1 assert. The relay asserts RT3P1 (Three-Pole Retrip) when timer RT3PPU1 times out. You can use just output RT3P1 for three-pole retrip without current supervision. Relay Word bit RTS3P1 (Breaker 1 Current Supervised Three-Pole Retrip) asserts immediately after timer RT3PPU1 expires, if one of the phase current level detectors is picked up.

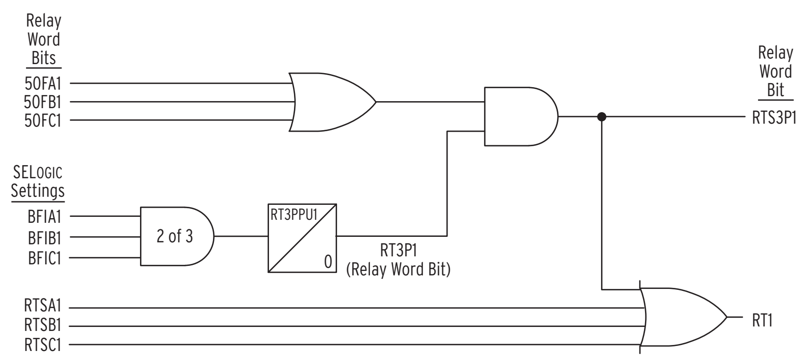

Figure 1.75 Current-Supervised Three-Pole Retrip Logic

Figure 1.76 illustrates the current-supervised single-pole retrip logic. Timer RTPU1 (Breaker 1 Retrip Time Delay on Pickup Timer) begins timing when initiation Relay Word bit BFIA1 asserts. Relay Word bit RTA1 (Breaker 1 A-Phase Retrip) asserts immediately after timer RTPU1 expires. You can use just the RTA1 output for single-pole retrip without current supervision. Relay Word bit RTSA1 (Breaker 1 Current Supervised A-Phase Retrip) asserts if 50FA1 is picked up.

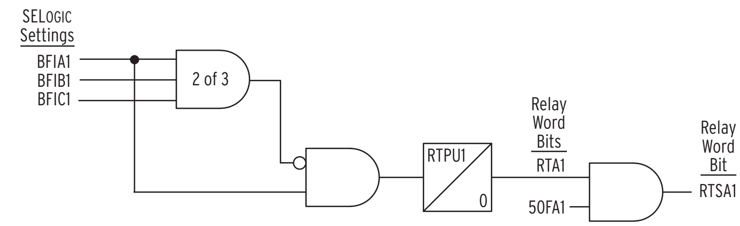

Figure 1.76 Current-Supervised Single-Pole Retrip Logic

Circuit Breaker Failure Initiation Dropout and Seal-In

The SEL-421 circuit breaker failure protection features breaker failure initiation extension and a breaker failure seal-in latch. The lower portion of *Figure 1.78* shows the dropout and seal-in logic.

Dropout Delay

Set timer BFIDO1 (Breaker Failure Initiate Dropout Delay—BK1) to stretch a short pulsed circuit breaker failure initiation. Use this feature for protecting dual circuit breakers when separate 86 BF lockout relays have differing energizing times.

Seal-In Delay

Set timer BFISP1 (Breaker Failure Initiate Seal-In Delay—BK1) to qualify extended circuit breaker failure initiation latch seal-in. When you set BFISP1 longer than BFIDO1 and the circuit breaker failure initiate is greater than the difference of the two timers, the relay seals in the circuit breaker failure extended initiation after the initiate signal deasserts until the BFIDO1 time expires and all 50Fϕ*n* elements deassert.

No Current/Residual Current Circuit Breaker Failure Protection Logic

The SEL-421 has separate circuit breaker failure logic that operates on zero-sequence current rather than phase current. Use this logic to detect a circuit breaker failure and take appropriate action when a weak source drives the fault or if the protected circuit breaker fails to trip during a high-resistance ground fault. The residual current input to this logic is the 50R1 residual overcurrent element (see *Figure 1.77*). Setting 50RP1 (Residual Current Pickup—BK1) is the pickup threshold setting for the 50RP element.

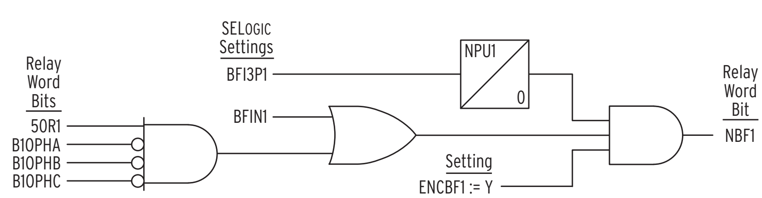

Figure 1.77 No Current/Residual Current Circuit Breaker Failure Protection Logic Diagram

Relay Word bit NBF1 (Breaker 1 Low Current Breaker Failure) asserts when timer NPU1 (Low Current Breaker Failure Time Delay on Pickup) expires and one of the following conditions exists:

- Circuit Breaker 1 residual overcurrent element 50R1 is asserted and the relay does not detect an open pole in any of the three phases for Circuit Breaker 1 (i.e., NOT B1OPHA, NOT B1OPHB, or NOT B1OPHC)
- Relay Word bit BFIN1 (No Current Breaker Failure Initiation) is asserted

For no current applications, such as a digital signal indicating a loss-of-field from a generator, use inputs BFI3P1 and BFIN*n*. Circuit breaker failure clearing can occur after timer NPU1 times out. For no current/residual current breaker failure trips, insert NBF1 in the circuit breaker failure trip SELOGIC control equation BFTR1 (see *Circuit Breaker Failure Trip Logic on page R.1.123*).

Failure to Interrupt Load Current Protection Logic

The circuit breaker failure protection used during load conditions is independent from circuit breaker failure protection that you use during fault conditions. Use circuit breaker failure protection for load conditions either alone or in addition to circuit breaker failure protection for fault conditions as a second level of breaker failure protection. *Figure 1.79* shows that the output of the load current protection is Relay Word bit LCBF1 (Load Current Breaker Failure). Use this output to activate an external alarm, retrip the circuit breaker, or energize a lockout relay.

Load Current Detection: 50LP1

This scheme detects failures of the circuit breaker to open when circuit breaker current is greater than the 50LP1 setting. The 50LP1 element should pick up when the protected circuit breaker is closed.

If the protected circuit breaker is in a ring-bus or circuit breaker-and-a-half arrangement, set 50LP1 to pick up for the line-charging current of the shortest line that circuit breaker services. Use the following equation to calculate the charging current for a given line:

$$I_c = V_g \cdot B_c \text{ A primary} \qquad \textbf{Equation 1.15}$$

where:

V_g = Line-to-ground voltage
B_c = Total line capacitive susceptance

Time Delay on Pickup: LCPU1

The time delay setting for this protection scheme is typically longer than fault current conditions because of lower current duties associated with this type of circuit breaker failure operation. Extending the time delay allows more time for a slow but operative circuit breaker to clear a low-current fault. A disadvantage with the extended time delay is that a fault continues if the circuit breaker fails. Weigh these considerations when selecting time delays for this scheme. Please note that some circuit breakers take more time than other circuit breakers to break low amounts of current; consult the manufacturer of the protected circuit breaker for details.

The recommended setting for LCPU1 is the sum of the following:

- Nominal circuit breaker operate time
- 50LP1 dropout time
- Safety margin

Calculate the safety margin by subtracting all conditions required to isolate the fault during a circuit breaker failure condition from the maximum acceptable fault clearing time. The safety margin will be longer in this case than for the fault current logic because the total acceptable time to clear the fault at these lower fault duties is longer.

Load Current Circuit Breaker Failure Initiation: BFILC1

Program SELOGIC control equation BFILC1 (Load Current Breaker Failure Initiation) to initiate this scheme. For example, use the auxiliary contacts from the circuit breaker to detect when the circuit breaker is open. Relay Word bit LCBF11 asserts if Relay Word bit BFILC1 remains asserted for time LCPU1 and the relay detects load current.

Circuit Breaker Flashover Protection

Circuit breaker failure protection during flashover conditions is independent of the other circuit breaker protection functions. Use this protection either alone or in addition to the other protection.

Use current flow to detect when an open circuit breaker pole flashes over. Set BLKFOA1 to TPA or CLS1 to block flashover protection for 6 cycles if an A-phase single-pole trip occurs, or when circuit breaker BK1 closes.

Figure 1.80 shows the flashover circuit breaker failure logic. Flashover timer FOPU1 (Flashover Time Delay—BK1) starts timing if the circuit breaker is open and current exceeds setting 50FO1 (Flashover Current Pickup—BK1). The relay uses pole-open logic BnOPHϕ to determine whether the circuit breaker is open.

The output of the flashover protection is Relay Word bit FOBF1. Use this output to activate an external alarm, retrip the circuit breaker, or energize a lockout relay.

Circuit Breaker Failure Trip Logic

The SEL-421 has dedicated circuit breaker failure trip logic (see *Figure 1.81*). Set SELOGIC control equation BFTR1 (Breaker Failure Trip—BK1) to assert for circuit breaker failure trips from Relay Word bits FBF1, NBF1, LCBF1, and FOBF1.

When this SELOGIC control equation asserts, the relay sets Relay Word bit BFTRIP1 (Breaker Failure Trip for Circuit Breaker BK1) to logical 1 until BFTR1 deasserts, timer TDUR3D times out, and an unlatch or reset condition is active.

Unlatch Circuit Breaker Failure Trip Equation

Use SELOGIC control equation BFULTR1 (Breaker Failure Unlatch Trip—BK1) to define the conditions that unlatch the control outputs that assert during a circuit breaker failure trip. BFULTR1 unlatches the circuit breaker trip condition BFTRIP1.

Table 1.77 Circuit Breaker Failure Protection Logic Settings[a]

Setting	Description	Range	Default (5 A)
50FP1	Phase Fault Current Pickup—BK1 (A)	0.50–50	6.000
BFPU1	Breaker Failure Time Delay—BK1 (cycles)	0.000–6000	9.000
SPBFPU1	Single-Pole Trip Circuit Breaker Failure Time Delay—BK1 (cycles)	0.000–6000	6.000
RTPU1	Retrip Time Delay—BK1 (cycles)	0.000–6000	3.000
RT3PPU1	Three-Pole Retrip Time Delay—BK1 (cycles)	0.000–6000	3.000
BFI3P1	Three-Pole Breaker Failure Initiate—BK1	SELOGIC Equation	NA
BFIA1	A-Phase Breaker Failure Initiate—BK1	SELOGIC Equation	NA
BFIB1	B-Phase Breaker Failure Initiate—BK1	SELOGIC Equation	NA
BFIC1	C-Phase Breaker Failure Initiate—BK1	SELOGIC Equation	NA
BFIDO1	Breaker Fail Initiate Dropout Delay—BK1 (cycles)	0.000–1000	1.500
BFISP1	Breaker Fail Initiate Seal-In Delay—BK1 (cycles)	0.000–1000	2.000
ENCBF1	No Current/Residual Current Logic—BK1	Y, N	N
50RP1	Residual Current Pickup—BK1 (A)	0.25–50	1.00
NPU1	No Current Breaker Failure Delay—BK1 (cycles)	0.000–6000	12.000
BFIN1	No Current Breaker Failure Initiate—BK1	SELOGIC Equation	NA
ELCBF1	Load Current Breaker Logic Failure—BK1	Y, N	N
50LP1	Phase Load Current Pickup—BK1 (A)	0.25–50	0.50
LCPU1	Load Pickup Time Delay—BK1 (cycles)	0.000–6000	9.000
BFILC1	Breaker Failure Load Current Initiation—BK1	SELOGIC Equation	NA
EFOBF1	Breaker Failure Flashover Logic—BK1	Y, N	N
50FO1	Flashover Current Pickup—BK1 (A)	0.25–50	0.50
FOPU1	Flashover Time Delay—BK1 (cycles)	0.000–6000	9.000
BLKFOA1	Block A-Phase Flashover—BK1	SELOGIC Equation	NA
BLKFOB1	Block B-Phase Flashover—BK1	SELOGIC Equation	NA
BLKFOC1	Block C-Phase Flashover—BK1	SELOGIC Equation	NA
BFTR1	Breaker Failure Trip—BK1	SELOGIC Equation	NA
BFULTR1	Breaker Failure Unlatch Trip—BK1	SELOGIC Equation	NA

[a] For Circuit Breaker 2, replace 1 with 2 in the setting label.

Table 1.78 Circuit Breaker Failure Relay Word Bits[a] (Sheet 1 of 2)

Name	Description
BFI3P1	Three-pole circuit breaker failure initiation
BFIA1	A-phase circuit breaker failure initiation
BFIB1	B-phase circuit breaker failure initiation
BFIC1	C-phase circuit breaker failure initiation
BFIN1	No current circuit breaker failure initiation

Table 1.78 Circuit Breaker Failure Relay Word Bits[a] (Sheet 2 of 2)

Name	Description
BFILC1	Load current breaker failure initiation
BFI3PT1	Three-pole circuit breaker failure extended initiation
BFIAT1	A-phase circuit breaker failure extended initiation
BFIBT1	B-phase circuit breaker failure extended initiation
BFICT1	C-phase circuit breaker failure extended initiation
FBFA1	A-phase circuit breaker failure
FBFB1	B-phase circuit breaker failure
FBFC1	C-phase circuit breaker failure
FBF1	Circuit breaker failure
NBF1	No current/residual current circuit breaker failure
LCBF1	Load current circuit breaker failure
BLKFOA1	Block A-phase flashover detection
BLKFOB1	Block B-phase flashover detection
BLKFOC1	Block C-phase flashover detection
FOA1	A-phase flashover detected
FOB1	B-phase flashover detected
FOC1	C-phase flashover detected
FOBF1	Flashover detected
RT3P1	Three-pole retrip
RTA1	A-phase retrip
RTB1	B-phase retrip
RTC1	C-phase retrip
RT1	Retrip
RTS3P1	Three-pole current supervised retrip
RTSA1	A-phase current supervised retrip
RTSB1	B-phase current supervised retrip
RTSC1	C-phase current supervised retrip
50FA1	A-phase current threshold
50FB1	B-phase current threshold
50FC1	C-phase current threshold
50R1	Residual current threshold
50LCA1	A-phase load current threshold
50LCB1	B-phase load current threshold
50LCC1	C-phase load current threshold
50FOA1	A-phase flashover current threshold
50FOB1	B-phase flashover current threshold
50FOC1	C-phase flashover current threshold
BFTRIP1	Breaker 1 circuit breaker failure trip

[a] For Circuit Breaker 2, replace 1 with 2 in the setting label.

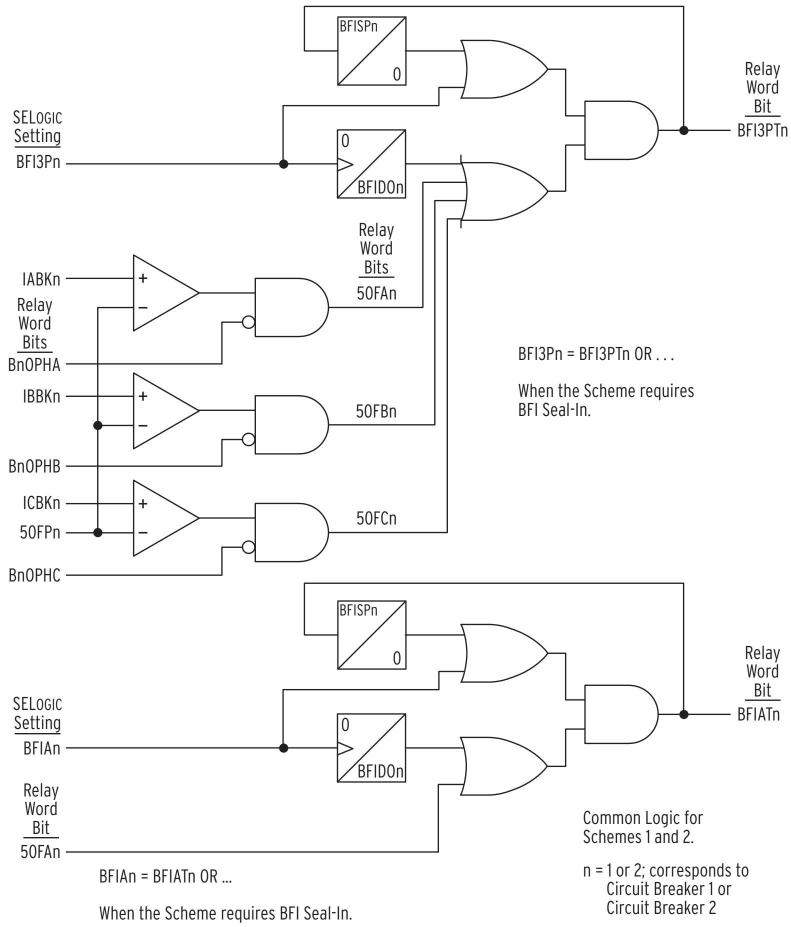

Figure 1.78 Circuit Breaker Failure Seal-In Logic Diagram

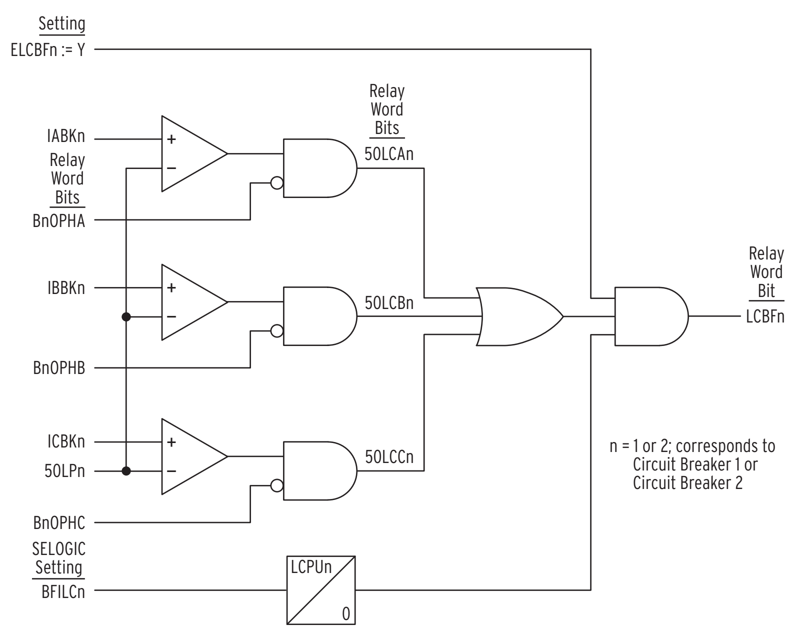

Figure 1.79 Failure to Interrupt Load Current Logic Diagram

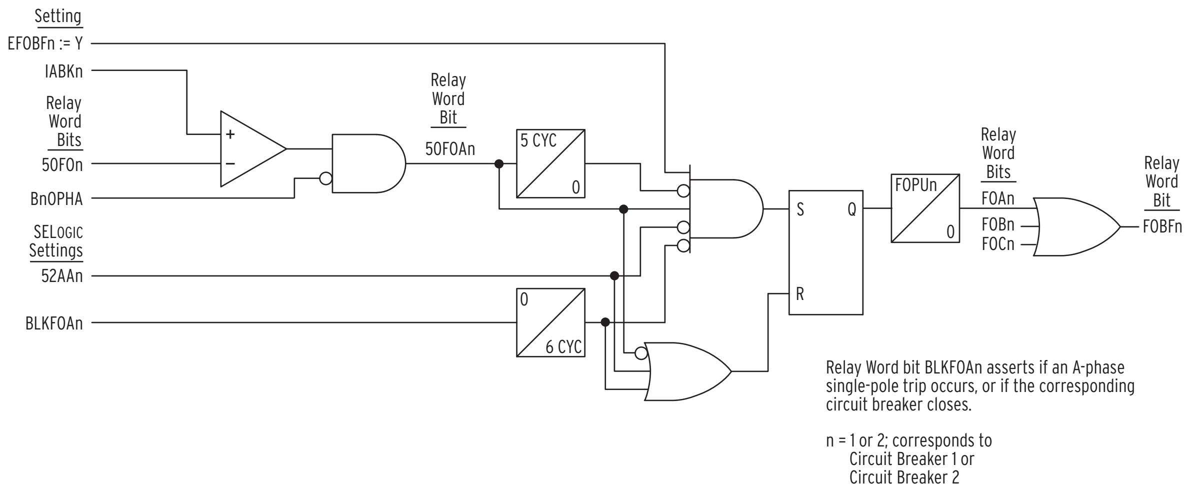

Figure 1.80 Flashover Protection Logic Diagram

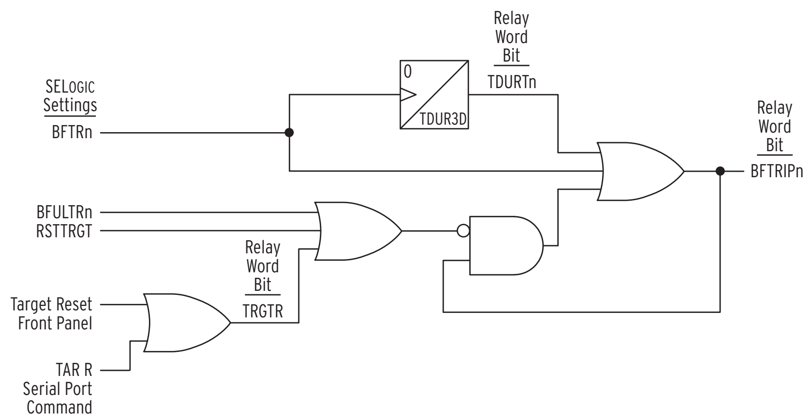

Figure 1.81 Circuit Breaker Failure Trip Logic Diagram

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Section 2

Auto-Reclosing and Synchronism Check

This section describes the operation of auto-reclose logic in the SEL-421 Relay. Also included in this section is a discussion of Voltage Check logic and Synchronism Check logic that can be used with auto-reclosing, or applied independently. This section covers the following topics:

The SEL-421 Relay auto-reclose and synchronism-check functions provide complete control for single circuit breaker and two circuit breaker reclosing schemes. The auto-reclose function accommodates both single-pole and three-pole reclosing. You can set the SEL-421 for a total of two single-pole and four three-pole reclose shots. The single-pole shots have a common dead time, while the three-pole shots have individual dead times. You can designate the leader and follower circuit breakers in a two circuit breaker configuration; the SEL-421 recloser can dynamically change leader and follower designations based on settings and operating conditions.

You can program the auto-reclose 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 auto-reclose; simply select the open interval time accordingly.

NOTE: The SEL-421 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 auto-reclose modes are available when using the SEL-421 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.

The SEL-421 synchronism-check function uses single-phase input voltages V_{S1}, V_{S2} (source voltages), and reference V_P (polarizing voltage) to provide synchronism check for one or two circuit breakers. The relay determines when V_{S1} and V_{S2} are within programmable voltage magnitudes and slip frequency windows compared to V_P. In addition, the synchronism-check function can use settable circuit breaker closing times and the measured slip frequencies to compensate the angle difference calculation between V_{S1} and V_P (plus V_{S2} and V_P). The relay checks this angle difference calculation in a programmable synchronism angle window.

Auto-Reclosing

Logical States

The auto-reclose logic for either circuit breaker can be in one of five states (see *Figure 2.1*):

- Start (common to both circuit breakers) (79STRT)
- Reset per circuit breaker (BK1RS, BK2RS)
- Single-pole auto-reclose cycle (common to both circuit breakers) (79CY1)
- Three-pole auto-reclose cycle (common to both circuit breakers) (79CY3)
- Lockout, per circuit breaker (BK1LO, BK2LO)

Start (79STRT)

The auto-reclose logic is in the Start state for both circuit breakers during the following conditions:

- Power up
- Restart
- Any relay settings change

The SEL-421 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 power up 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 auto-reclose logic is in the reset or ready state for either circuit breaker when the circuit breaker is ready to begin an auto-reclose 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 and 3PRCD.

Single-Pole Auto-Reclose (79CY1)

The auto-reclose logic is in a single-pole auto-reclose cycle for either circuit breaker if the following conditions are satisfied:

- Single-pole trip occurs
- Condition(s) to initiate a single-pole auto-reclose cycle are satisfied
- Circuit breaker(s) is in-service and ready to begin a single-pole auto-reclose cycle (that is, reset)

Three-Pole Auto-Reclose (79CY3)

The auto-reclose logic is in a three-pole auto-reclose cycle for either circuit breaker if the following conditions are satisfied:

- Three-pole trip occurs
- Condition(s) to initiate a three-pole auto-reclose cycle are satisfied
- Circuit breaker(s) is in-service and ready to begin a three-pole auto-reclose cycle (that is, reset)

Lockout (BK1LO, BK2LO)

The lockout state is the default state of any circuit breaker after power up. Other conditions place the recloser in the LO state. The SEL-421 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. If supervisory Relay Word bits SP*n*CLS or 3P*n*CLS do not assert within the BK*n*CLSD time, or if the circuit breaker does not close within the BKCFD time, then the circuit breaker enters the lockout state. The timer for both supervisory Relay Word bits SP*n*CLS and 3P*n*CLS is setting BK*n*CLSD.

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 auto-reclose cycle unless the auto-reclose 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 SEL-421 auto-reclose function runs at 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 2.1 illustrates how the auto-reclose 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 2.1*). 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 2.1 describes each of the five states with respect to Circuit Breaker 1, along with the corresponding Relay Word bits.

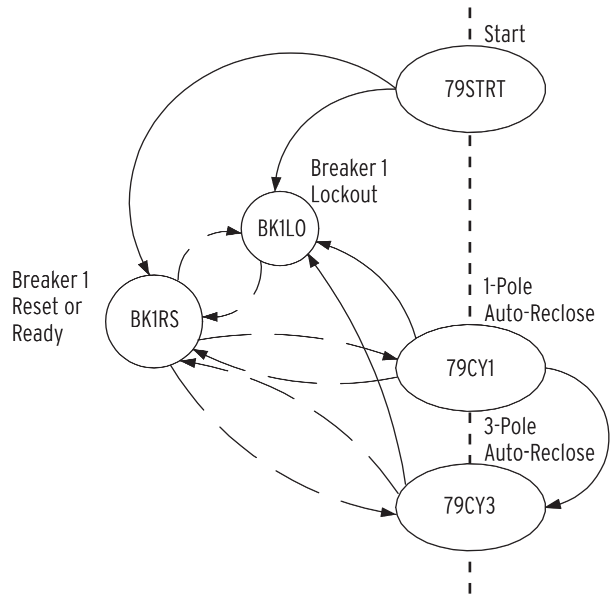


Figure 2.1 Auto-Reclose State Diagram for Circuit Breaker 1

Table 2.1 Auto-Reclose Logical States for Circuit Breaker 1

State	Description	Relay Word Bit
Start	Power up, or relay settings change	79STRT
Reset	Circuit Breaker 1 reset	BK1RS
Single-pole auto-reclose cycle	Single-pole auto-reclose	79CY1
Three-pole auto-reclose cycle	Three-pole auto-reclose cycle	79CY3
Lockout	Lockout	BK1LO

One-Circuit-Breaker Auto-Reclosing

One Circuit Breaker Auto-Reclose Modes

The SEL-421 auto-reclose logic operates in three modes:

- 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 auto-reclose mode (see *Recloser Mode Enables on page R.2.9*). 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 2.8* and *Figure 2.9*. SPARC asserts when all necessary conditions to begin a single-pole auto-reclose cycle are satisfied (ESPR1, for example) and the recloser receives a single-pole reclose initiation SPRI (see *Figure 2.8*).

Relay Word bit 3PARC asserts when all necessary conditions to begin a three-pole auto-reclose cycle are satisfied (E3PR1, for example) and the recloser receives a three-pole reclose initiation 3PRI (see *Figure 2.9*).

Other recloser settings include the initial recloser settings (see *Enable Auto-Reclose Logic for Two Circuit Breakers on page R.2.23*) 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 on page R.2.9*).

Single-Pole Mode

Figure 2.10 shows the one circuit breaker single-pole auto-reclose 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. If the circuit breaker does not open within 10 cycles, the recloser goes to the lockout state. 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 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 auto-reclose 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 auto-reclose 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 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, or any time Relay Word bit 79DTL asserts.

Three-Pole Mode

Figure 2.11 shows the one circuit breaker auto-reclose 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 as long as 15 cycles for the circuit breaker to open, as indicated by Relay Word bit 3POLINE. If the circuit breaker does not open in 15 cycles, the recloser goes to the lockout state. 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 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 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, or any time Relay Word bit 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 R.2.5*. 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 auto-reclose cycle state 79CY3. The recloser proceeds through the 79CY3 state and exits this state as described in *Three-Pole Mode on page R.2.6*.

Three-Pole Priority

If a single-pole auto-reclose cycle 79CY1 is in progress and the relay receives an initiation for three-pole reclosing 3PRI, the recloser immediately starts a three-pole auto-reclose cycle 79CY3.

Active Circuit Breakers

Two Relay Word bits describe when Circuit Breaker 1 is active for the auto-reclose 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 auto-reclose logic is reset, or if the auto-reclose logic is in an auto-reclose cycle (79CY1 or 79CY3). NBK0 equals logical 1 when Circuit Breaker 1 is open and not in an auto-reclose cycle (79CY1 or 79CY3), or if the auto-reclose logic is locked out (BK1LO).

Enable Auto-Reclose Logic for One Circuit Breaker

Three-Pole Trip Circuit Breaker

The initial settings necessary to enable auto-reclose for a single three-pole trip circuit breaker are shown in *Table 2.2*.

Table 2.2 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	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

For additional settings to set specific operating parameters for the recloser, refer to *Auto-Reclose and Synchronism Check Example on page A.1.137*.

Single-Pole Trip Circuit Breaker

The initial settings necessary to enable auto-reclose for one single-pole trip circuit breaker are shown in *Table 2.3*.

Table 2.3 One-Circuit-Breaker Single-Pole Reclose Initial Settings (Sheet 1 of 2)

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

Table 2.3 One-Circuit-Breaker Single-Pole Reclose Initial Settings (Sheet 2 of 2)

Setting	Description	Entry
Relay Configuration (Group)		
E79	Reclosing	Y

For additional settings to set specific operating parameters for the recloser, refer to *Auto-Reclose and Synchronism Check Example on page A.1.137*.

Recloser Mode Enables

The SELOGIC control equations E3PR1 and ESPR1 set the SEL-421 for the auto-reclose modes. *Table 2.4* illustrates how to enable the auto-reclose modes for Circuit Breaker 1.

Table 2.4 One Circuit Breaker Modes of Operation

E3PR1	ESPR1	Result
0	0	Auto-reclose disabled
0	1	Single-pole auto-reclose only enabled
1	0	Three-pole auto-reclose only enabled
1	1	Single- and three-pole auto-reclose enabled

E3PR1 is the SELOGIC control equation that enables three-pole auto-reclose 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 auto-reclose 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 auto-reclose 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 auto-reclose cycle for Circuit Breaker 1. If ESPR1 equals logical 0, the relay cannot initiate a single-pole auto-reclose cycle.

Set either or both E3PR1 and ESPR1 according to your reclosing requirements. For single-pole reclosing, set ESPR1 to evaluate to logical 1 and set NSPSHOT to the number of single-pole reclose shots you want. For three-pole reclosing, set E3PR1 to evaluate to logical 1 and set N3PSHOT for the number of three-pole shots you want. 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 number of reclose shots of each type that you want. See *Recloser Mode Enables on page R.2.9*.

Trip Logic and Reclose Sources

Internal Recloser

Program the SEL-421 recloser function to drive the trip logic with Relay Word bits R3PTE (Recloser Three-Pole Trip Enable) and R3PTE1 (Recloser 3-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 SEL-421 recloser for both three-pole reclosing and single-pole reclosing. Enter enable settings ESPR1 and E3PR1 as appropriate for your application.

The SEL-421 is a single-pole tripping relay; if E3PT and E3PT1 are logical 0, the relay is enabled for single-pole tripping. Conversely, if E3PT and E3PT1 are logical 1, the relay is enabled for three-pole tripping only.

Relay Word bits R3PTE and R3PTE1 are logical 1 for any 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 2.8*):

- 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 SEL-421.

Two-Circuit-Breaker Auto-Reclosing

Two Circuit Breaker Auto-Reclose Modes

NOTE: In the following discussion, n is 1 or 2 for Circuit Breaker BK1 or BK2.

The SEL-421 auto-reclose logic operates in three modes:

- Single-pole mode (SPAR)
- Three-pole mode (3PAR)
- Single- and three-pole mode (SPAR/3PAR)

Relay settings ESPR*n* (Single-Pole Reclose Enable—BK*n*) and E3PR*n* (Three-Pole Reclose Enable—BK*n*) determine the auto-reclose mode (see *Recloser Mode Enables on page R.2.24*). 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 2.8* and *Figure 2.9*. SPARC asserts when all necessary conditions to begin a single-pole auto-reclose cycle are satisfied (ESPR*n*, for example) and the recloser receives a single-pole reclose initiation SPRI (see *Figure 2.8*). Relay Word bit 3PARC asserts when all necessary conditions to begin a three-pole auto-reclose cycle are satisfied (E3PR*n*, for example) and the recloser receives a three-pole reclose initiation 3PRI (see *Figure 2.9*).

Other recloser settings include the initial recloser settings (see *Enable Auto-Reclose Logic for One Circuit Breaker on page R.2.8*) 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 on page R.2.26*).

Single-Pole Mode

Figure 2.12 and *Figure 2.13* show the two circuit breaker single-pole auto-reclose 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 SPnCLS is satisfied within the duration of timer BKnCLSD. 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 auto-reclose 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 auto-reclose 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 BK1CLSD 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 2.14 and *Figure 2.15* show the two circuit breaker three-pole auto-reclose 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 2.6*)
- ➤ if E79 := Y1, 3POLINE asserts when at least one breaker (leader *or* follower) opens (see *Figure 2.7*)

If 3POLINE asserts, the recloser proceeds to timing 3POID1 (Three-Pole Open Interval 1 Delay). In applications where 3POLINE may not reliably assert while in the 79CY3 state, we recommend forcing the auto-reclose cycle into a drive-to-lockout state (79DTL = 1) after a fixed time delay. You can do this by using the entry into the cycle state (79CY3 = 1) as an input to a conditioning timer. The conditioning timer applies a pickup delay, and the relay 79DTL setting includes the conditioning timer output. The time delay should be long enough to allow normal breaker operation to occur, while preventing the auto-reclose logic from stalling while waiting indefinitely for 3POLINE to assert. 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 the number of trips exceeds the maximum number of shots (N3PSHOT), supervision condition 3P*n*CLS 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, or any time Relay Word bit 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 R.2.11*. 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 auto-reclose cycle state 79CY3. The recloser proceeds through the 79CY3 state and exits this state as described in *Three-Pole Mode on page R.2.12*.

Three-Pole Priority

If a single-pole auto-reclose cycle is in progress (79CY1) and the relay receives an initiation for three-pole reclosing (3PRI), the recloser immediately starts a three-pole auto-reclose cycle (79CY3).

Active Circuit Breakers

The following three Relay Word bits describe when Circuit Breaker BK1 and Circuit Breaker BK2 are active for the auto-reclose 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 2.2* illustrates a multiple circuit breaker arrangement. The leader recloses first. If the leader recloses successfully, the follower also typically recloses.

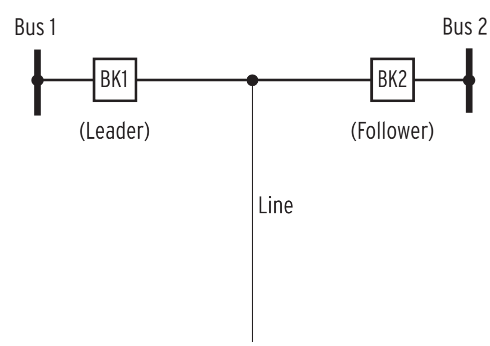


Figure 2.2 Multiple Circuit Breaker Arrangement

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 SEL-421 can automatically make Circuit Breaker BK2 the leader.

The relay freezes the leader, follower, and number of active circuit breaker designations during an auto-reclose 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 1 as the leader; set SLBK2 := 1 to select Circuit Breaker 2 as the leader. SLBK1 has priority over SLBK2; if you set both settings to 1 or both to 0, Circuit Breaker 1 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 SLBK := 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 SEL-421 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 SEL-421 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 SEL-421 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 2.5* shows the permutations of these settings.

Table 2.5 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 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 R.2.18* for another method to prevent BK2 from becoming the leader.

The following examples help illustrate how the SEL-421 auto-reclose 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 2.3*.

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 2.6*.

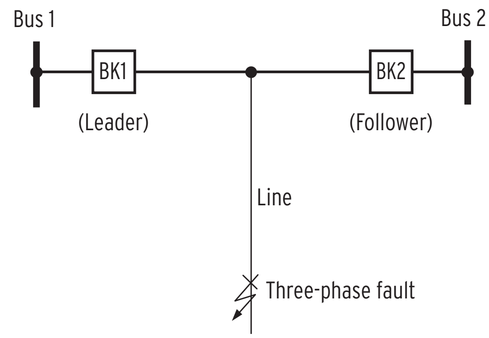


Figure 2.3 Multiple Circuit Breaker Arrangement

Table 2.6 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 auto-reclose logic resets for both circuit breakers. *Table 2.7* defines the logical state of the auto-reclose logic for this example prior to the initiation of an auto-reclose cycle.

Table 2.7 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 2.8* defines the logical state of the auto-reclose logic at this point.

Table 2.8 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 2.9* defines the logical state of the auto-reclose logic at this point.

Table 2.9 Example One: Reset State After Reclaim Time

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

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 2.10*).

Table 2.10 Leader/Follower Selection

Setting Label	Value
SLBK1	1
SLBK2	0
FBKCEN	1

Reset State

Prior to receiving initiation for a three-phase fault, the auto-reclose logic resets for both circuit breakers. At the start of the reclose cycle, Relay Word bits LEADBK1, FOLBK2, and NBK2 are asserted (see *Table 2.11*).

Table 2.11 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 2.12*). 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 2.12 Example Two: Final Reset State (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

Table 2.12 Example Two: Final Reset State (Sheet 2 of 2)

Relay Word Bit	Description	Logical State
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 2.13*.

Table 2.13 Leader/Follower Selection

Setting Label	Value
SLBK1	1
SLBK2	0
FBKCEN	52AA1

Reset State

Prior to receiving initiation for a three-phase fault, the auto-reclose logic resets for both circuit breakers. *Table 2.14* defines the logical state of the auto-reclose logic for this example prior to the initiation of an auto-reclose cycle.

Table 2.14 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 SEL-421 auto-reclose logic receives a three-pole initiation. *Table 2.15* defines the logical state of the auto-reclose logic for this example during the three-pole auto-reclose cycle.

Table 2.15 Example Three: Three-Pole Cycle State (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	0
NBK2	Two Active Breakers in Reclose Scheme	1
LEADBK0	No Leader Breaker	0
LEADBK1	Leader Breaker = Breaker 1	1

Table 2.15 Example Three: Three-Pole Cycle State (Sheet 2 of 2)

Relay Word Bit	Description	Logical State
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 2.16* defines the logical state of the auto-reclose logic for this example following the unsuccessful reclose attempt.

Table 2.16 Example Three: Lockout State, BK1

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 2.4 illustrates a circuit breaker-and-a half configuration for this particular example. The leader and follower selection settings are shown in *Table 2.17*. Circuit Breaker BK1 is out of service for maintenance and Disconnect Switch 1 is open.

Table 2.17 Leader/Follower Selection

Setting Label	Setting
SLBK1	IN106 (Disconnect 1 a contacts)
SLBK2	IN107 (Disconnect 2 a contacts)
FBKCEN	0

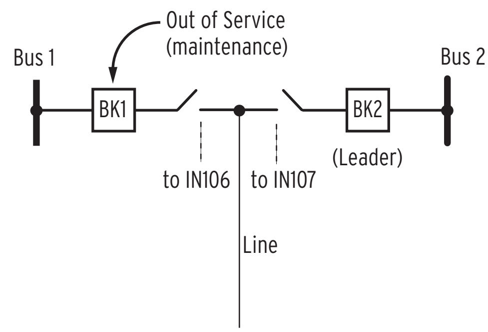


Figure 2.4 Leader/Follower Selection by Relay Input

Table 2.18 defines the logical state of the auto-reclose logic for this example prior to the initiation of an auto-reclose cycle. These conditions are frozen during an auto-reclose cycle. The SEL-421 auto-reclose logic can unfreeze these conditions if the relay receives another initiation.

Table 2.18 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 Auto-Reclose Logic for Two Circuit Breakers

Three-Pole Trip Circuit Breakers

The initial settings necessary to enable auto-reclose for two three-pole trip circuit breakers are shown in *Table 2.19*.

Table 2.19 Two-Circuit-Breaker Three-Pole Reclose Initial Settings

Setting	Description	Entry
NUMBK	Number of Breakers in Scheme	2
Breaker Configuration (Breaker Monitor)		
BK1TYP	Breaker 1 Trip Type	3
BK2TYP	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

For additional settings to set specific operating parameters for the recloser, refer to *Auto-Reclose and Synchronism Check Example on page A.1.137*.

Single-Pole Trip Circuit Breakers

The initial settings necessary to enable auto-reclose for two single-pole trip circuit breakers are shown in *Table 2.20*.

Table 2.20 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

For additional settings to set specific operating parameters for the recloser, refer to *Auto-Reclose and Synchronism Check Example on page A.1.137*.

Recloser Mode Enables

The SELOGIC control equations E3PR*n* and ESPR*n* set the SEL-421 for the three auto-reclose modes. *Table 2.21* and *Table 2.22* illustrate how to enable the auto-reclose modes per circuit breaker.

Table 2.21 Circuit Breaker BK1 Modes of Operation

E3PR1	ESPR1	Result
0	0	Auto-reclose disabled
0	1	Single-pole auto-reclose only enabled
1	0	Three-pole auto-reclose only enabled
1	1	Single- and three-pole auto-reclose enabled

E3PR1 is the SELOGIC control equation that enables three-pole auto-reclose for Circuit Breaker BK1. You can assign this setting to a control input. ESPR1 is the SELOGIC control equation that enables single-pole auto-reclose 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 auto-reclose cycle for Circuit Breaker BK1. If ESPR1 equals logical 0, the relay cannot initiate a single-pole auto-reclose cycle for Circuit Breaker BK1.

When E3PR1 equals logical 1, the relay can attempt a three-pole auto-reclose 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 2.22 Circuit Breaker BK2 Modes of Operation

E3PR2	ESPR2	Result
0	0	Auto-reclose disabled
0	1	Single-pole auto-reclose only enabled
1	0	Three-pole auto-reclose only enabled
1	1	Single- and three-pole auto-reclose enabled

E3PR2 is the SELOGIC control equation that enables three-pole auto-reclose for Circuit Breaker BK2. You can assign this setting to a control input. ESPR2 is the SELOGIC control equation that enables single-pole auto-reclose 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 auto-reclose cycle for Circuit Breaker BK2. If ESPR2 equals logical 0, the relay cannot initiate a single-pole auto-reclose cycle for Circuit Breaker BK2.

When E3PR2 equals logical 1, the relay can attempt a three-pole auto-reclose 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 number of single-pole reclose shots you want. For three-pole reclosing, set E3PR1 := 1 and set N3PSHOT for the number of three-pole shots you want. For both single-pole and three-pole reclosing, set ESPR1 := 1, E3PR1 := 1, and configure settings NSPSHOT and N3PSHOT for the number of reclose shots of each type that you want (see *Recloser Mode Enables on page R.2.9*).

EXAMPLE 2.1 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

Internal Recloser

Program the SEL-421 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 SEL-421 recloser for both three-pole reclosing and single-pole reclosing.

Enter enable settings ESPR1 and E3PR1 as appropriate for your application. The SEL-421 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 1. The same conditions apply to setting E3PT2 and Circuit Breaker BK2.

Table 2.23 summarizes the relay trip logic enable options.

Table 2.23 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 2.8*):

- ➤ 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 SEL-421.

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. See *Figure 1.71*. 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.

Auto-Reclose Logic Diagrams

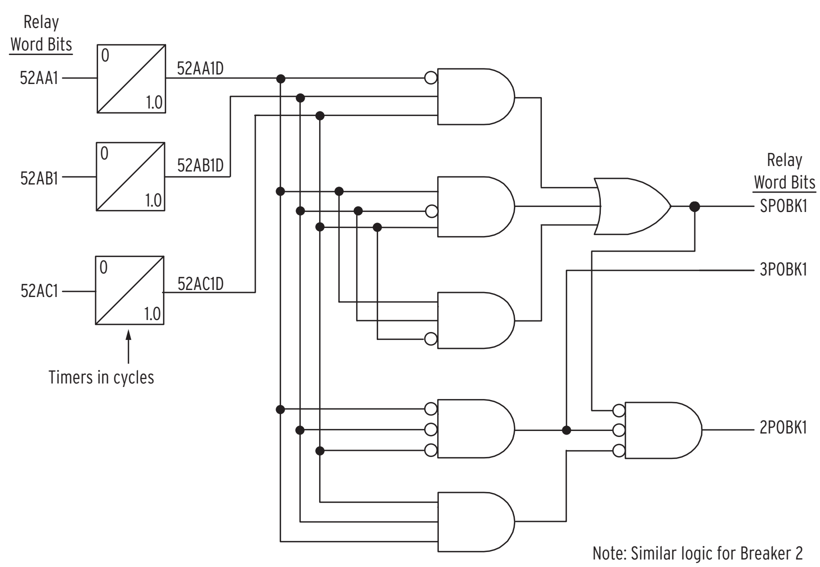


Figure 2.5 Circuit Breaker Pole-Open Logic Diagram

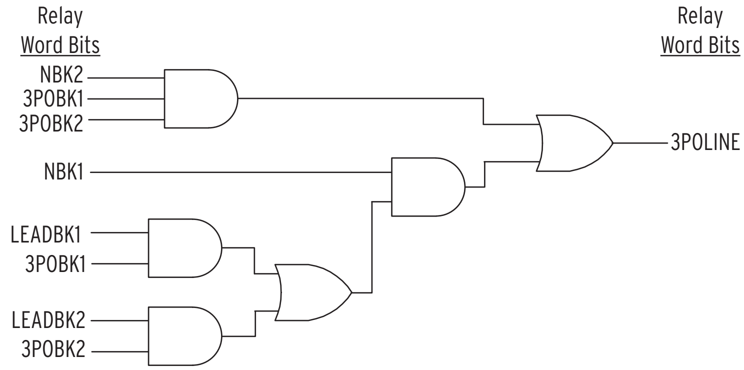


Figure 2.6 Line-Open Logic Diagram When E79 := Y

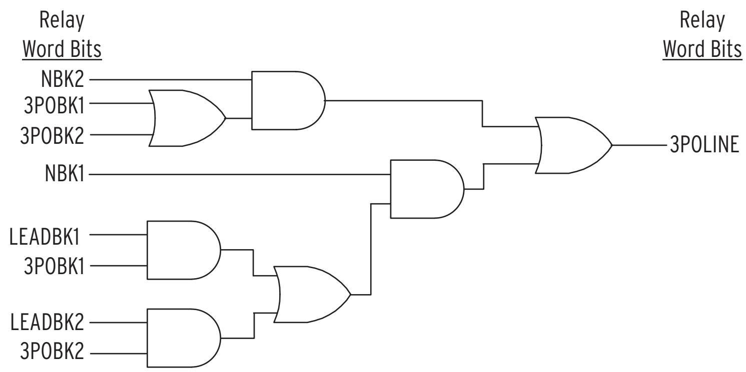


Figure 2.7 Line-Open Logic Diagram When E79 := Y1

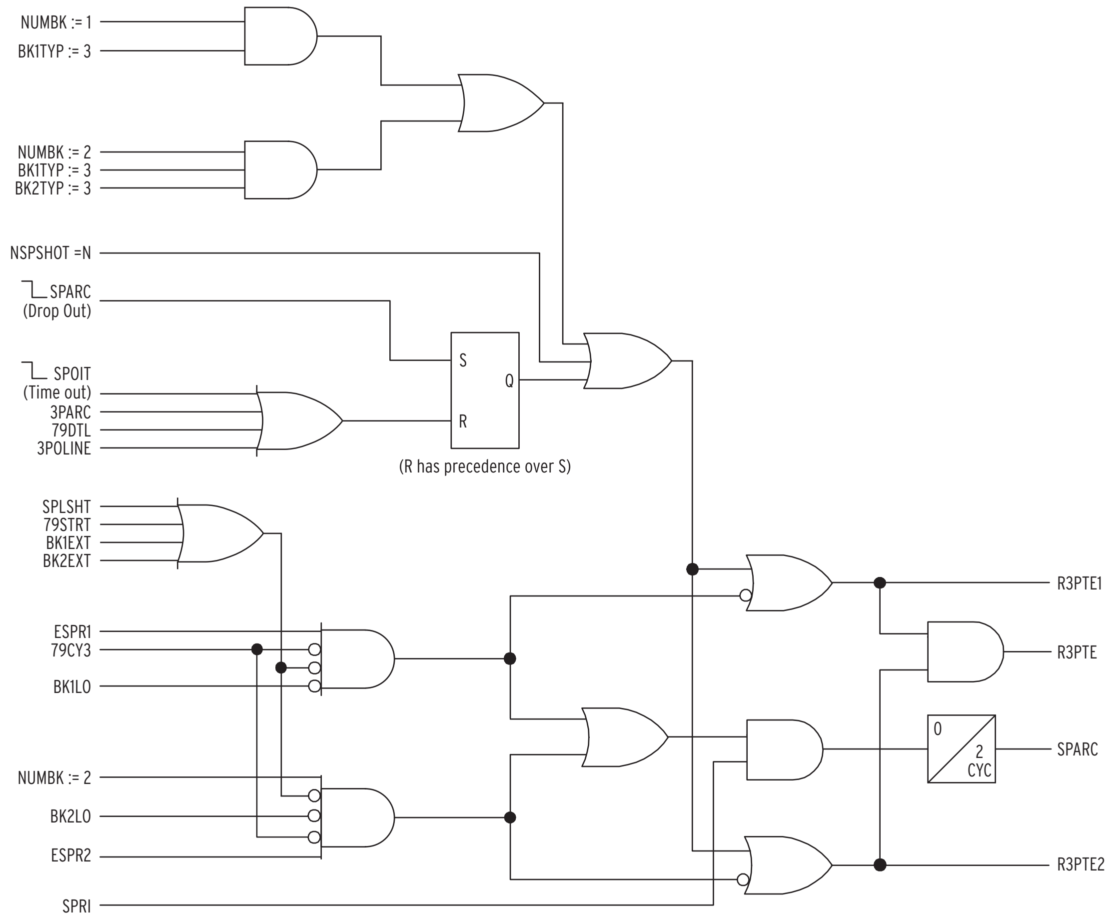


Figure 2.8 Single-Pole Reclose Enable

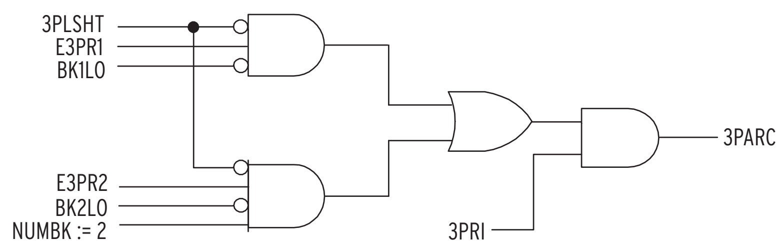


Figure 2.9 Three-Pole Reclose Enable

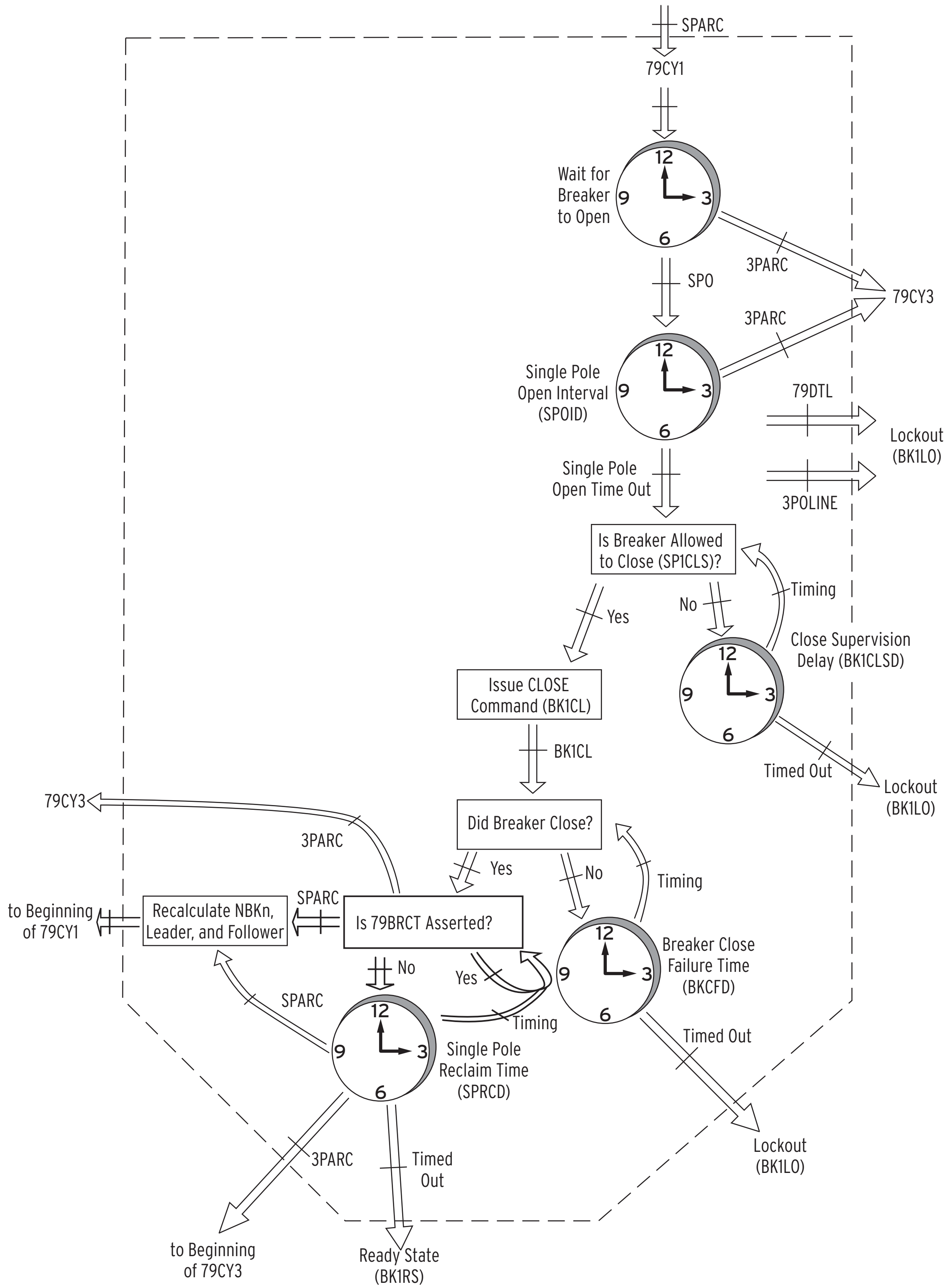
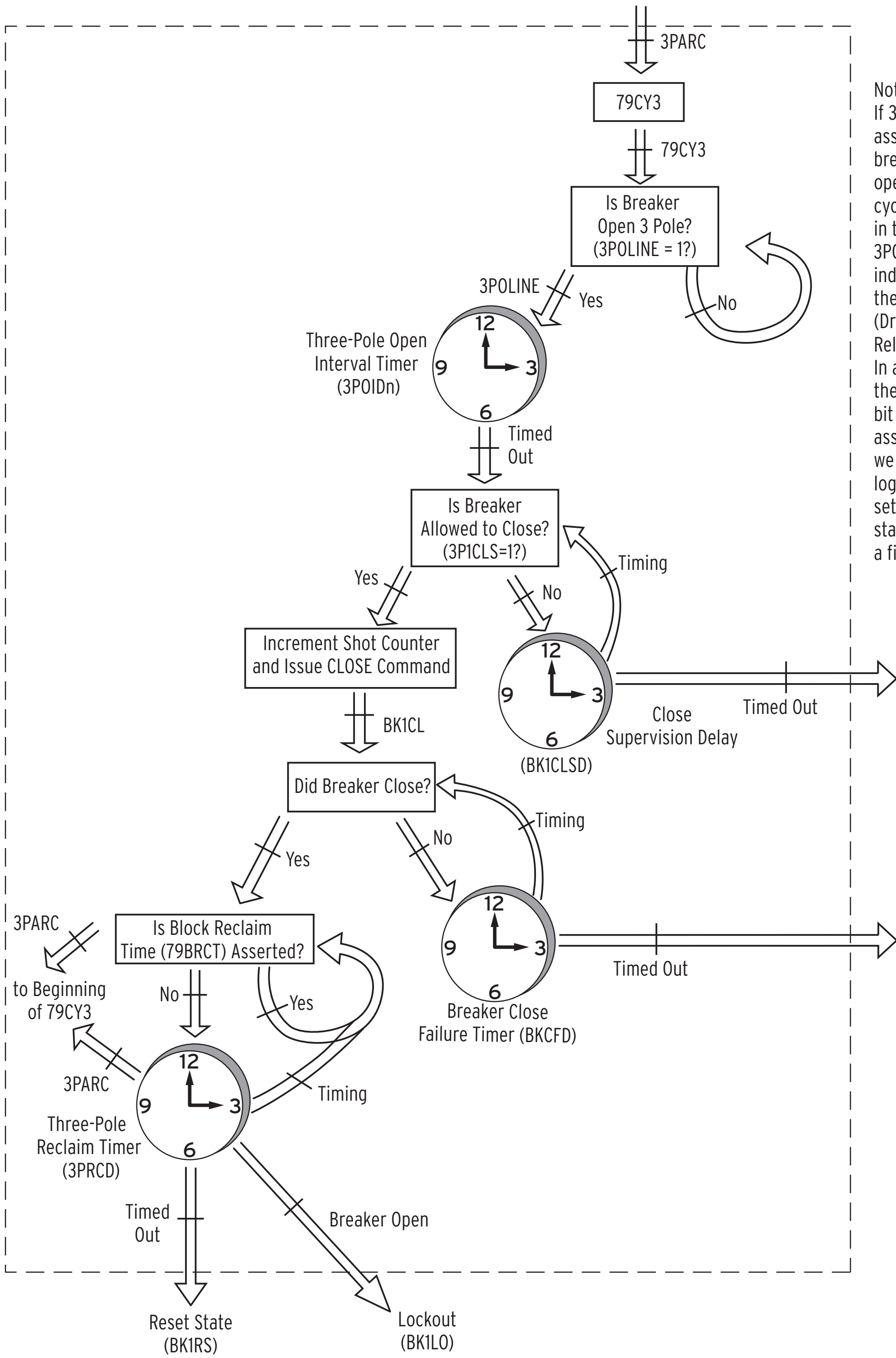


Figure 2.10 One Circuit Breaker Single-Pole Cycle State (79CY1)



Note:
If 3POLINE does not assert (three-pole breaker does not open), the auto-reclose cycle state will remain in the check for the 3POLINE = 1 condition indefinitely, or until the 79DTL logic (Drive to Lockout) Relay Word bit asserts. In applications where the 3POLINE Relay Word bit may not reliably assert at this point, we recommend using logic in the 79DTL setting to bypass this stall condition after a fixed time delay.

Figure 2.11 One Circuit Breaker Three-Pole Cycle State (79CY3)

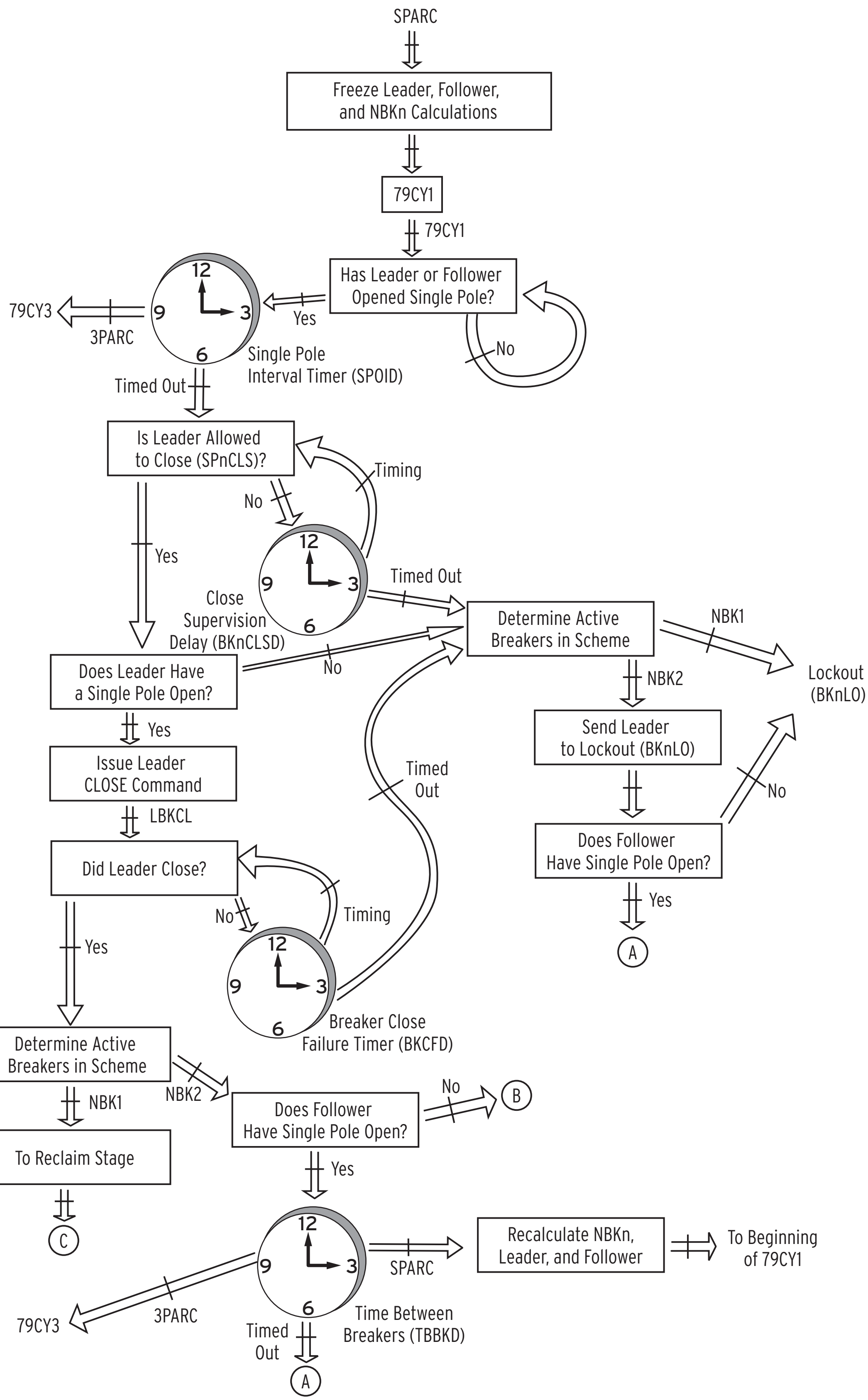


Figure 2.12 Two Circuit Breakers Single-Pole Cycle State (79CY1) When E79 := Y

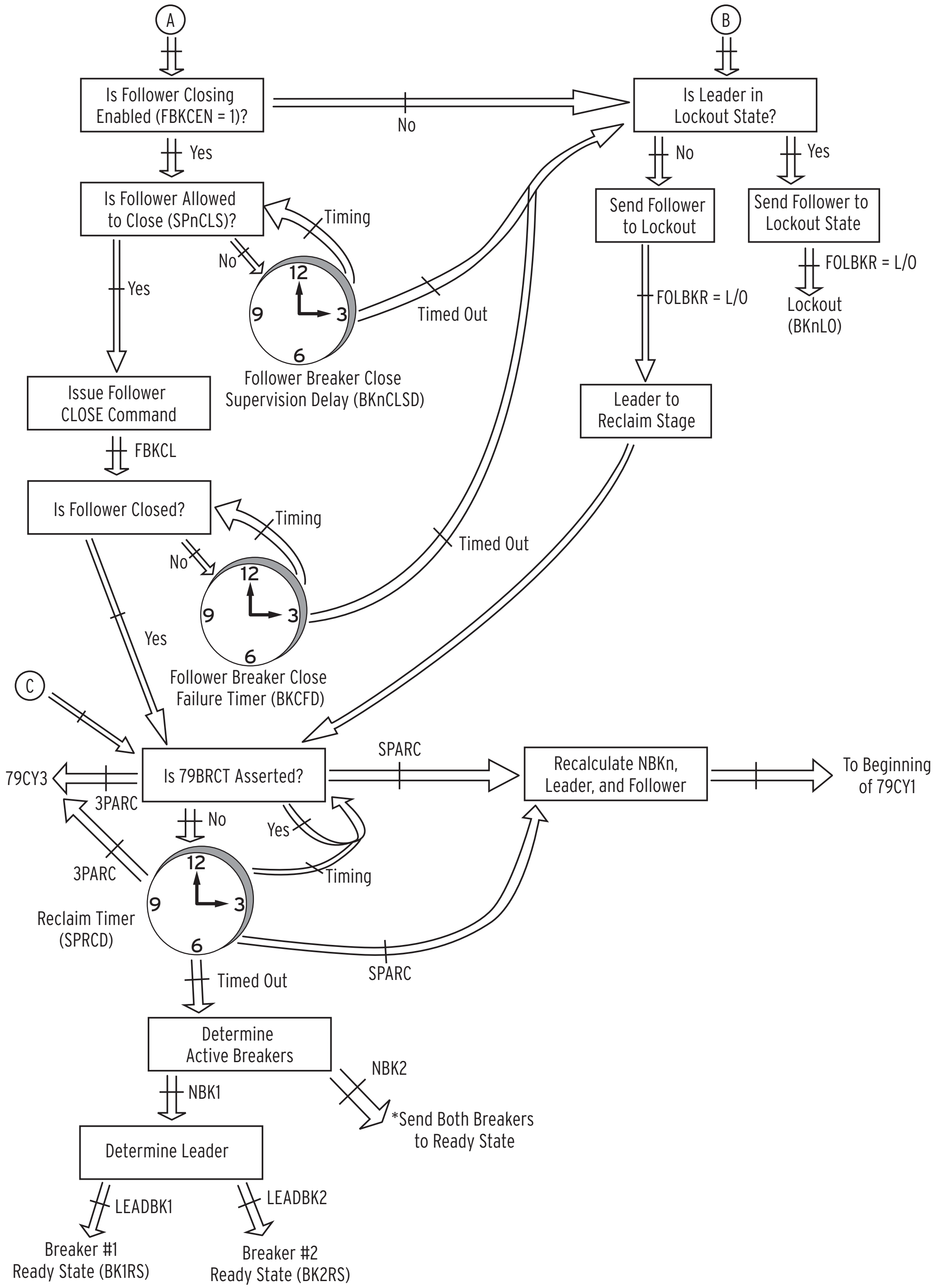


Figure 2.12 Two Circuit Breakers Single-Pole Cycle State (79CY1) When E79 := Y (continued)

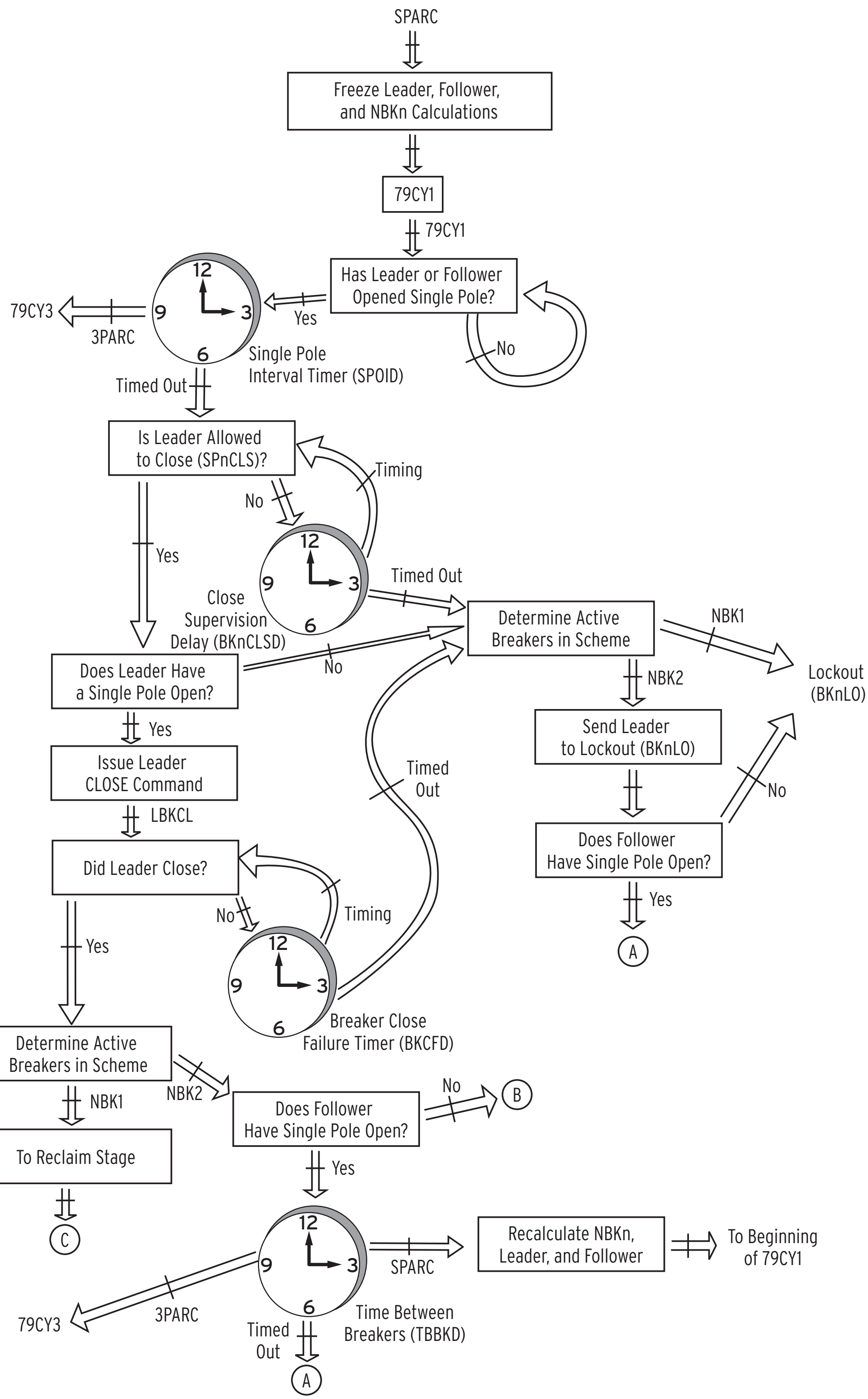


Figure 2.13 Two Circuit Breakers Single-Pole Cycle State (79CY1) When E79 := Y1

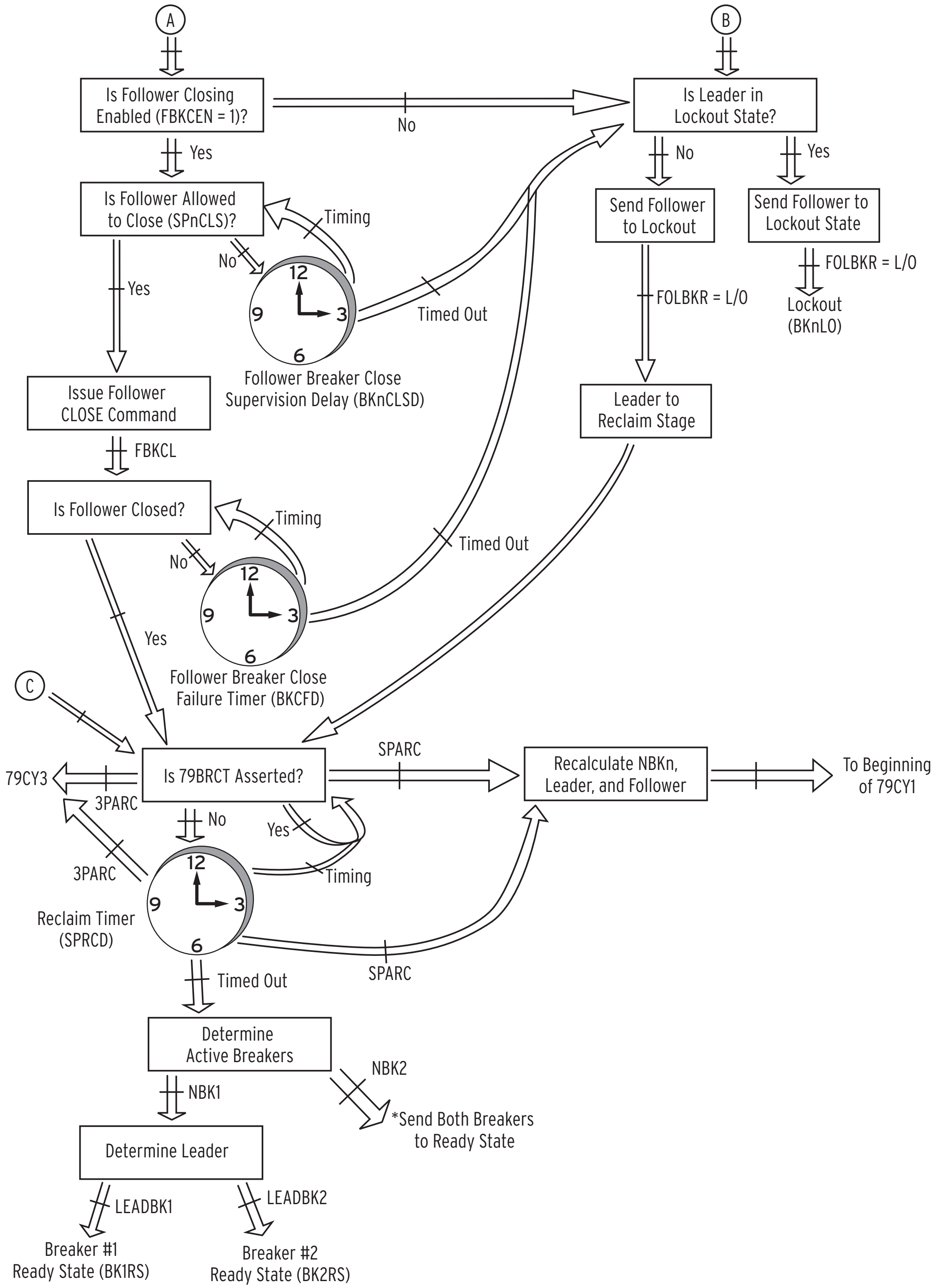


Figure 2.13 Two Circuit Breakers Single-Pole Cycle State (79CY1) When E79 := Y1 (continued)

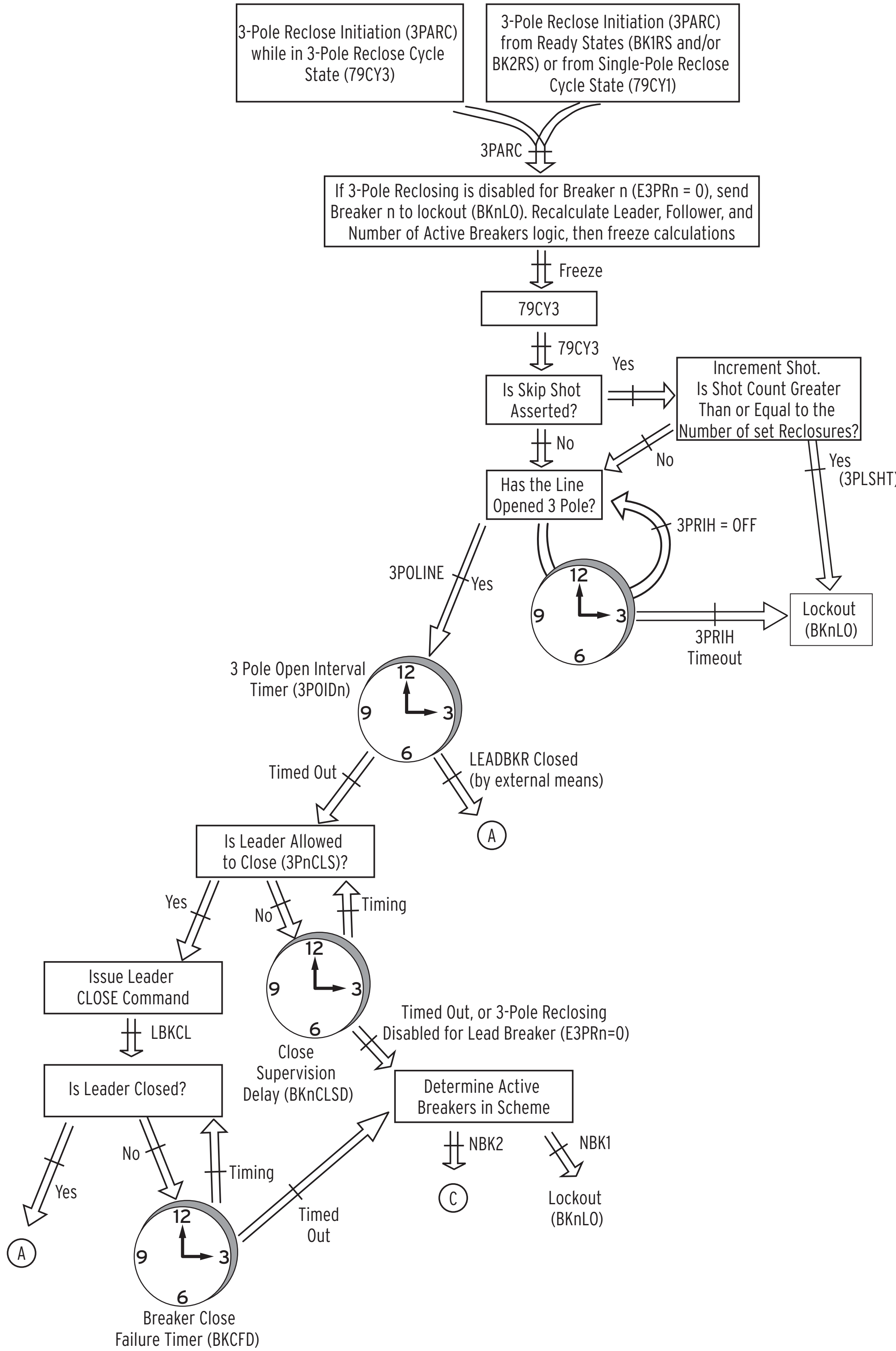


Figure 2.14 Two Circuit Breakers Three-Pole Cycle State (79CY3) When E79 := Y

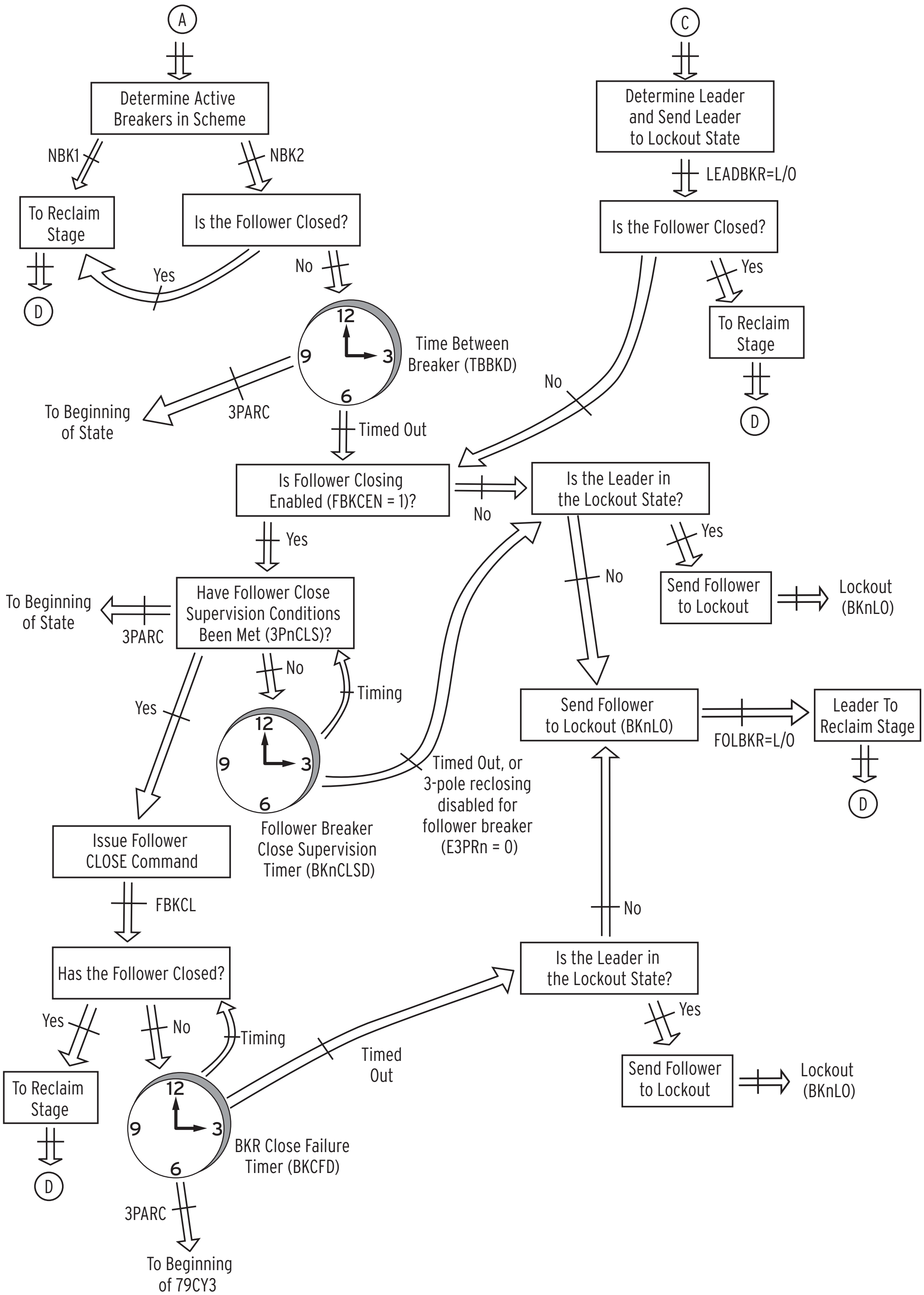


Figure 2.14 Two Circuit Breakers Three-Pole Cycle State (79CY3) When E79 := Y (continued)

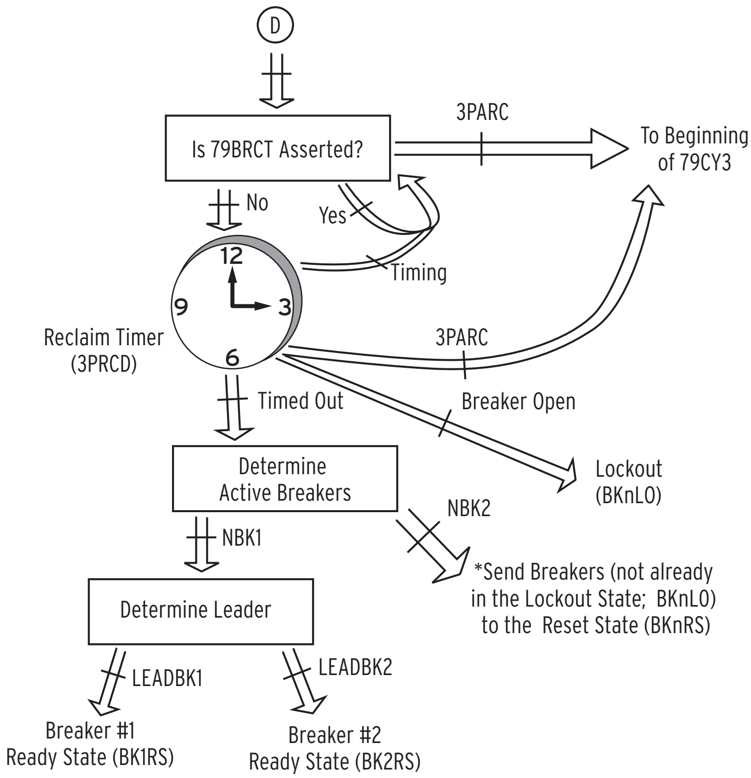


Figure 2.14 Two Circuit Breakers Three-Pole Cycle State (79CY3) When E79 := Y (continued)

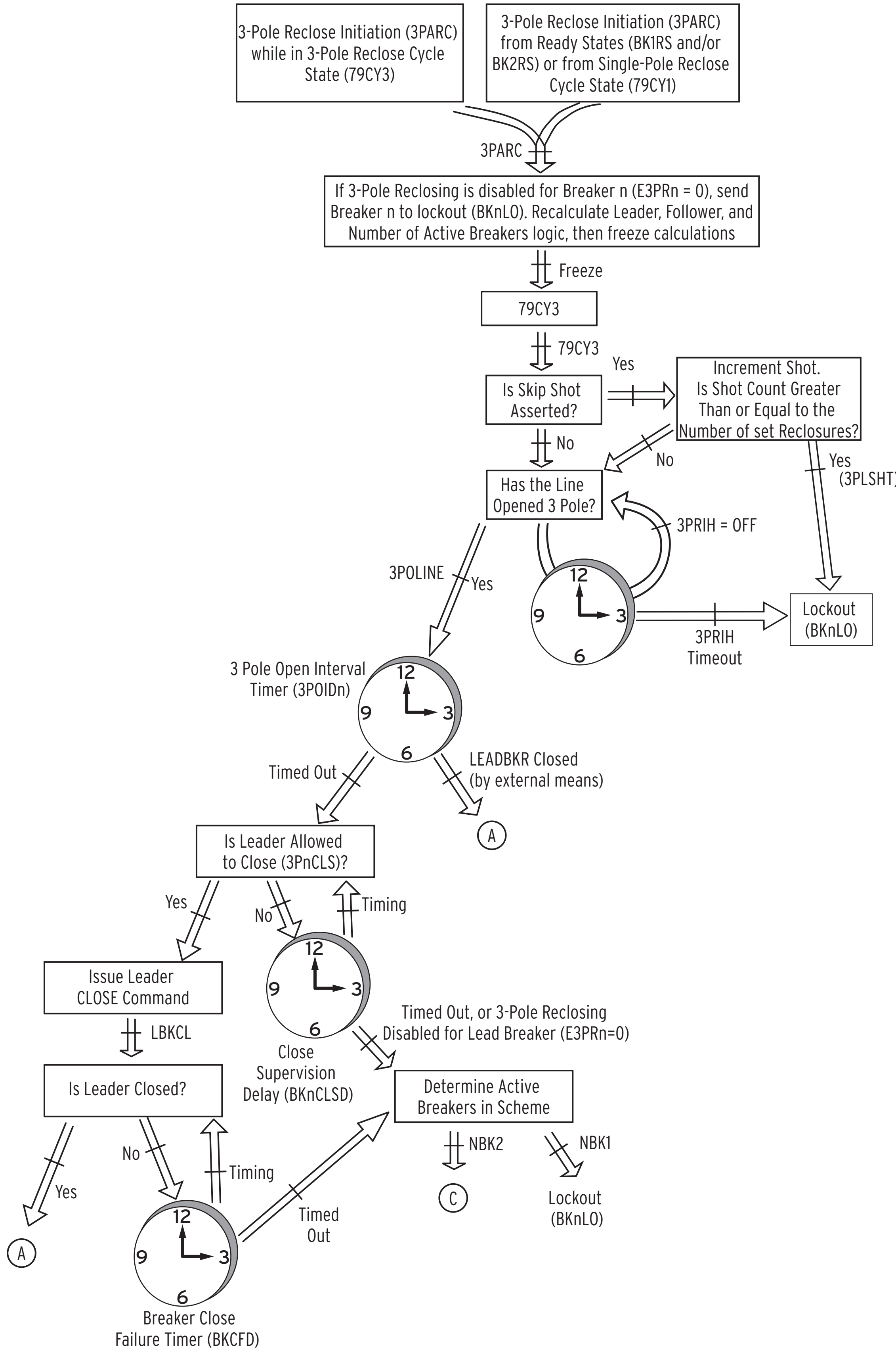


Figure 2.15 Two Circuit Breakers Three-Pole Cycle State (79CY3) When E79 := Y1

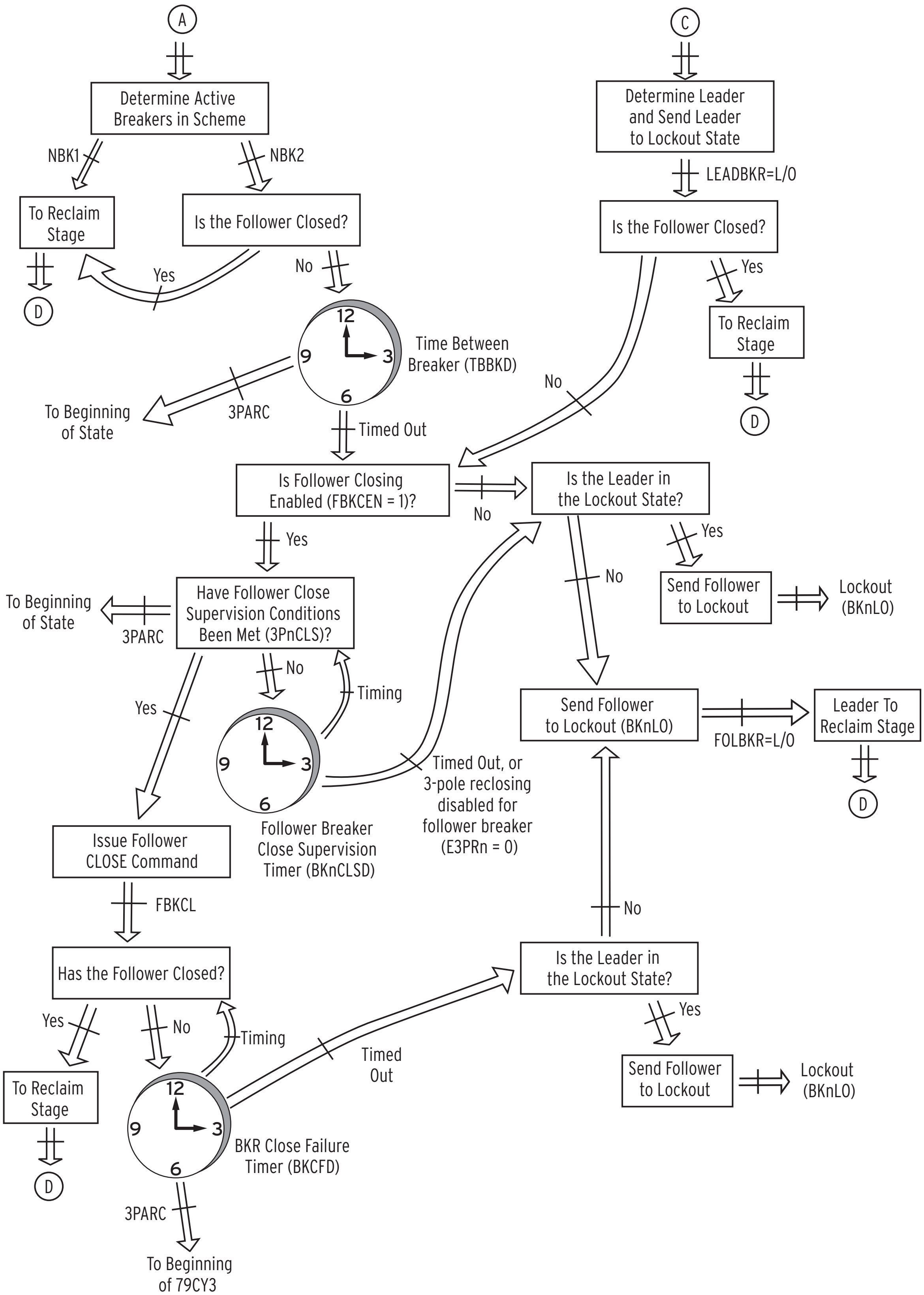


Figure 2.15 Two Circuit Breakers Three-Pole Cycle State (79CY3) When E79 := Y1 (continued)

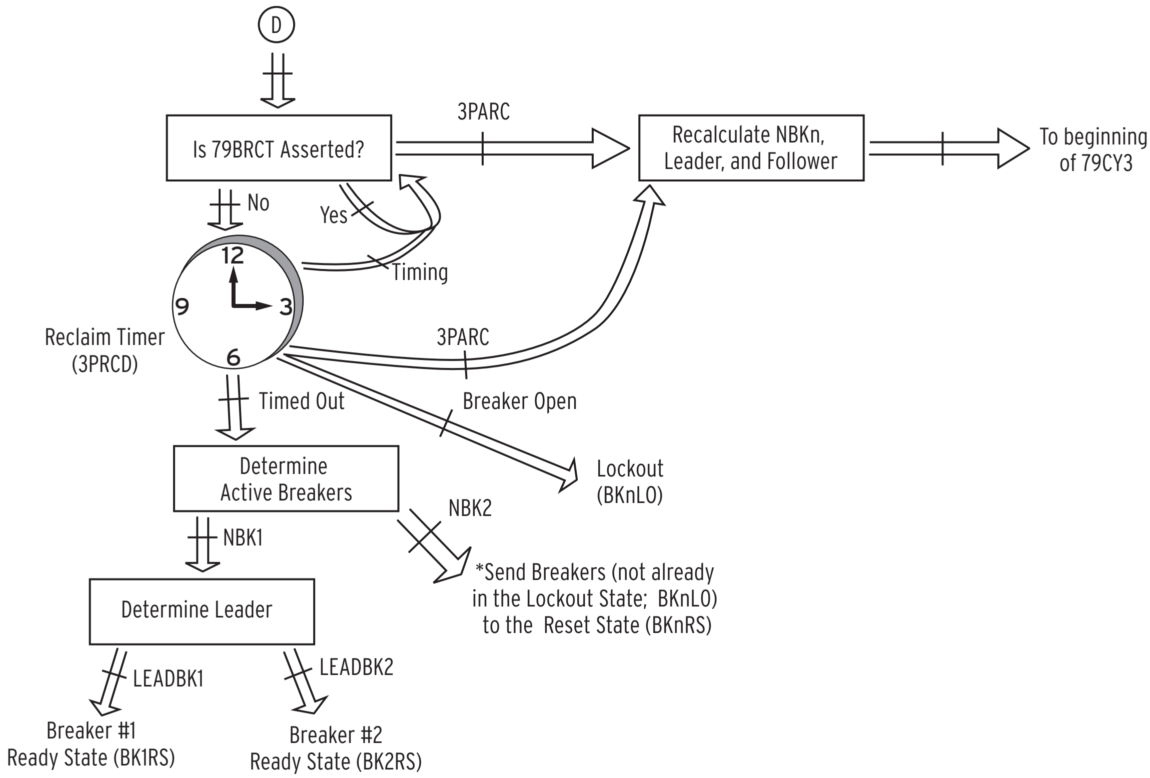


Figure 2.15 Two Circuit Breakers Three-Pole Cycle State (79CY3) When E79 := Y1 (continued)

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 auto-reclosing (Relay Word bits BK1CL and BK2CL for up to two circuit breakers). The manual close logic can be user-configured in most any manner with SELOGIC settings BK1MCL and BK2MCL. *Figure 2.16* is a flowchart of the manual close logic. This logic is enabled with Manual Closing enable setting EMANCL := Y.

Figure 2.16 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 2.16* is the substitution of settings and logic outputs (BK2MCL for BK1MCL, ULCL2 for ULCL1, etc.). A manual close is issued for breaker BK1 if:

- ➤ 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),
- ➤ And 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
- ➤ And the close failure timer starts timing

If breaker BK1 closes successfully, then:

- ➤ The unlatch close condition asserts (indicating breaker closure)
- ➤ And 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)
- ➤ And close logic output BK1CL deasserts

Note in *Figure 2.16* that if breaker BK1 manual close logic is actively operating (as described in the preceding steps), then the breaker BK2 manual close logic cannot be actively operating. The breaker BK2 manual close logic only has a chance to operate if the breaker BK1 manual close logic is not actively operating and two breakers are enabled for the scheme (global setting NUMBK := 2). Thus, manually closing can only be attempted for one breaker at a time.

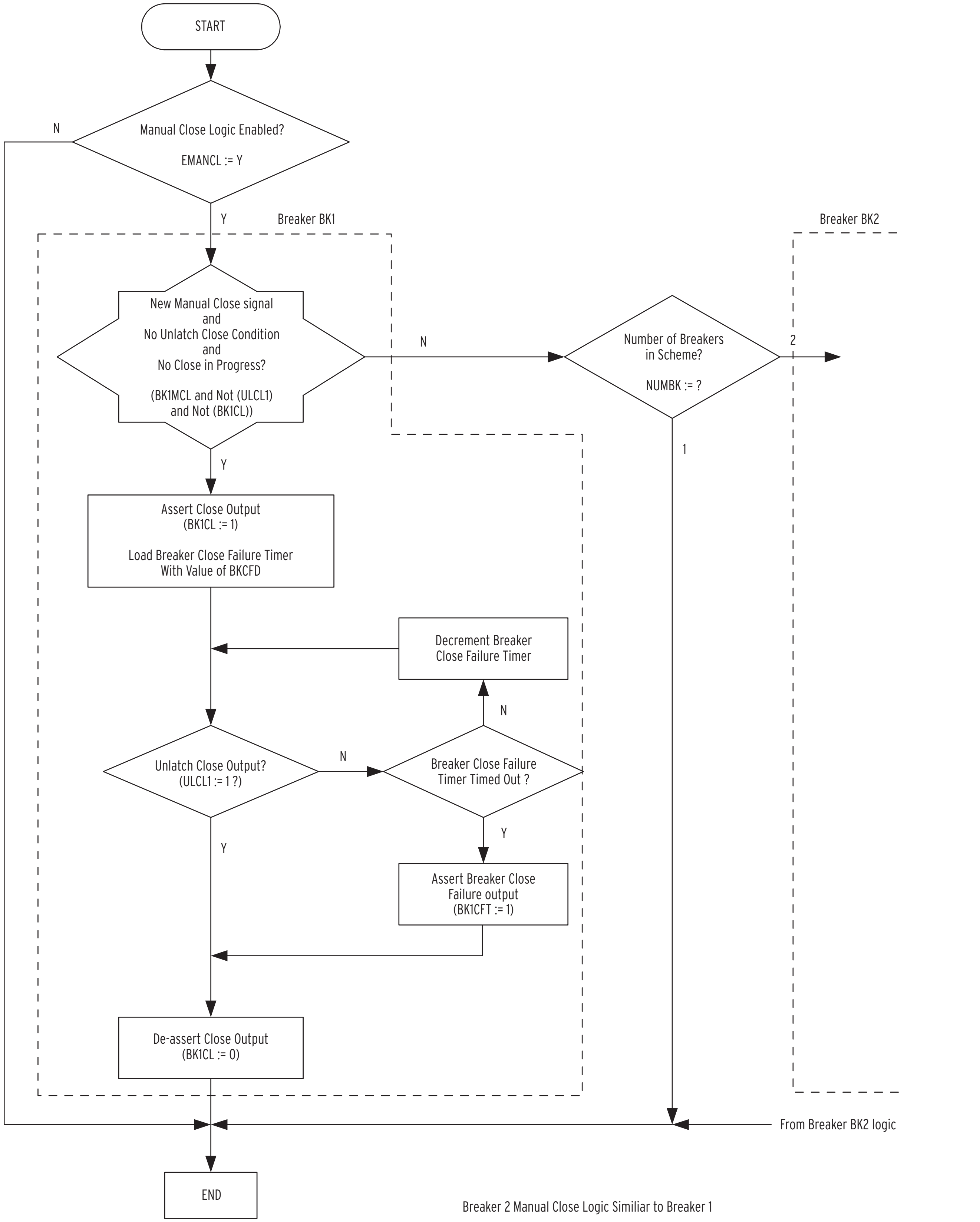


Figure 2.16 Manual Close Logic

Voltage Checks for Auto-Reclosing and Manual Closing

Voltage elements are available for a final check of line and bus voltages before an auto-reclose or manual close is issued. These voltage elements and corresponding pickup settings are enabled with Reclosing Voltage Check enable setting EVCK := Y. *Figure 2.17* shows the application of these voltage elements and *Figure 2.18* shows their implementation. Check voltages for arrangements of up to two circuit breakers (global setting NUMBK := 2), as shown in *Figure 2.17*. If the SEL-421 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.

Voltages V_P, V_{S1}, and V_{S2} in *Figure 2.17* and *Figure 2.18* come from corresponding voltage source selection settings SYNCP, SYNCS1, and SYNCS2 in the *Synchronism Check* subsection (see *Figure 2.22*). *Figure 2.24*, *Figure 2.25*, *Figure 2.26*, and accompanying text in *Synchronism Check on page R.2.50* explain an example where:

SYNCP = **VAY** (V_P is the voltage from voltage input VAY, referred to as the line voltage)

SYNCS1 = **VAZ** (V_{S1} is the normalized voltage from voltage input VAZ, referred to as the bus 1 voltage)

SYNCS2 = **VBZ** (V_{S2} is the normalized voltage from voltage input VBZ, referred to as the bus 1 voltage)

Figure 2.25, *Figure 2.26*, and accompanying text in *Synchronism Check* explain the origin and normalization of voltages V_{S1} and V_{S2} to the V_P voltage base. This normalization example concerns both voltage angle and magnitude. The pickup settings in *Figure 2.18* are made on the V_P voltage base. V_P is the voltage reference for voltage angle and magnitude. Only voltage magnitude is of concern for the settings in *Figure 2.18*, not voltage angle.

Figure 2.17 implies that three-phase voltage is available from the line PTs. But, resultant voltage V_P corresponds to only one phase of this three-phase voltage (e.g., setting SYNCP = VAY; V_P is the normalized voltage from voltage input VAY). All the voltage elements in *Figure 2.18* 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 and E25BK2 := Y) in order that the corresponding voltage source selection settings (SYNCP, SYNCS1, and SYNCS2) can be made.

Live Line/Live Bus

Note in *Figure 2.17* that live line/live bus is not available for either circuit breaker. Voltage elements 59VP, 59VS1, and 59VS2 in *Synchronism Check* (see *Figure 2.23* and *Figure 2.27*) 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 Auto-Reclosing

For a fault on the line in *Figure 2.17*, 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 2.17*). Then, after successful reclose of the lead breaker, the follower breaker closes on synchronism check (see *Figure 2.23*). 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 2.17*) 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 (...)**

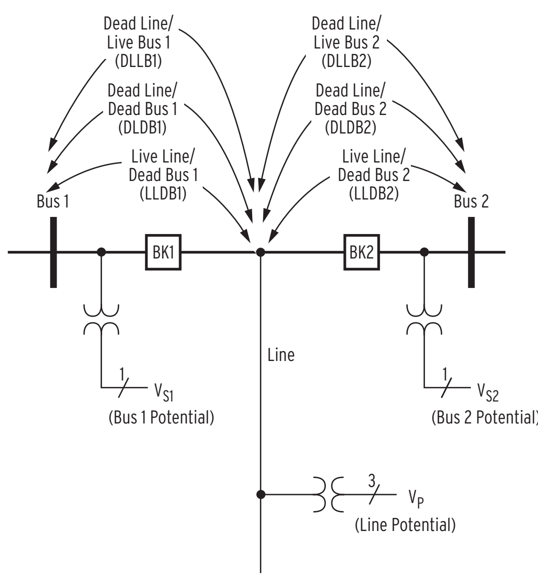


Figure 2.17 Voltage Check Element Applications

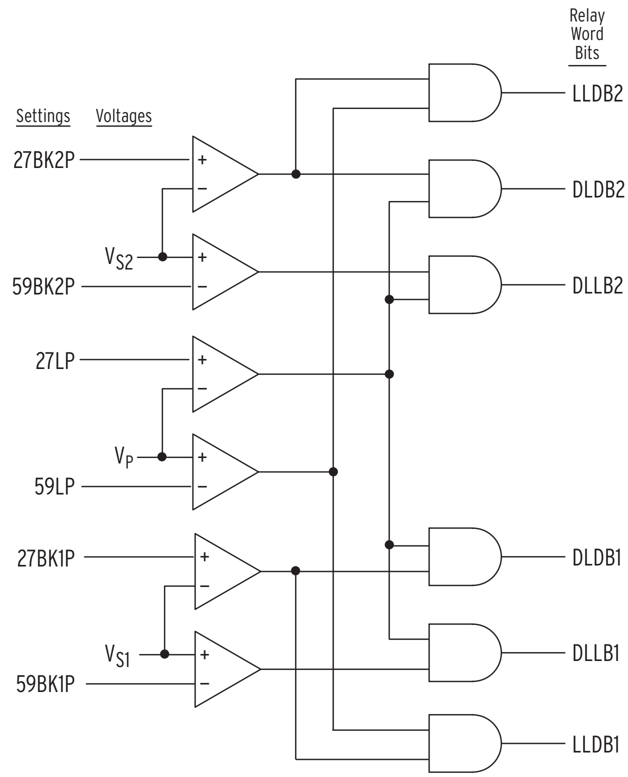


Figure 2.18 Voltage Check Element Logic

Settings and Relay Word Bits for Auto-Reclosing and Manual Closing

Table 2.24 shows the auto-reclose logic settings. *Table 2.25* provides all of the Relay Word bits for auto-reclosing.

Table 2.24 Auto-Reclose Logic Settings (Sheet 1 of 3)[a]

Label	Prompt	Default Value
Recloser Closing		
NSPSHOT	Number of Single-Pole Reclosures (N, 1, 2)	N
ESPR1	Single-Pole Reclose Enable—BK1 (SELOGIC Equation)	NA
ESPR2	Single-Pole Reclose Enable—BK2 (SELOGIC Equation)	NA
N3PSHOT	Number of Three-Pole Reclosures (N, 1–4)	2
E3PR1	Three-Pole Reclose Enable—BK1 (SELOGIC Equation)	PLT06
E3PR2	Three-Pole Reclose Enable—BK2 (SELOGIC Equation)	PLT06
TBBKD	Time Between Breakers for Automatic Reclose (1–99999 cycles)	300
BKCFD	Breaker Close Failure Delay (OFF, 1–99999 cycles)	300

Table 2.24 Auto-Reclose Logic Settings (Sheet 2 of 3)[a]

Label	Prompt	Default Value
SLBK1	Lead Breaker = Breaker 1 (SELOGIC Equation)	1
SLBK2	Lead Breaker = Breaker 2 (SELOGIC Equation)	NA
FBKCEN	Follower Breaker Closing Enable (SELOGIC Equation)	1
ULCL1	Unlatch Closing for Breaker 1 (SELOGIC Equation)	52AA1 AND 52AB1 AND 52AC1
ULCL2	Unlatch Closing for Breaker 2 (SELOGIC Equation)	52AA2 AND 52AB2 AND 52AC2
79DTL	Recloser Drive to Lockout (SELOGIC Equation)	NA
79BRCT	Block Reclaim Timer (SELOGIC Equation)	NA
BK1MCL	Breaker 1 Manual Close (SELOGIC Equation)	(CC1 OR PB7_PUL) AND PLT05
BK2MCL	Breaker 2 Manual Close (SELOGIC Equation)	NA
3PMRCD	Manual Close Reclaim Time Delay (1–99999 cycles)	900
BK1CLSD	BK1 Reclose Supervision Delay (OFF, 1–99999 cycles)	7200
BK2CLSD	BK2 Reclose Supervision Delay (OFF, 1–99999 cycles)	7200
Single-Pole Reclose		
SPOISC	Single-Pole Open Interval Supervision (SELOGIC Equation)[b]	1
SPOISD	Single-Pole Open Interval Supervision Delay (OFF, 1–99999 cycles)	1
SPOID	Single-Pole Open Interval Delay (1–99999 cycles)	60
SPRCD	Single-Pole Reclaim Time Delay (1–99999 cycles)	900
SPRI	Single-Pole Reclose Initiation (SELOGIC Equation)	SPT
SP1CLS	Single-Pole BK1 Reclose Supervision (SELOGIC Equation)[b]	1
SP2CLS	Single-Pole BK2 Reclose Supervision (SELOGIC Equation)[b]	1
Three-Pole Reclose		
3POISC	Three-Pole Open Interval Supervision (SELOGIC Equation)[b]	1
3POISD	Three-Pole Open Interval Supervision Delay (OFF, 1–99999 cycles)	1
3POID1	Three-Pole Open Interval 1 Delay (1–99999 cycles)	180
3POID2	Three-Pole Open Interval 2 Delay (1–99999 cycles)	180
3POID3	Three-Pole Open Interval 3 Delay (1–99999 cycles)	180

Table 2.24 Auto-Reclose Logic Settings (Sheet 3 of 3)[a]

Label	Prompt	Default Value
3POID4	Three-Pole Open Interval 4 Delay (1–99999 cycles)	180
3PFARC	Three-Pole Fast Automatic Reclose Enable (SELOGIC Equation)	NA
3PFOID	Three-Pole Fast Open Interval Delay (1–99999 cycles)	60
3PRCD	Three-Pole Reclaim Time Delay (1–99999 cycles)	900
3PRI	Three-Pole Reclose Initiation (SELOGIC Equation)	3PT AND NOT (M2PT OR Z2GT OR M3PT OR Z3GT OR SOTFT)
3PRIH	Three-Pole Line Open Failure Delay (OFF, 1–99999)	15
79SKP	Skip Reclosing Shot (SELOGIC Equation)	NA
3P1CLS	Three Pole BK 1 Reclose Supervision (SELOGIC Equation)[b]	1
3P2CLS	Three Pole BK 2 Reclose Supervision (SELOGIC Equation)[b]	1
Voltage Elements		
EVCK	Reclosing Voltage Check (Y, N)	N
27LP	Dead Line Voltage (1.0–200 V secondary)	14.0
59LP	Live Line Voltage (1.0–200 V secondary)	53.0
27BK1P	Breaker 1 Dead Busbar Voltage[c] (1.0–200 V secondary)	14.0
59BK1P	Breaker 1 Live Busbar Voltage[c] (1.0–200 V secondary)	53.0
27BK2P	Breaker 2 Dead Busbar Voltage[c] (1.0–200 V secondary)	14.0
59BK2P	Breaker 2 Live Busbar Voltage[c] (1.0–200 V secondary)	53.0

[a] Adjust all timers in 1-cycle steps.
[b] These settings cannot be set to NA or to logical 0.
[c] These settings must be made on the normalized voltage scale if setting KS1M ≠ 1.00. or KS2M ≠ 1.00; see Voltage Magnitude and Angle Compensation on page R.2.56

Table 2.25 Auto-Reclose Logic Relay Word Bits (Sheet 1 of 3)

Name	Description
BK1RS	Breaker 1 in Reset State
BK2RS	Breaker 2 in Reset State
79CY1	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	Single-Pole Reclose Initiate Qualified
SPOISC	Single-Pole Open Interval Supervision Condition
SPOI	Single-Pole Open Interval Timing

Table 2.25 Auto-Reclose Logic Relay Word Bits (Sheet 2 of 3)

Name	Description
SPSHOT0	Single-Pole Shot Counter = 0
SPSHOT1	Single-Pole Shot Counter = 1
SPSHOT2	Single-Pole Shot Counter = 2
SPLSHT	Single-Pole Reclose Last Shot
SPRCIP	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	Single-Pole Open Breaker 1
2POBK1	Two Poles Open Breaker 1
3POBK1	Three-Pole Open Breaker 1
SPOBK2	Single-Pole Open Breaker 2
2POBK2	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
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

Table 2.25 Auto-Reclose Logic Relay Word Bits (Sheet 3 of 3)

Name	Description
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)

Synchronism Check

Synchronism-check elements prevent circuit breakers from closing if the corresponding phases across the open circuit breaker are excessively out of phase. The SEL-421 synchronism-check elements selectively close circuit breaker poles under the following criteria:

- The systems on both sides of the open circuit breaker are in phase (within a settable voltage angle difference).
- The voltages on both sides of the open circuit breaker are healthy (within a settable voltage magnitude window).

You can use synchronism-check elements to program the relay to supervise circuit breaker closing; include the synchronism-check element outputs in the close SELOGIC control equations. These element outputs are Relay Word bits 25W1BK1, 25A1BK1, 25W2BK1, 25A2BK1, 25W1BK2, 25A1BK2, 25W2BK2, and 25A2BK2 (see *Synchronism-Check Logic Outputs on page R.2.53* and *Angle Checks and Synchronism-Check Element Outputs on page R.2.60*).

An example best demonstrates the synchronism-check capability in the SEL-421. This subsection presents a typical synchronism-check system.

Generalized System

The generalized system single-line drawing in *Figure 2.19* shows a partial circuit breaker-and-a-half or ring-bus substation arrangement. Presuming that both Circuit Breakers BK1 and BK2 are open, the system is split into three sections: Bus 1, Bus 2, and Line.

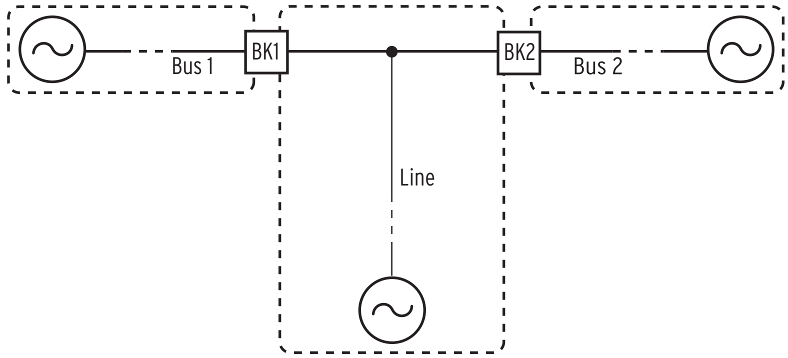


Figure 2.19 Partial Breaker-and-a-Half or Partial Ring-Bus Breaker Arrangement

Paralleled and Asynchronous Systems

Figure 2.19 shows remote sources for each section. Often, a portion of the power system is paralleled beyond the open Circuit Breakers BK1 and BK2; the remote sources are really the same aggregate source. If the aggregate source is much closer to one side of the open circuit breaker than the other, there is a noticeable voltage angle difference across the system (it is not simply zero degrees). The corresponding angular separation results from load flow and the impedance of the parallel system.

Here is a simple method to calculate the voltage angle across the circuit breaker if a load flow study is not readily available. Be aware that the angle resulting from load flow is typically larger than the angle calculated in *Equation 2.1* and shown in *Figure 2.20*.

Voltage Angle Difference Estimate

The propagation of the electric signal at nearly the speed of light causes a voltage angle to appear across the open circuit breaker. *Figure 2.20* illustrates the angle difference. Note that the aggregate source is near one end of the open circuit breaker, but is 80 kilometers away from the other end. The angle difference is calculated in *Equation 2.1*:

$$80\ \text{km} \bullet \frac{\text{s}}{300\text{x}10^{3}\text{km}} \bullet \frac{60\ \text{cyc}}{\text{s}} \bullet \frac{360°}{\text{cyc}} \approx 6°$$

Equation 2.1

Therefore, even though this system is paralleled beyond the open circuit breaker, a 6-degree voltage angle difference results across the circuit breaker (even with no load flow through the parallel path).

You must consider this angle difference when setting the synchronism-check element for a paralleled system. In this example, do not set the voltage angle difference setting to less than 15–20 degrees nominal. A paralleled system does not imply a zero degree voltage angle difference at every measuring point.

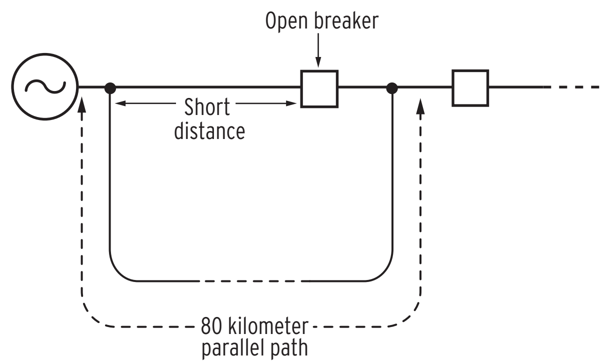


Figure 2.20 Voltage Angle Difference in a Paralleled System

Alternatively, if the remote sources in each section of the example system shown in *Figure 2.19* are not paralleled beyond the open circuit breakers, the systems are asynchronous. The corresponding phase voltages of two such systems are only in phase at infrequent times—when one of the systems slips by the other. At all other times, the corresponding phase voltages of two such systems are out of phase (sometimes as much as 180 degrees out of phase) as the systems continue to slip by each other.

Single-Phase Voltage Inputs

Figure 2.21 shows single-phase voltage transformers (1 PT) on Bus 1 and Bus 2. Use these single-phase voltage sources to perform a synchronism check across the two circuit breakers.

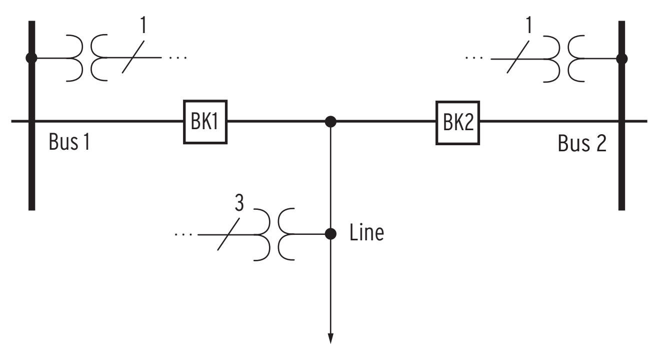


Figure 2.21 Synchronism-Check Voltages for Two Circuit Breakers

Synchronism check occurs on a single-phase voltage basis—see the single-phase potential transformers (1 PT) shown on each bus in *Figure 2.21*. The assumption is that, if the monitored single-phase voltage inputs are in phase (within a settable voltage angle difference) and are healthy (within a settable voltage magnitude window), the other phase-to-neutral voltages are likewise in phase and healthy. The line voltage source is three-phase, but you only need a single-phase bus voltage to perform a synchronism check across the corresponding circuit breaker. The relay uses the three-phase voltage from the line for other functions such as distance protection and metering.

Synchronism-Check Settings

This example uses a two-circuit breaker arrangement (see *Figure 2.21*). Set the synchronism-check enable settings:

E25BK1 := **Y** Synchronism Check for Circuit Breaker BK1 (Y, N)

E25BK2 := **Y** Synchronism Check for Circuit Breaker BK2 (Y, N)

If you are using the SEL-421 on a single circuit breaker, enable synchronism check for only one circuit breaker (E25BK1 := Y and E25BK2 := N).

Figure 2.22 shows the correspondence between the synchronism-check settings and the two-circuit breaker application example. All of these settings are listed in *Section 10: Settings*. The following subsections explain these settings and include an explanation of Alternative Synchronism-Check Voltage Source 2 settings (see *Figure 2.32*).

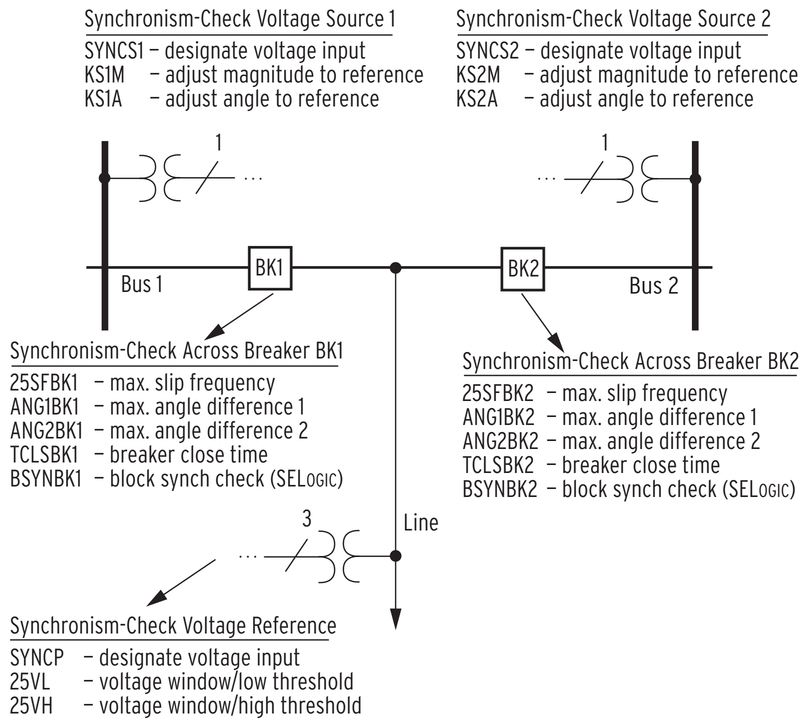


Figure 2.22 Synchronism-Check Settings

Synchronism-Check Logic Outputs

Figure 2.23 shows the correspondence between synchronism-check logic outputs (Relay Word bits) and the two-circuit breaker arrangement. These Relay Word bits assert to logical 1 (e.g., 59VP equals logical 1) if true and deassert to logical 0 (e.g., 59VS1 equals logical 0) if false. *Table 2.26* lists these Relay Word bits.

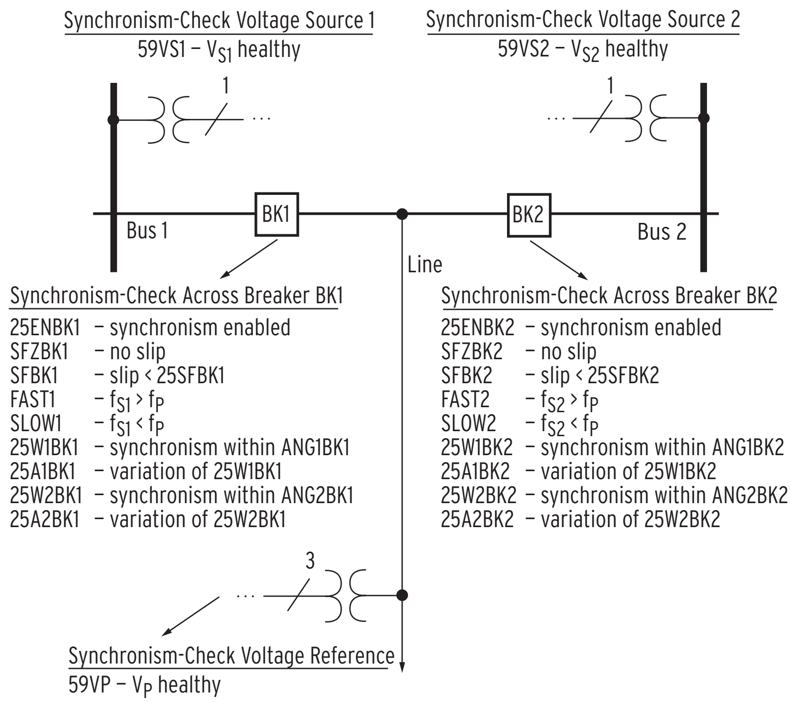


Figure 2.23 Synchronism-Check Relay Word Bits

Table 2.26 Synchronism-Check Relay Word Bits (Sheet 1 of 2)

Relay Word Bit	Description
59VP	V_P within healthy voltage window
59VS1	V_{S1} within healthy voltage window
25ENBK1	Circuit Breaker BK1 synchronism-check element enabled
SFZBK1	Circuit Breaker BK1 slip frequency less than 0.005 Hz ("no slip" condition)
SFBK1	0.005 Hz ≤ Circuit Breaker BK1 slip frequency < 25SFBK1
25W1BK1	Voltage angle across Circuit Breaker BK1 < ANG1BK1
25W2BK1	Voltage angle across Circuit Breaker BK1 < ANG2BK1
25A1BK1	Same operation as 25W1BK1, except for the restrictive operation (0° closure attempt) when setting 25SFBK1 ≠ OFF and the system is slipping (see *Figure 2.31*)
25A2BK1	Same operation as 25W2BK1, except for the restrictive operation (0° closure attempt) when setting 25SFBK1 ≠ OFF and the system is slipping (see *Figure 2.31*)
FAST1	Bus 1 frequency greater than line frequency ($f_{S1} > f_P$)
SLOW1	Bus 1 frequency less than line frequency ($f_{S1} < f_P$)
59VS2	V_{S2} within healthy voltage window
25ENBK2	Circuit Breaker BK2 synchronism-check element enabled
SFZBK2	Circuit Breaker BK2 slip frequency less than 0.005 Hz ("no slip" condition)
SFBK2	0.005 Hz ≤ Circuit Breaker BK2 slip frequency < 25SFBK2
25W1BK2	Voltage angle across Circuit Breaker BK2 < ANG1BK2
25W2BK2	Voltage angle across Circuit Breaker BK2 < ANG2BK2

Table 2.26 Synchronism-Check Relay Word Bits (Sheet 2 of 2)

Relay Word Bit	Description
25A1BK2	Same operation as 25W1BK2, except for the restrictive operation (0° closure attempt) when setting 25SFBK2 ≠ OFF and the system is slipping (see *Figure 2.31*)
25A2BK2	Same operation as 25W2BK2, except for the restrictive operation (0° closure attempt) when setting 25SFBK2 ≠ OFF and the system is slipping (see *Figure 2.31*)
FAST2	Bus 2 frequency greater than line frequency ($f_{S2} > f_P$)
SLOW2	Bus 2 frequency less than line frequency ($f_{S2} < f_P$)

Supervising Circuit Breaker Closing via Synchronism Check

Use the synchronism-check element outputs to control circuit breaker closing. Some examples follow (the ellipsis indicates other elements that you can add to these SELOGIC control equations):

Supervising Auto-Reclosing of Circuit Breaker BK1

3P1CLS := **25A1BK1 OR ...** Three-Pole BK1 Reclose Supervision (SELOGIC Equation)

Manual Closing of Circuit Breaker BK1

BK1MCL := **25W2BK1 OR ...** Circuit Breaker BK1 Manual Close (SELOGIC Equation)

PT Connections

Figure 2.24 is an example of connecting PTs to the SEL-421 for two circuit breakers. The Bus 1 and Bus 2 single-phase voltages are connected to relay voltage inputs VAZ and VBZ, respectively. They could just as easily have been connected to any of the other voltage inputs. The voltage connected to voltage input VAZ (setting SYNCS1 := VAZ; see *Figure 2.24*) is not necessarily from A-phase on Bus 1. Likewise, the voltage connected to voltage input VBZ (setting SYNCS2 := VBZ; see *Figure 2.24*) is not necessarily from B-phase on Bus 2. The connection can be from any phase-to-neutral or phase-to-phase voltage (as long as you do not exceed the relay voltage input ratings). Settings in the SEL-421 compensate for any steady-state magnitude or angle difference with respect to a synchronism-check voltage reference, as discussed next in this example.

Three-phase line voltages are connected to relay voltage inputs VAY, VBY, and VCY (these voltage inputs are also used for distance elements fault location, loss-of-potential, load encroachment, and directionality). Only one of these single-phase voltage inputs is designated for use in synchronism check. In this example, this voltage input is also designated the synchronism-check voltage reference (setting SYNCP := VAY; see *Figure 2.24*). As the synchronism-check voltage reference, the relay makes all steady-state magnitude and angle adjustments for the Bus 1 and Bus 2 synchronism check voltages (connected to voltage inputs FAZ and FBZ, respectively, as discussed in the preceding paragraph) with respect to this designated reference line voltage, VAY, as discussed later in this example.

For a single-circuit breaker application, you can use either bus-side potentials or line-side potentials for line relaying; connect the three-phase voltage source to potential inputs VAY, VBY, and VCY. If a single-phase voltage source is available on the other side of the circuit breaker for synchronism check, connect the source to potential input VAZ, VBZ, or VCZ.

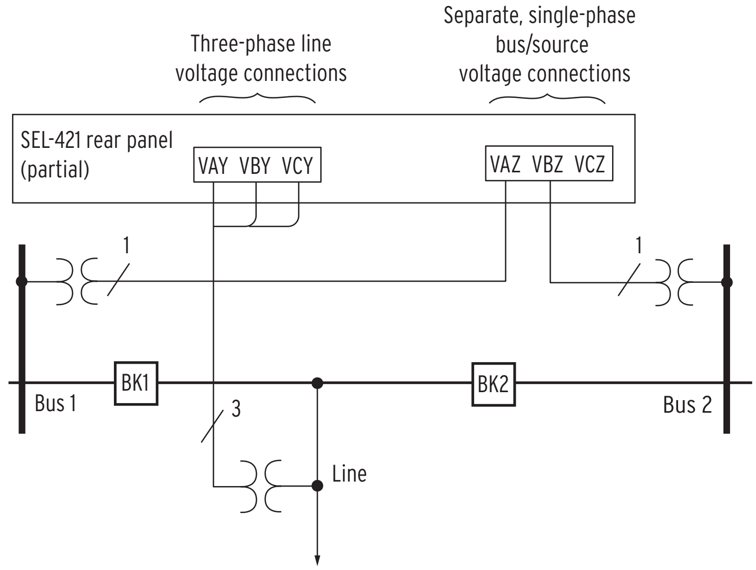


Figure 2.24 Example Synchronism-Check Voltage Connections to the SEL-421

Voltage Magnitude and Angle Compensation

The *Figure 2.24* example continues in *Figure 2.25*. The *Figure 2.25* example demonstrates possible voltage input connections (presuming ABC phase rotation). The synchronism-check voltage reference (V_P) is from the A-phase voltage (V_A) of the line. You can connect phase-to-phase voltage V_{BC} originating from Bus 1, and connect phase-to-neutral voltage V_C from Bus 2. Thus, Bus 1 voltage V_{BC} lags synchronism-check voltage reference V_P by 90 degrees, and Bus 2 voltage V_C lags the synchronism-check voltage reference V_P by 240 degrees. To compensate for these steady-state angle differences, set KS1A for Bus 1 and KS2A for Bus 2.

KS1A := **90** Synchronism Source 1 Angle Shift (0, 30, …, 330 degrees)

KS2A := **240** Synchronism Source 2 Angle Shift (0, 30, …, 330 degrees)

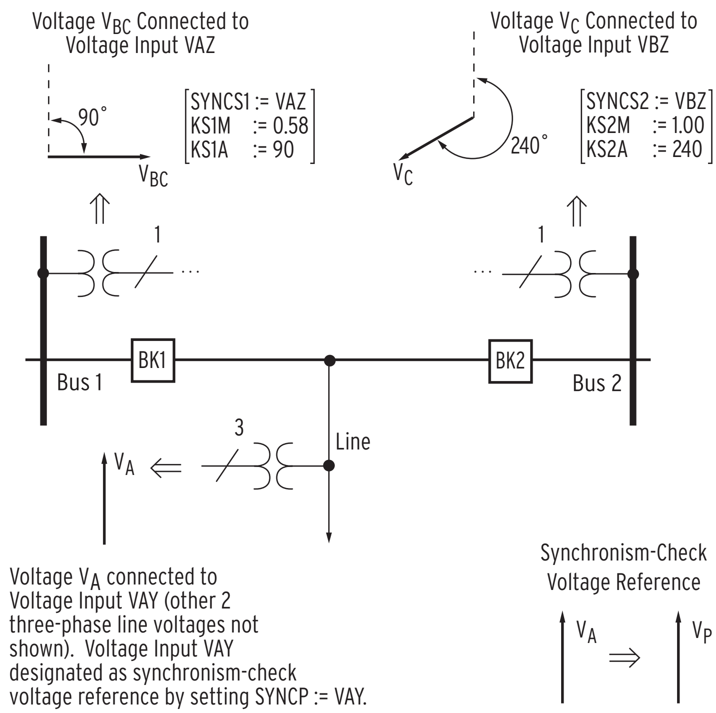


Figure 2.25 Synchronism-Check Voltage Reference

For a given secondary base voltage, phase-to-phase voltages are a factor of 1.73 ($\sqrt{3}$) times the magnitude of the phase-to-neutral voltages. In reverse, phase-to-neutral voltages are a factor of 0.58 ($1/\sqrt{3}$) times the magnitude of the phase-to-phase voltages. Therefore, you must compensate the Bus 1 voltage V_{BC} magnitude with setting KS1M to reference it to the synchronism-check voltage reference V_P magnitude.

KS1M := **0.58** Synchronism Source 1 Ratio Factor (0.10–3)

You do not need special magnitude compensation for the Bus 2 voltage V_C to reference Synchronism Source 2 to the synchronism-check voltage reference V_P magnitude; these are both phase-to-neutral voltages with the same nominal rating (for example, 67 V secondary).

KS2M := **1.00** Synchronism Source 1 Ratio Factor (0.10–3)

As another example of synchronism-source magnitude adjustment flexibility, suppose Bus 1 voltage V_{BC} is 201 V secondary (phase-to-phase), and the synchronism-check voltage reference V_P is 67 V secondary (phase-to-neutral). Then, the magnitude compensation setting would be as in *Equation 2.2*.

$$\text{KS1M} = \frac{67\text{ V}}{201\text{ V}} := 0.33 \qquad \textbf{Equation 2.2}$$

Normalized Synchronism-Check Voltage Sources V_{S1} and V_{S2}

The *Figure 2.25* example continues in *Figure 2.26*, which graphically illustrates how the introduced settings adjust the Bus 1 and Bus 2 synchronism-check input voltages in angle and magnitude to reference to the synchronism-check voltage reference V_P. The resultant Bus 1 and Bus 2 voltages are the normalized synchronism-check voltage sources V_{S1} and V_{S2}, respectively.

Voltages V_P, V_{S1}, and V_{S2} are used in the logic in the balance of this section to check for healthy voltage and determine voltage phase angle for synchronism-check element operation.

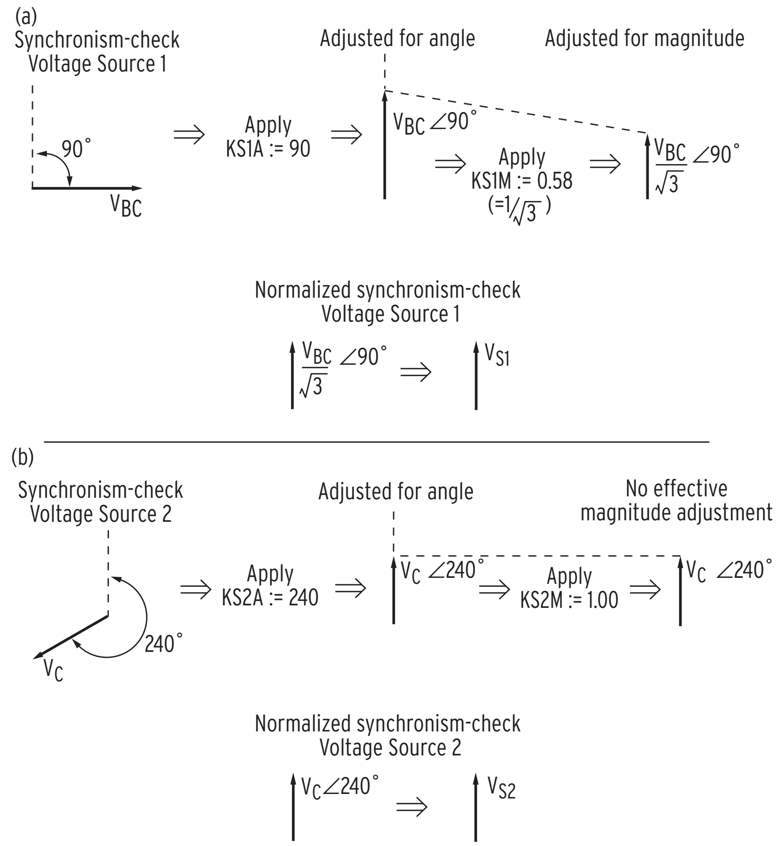


Figure 2.26 Normalized Synchronism-Check Voltage Sources VS1 and VS2

Voltage Checks and Blocking Logic

Two conditions can cause the synchronism-check function in the SEL-421 to abort. These conditions are out-of-range synchronism-check input voltages and block synchronism check configurations that you specify in SELOGIC control equations.

Voltage Magnitude Checks

For synchronism check to proceed for a given circuit breaker (BK1 or BK2), the voltage magnitudes of the synchronism-check voltage reference V_P and the corresponding normalized synchronism-check voltage source on the other side of the circuit breaker (normalized voltage V_{S1} for Circuit Breaker BK1 and normalized voltage V_{S2} for Circuit Breaker BK2) must lie within a healthy voltage window, bounded by voltage threshold settings 25VH and 25VL (see *Figure 2.27*).

The relay asserts Relay Word bits 59VP, 59VS1, and 59VS2 to indicate healthy synchronism-check voltages V_P, V_{S1}, and V_{S2}, respectively (see *Figure 2.27*). If either of the voltage pairs (V_P and V_{S1} or V_P and V_{S2}) does not meet this healthy voltage criterion, synchronism check cannot proceed for the circuit breaker associated with the corresponding voltage pair.

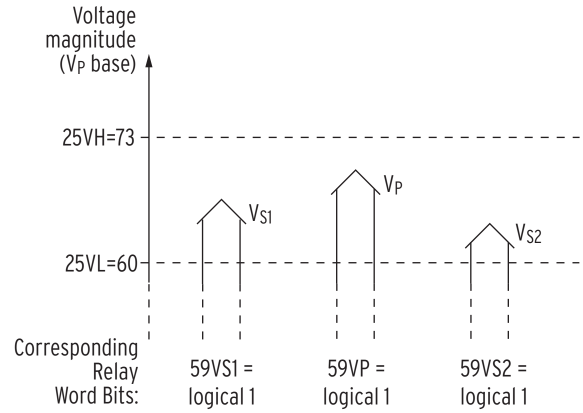


Figure 2.27 Healthy Voltage Window and Indication

Block Synchronism Check

If the block synchronism check BSYNBK*n* SELOGIC control equation (where *n* = 1 or 2 for Circuit Breaker BK1 or Circuit Breaker BK2, respectively) asserts, synchronism check cannot proceed for the corresponding circuit breaker. Following is an example for Circuit Breaker BK1:

BSYNBK1 := **52AA1 AND 52AB1 AND 52AC1** Block Synchronism Check—BK1 (SELOGIC Equation)

If Circuit Breaker BK1 is closed, the three-pole indication back to the relay shows 52AA1 equals 52AB1 equals 52AC1 equals logical 1. Thus, BSYNBK1 equals logical 1, and synchronism check is blocked for Circuit Breaker BK1. There is no need to qualify or continue with the synchronism check for circuit breaker closing; the circuit breaker is already closed.

Synchronism-Check Enable Logic

The relay combines the voltage check elements and block synchronism check condition to create a synchronism-check enable condition for each circuit breaker, as shown in *Figure 2.28*.

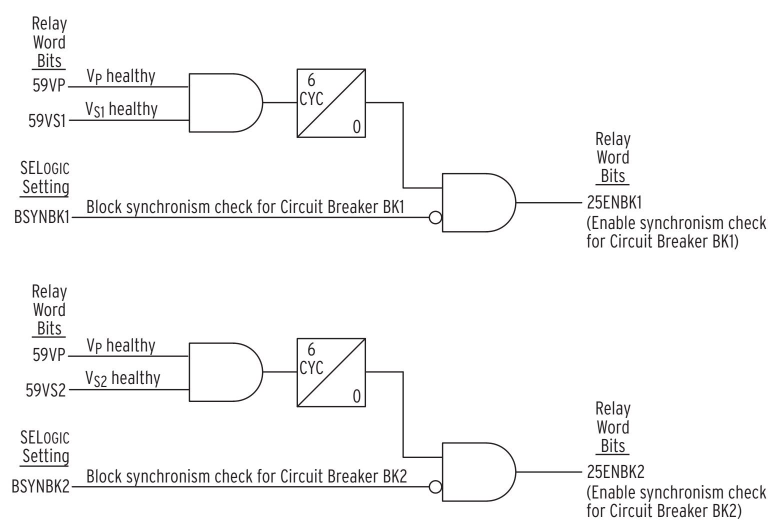


Figure 2.28 Synchronism-Check Enable Logic

Angle Checks and Synchronism-Check Element Outputs

After the relay determines that voltage magnitudes are healthy and determines that no block synchronism check conditions exist, the relay must check voltage phase angles across the circuit breakers before a final synchronism-check element output can be available for supervising circuit breaker closing.

The following discussion/examples use Circuit Breaker BK1. Synchronism-check element output operation for Circuit Breaker BK2 is similar (replace BK2 for BK1 in associated settings and Relay Word bits).

Angle Difference Settings ANG1BK1 and ANG2BK1

Each circuit breaker has two angle difference windows. For Circuit Breaker BK1, the maximum angle difference settings are ANG1BK1 and ANG2BK1.

Often, a greater phase angle across the circuit breaker is tolerated for a manual close. Typically, you set angle setting ANG1BK1 for synchronism check in auto-reclosing Circuit Breaker BK1 (e.g., ANG1BK1 := 20 degrees), and you set angle setting ANG2BK1 for synchronism check when manually closing Circuit Breaker BK1 (e.g., ANG2BK1 := 35 degrees).

Synchronism-Check Element Outputs 25W1BK1 and 25A1BK1

Angle difference setting ANG1BK1 affects synchronism-check element outputs 25W1BK1 and 25A1BK1. *Figure 2.29*, *Figure 2.30*, and *Figure 2.31* illustrate the operation of synchronism-check element outputs 25W1BK1 and 25A1BK1.

These outputs operate for a voltage phase angle within and without the angle difference setting ANG1BK1 for the following three conditions:

- no slip
- slip—no compensation
- slip—with compensation

The operational differences between synchronism-check element outputs 25W1BK1 and 25A1BK1 are apparent in the “slip—with compensation” example (*Figure 2.31*).

The second angle difference setting (ANG2BK1) for Circuit Breaker BK1 operates similarly to affect synchronism-check element outputs 25W2BK1 and 25A2BK1.

“No Slip” Synchronism Check

Refer to the paralleled system beyond the open circuit breaker in *Figure 2.20*. For such a system, there is essentially no slip across the open circuit breaker (the monitored voltage phasors on each side are not moving with respect to one another). In a “no slip” system, any voltage angle difference across the open circuit breaker remains relatively constant.

The four drawings shown in *Figure 2.29* are separate, independent cases for a “no slip” paralleled system. If the phase angle between the synchronism-check voltage reference V_P and the normalized synchronism-check voltage source V_{S1} is less than angle setting ANG1BK1, synchronism-check element outputs 25W1BK1 and 25A1BK1 both assert to logical 1. The relay declares that the per-phase voltages across Circuit Breaker BK1 are in synchronism. Otherwise, if the phase angle is greater than or equal to angle setting ANG1BK1, element outputs 25W1BK1 and 25A1BK1 both deassert to logical 0; the relay declares that the per-phase voltages across Circuit Breaker BK1 are out-of-synchronism.

The out-of-synchronism phase angles in *Figure 2.29* appear dramatic for a "no slip" paralleled system. This is for illustrative purposes; these angles are not usually this large in actual systems.

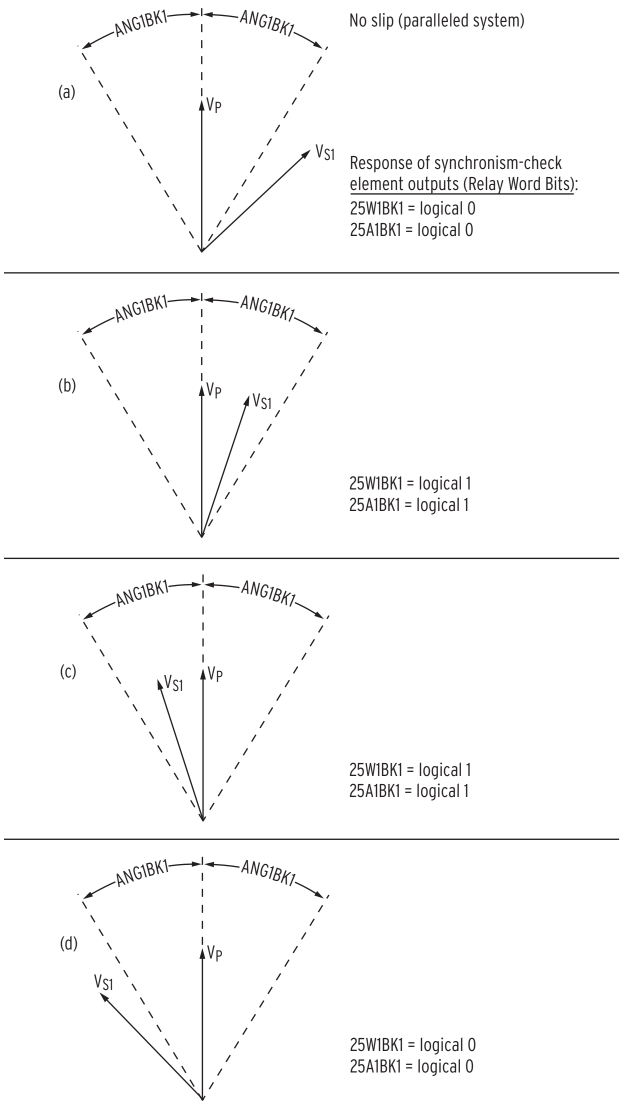


Figure 2.29 "No Slip" System Synchronism-Check Element Output Response

Slip Frequency and SFZBK1

Relay Word bit SFZBK1 (BK1 Slip Frequency less than 0.005 Hz) also asserts to logical 1, indicating a "no slip" condition across Circuit Breaker BK1. In other words, the slip frequency is less than 0.005 Hz ($|f_{S1}-f_P| < 0.005$ Hz).

Synchronism-Check Element Output Effects

Note that element outputs 25W1BK1 and 25A1BK1 operate identically in all of the "no slip" cases in *Figure 2.29* (both assert to logical 1 or deassert to logical 0).

"Slip—No Compensation" Synchronism Check

The four cases [(a), (b), (c), and (d)] shown in *Figure 2.30* are "slip—no compensation" cases for asynchronous systems (not paralleled). The cases progress in time from top to bottom. The normalized synchronism-check voltage source V_{S1} slips with respect to synchronism-check voltage reference V_P. The indication of the rotation arrow on phasor V_{S1} (and the time progression down the page) shows that the system corresponding to V_{S1} has a higher system frequency f_{S1} than the system corresponding to reference V_P with system frequency f_P. The slip frequency across Circuit Breaker BK1 is $f_{S1}–f_P$.

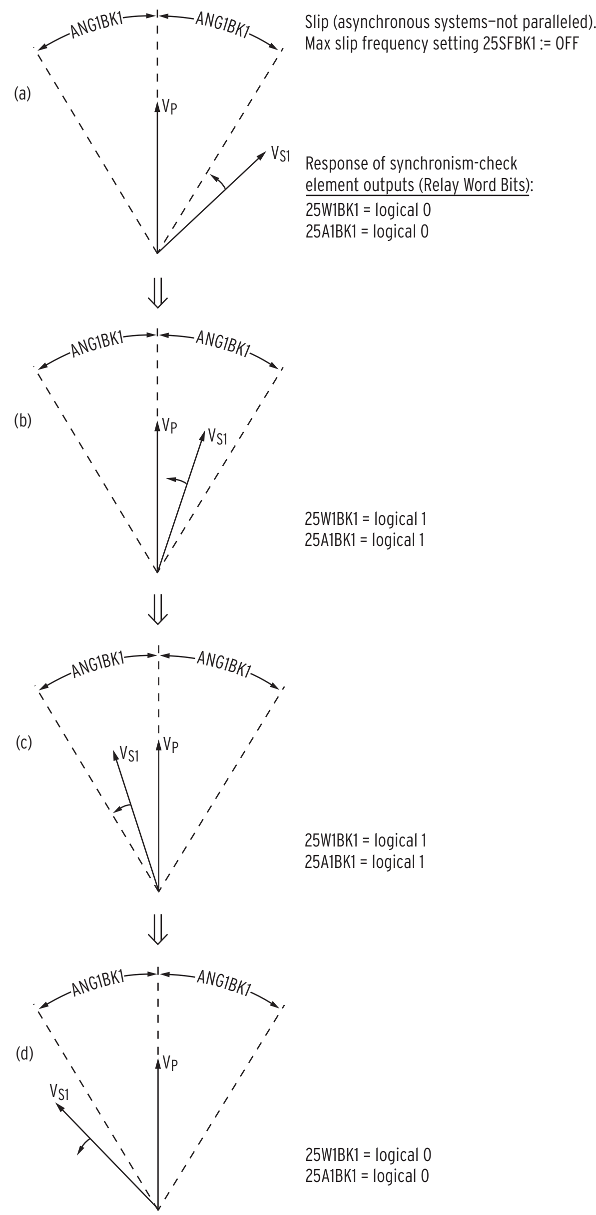


Figure 2.30 "Slip—No Compensation" Synchronism-Check Element Output Response

Positive Slip Frequency

If the slip frequency is positive, V_{S1} is slipping ahead of reference V_P (the system corresponding to V_{S1} has a higher system frequency than the system corresponding to V_P; $f_{S1} > f_P$). Positive slip frequency is the counter-clockwise rotation of V_{S1} with respect to reference V_P, as shown in *Figure 2.30*. Relay Word bit FAST1 asserts to logical 1 (and Relay Word bit SLOW1 deasserts to logical 0) to indicate this condition.

Negative Slip Frequency

If the slip frequency is negative, V_{S1} is slipping behind reference V_P (the system corresponding to V_{S1} has a lower system frequency than the system corresponding to V_P; $f_{S1} < f_P$). For such a case, V_{S1} rotates clockwise with respect to reference V_P. Relay Word bit SLOW1 asserts to logical 1 (and Relay Word bit FAST1 deasserts to logical 0) to indicate this condition.

"No-Slip" Condition

If the absolute value of the slip is less than 0.005 Hz ($|f_{S1}–f_P| < 0.005$ Hz; a "no-slip" condition), both Relay Word bits FAST1 and SLOW1 deassert to logical 0 and Relay Word bit SFZBK1 asserts to logical 1. A "no-slip" condition is confirmed when FAST1 and SLOW1 are deasserted, and SFZBK1 is asserted.

Synchronism-Check Element Output Effects

Compare the corresponding "slip—no compensation" cases in *Figure 2.30* to the previous "no-slip" cases in *Figure 2.29*. Note that synchronism-check element outputs 25W1BK1 and 25A1BK1 operate identically in all cases of the "slip—no compensation" examples in *Figure 2.30* (both assert to logical 1 or deassert to logical 0). The condition of "no slip" or "slip—no compensation" does not affect the operation of element outputs 25W1BK1 and 25A1BK1 in the scenarios depicted in *Figure 2.29* and *Figure 2.30*.

The similarity of element outputs 25W1BK1 and 25A1BK1 for the "no slip" condition (*Figure 2.29*) and the "slip—no compensation" (*Figure 2.30*) condition results from the maximum slip frequency setting 25SFBK1 := OFF. Setting 25SFBK1 has no effect in a "no slip" scenario (*Figure 2.29*), but the setting does affect the operation of synchronism-check element output 25A1BK1 (see the "slip—no compensation" scenario, *Figure 2.30*).

With setting 25SFBK1 := OFF, the relay does not compensate for the further angular travel of V_{S1} (with respect to reference V_P) during the Circuit Breaker BK1 close time setting TCLSBK1. The relay measures the phase angle directly with no compensation between reference V_P and V_{S1} for synchronism-check element output 25A1BK1.

The relay always measures the phase angle directly (without compensation) between reference V_P and V_{S1} for element output 25W1BK1. Setting 25SFBK1, time setting TCLSBK1, and whether system conditions are "no slip" (*Figure 2.29*) (see the "slip—no compensation" in *Figure 2.30*) have no effect on element output 25W1BK1.

"Slip—With Compensation" Synchronism Check

Figure 2.31 is derived from *Figure 2.30*, but with the maximum slip frequency setting 25SFBK1 set to some value other than OFF; thus the SEL-421 compensates for circuit breaker closing time with setting TCLSBK1. This results in a compensated normalized synchronism-check voltage source V'_{S1}

Synchronism-check element output 25W1BK1 in *Figure 2.31* operates the same as in *Figure 2.30*. Element output 25W1BK1 is unaffected by relay settings 25SFBK1 and TCLSBK1, and by whether system conditions are slipping. Element 25W1BK1 follows normalized synchronism-check voltage source V_{S1}.

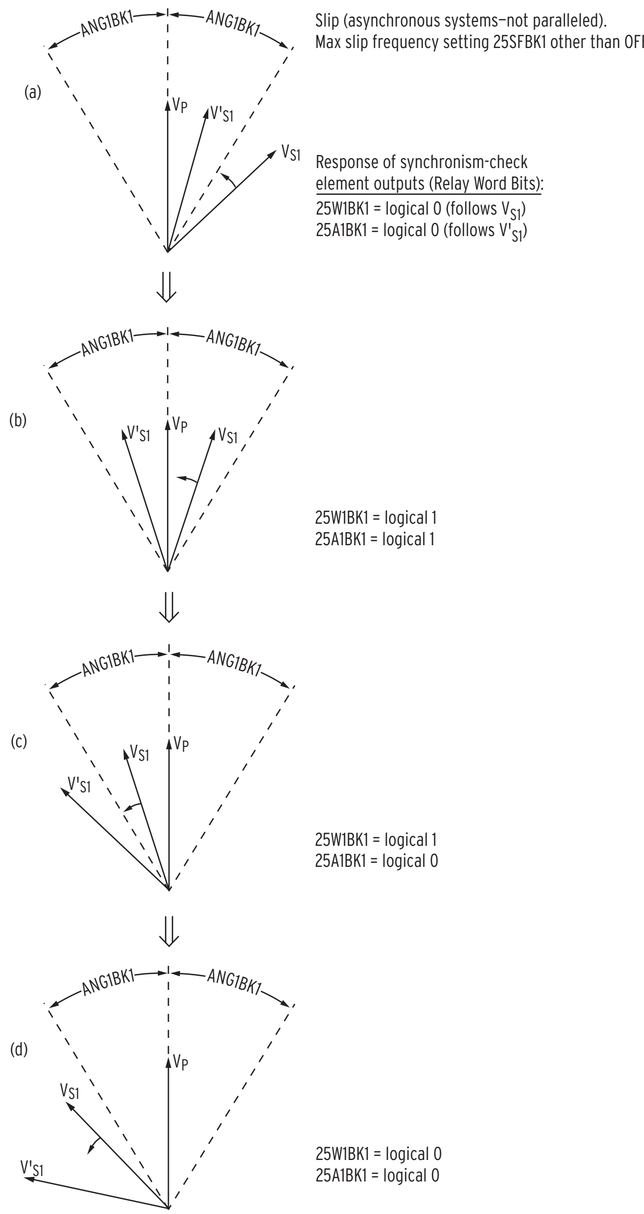


Figure 2.31 "Slip—With Compensation" Synchronism-Check Element Output Response

Element 25A1BK1 follows V'_{S1}. With setting 25SFBK1 (maximum slip frequency) set to other than OFF, the relay calculates V'_{S1} derived from V_{S1}. Phasor V'_{S1} leads V_{S1} by an angle described by *Equation 2.3*:

$$\text{angle} = \frac{(f_{S1} - f_P)\ \text{slip cycle}}{s \bullet \dfrac{60\ \text{cyc}}{s}} \bullet \frac{360^\circ}{\text{slip cycle}} \bullet \text{TCLSBK1 (cyc)}$$

Equation 2.3

From *Equation 2.3* note that the angle between V_{S1} and V'_{S1} increases for a greater slip between V_{S1} and V_P (f_{S1}–f_P), a greater Circuit Breaker BK1 close time setting TCLSBK1, or both in combination.

For any case [(a), (b), (c), or (d)] in *Figure 2.31*, the location of V'_{S1} is the location of V_{S1} a period later (this period is setting TCLSBK1, Circuit Breaker BK1 Close Time). Consider, for example, issuing a close command to Circuit Breaker BK1. If case (b) in *Figure 2.31* represents the time at which the close command occurs, then V_{S1} is the normalized synchronism-check voltage source position at the instant the close is issued and V'_{S1} is the position of V_{S1} when Circuit Breaker BK1 actually closes.

Slip Frequency

If the slip frequency exceeds setting 25SFBK1, synchronism check cannot proceed via element output 25A1BK1. Synchronism check stops because element output 25A1BK1 deasserts to logical 0 for an out-of-range slip frequency condition, regardless of other synchronism-check conditions such as healthy voltage magnitudes.

Synchronism check remains possible (although not necessarily advantageous) if you use element output 25W1BK1 and the slip frequency exceeds setting 25SFBK1. Synchronism-check element 25W1BK1 does not measure slip. In this instance, synchronism check occurs (25W1BK1 is logical 1) when the phase angle difference between reference V_P and V_{S1} is less than angle setting ANG1BK1.

Synchronism-Check Element Output Effects

A contradiction seems to result from analysis of case (a) in *Figure 2.31*; it appears that element output 25A1BK1 should assert to logical 1 because V'_{S1} is within angle setting ANG1BK1. Note in this case, however, that V'_{S1} is approaching synchronism-check reference V_P. This is where element output 25A1BK1 behaves differently than element output 25W1BK1, for setting 25SFBK1 set to some value other than OFF. As V'_{S1} approaches V_P, 25A1BK1 remains deasserted (equals logical 0) until the phase angle difference between reference V_P and V'_{S1} equals zero degrees.

At this zero degrees difference between V_P and V'_{S1} point, element output 25A1BK1 asserts to logical 1. We know the systems will truly be in synchronism (0 degrees between reference V_P and V_{S1}) a period later (this period is setting TCLSBK1, Circuit Breaker BK1 Close Time). Thus, if a close command occurs right at the instant that element output 25A1BK1 asserts to logical 1, then there will be a zero degree phase angle difference across Circuit Breaker BK1 when Circuit Breaker BK1 actually closes. Closing Circuit Breaker BK1 at a phase angle difference of 0 degrees between reference V_P and V'_{S1} minimizes system shock when you bring two asynchronous systems together.

Element output 25A1BK1 remains asserted to logical 1 as V'_{S1} moves away from reference V_P. When the phase angle difference between reference V_P and V'_{S1} is again greater than angle setting ANG1BK1, element output 25A1BK1 deasserts to logical 0.

Alternative Synchronism-Check Source 2 Settings

You can program alternative input sources for the synchronism-check function in the SEL-421. Alternative inputs give you additional flexibility to synchronize other portions of your power system.

The SELOGIC control equation ALTS2 determines when the relay uses alternate Synchronism-Check Voltage Source 2 in place of regular Synchronism-Check Voltage Source 2. When ALTS2 is logical 1, the relay substitutes alternative Synchronism-Check Voltage Source 2 (ASYNCS2) and corresponding settings AKS2M and AKS2A for the regular Synchronism-Check Voltage Source 2 values SYNCS2, KS2M, and KS2A. The result is a normalized synchronism-check voltage source V_{S2} derived from the alternative source.

EXAMPLE 2.2 Setting Alternative Synchronism-Check Source 2

Figure 2.32 shows an extra circuit breaker (BK3) and a generator position added to the existing example system of Figure 2.21. You can monitor the voltage at the generator position by connecting a single-phase voltage to remaining voltage input VCZ (see Figure 2.24). Make setting ASYNCS2 := VCZ to designate this relay voltage input as the alternate synchronism-check voltage source.

ASYNCS2 := **VCZ** Alternative Synchronism Source 2 (VAY, VBY, VCY, VAZ, VBZ, VCZ)

For this new synchronism source voltage connection, adjust the source-to-reference magnitude ratio with setting AKS2M and the source-to-reference angle compensation with setting AKS2A, considering the settings for Voltage Magnitude and Angle Compensation on page R.2.56.

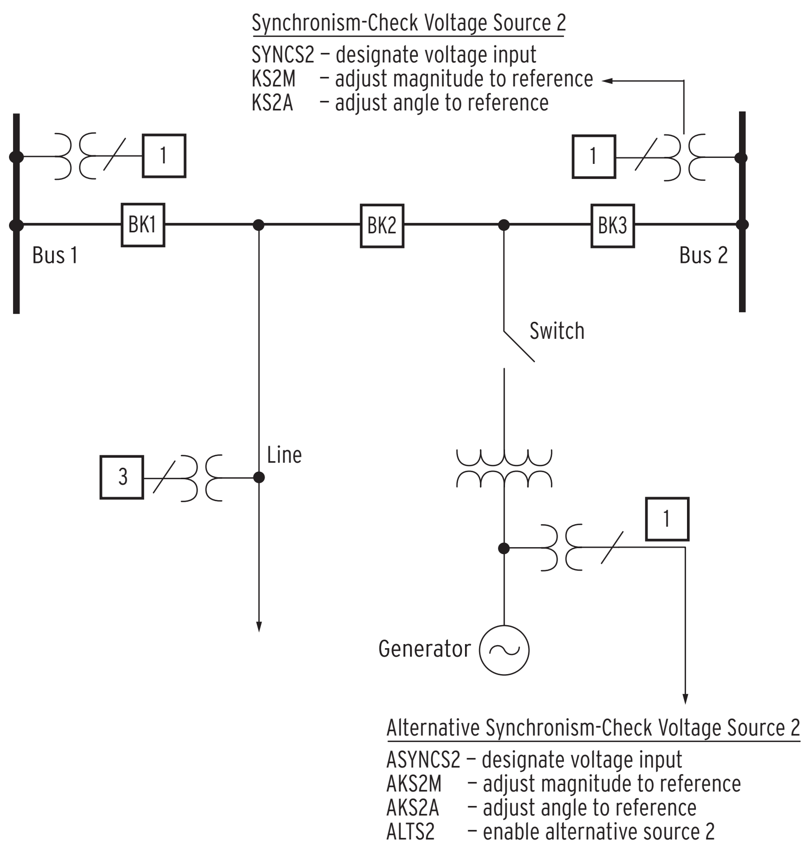


Figure 2.32 Alternative Synchronism-Check Source 2 Example and Settings

For example, in Figure 2.32, the Bus 2 voltage is the regular Synchronism-Check Voltage Source 2 for synchronism check across Circuit Breaker BK2. However, if Circuit Breaker BK3 is open and the generator switch is closed, the Synchronism-Check Voltage Source 2 transfers to the alternative Synchronism-Check Voltage Source 2 the voltage from the generator position.

For circuit breaker status, make the following 52A auxiliary contact connections from the circuit breaker and switch to control inputs on the SEL-421:

- Circuit breaker BK3 to IN103
- Generator switch to IN104

These input connections are for this application example only; use relay inputs that are appropriate for your system.

Set the ALTS2 SELOGIC control equation to assert when Circuit Breaker BK3 is open and the generator switch is closed.

ALTS2 := **NOT IN103 AND IN104** Alternative Synchronism Source 2 (SELOGIC Equation)

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Section 3

SELOGIC Control Equation Programming

This section describes use of SELOGIC® control equation programming to customize relay operation and automate substations. This section covers the following topics:

SELOGIC Control Equation History

SEL introduced SELOGIC control equations in the SEL-300 series relays to provide relay operation customization. SELOGIC control equations in the SEL-421 Relay provide both protection application flexibility and a platform for substation automation.

SELOGIC control equation programming in the SEL-421 includes several features and capabilities not included in SEL-300 series relays. The new features with a brief description are listed in *Table 3.1*.

Table 3.1 Advanced SEL-421 SELOGIC Control Equation Features (Sheet 1 of 2)

Feature	Description
Protection/automation separation	Segregation of protection and automation work and settings
Free-form logic	Custom logic operation and execution order
Comments	Documentation of SELOGIC control equations within the equation
Math operations	Calculations for automation or extended protection functions
Sequencing timers	Additional timers designed for sequencing automated operations

Table 3.1 Advanced SEL-421 SELOGIC Control Equation Features (Sheet 2 of 2)

Feature	Description
Counters	Increased sophistication in custom protection and automation programming
Aliases	Custom programming is more readable when you rename as many as 200 analog or digital quantities

Use SELOGIC control equations in the SEL-421 to customize protection operation, create custom protection elements, and automate substation operation. The SEL-421 introduces several advanced programming features, operators, and methods. *Table 3.2* is a summary that compares SELOGIC control equation programming in SEL-351 series relays and SEL-311 series relays with the SEL-421.

Table 3.2 SEL-421 SELOGIC Control Equation Programming Summary

Element	SEL-351 Series/ SEL-311 Series	SEL-421	
		Protection Free Form	Automation Free Form
SELOGIC control equation variables	16	64	256
SELOGIC math variables	0	64	256
Conditioning timers[a]	16	32	0
Sequencing timers	0	32	32
Counters	0	32	32
Latch bits	16	32	32

[a] Similar to SEL-300 series relay SELOGIC control equation programming.

Separation of Protection and Automation Areas

The SEL-421 acts as a protective relay and as a smart node 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.

The SEL-421 contains several separate programming areas discussed in *SELOGIC Control Equation Setting Structure on page R.3.6*. 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 free-form SELOGIC control equation programming and Access Level A to access automation programming.

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 3.1*.

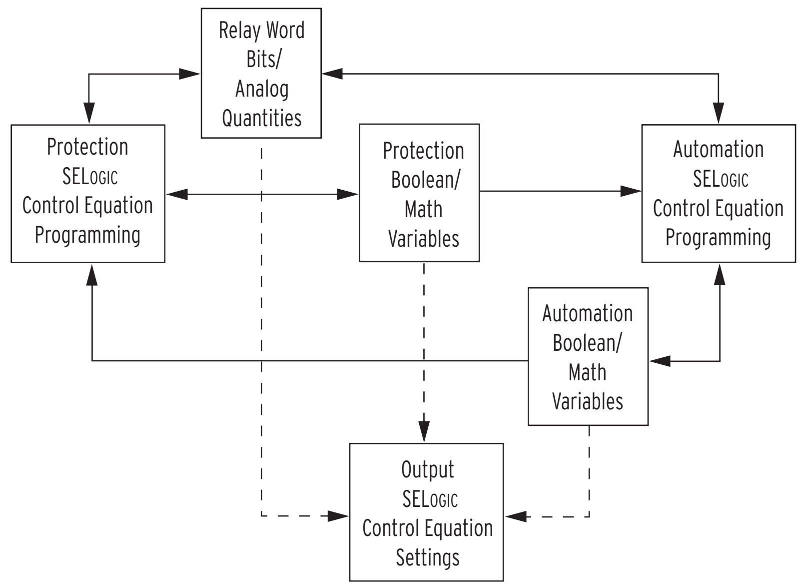

Figure 3.1 Protection and Automation Separation

Figure 3.1 illustrates how the SEL-421 keeps 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 Programming

There are two major areas where the SEL-421 uses 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 free-form SELOGIC control equations for free-form 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.

SEL-421 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 3.1*.

EXAMPLE 3.1 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 free-form area controls OUT101. The result of the free-form 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.

Free-Form SELOGIC Control Equations

Free-form SELOGIC control equations provide advanced relay customization and automation programming. There are free-form SELOGIC control equation programming areas used for protection and automation. You can use free-form 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 free-form SELOGIC control equation programming areas. An example of free-form SELOGIC control equation programming is shown in *Example 3.2*.

EXAMPLE 3.2 Free-Form SELOGIC Control Equations

The following equations are examples of free-form 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.

Free-form 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 free-form 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 free-form 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 SEL-421 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 free-form programming, enter AMV034 := 5 * BK1IAFM to store the product of 5 and the Circuit Breaker 1 A-phase current in automation math variable 34. *Example 3.3* lists several examples of Boolean and math SELOGIC control equations.

EXAMPLE 3.3 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. You can start a comment anywhere in a SELOGIC control equation with the # character. The comment then continues to the end of the line. If you begin a SELOGIC control equation with a 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 in the SEL-421. You can use comments liberally; comments do not reduce SELOGIC control equation execution capacity.

SELOGIC Control Equation Setting Structure

The SEL-421 uses SELOGIC control equations in three major areas. First, you can customize protection operations with SELOGIC control equation settings and free-form programming. Second, there is a free-form 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 3.2*. 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: The SEL-421-1 and the SEL-421-2 have only one 100-line automation programming block.

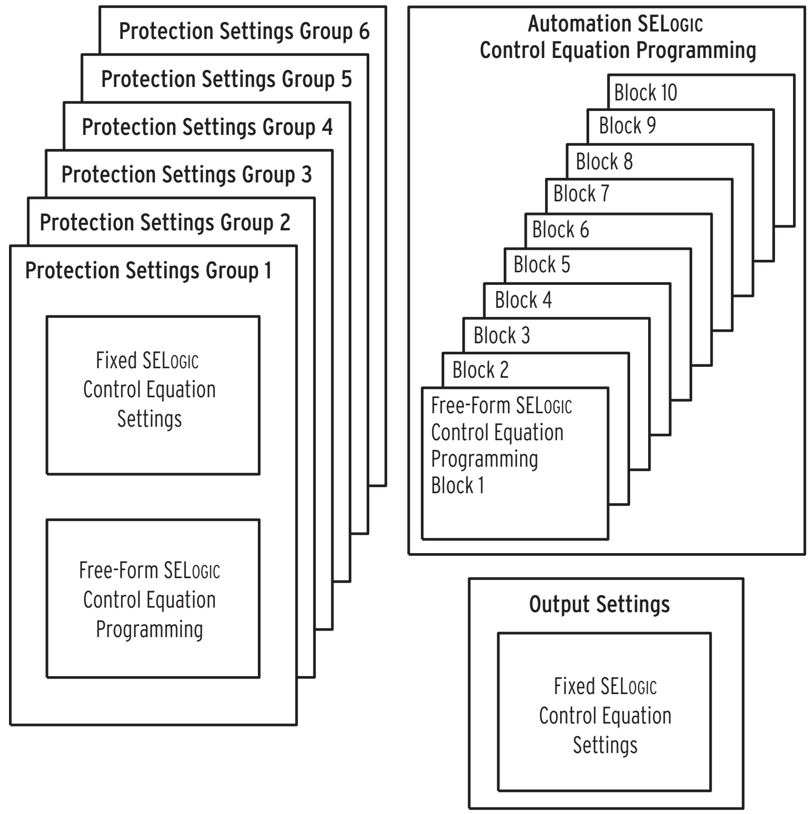

Figure 3.2 SELOGIC Control Equation Programming Areas

Protection

Protection SELOGIC control equation programming includes a fixed area and a free-form 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 free-form 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 free-form 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 R.3.8* 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 using the **COPY** command documented in *Section 9: ASCII Command Reference*. 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 free-form and fixed programming to extend and customize protection operation.

Automation

Automation SELOGIC control equation programming is a large free-form programming area that consists of 10 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.

The SEL-421 dedicates a minimum processing time when executing automation SELOGIC control equations. If the processing load is light, the relay uses more processing time for executing 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 free-form 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 free-form 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 free-form SELOGIC control equations and set TR to the protection SELOGIC control equation variable that contains the result.

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 communications card control points. The relay executes output logic and processes outputs at the protection processing interval.

Multiple Setting Groups

The SEL-421 has six (6) independent setting groups, as shown in the left-hand side of *Figure 3.2*. Each setting group has complete relay settings (distance, directional, overcurrent, reclosing, etc.—see *SHO on page R.9.44*) and protection SELOGIC settings (see *SHO L on page R.9.46*). The active setting group can be:

➤ Shown or selected with the SEL ASCII serial port **GROUP** command—see *GROUP on page R.9.22*.

➤ Shown or selected with the `MAIN` menu `Set/Show` menu item and the `Active Group` submenu item as described in *Figure 5.34 on page U.5.31*.

- 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, and Fast SER Messages on page R.5.8*.
- Shown with DNP3 Objects 20 and 22 as described in *Table 6.10* 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

NOTE: The SEL-421-1 and the SEL-421-2 have only one 100-line automation programming block.

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 3.3*.

Table 3.3 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

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 one cycle.

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 3.4*.

Table 3.4 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

The SEL-421 is disabled for less than 1 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 LB32), remote bit (RB01 through RB32), 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 5.4*

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.

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

The SEL-421 provides storage space for as many as 250 lines of protection free-form programming. Because the relay executes protection fixed and free-form 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.

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 that can be active. When a protection settings group is active, the relay executes SELOGIC control equations in the Global Settings, Protection Group Settings, Protection Free-Form 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 free-form logic.

Automation

The SEL-421 provides storage space for 10 blocks of as many as 100 lines of automation free-form programming each. The relay executes automation programming differently than protection logic programming. The result is that automation free-form logic execution time varies with the amount of free-form logic expressions that you enter. As you enter more expressions, the time required for the relay to execute all expressions increases. You can display the peak and average execution time using the **STATUS S** command.

NOTE: The SEL-421-1 and the SEL-421-2 have only one 100-line automation programming block.

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 Elements

SELOGIC control equation elements are a collection of storage locations, timers, and counters that you can use to customize the operation of your SEL-421 and use the relay to automate substation operation. The elements that you can use in SELOGIC control equations are summarized in *Table 3.5*.

Table 3.5 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. *Appendix A: Relay Word Bits* contains a list of Relay Word bits available within the SEL-421. Analog quantities are analog values within the relay including measured and calculated values. *Appendix B: Analog Quantities in the Reference Manual* contains a list of analog quantities available within the SEL-421.

Special Condition Bits

Several Relay Word bits are available for special conditions related to SELOGIC control equation programming in the SEL-421. 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 3.6*.

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 3.6*, *Table 3.7*, and *Table 3.8*. 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 3.6 First Execution Bit Operation on Power-Up

Name	Description
AFRTEXA	Relay sets on power-up and clears after each automation programming block has been executed once.
AFRTEXP	Relay sets on power-up. Relay clears after it enables protection and all automation programming blocks have been executed once.
PFRTEX	Relay sets on power up. Relay clears after protection runs for one cycle.

Table 3.7 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 one cycle.

Table 3.8 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 one cycle.

SELOGIC Control Equation Variables

SELOGIC control equation variables are Boolean 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 when you evaluate Boolean logic statements. The quantities of SELOGIC control equation variables available in the different programming areas are listed in *Table 3.9*.

Table 3.9 SELOGIC Control Equation Variable Quantities

Type	Quantity	Name Range
Protection SELOGIC control equation variables	64	PSV01–PSV64
Automation SELOGIC control equation variables	256	ASV001–ASV256

Use the SELOGIC control equation variables in free-form logic statements in any order you want. Use a SELOGIC control equation variable more than once in free-form logic programming, and use SELOGIC control equation variables as arguments in SELOGIC control equations. *Example 3.4* illustrates SELOGIC control equation variable usage.

EXAMPLE 3.4 SELOGIC Control Equation Variables

The equations below show free-form SELOGIC control equation programming examples that use SELOGIC control equation 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 free-form 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 variables, there are separate storage areas for protection and automation math calculations. The quantities of SELOGIC control equation math variables available in the SEL-421 are shown in *Table 3.10*.

Table 3.10 SELOGIC Control Equation Math Variable Quantities

Type	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 free-form programming to store the results of math calculations as arguments in math calculations and comparisons. *Example 3.5* illustrates SELOGIC control equation math variable usage.

EXAMPLE 3.5 SELOGIC Control Equation Math Variables

The equations below show free-form SELOGIC control equation programming examples that use SELOGIC control equation math variables. 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 free-form 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 3.11*. Latch bits have two input parameters, Reset and Set, and one Latched Value, as shown in *Table 3.12*.

Table 3.11 Latch Bit Quantities

Type	Quantity	Name Range
Protection free-form latch bits	32	PLT01–PLT32
Automation latch bits	32	ALT01–ALT32

Table 3.12 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 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.

Latch bits are available in two different programming areas of the SEL-421. 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 free-form programming.

Protection Latch Bits

Program the 32 latch bits, PLT01–PLT32, in the protection free-form SELOGIC control equation programming area. There is a separate protection free-form 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 free-form 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 3.6* illustrates protection latch bit usage.

EXAMPLE 3.6 Protection Latch Bits

In this example, Remote Bit 2 (RB02) is a blocking command for remote control to the relay. A latch bit stores the incoming command and preserves the state associated with the command through a power cycle. Remote Bit 1 sends the operator-initiated circuit breaker open/close command. Because the protection design uses protection settings groups 1 through 3, the settings shown below are duplicated in protection SELOGIC control equation free-form programming areas associated with protection settings groups 1 through 3.

```
#
# Store incoming remote command block in Protection Latch Bit 2
#
PLT01R := RB02 AND PLT01 # Reset latch if RB02 off and latch set
PLT01S := RB02 AND NOT PLT01 # Set latch if RB02 on and latch not set
#
# Use PSV30, PSV31 to calculate open and close conditions
#
PSV30 := RB01 AND NOT PLT01 # Open if RB01 and not blocked
PSV32 := R_TRIG PSV30 # One processing interval Open command
PSV31 := NOT RB01 AND NOT PLT01 # Close if RB01 off and not blocked
PSV33 := R_TRIG PSV31 # One processing interval Close command
```

In this example, PSV32 and PSV33 are used in the trip and close equations. PSV34 will be set to 1 for an open command and reset to 0 for a trip command. The TRIP and CLOSE equations are shown below:

```
BK1MTR := PSV32 # Remote manual trip RB02 supervised with RB01 enable
BK1MCL := PSV33 # Remote manual close RB02 supervised with RB01 enable
```

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 free-form area dominates, and the relay uses this equation to evaluate the latch.

Automation Latch Bits

The automation latch bits, ALT01–ALT32, are available in automation free-form settings. Write free-form 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 free-form 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 free-form 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 free-form area, as shown in *Table 3.13*. Conditioning timers have the three input parameters and one output shown in *Table 3.14*.

Table 3.13 Conditioning Timer Quantities

Type	Quantity	Name Range
Protection free-form conditioning timers	32	PCT01–PCT32

Table 3.14 Conditioning Timer Parameters

Type	Item	Description	Setting	Name Examples
Input	Input	Value that the relay times	Boolean SELOGIC control equation setting	PCT01IN
Input	Pickup Time	Time that the input must be on before the output turns on	Time value in cycles	PCT01PU
Input	Dropout Time	Time that the output stays on after the input turns off	Time value in cycles	PCT01DO
Output	Output	Timer output	Value for Boolean SELOGIC control equations	PCT01Q

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 3.3*. 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.

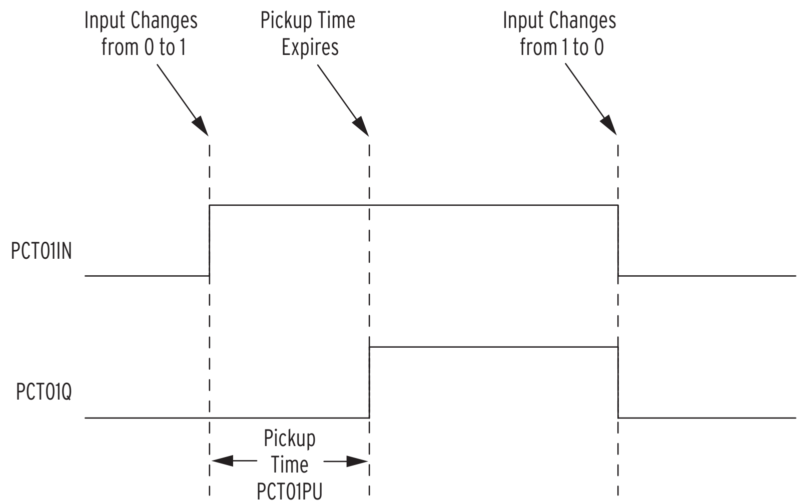

Figure 3.3 Conditioning Timer With Pickup and No Dropout Timing Diagram

If the Pickup Time is not satisfied, the timer Output never turns on, as illustrated in *Figure 3.4*.

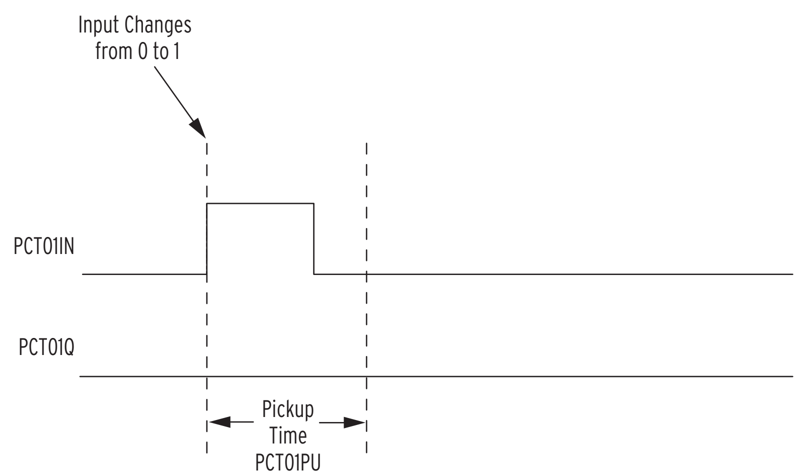

Figure 3.4 Conditioning Timer With Pickup Not Satisfied Timing Diagram

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 3.5*. 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.

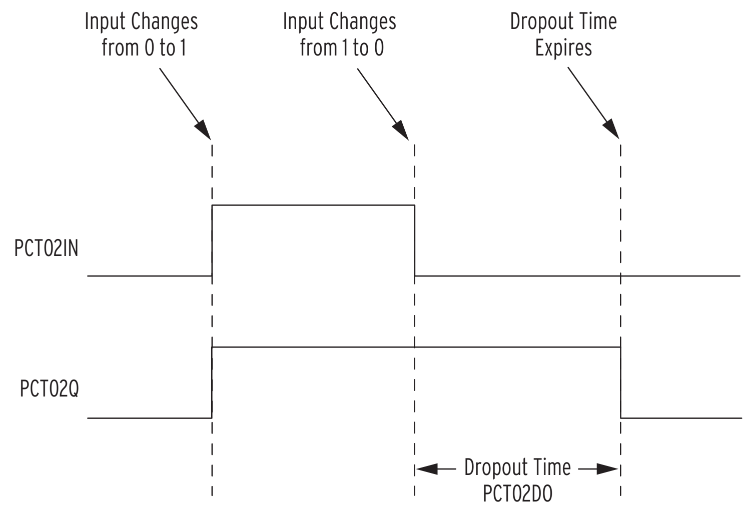

Figure 3.5 Conditioning Timer With Dropout and No Pickup Timing Diagram

Combining the features shown above, *Figure 3.6* 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.

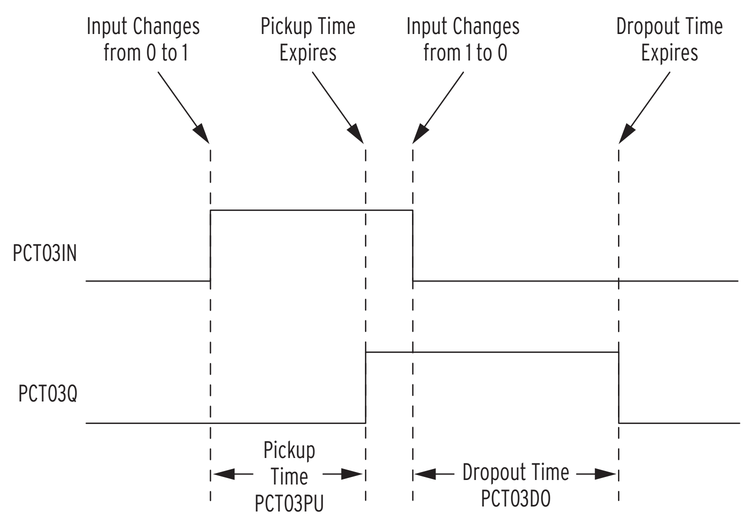

Figure 3.6 Conditioning Timer With Pickup and Dropout Timing Diagram

Set the conditioning timer settings for Pickup and Dropout in cycles and fractions of a cycle (represented in decimal form). The relay processes 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 the SEL-421, the protection processing interval is 1/8 cycle. Actual settings, programming, and operation are illustrated in *Example 3.7*.

EXAMPLE 3.7 Conditioning Timer Programming and Operation

This example uses Protection Free-Form Conditioning Timer Seven, PCT07. The free-form settings are as shown here:

PCT07PU := **5.3** # Pickup set to 5.3 cycles

PCT07DO := **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 3.7. 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.

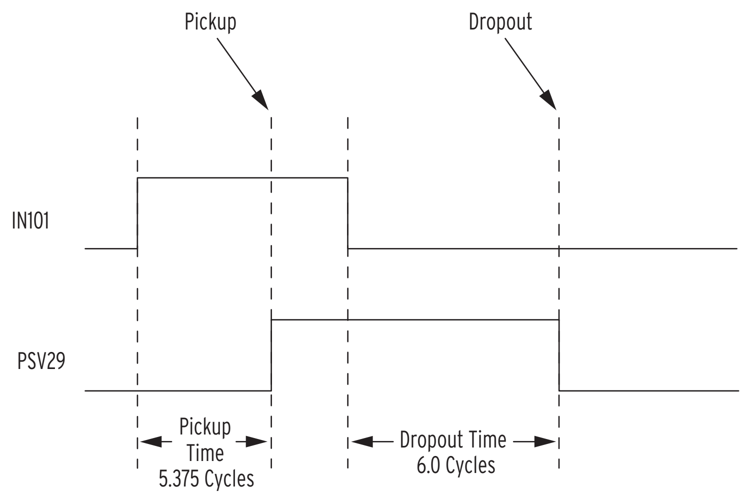

Figure 3.7 Conditioning Timer Timing Diagram for Example 3.7

In protection free-form programming, the relay evaluates the timer at execution of the timer Input SELogic control equation (PCT*nn*IN). The relay loads the Pickup Time (PCT*nn*PU) and Dropout Time (PCT*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 3.7*.

Sequencing 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 free-form area and automation free-form area as shown in *Table 3.15*. Sequencing timers have three input parameters and two outputs listed in *Table 3.16*.

Table 3.15 Sequencing Timer Quantities

Type	Quantity	Name Range
Protection free-form sequencing timers	32	PST01–PST32
Automation free-form sequencing timers	32	AST01–AST32

Table 3.16 Sequencing Timer Parameters

Type	Item	Description	Setting	Name Examples
Input	Input	Value that the relay times	Boolean SELOGIC control equation setting	PST01IN AST07IN
Input	Preset Time	Time the input must be on before the output turns on	Time value. Protection uses cycles, 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 cycles, while automation uses seconds.	PST01ET AST07ET
Output	Output	Timer output	Value for Boolean SELOGIC control equations	PST01Q AST07Q

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 3.8 is a timing diagram for typical sequencing timer operation.

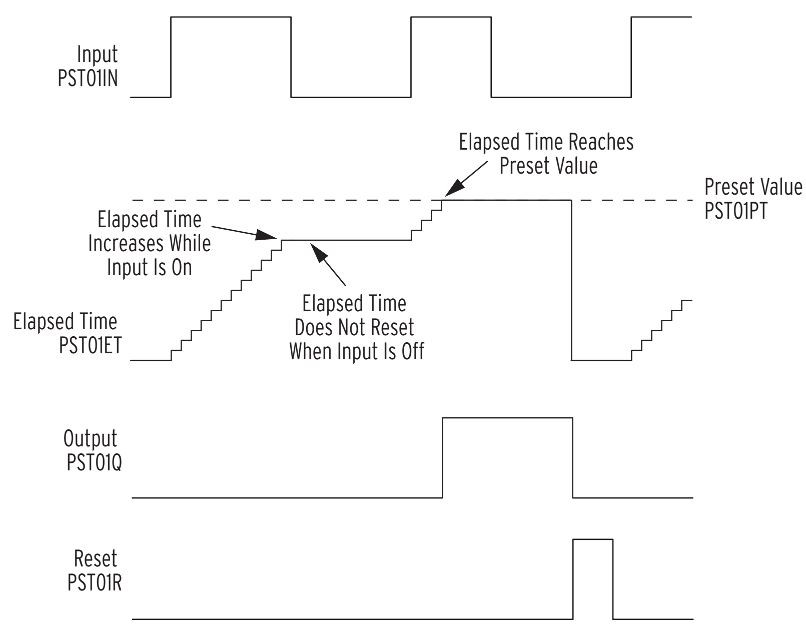

Figure 3.8 Sequencing Timer Timing Diagram

Timers in protection programming operate in cycles, while timers in automation programming operate in seconds. As with sequencing timers, operation depends on the logic processing interval. For protection programming, the logic processing interval is 1/8 cycle, so the relay effectively rounds up all operation to the nearest 1/8 cycle. 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 free-form programming, you must also check the new automation average execution cycle to verify that you will obtain satisfactory accuracy for your application. *Example 3.8* describes typical timer programming and describes the resulting operation.

EXAMPLE 3.8 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 free-form 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 3.8*.

Counters

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 free-form area and automation free-form area, as shown in *Table 3.17*. Counters have three input parameters, Input, Preset Value, and Reset; and two outputs, Current Value and Output as listed in *Table 3.18*.

Table 3.17 Counter Quantities

Type	Quantity	Name Range
Protection counters	32	PCN01–PCN32
Automation counters	32	ACN01–ACN32

Table 3.18 Counter Parameters

Type	Item	Description	Setting	Name Examples
Input	Input	Value that the relay counts	Boolean SELOGIC control equation setting	PCN01IN ACN09IN
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
Output	Output	Counter output	Value for Boolean SELOGIC control equations	PCN01Q ACN09Q

In free-form 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 3.9*.

EXAMPLE 3.9 Counter Programming

The free-form programming equations that follow demonstrate how to enter settings to control a protection counter in protection free-form SELOGIC control equation programming. Programming for an automation counter is similar.

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 three-pole 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 three-pole 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

Aliases

Although the SEL-421 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 in order to improve the readability of the program. *Example 3.10* provides examples of assigning aliases.

EXAMPLE 3.10 Assigning and Removing Aliases

The following free-form math SELOGIC control equations show you how to create aliases.

Assign the alias names with the **SET T** command

SET T

PMV01,THETA # Assign the alias "THETA" to PMV01

PMV02,TAN # Assign the alias "TAN" to PMV02

Use the alias names "THETA" and "TAN " in a free-form SELOGIC control equation:

Calculate the tangent of THETA

TAN := **SIN(THETA)/COS(THETA)**

To remove the alias from the alias setting, issue the **SET T** command and press **<Enter>** until the alias appears; then type **DELETE <Enter>**:

SET T

nn: PMV01,THETA # (where nn = line number)

DELETE

Assign as many as 200 alias names to any Relay Word bit or analog quantity, using the **SET T** command. The maximum length of an alias is seven characters. Valid characters are 0–9, A–Z (only uppercase) and _ (underscore). Make sure 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.

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 free-form programming. If the LVALUE is a Boolean type (52AA1, 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 SEL-421 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 3.19*.

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 3.20* contains a summary of Boolean operators available in the SEL-421.

Table 3.19 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

Table 3.19 Operator Precedence from Highest to Lowest (Sheet 2 of 2)

Operator	Description
–	Subtract
<, >, <=, >=	Comparison
=	Equality
<>	Inequality
AND	Boolean AND
OR	Boolean OR

Table 3.20 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 3.21* is a truth table for an example operation that illustrates how parentheses can affect equation evaluation.

Table 3.21 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 3.22*.

Table 3.22 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 3.23*.

Table 3.23 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 3.24*.

Table 3.24 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 3.9*. Use R_TRIG to sense when a value changes from logical 0 to logical 1 and take action only once when the value changes.

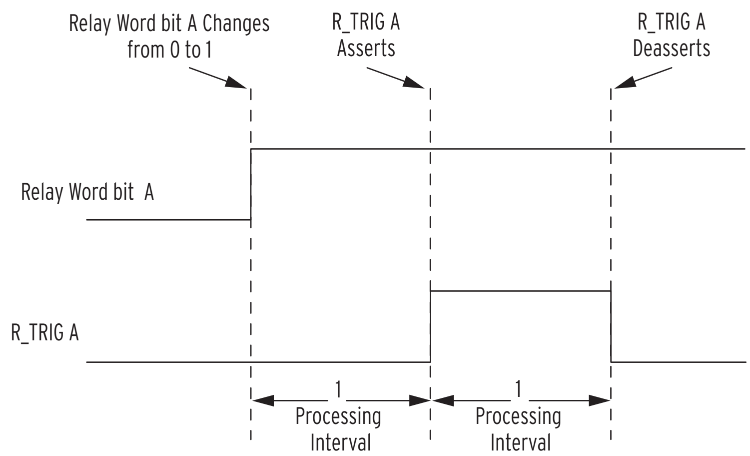

Figure 3.9 R_TRIG Timing Diagram

The argument of an R_TRIG statement must be a single bit within the SEL-421. An example of the relay detecting a rising edge of a calculated quantity is shown in *Example 3.11*.

EXAMPLE 3.11 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 3.11*. Use F_TRIG to sense when a value changes from logical 1 to logical 0 and take action only after the value changes state.

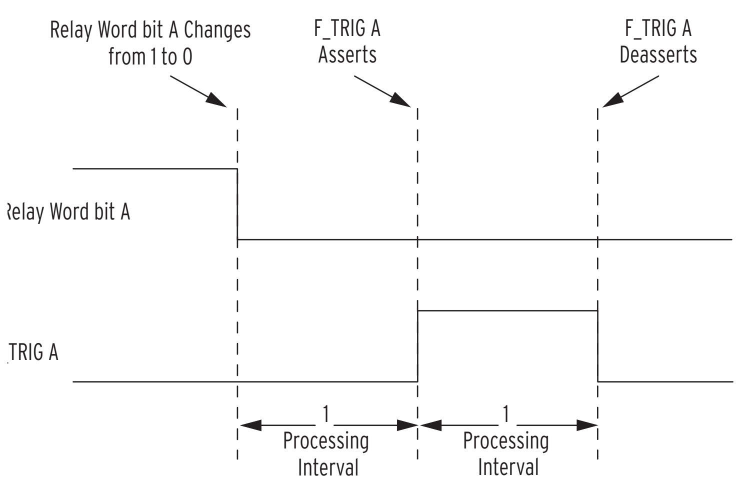

Figure 3.10 F_TRIG Timing Diagram

The argument of an F_TRIG statement must be a single bit within the SEL-421. An example of the relay detecting a falling edge of a calculated quantity is shown in *Example 3.12*.

EXAMPLE 3.12 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 3.25*.

Table 3.25 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 3.26* summarizes the operators available for math SELogic control equations.

Table 3.26 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 towards infinity
FLOOR	Rounds to the nearest integer towards 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 3.13* shows how parentheses affect the operation and evaluation of math operations.

EXAMPLE 3.13 Using Parentheses in Math Equations

The free-form 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 SEL-421 turns on the math error bit, MATHERR, in the Relay Word. A settings change or the **STATUS SC** command provides reset for 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 3.27 Math Error Examples

Example	Value in PMV01	Type	MATHERR
PMV01 := PMV02 / 0	Infinity	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.

A math error is also declared when the ratio of settings B1KASP3/B1KASP1 is outside the range: 5 ≤ B1KASP3/B1KASP1 ≤ 100.

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.

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 SEL-421 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 3.14* contains examples of arithmetic operations in use.

EXAMPLE 3.14 Using Arithmetic Operations

The free-form 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**

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 on page R.3.30*. *Example 3.15* shows examples of the SQRT operator in use.

EXAMPLE 3.15 Using the SQRT Operator

The free-form 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 on page R.3.30*. EXP calculates the value of e raised to the power of the argument. *Example 3.16* shows examples of expressions that use the LN, EXP, and LOG operators.

EXAMPLE 3.16 Using the LN, EXP, and LOG Operators

The free-form 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

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-421 uses to express metering quantities. *Example 3.17* shows examples of SIN and COS.

EXAMPLE 3.17 Using the SIN and COS Operators

The free-form 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 R.3.30*. *Example 3.18* shows examples of ASIN and ACOS.

EXAMPLE 3.18 Using the ASIN and ACOS Operators

The free-form 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 3.19* contains examples of the ABS operator in use.

EXAMPLE 3.19 Using the ABS Operator

The free-form 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 towards infinity. Use parentheses to group a math expression as the argument of a CEIL operation. *Example 3.20* contains examples of the CEIL operator.

EXAMPLE 3.20 Using the CEIL Operator

The free-form 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 towards minus infinity. Use parentheses to group a math expression as the argument of a FLOOR operation. *Example 3.21* contains examples of the FLOOR operator.

EXAMPLE 3.21 Using the FLOOR Operator

The free-form 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 3.22* contains examples of expressions that utilize the negation operator.

EXAMPLE 3.22 Using the Negation Operator

The free-form 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 the SEL-421 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 free-form SELOGIC control equations, and store these comments in the SEL-421. 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 free-form programming environments such as Visual Basic, C, and free-form SELOGIC control equations. *Example 3.23* shows how to use comments to divide and structure free-form SELOGIC control equation programming.

EXAMPLE 3.23 Comments in Free-Form SELOGIC Control Equation Programming

Use comments to divide and direct your eye through free-form programming.

```
#
# This is a header comment that divides sections of free-form 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.

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.

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.

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** or **MET AMV** commands to display the contents of the last 16 protection or automation math variables.

SEL-311 and SEL-351 Series Users

You can convert logic that you have used in SEL-311 series relays and SEL-351 series relays to logic for the SEL-421. In the SEL-311 series relays, SELOGIC control equation programming is restricted to equations where the left side value, LVALUE, is fixed. The SEL-421 uses primarily free-form programming. *Table 3.28* shows comparable features between the SEL-311 series relays and the SEL-421. Convert programming into either the free-form style or the fixed style of SELOGIC control equations, or whatever combination you deem appropriate for your application.

Table 3.28 SEL-311 Series Relays and SEL-421 SELOGIC Control Equation Programming Features

Feature	SEL-311 Series	SEL-421 Protection Free-Form 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 3.29 shows the SEL-421 Boolean operators compared to the operators used in the SEL-311 series relays.

Table 3.29 SEL-311 Series Relays and SEL-421 SELOGIC Control Equation Boolean Operators

Feature	SEL-311 Series	SEL-421
Logical AND operator	*	AND
Logical OR operator	+	OR
Logical NOT operator	!	NOT
Parentheses	( )	( )
Rising, falling edge operators	/, \	R_TRIG, F_TRIG

In the SEL-311 series relays, SELOGIC control equation variables and timers are connected. Each SELOGIC control equation variable is the input to a timer. In the SEL-421, timers and SELOGIC control equation variables are independent.

The SELOGIC control equation Boolean operators in the SEL-421 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 for the SEL-421, you must convert the operators. *Example 3.24* and *Example 3.25* demonstrate conversion of several settings to the SEL-421 setting.

EXAMPLE 3.24 Converting SEL-311 Series Relay SELOGIC Control Equation Variables

If you have the following SELOGIC control equation in an SEL-311 series relay, convert it as shown below.

```
SV1 = IN101 + RB3 * LT4
```

In the SEL-421, use the line shown below.

PSV01 := **IN101 OR RB03 AND PLT04** # Free-form example .

In the example above, first convert the + and * operators in the expression to the OR and AND operators. In the free-form 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 3.25.

EXAMPLE 3.25 Converting SEL-311 Series Relay SELOGIC Control Equation Timers

If you have the following SELOGIC control equation timer in an SEL-311 series relay, convert it as shown below.

```
SV1 = IN101

SV1PU = 5.25

SV1DO = 3.5
OUT101 = SV1T
```

In the SEL-421, use the format shown below.

#

Free-form 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 3.26 Converting SEL-311 Series Relay Latch Bits

If you have the following SELOGIC control equation latch programming in an SEL-311 series relay, convert it as shown below.

```
SET1 = RB4
RST1 = RB5
OUT101 = LT1
```

In the SEL-421, use the format shown below.

Protection free-form style settings:

```
#
# Free-form 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
```

Section 4

Communications Interfaces

This section provides information on communications interface options for the SEL-421 Relay. The following topics are discussed:

Communications Interfaces

The SEL-421 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. You must enter settings to configure the SEL-421 to protect and monitor your power system properly. 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 SEL-421 has three rear-panel serial ports and one front-panel serial port. These serial ports conform to the EIA/TIA-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 a communications card slot for additional optional communications interfaces including Ethernet.

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 SEL-421, see the instruction manual sections listed in *Table 4.1*.

Table 4.1 SEL-421 Communications Protocols (Sheet 1 of 2)

Communications Protocol	Communications Interface	For More Information See
DNP3 (serial)	EIA-232[a]	*Section 6: DNP3 Communications*
DNP3 (LAN/WAN)	Ethernet Card	*Section 6: DNP3 Communications*
IEC 61850	Ethernet Card	*Section 8: IEC 61850 Communications*
Distributed Port Switch (LMD)	SEL-2885 EIA-232 to EIA-485 transceiver on an EIA-232 port	*Section 5: SEL Communications Protocols*

Table 4.1 SEL-421 Communications Protocols (Sheet 2 of 2)

Communications Protocol	Communications Interface	For More Information See
SEL Binary Protocols (Fast Meter, Fast Operate, Fast SER)	EIA-232[a] or Telnet using Ethernet card	*Section 5: SEL Communications Protocols*
SEL Fast Message RTD protocol	EIA-232[a]	*Section 5: SEL Communications Protocols*
MIRRORED BITS® communications	EIA-232[a]	*Section 5: SEL Communications Protocols*
Phasor Measurement Protocols (C37.118 and SEL Fast Message)	EIA-232[a] Ethernet Card[b]	*Section 7: Synchrophasors*
ASCII Commands	EIA-232 or Telnet using Ethernet card[a]	*Section 9: ASCII Command Reference*

[a] You can add converters to transform EIA-232 to other physical interfaces.
[b] Phasor Measurement over the Ethernet card is only C37.118 protocol.

Section 6: SEL Communications Processor Applications in the Applications Handbook and *Section 7: Direct Network Communication in the Applications Handbook* include more information on communication topologies and protocols.

Serial Communication

Each SEL-421 has four serial ports that you can use for serial communication with other devices. While these ports are all EIA-232, you can add transceivers or converters to operate on different physical media including EIA-485 and fiber-optic cable.

EIA-232

The SEL-421 has four EIA-232 communications interfaces. The serial port locations for the 3U chassis are shown in *Figure 4.1* and *Figure 4.2*; 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**.

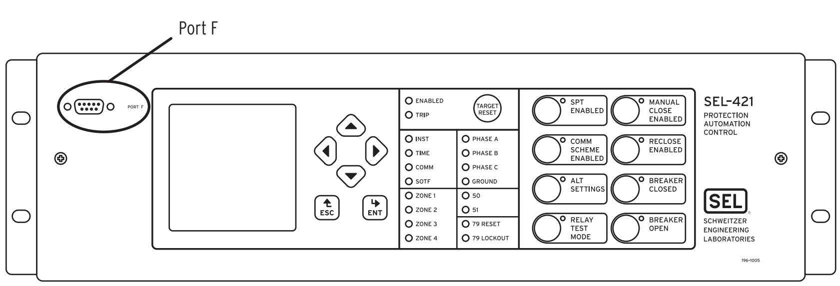

Figure 4.1 SEL-421 3U Chassis Front-Panel Layout

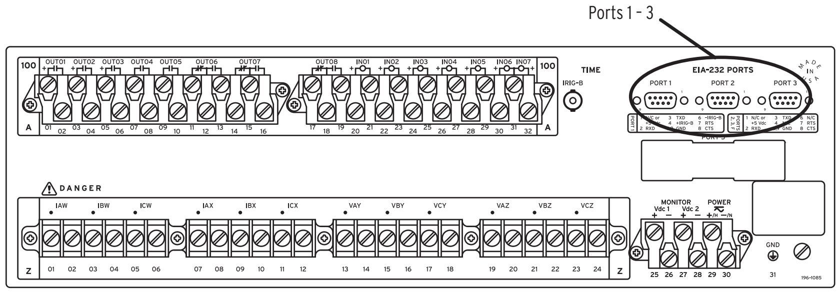

Figure 4.2 SEL-421 3U Rear-Panel Layout

The EIA-232 ports are standard female 9-pin connectors with the pin numbering shown in *Figure 4.3*. The pin functions are listed in *Table 4.2*. See the manual section listed in *Table 4.1* for a description of how the relay uses these pins with your specific protocol. Pin 1 can provide power to an external device. See *Serial Port Jumpers on page U.2.21* for more information on installing the jumper to provide voltage on Pin 1.

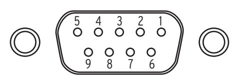

Figure 4.3 EIA-232 Connector Pin Numbers

Table 4.2 EIA-232 Pin Assignments

Pin	Signal Name	Description	Comments
1	5 Vdc	Modem power	Jumper selectable on **PORT1**–**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. See Section 2: Installation in the User's Guide.

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 the SEL website www.selinc.com.

⚠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.

You can connect to a standard 9-pin computer port with the SEL cable C234A for relay configuration and programming with a terminal program or with the ACSELERATOR QuickSet® SEL-5030 software. See *Figure 2.41 on page U.2.47* for the construction of SEL cable C234A.

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 family 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 SEL-421. You can install an SEL-2885 or SEL-2884 transceiver to convert one of the rear-panel EIA-232 ports (**PORT 1** or **PORT 3**) on the relay to an EIA-485 port. The SEL-2885 and SEL-2884 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 flyers for more information. The SEL-2885 offers the SEL distributed port switch (LMD) protocol. 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 protocol in *Section 5: SEL Communications Protocols in the Reference Manual*.

Communications Card

PORT 5 of the SEL-421 is a communications card slot. You can order the relay with the card installed at the factory. The communications card slot provides an interface to SEL-2700 series communications cards. As with other SEL products, SEL has designed and tested SEL communications cards for operation in harsh environments.

Ethernet Card

The optional Ethernet card provides Ethernet communications for the SEL-421. The Ethernet card is available with standard twisted-pair and fiber-optic physical interfaces. 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 *SEL Communications Processor Applications on page A.6.1*, *Direct Network Communication on page A.7.1*, *Section 6: DNP3 Communications in the Reference Manual*, and *Section 8: IEC 61850 Communications in the Reference Manual*.

Once installed in an SEL-421, the Ethernet card settings become part of the relay settings. The card cannot be set directly–it must be set as relay **PORT 5**. The settings needed for network operation and data exchange protocols, including DNP3 and IEC 61850, are available in the **PORT 5** settings.

The Relay Word bit CCOK indicates that a connected communications card (SEL-2702) is operating normally. The CCOK bit asserts if all of the following actions occur.

- A communications card is detected as installed.
- The communications card reports no diagnostic failures.
- The continuous "are you alive?" self-test is acknowledged within a specified time.

Ethernet Network Operation Settings

Several settings control how the SEL-421 with the optional Ethernet card operates on an Ethernet network. These settings include IP addressing information, network port fail-over options, and network speed.

Network Configuration

Use the network configuration settings shown in *Table 4.3* to configure the SEL-421 for operation on an IP network and to set other parameters affecting the physical Ethernet network interface operation.

Table 4.3 Ethernet Card Network Configuration Settings

Label	Description	Range	Default
IPADDR	IP network address	IP address	192.92.92.92
SUBNETM	IP network subnet mask	IP address	255.255.255.0
DEFRTR	Default router	IP address	NA
ETCPKA[a]	TCP keep-alive functionality enable[a]	Y, N	N
KAIDLE	Length of time to wait with no detected activity before sending a keep-alive packet	1–20 s (must be greater than or equal to KAINTV)	10
KAINTV	Length of time to wait between sending keep-alive packets after receiving no response for the prior keep-alive packet	1–20 s (must be less than or equal to KAIDLE)	1
KACNT	Maximum number of keep-alive packets to send	1–20	6
NETPORT	Primary network port (D disables all network ports)	A, B, D	A
FAILOVR	Automatic fail-over enable	Y, N	Y
FTIME	Fail-over time out	5–65535 ms	5
NETASPD[b]	Network speed or auto-detect on Port A	A, 10 Mbps, 100 Mbps	A
NETBSPD[b]	Network speed or auto-detect on Port B	A, 10 Mbps, 100 Mbps	A

[a] This setting applies only to IEC 61850 communications.
[b] This setting applies only to twisted-pair ports (10/100BASE-T).

The SEL-421 uses the IPADDR and SUBNETM settings to determine its local network and node address. The SUBNETM setting defines the 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.

The SEL-421 uses the DEFRTR address setting to determine how to communicate with nodes on other local networks. The SEL-421 communicates with the default router to send data to nodes on other local networks. If you change the DEFRTR setting from the default value of Null (meaning that there is no default router), then the default router must be on the same local network as the SEL-421 or the SEL-421 will reject the DEFRTR setting. You must also coordinate the default router with your general network implementation and administration plan. See *Table 4.4* for examples of how IPADDR and SUBNETM define the network and node and how these settings affect the DEFRTR setting.

Table 4.4 DEFRTR Address Setting Examples

IPADDR	SUBNETM	Network Number	Node Address	DEFRTR
192.92.92.92	255.255.255.0	192.92.92	92	192.92.92.a[a]
192.92.92.92	255.255.0.0	192.92	92.92	192.92.a[a], b[a]
192.92.92.92	255.0.0.0	192	92.92.92	192.a[a], b[a], c[a]
192.92.92.92	0.0.0.0	n/a	192.92.92.92	a[a], b[a], c[a], d[a]

[a] Value in the range 0–255.

If the SEL-421 is purchased with IEC 61850 support, 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 SEL-421 does not transmit any TCP data within the interval specified by the KAIDLE setting, the SEL-421 sends a keep-alive packet to the remote computer. If the SEL-421 does not receive a response from the remote computer within the time specified by KAINTV, the keep-alive packet is re-transmitted as many as KACNT times. After this count is reached, the SEL-421 remote device is no longer available, so the SEL-421 can terminate the connection without waiting for the idle timer (TIDLE or FTPIDLE) to expire.

The SEL-421 Ethernet card operates over either twisted-pair or fiber-optic media. Each Ethernet card is equipped with two network ports. With an initial ordering option, you can select the medium for each port (10/100 Mbps twisted pair or 100 Mbps fiber optic). Speeds for the physical media are fixed for fiber-optic connections. For twisted-pair connections, the Ethernet card can auto-detect the network speed or you can set a fixed speed.

Network Port Fail-Over Operation

The SEL-421 Ethernet card has two network ports. Network port fail-over mode enables the Ethernet card to operate as a single network adapter with a primary and standby physical interface. You can connect the two network ports to the same network or different networks depending on your specific Ethernet network architecture. If you have a single network and want to use only one network port, set NETPORT to the port you want to use and set

FAILOVR to N. Only one network port operates at a time. The fail-over mode operation determines the active port. To use fail-over mode, proceed with the following steps.

Step 1. Set NETPORT to the preferred network interface.

Step 2. Set FAILOVR to Y.

Step 3. Set FTIME to the desired network port fail-over time.

NOTE: If you change settings for the host port where the Ethernet card is installed and the standby network port is active, the Ethernet card resets and returns to operation on the primary port.

If the Ethernet card detects a link failure on the primary port, it activates the standby port after the fail-over time, FTIME, elapses. If the link status on the primary link returns to normal before the fail-over time expires, the fail-over timer resets; uninterrupted operation continues on the primary network port. The Ethernet card checks the primary link periodically and continues checking until it detects a normal link status. The Ethernet card returns to operation on the primary link when it detects a normal link status.

Network Address Resolution

The SEL-421 Ethernet card can resolve 20 network host names to corresponding IP addresses. Settings for Network Address Resolution (NAR) are shown in *Table 4.5*. The Ethernet card uses address resolution any place settings or commands require an IP network name. NAR is similar to DNS (Domain Name Services) used on the Internet, except that NAR uses a local name list rather than a remote name server. You can use names rather than numeric IP addresses for settings like DEFRTR (default router) or when using the Ethernet card **PING** command. If a remote network host name (HOST1–HOST20) is set NA, then the Ethernet card ignores the corresponding IP address setting (IPADR 1–IPADR 20).

Table 4.5 IP Network Address Resolution Settings

Label	Description	Range	Default
HOST1	Remote network host name	16 characters	NA
IPADR1	Remote network host IP address	IP address	NA
HOST 2	Remote network host name	16 characters	NA
IPADR2	Remote network host IP address	IP address	NA
•			
•			
•			
HOST20	Remote network host name	16 characters	NA
IPADR20	Remote network host IP address	IP address	NA

Data Access Settings

Access data using either the standard TCP/IP Telnet and FTP interfaces or, optionally, through the 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 SEL-421 Ethernet card operates as an FTP server. It presents Ethernet card and host files to FTP clients. The

SEL-421 Ethernet card can support as many as three simultaneous FTP sessions, allowing simultaneous FTP access to as many as three separate users.

The host maintains the access control list that determines FTP log-in IDs and passwords. The host also determines which files are available. Some files are available at specific log-in levels, while other files are read-only access. Subsequent host-specific sections describe access control for each host.

File Structure

The basic file structure common to all hosts is organized as a directory and subdirectory tree similar to that used by Unix, DOS, Windows, and other operating systems. The root directory is "/" and has at least one subdirectory. The basic file structure is shown in *Table 4.6*.

Table 4.6 Basic File Structure

Host Directory	Subdirectories	Files
/	Host	See the host-specific sections for available files and directories.
	SEL-2702	DIAGNOSTICS.TXT ERR.TXT
	DD01_DeviceID	REGION1.TXT
	DD*nn_DeviceID*	REGION1.CAS • • • REGION*n*.TXT REGION*n*.CAS

The root directory contains the following files if the IEC 61850 protocol is installed and enabled:

➤ CID (Configured IED Description) file—contains the IEC 61850 SCL configuration for the SEL-421

➤ ERR.TXT file—contains any errors found during downloading of the CID file, and is present when the download is complete

➤ CFG.XML file—contains the Ethernet card and SEL-421 configuration information

The first subdirectory is for the host. Some hosts do not have a subdirectory. The HOST_ID string, if set, determines this subdirectory name. The Ethernet card strips any leading or following white-space characters. The Ethernet card then substitutes the "_" character for any white-space or delimiter characters. For example, if the HOST_ID is IED#983 Sub#45, then the host subdirectory name is IED_983_Sub_45. If the converted HOST_ID is longer than 31 characters, the host subdirectory name becomes the first 31 characters of the converted HOST_ID. The host subdirectory contains settings, reports, and diagnostic files for the host.

The next subdirectory is SEL-2702. This subdirectory contains the file DIAGNOSTICS.TXT that contains records for Ethernet card system failures. The time and date for the diagnostics file are the same as the time and date of the last system failure event. This directory will also contain the DNPMAP.TXT and DNPMAPx.TXT files if DNP LAN/WAN is enabled. The

ERR.TXT file contains any error messages generated by the Ethernet card and host pertaining to these files.

The Ethernet card creates a subdirectory for each virtual device in the host. The subdirectory name is DD*nn_DeviceID*, where *nn* is the virtual device number and DeviceID is the device name derived from an identification string stored in the host that is associated with the virtual device. The Ethernet card uses the first identification string that it finds in the PORTID, DEVICEID, and FIDID strings. The same substitution rules that govern substitutions for the host subdirectory name govern creation of the substring. For example, if you have an SEL-351 connected to an SEL-2030 on Port 3 with a PORTID setting of “Feeder 1,” the subdirectory name will be “DD03_Feeder_1.”

Each virtual device subdirectory contains files that represent valid host data regions associated with the virtual device. Data region files provide snapshots of the corresponding host database regions. When an FTP client requests the file, the Ethernet card sends a file containing values from the host database region. If the voltage VA is 12.47 kV when you make an FTP request for the METER.TXT file, then the file METER.TXT will contain VA = 12.47. If you request the file at another time, when VA is 12.40, the file will contain VA = 12.40. Two file formats are available, ASCII text and compressed ASCII (CASCII). Names of the files correspond to the data region name (i.e., METER.TXT, METER.CAS).

Access Control

FTP settings control some basic file access features. The host is responsible for maintaining names and passwords for access control. The special FTP user name “anonymous” does not require a password. It has the same access rights as the user name in the FTPAUSR setting. For example, if FTPAUSR is set to ACC, the FTP anonymous user has Access Level 1 rights. See the host-specific sections for additional information about access rights. *Table 4.7* lists the settings that affect FTP server operation.

NOTE: 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 user name “anonymous.” If you enable anonymous FTP logins, you are allowing unrestricted access to the Ethernet card and host files.

Table 4.7 Ethernet Card FTP Settings

Label	Description	Range	Default
FTPSERV[a]	FTP session enable	Y, N	N
FTPCBAN	FTP connect banner	254 characters	FTP SERVER:
FTPIDLE[a]	FTP connection timeout	5–255 minutes	5
FTPANMS[a]	Anonymous login enable	Y, N	N
FTPAUSR	Host user from which anonymous FTP client inherits access rights	See host-specific section	Empty String

[a] If you change these settings and accept the new settings, the Ethernet card closes all active network connections and briefly pauses network operation.

Telnet

Telnet is also part of the TCP/IP protocol suite. You can use Telnet to establish terminal access to a remote device. A Telnet connection provides access to the user interface of either the host or the Ethernet card. Host user interface access is similar to an ASCII terminal connection to the front port of an SEL device.

You can use Telnet in the Ethernet card in one of three ways:

1. Connect from your PC to the Ethernet card user interface.
2. Connect from your PC to the host user interface.
3. Connect from a host to another Telnet server.

To determine which modes are available in your installation, see the host-specific section. The Ethernet card acts as a Telnet server for connections to the Ethernet card user interface. The user interface provides access to commands for diagnostics and other special features of the Ethernet card. Telnet settings are listed in *Table 4.8*.

Table 4.8 Ethernet Card Telnet Settings

Label	Description	Range	Default
T1CBAN	Host Telnet connect banner	254 characters	HOST TERMINAL SERVER:
T1INIT	Telnet session from host enable	Y, N	Y
T1RECV	Telnet session to host enable	Y, N	N
T1PNUM[a]	Host Telnet TCP/IP port	1–65534 except 20, 21, 102	23
T2CBAN	Ethernet card Telnet connect banner	254 characters	CARD TERMINAL SERVER:
T2RECV	Telnet session to Ethernet card enable	Y, N	N
T2PNUM[a]	Ethernet card Telnet TCP/IP port	1–65534 except 20, 21, 102	1024
TIDLE	Telnet connection timeout (0 prevents timeout)	0–255 minutes	5

[a] If you change these settings and accept the new settings, the Ethernet card closes all active network connections and briefly pauses network operation.

Ethernet Card Commands

The SEL-421 Ethernet card user interface accepts Ethernet card commands. There are two ways you can connect to the Ethernet card. First, if your host allows, you can make a transparent connection to the Ethernet card. Second, you can establish a Telnet connection to the Ethernet card user interface. See the host-specific sections for more information on connecting to the Ethernet card user interface. Other connections to the Ethernet card, including FTP, require standard protocol commands and do not respond to the Ethernet card user-interface commands.

Using Commands

When you type commands, you can type in either the entire command or just use the first three letters. For example, if you type **STATUS <Enter>** or **STA <Enter>**, the Ethernet card displays status information. Commands are not case sensitive; you may use upper- or lowercase characters. Access level password entry is case sensitive. *Table 4.10* summarizes the user commands.

As with serial ports on SEL devices, you can control character transmission in a Telnet session using control characters. Send the control characters listed in *Table 4.9* to control long transmissions like event reports and SER reports.

Table 4.9 Control Characters

Control Characters	Key Commands	Results
XON	CTRL + Q	Restart paused transmission and enable subsequent transmissions.
XOFF	CTRL + S	Pause current transmission and block any subsequent transmissions.
CAN	CTRL + X	Cancel current transmission or command and return to cursor.

Command Summary

Table 4.10 summarizes the Ethernet card commands. Subsequent subsections provide full descriptions of each command in alphabetical order.

Table 4.10 Ethernet Card Command Summary

Command	Description	Access Level
2ACCESS	Go to Access Level 2.	1
ACCESS	Go to Access Level 1.	0 or 2
DATE	View or change date.	1[a] or 2
DNPMAP	Display data map(s) accessible to a DNP LAN/WAN master	1 or 2
GOOSE	Display GOOSE message multicast information and status for transmit and receive GOOSE messages.	1 or 2
HELP	Display available commands or command help.	Any
ID	View internal identification parameters for the Ethernet card.	1 or 2
MEMORY	Display RAM statistics for the Ethernet card.	1 or 2
PING	Ping another node on the network.	2
QUIT	Go to Access Level 0.	Any
STATUS	Display self-test status.	1 or 2
TIME	View or change internal clock.	1[a] or 2

[a] Limited functions at this access level. See command description below for details.

Access Levels

Access levels control whether you can perform different operations within SEL products. For example, at Access Level 1, you can view settings. You cannot change settings unless you are at Access Level 2. A complete list of access levels for the SEL-421 is shown in *Table 4.11*.

Table 4.11 Ethernet Card Access Levels

Access Level	Prompt	Allowed Ethernet Card User-Interface Operations
0	#	Log in to Access Level 1.
1	#>	View data and status information.
2	#>>	Perform all Access Level 1 functions plus advanced diagnostics and set date/time.

Each access level has a password. The Ethernet card uses passwords set in the host for the same access level. For example, if you have an SEL-2032 and

Ethernet card, and have set the SEL-2032 Access Level 2 password to SUB35L2, then SUB35L2 is the password for Access Level 2 on your Ethernet card.

The Ethernet card uses access levels and passwords in two ways. First, if you are connected to the Ethernet card user interface, the Ethernet card limits command access based on your access level. You are connected to the Ethernet card user interface if you are using a terminal or Telnet program and see one of the prompts shown in *Table 4.11*. For example, if your Ethernet card is installed in an SEL-2032, you can Telnet to the Ethernet card or make a transparent connection from one of the SEL-2032 serial ports to the Ethernet card.

Second, the Ethernet card uses access level names and passwords as user names and passwords for protocols that require you to log in to establish a connection. For example, if you are making an FTP connection to the Ethernet card, you will be prompted for an FTP user name and password. In this case, use host access levels and passwords to connect. Use the host access level for the FTP user name and the corresponding password for the FTP password. Access levels are listed with corresponding passwords in *Table 4.12*.

Table 4.12 Access Level User Names and Passwords

Access Level	User Name	Password
0	QUI	None
1	ACC	User-definable
2	2AC	User-definable

Connections that are closed manually by ending the network connection or by using the Ethernet card **QUIT** command are terminated. This means that to reestablish the connection and return to the original access level, you must log in using the access level commands and passwords.

When a connection with the Ethernet card or the host “times out,” the connection is closed and the access level is reduced to 0. There is a timeout setting associated with connections to the Ethernet card and connections to the host through the Ethernet card. The timeout settings and their specific operation are described in the host-specific sections.

Access failures cause the Ethernet card to close connections, assert the alarm bit, and prevent connections for a variable delay period.

2ACCESS

Use the **2ACCESS** command to change to Access Level 2. If the current level is not Access Level 1, the Ethernet card responds with “Invalid access level.” When you enter the **2AC** command, the Ethernet card prompts you to enter the Access Level 2 password. If the password is Null or you enter the password set in the host, the access level changes to Access Level 2. Passwords are case sensitive; you must enter them exactly as set. The host maintains the password and user list. For more details, see the host-specific sections.

If you are unable to enter the correct password after the third failed attempt, the Ethernet card asserts the ALARM bit in the Status register and terminates the connection for some connection types. See the host-specific sections for more information on how your host uses the ALARM bit from the Ethernet card.

If your connection to the Ethernet card has an inactivity timeout, the Ethernet card automatically closes the connection and changes to Access Level 0 when the timeout expires.

ACCESS

Use the **ACCESS** command to change to Access Level 1. For example, if you are at Access Level 0, the Ethernet card prompts you for the password and moves you to Access Level 1 if you enter the password correctly. For additional details on access level commands, see *2ACCESS*.

DATE

Table 4.13 illustrates how to use the **DATE** command to view or set the date.

Table 4.13 DATE Command

Command	Description
DATE	Display internal Ethernet card date.
DATE mm/dd/yyyy	Set the date if the date format setting for the host is mm/dd/yyyy, where mm is the month, dd is the day of month, and yyyy is the year.
DATE dd/mm/yyyy	Set the date if the date setting for the host is dd/mm/yyyy.
DATE yyyy/mm/dd	Set the date if the date setting for the host is yyyy/mm/dd.

The **DATE** command displays the internal clock date. A setting in the host determines the date format. In order to avoid confusion, the Ethernet card displays the date format along with the date. For example, if you set the host for a European style date, the Ethernet card displays the current date and the date format text “dd/mm/yyyy.” The date format options are mm/dd/yyyy, dd/mm/yyyy, and yyyy/mm/dd.

Use the **DATE** command with a date to set the internal clock date. Enter the year in four-digit form. Enter the date in a form that matches the date form of the host. Because there is no way to differentiate between mm/dd/yyyy and dd/mm/yyyy for certain dates (02/03/2001 could be February 3 or March 2), check the date format before entering the date. To see the date format, use the **DATE** command.

DNPMAP

Use the **DNPMAP** command to display the data (object types, indices, default variation and source) and controls (object type, indices and destination) that are accessible via DNP3. The output of the **DNPMAP** command documents the DNP3 data map in the SEL-421 to help with the configuration of the DNP3 master.

If the DNPMAP setting is set to CUSTOM, then an additional integer parameter corresponding to an assigned DNPMAP number (1–5) must be specified to view each custom DNP3 data map. For example, the command **DNPMAP 2** would be used to view the custom data map for DNP session 2. If a DNPMAP number is not specified, a summary of DNP3 map settings for all configured sessions will be displayed.

Summary and detailed map configurations are also available in the DNPMAP.TXT and DNPMAP*nn*.TXT files from the Ethernet card FTP interface. The individual file names associated with the detailed custom map settings follow the DNPMAP*nn*.TXT naming convention.

GOOSE

This command outputs the GOOSE multicast information and status for every GOOSE transmit and receive message connected to the SEL-421.

The multicast information displayed includes:

Field	Description
GOOSE Control Reference	A concatenation of the IED name, LN0 lnClass (Logical Node Class) and GSEControl name (GSE Control Block Name)
Multicast Address (MultiCastAddr)	Hexadecimal representation of the multicast addresses
Priority Tag (Ptag)	VLAN priority tag (3-bit decimal). If the priority tag is unknown, then empty spaces will be displayed in lieu of the value.
VLAN	Virtual LAN Setting (12-bit decimal value). If the Virtual LAN setting is unknown, then empty spaces will be displayed in lieu of a decimal value.

The status information includes:

Field	Description
State Number (StNum)	Increments each time a state changes
Sequence Number (SqNum)	Increments each time a GOOSE message is sent
Time to Live (TTL)	Remaining time in ms before the next message is expected
Code	Indicate a warning or error condition. See below for descriptions.

The status codes are abbreviated as:

Code Abbreviation	Description
OUT OF SEQUENC	Out of sequence error
CONF REV MISMA	Configuration Revision mismatch
NEED COMMISSIO	Needs Commissioning
TEST MODE	Test Mode
MSG CORRUPTED	Message Corrupted
TTL EXPIRED	Time to live expired
HOST DISABLED	Host disabled/not responding

Examples of GOOSE command outputs follow:

```
#>>GOO <Enter>

GOOSE Transmit Status

   MultiCastAddr   Ptag:Vlan  StNum      SqNum      TTL    Code
----------------------------------------------------------------------------
SEL_2701_GOOSE/LLN0$GO$GooseDSet1
   01-03-A7-00-00-01  2:5     1256       347        6
   Data Set: SEL_2701_GOOSE/LLN2$Master

GOOSE Receive Status

   MultiCastAddr   Ptag:Vlan  StNum      SqNum      TTL    Code
----------------------------------------------------------------------------
SEL-2701/LLN0$GO$GooseDSet13
   01-03-A7-00-00-01  3:1     1253758689 4786543985 123456 MSG CORRUPTED
   Data Set: SEL-2701-2/LLN0$Positions

GE-F60/LLN0$GO$GEGooseDSet
   01-03-A7-00-00-01  3:23    12568945   34         0      TTL EXPIRED
   Data Set: GE-F60/LLN1$Station1

GE-C30/LLN0$GO$GEGooseDSet
   01-03-A7-00-00-01  3:343   1945       34456      456
   Data Set: GE-C30/LLN2$Terminal

COOPER-EDISONPRO/LLN0$GO$CooperGooseDSet
   01-03-A7-00-00-01  3:4987  45         347        123456
   Data Set: COOPER-EDISONPRO/LLN2$Transmission

SEL-351-RECLOSING_DIRECTIONAL_OVERCURRENT/LLN0$GO$GooseDSet
   01-03-A7-00-00-01  3:5     12568945   34783456   123456
   Data Set: SEL-351-RECLOSING_DIRECTIONAL_OVERCURRENT/LLN3$Recloser

GEC_ALSTOM_123/LLN0$GO$GECGooseDSet
   01-03-A7-00-00-01  3:643   12568      56         126    MSG CORRUPTED
   Data Set: GEC_ALSTOM_123/LLN2$Relay

#>>
```

No GOOSE receive and/or GOOSE transmit subscriptions:

```
##>>GOO <Enter>

GOOSE Transmit Status

   MultiCastAddr   Ptag:Vlan  StNum   SqNum   TTL      Code
----------------------------------------------------------------------------
No GOOSE Tx subscriptions available

GOOSE Receive Status

   MultiCastAddr   Ptag:Vlan  StNum   SqNum   TTL      Code
----------------------------------------------------------------------------
No GOOSE Rx subscriptions available

##>>
```

GOOSE is disabled by settings (EGSE := N):

```
#>GOO <Enter>

GOOSE is disabled by settings.  No GOOSE statistics available.

#>
```

Error during the processing of the IEC 61850 CID file:

```
#>GOO <Enter>

Error detected in the CID file parsing. All GOOSE processing disabled.

#>
```

GOOSE command is executed during CID file processing:

```
#>GOO <Enter>

CID file is currently being parsed. No GOOSE statistics available.

#>
```

SEL-421 is disabled (after CID file parsed successfully):

```
#>GOO <Enter>

Host Disabled. All GOOSE processing disabled.

#>
```

The **GOOSE** command supports only one optional parameter, *cnt*. The *cnt* parameter causes the **GOOSE** command to be repeated *cnt* times. The valid range of *cnt* is from 1–65535; and the default value of *cnt* is 1.

HELP

Because only a limited set of commands may be available at your current access level, you may want to display a list of available commands. Use the **HELP** command to display a list of available commands for your current access level. The **HELP** command format and options are shown in *Table 4.14*.

Table 4.14 HELP Command Options

Command	Description
HELP	Display command information for the current access level.
HELP command	Display information for a specific command.

ID

It may be necessary to identify the firmware version of your Ethernet card for diagnostic purposes or to verify that it is compatible with the firmware version of your host. Use the **ID** command to identify the firmware version and several other internal parameters for your Ethernet card. The information displayed by the **ID** command is described in *Table 4.15*.

Table 4.15 ID Command Internal Parameters Displayed

Parameter	Description
FID	Firmware ID
BFID	SELBOOT Firmware ID
CID	Firmware Checksum
DEVID	Device ID
PARTNO	Part Number
CONFIG	Configuration ID

If the Ethernet card includes the IEC 61850 protocol option and the protocol is enabled (E61850 := Y), the **ID** command will display the following additional information:

- iedName: the IED name (e.g., SEL-421_OtterTail)
- type: the IED type (e.g., SEL_421)
- configVersion: the CID file configuration version (e.g., ICD-421-R100-V0-Z001001-20060512)

If the Ethernet card encounters an error while parsing the CID file, the value of the iedName, type, and configVersion fields shall be set to "PARSE FAILURE"; otherwise, the fields shall contain the CID file values as shown in the examples above.

MEMORY

The **MEMORY** command is a diagnostic command for determining if the Ethernet card is using onboard RAM properly. Use the **MEMORY** command to display RAM statistics for the following areas: memory in use, free memory, free memory blocks, and bytes in largest available block.

PING

When you are setting up or testing substation networks, it is helpful to determine if the network is connected properly and if the other devices are powered up and configured properly. Use the **PING** command to determine if another node on the network is available and connected to the network. The Ethernet card sends ping messages to the remote node until you interrupt the Ethernet card by pressing **<Enter>**. Command options for the **PING** command are shown in *Table 4.16*.

Table 4.16 PING Command Options

Command	Description
PING addr	Ping the address represented by addr every second.
PING addr n	Ping the address addr once every n seconds, where n is a value from 1–255.

The **PING** command requires the *addr* parameter, which can either be a name in the NAR table for the host, or an actual IP address. In response to the **PING** command, the Ethernet card displays the status of each ping attempt. When you stop the ping process, the Ethernet card displays several statistics to summarize the ping attempts.

QUIT

To close your connection to the Ethernet card and start a connection to another device without closing your terminal application, use the **QUIT** command. For example, use **QUIT** to log out and automatically terminate a Telnet session. You may then open a new Telnet session from your Telnet application. You can also use the **QUIT** command to log out of the Ethernet card for security purposes when the connection will not be closed. For example, if you are connected to an Ethernet card in a host from one of the host serial ports, you can log out without closing the transparent connection to the Ethernet card.

STATUS

Use the **STATUS** command to display the self-test status and configuration of the Ethernet card. The Ethernet card displays self-test results as either OK or FAIL. The Ethernet card displays network configuration information and network statistics.

If the Ethernet card includes the IEC 61850 protocol option and the protocol is enabled (E61850 := Y), the card shall append an error message to the output of the **STATUS** command if it fails to successfully parse the current CID file.

STATUS command example (including CID parse error):

```
#>STA <Enter>
ETHERNET PROCESSOR WITH IEC 61850 AND DNP                TIME: 14:11:25

FID=SEL-2702-R107-V2-Z000000-D20071225
BFID=SLBT-2701-R103-V0-Z000000-D19981001
  MAC: 00-30-A7-00-01-01

  SELF-TEST
   RAM       SRAM      EXE       SLBT      SETTINGS  STORAGE   CONFIG    HOST
   OK        OK        OK        OK        OK        OK        OK        OK

              PORT      MEDIA           SPEED
  PRIMARY     B         10/100 BASE-T   100
  STANDBY     A         10/100 BASE-T   100
  ACTIVE PORT:  PRIMARY   LINK OK

  IP ADDRESS: 192.168.0.97
  SUBNET MASK: 255.255.0.0
  DEFAULT ROUTER: 192.168.0.1

  PACKETS:      IP                    BYTES:       IP
   SENT:        33                     SENT:       2051
   RECEIVED:    48                     RECEIVED:   3780

  CONNECTIONS:                        ERRORS DETECTED:
   LISTENING:   6                      SENT:       0
   ACTIVE:      1                      RECEIVED:   0

Error detected in the CID file parsing. All IEC61850 processing disabled.

#>
```

TIME

The **TIME** command is described in *Table 4.17*.

Table 4.17 TIME Command

Command	Description	Access Level
TIME	Display internal clock date.	1 or 2
TIME hh:mm	Set internal clock time to hh hours (24 hour time), mm minutes and 0 seconds.	2
TIME hh:mm:ss	Set internal clock time to hh hours (24 hour time), mm minutes, and ss seconds.	2

Some hosts support time synchronization of the Ethernet card from the host or time synchronization of the host from the Ethernet card. See the host-specific section for more information on time synchronization.

Communications Card Database

The SEL-421 presents a database to an installed communications card. This database includes a variety of data within the relay that are available for the communications card. The database includes the regions and data described in *Table 4.18*. Use the **MAP** and **VIEW** commands to display maps and contents of the database regions. See *Section 9: ASCII Command Reference in the Reference Manual* for more information.

Table 4.18 Communications Card Database Regions

Region Name	Contents	Update Rate
LOCAL	Relay identification data including FID, Relay ID, and active protection settings group	Updated on settings change and whenever monitored values change
METER	Real-time metering and measurement data	0.5 s
DEMAND	Demand and peak demand measurement data	15 s
TARGET	Selected rows of Relay Word bit data	0.5 s
HISTORY	Relay event history records for the 20 most recent events	Within 15 s of any new event
BREAKER	Summary circuit breaker monitor data updated every 15 s	15 s
STATUS	Self-test diagnostic status data	5 s
ANALOGS	Protection and automation math variables	0.5 s
STATE	Elements defined as SER points	0.5 s of any new event

Data within the communications card regions is available for mapping to any protocol over the Ethernet interface.

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 4.19*.

Table 4.19 SEL-421 Communications Card 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	Bit map of status flags: 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 4.20* for the Map.

Table 4.20 SEL-421 Communications Card Database Structure—METER Region (Sheet 1 of 2)

Address (Hex)	Name	Type	Description
1000	_YEAR	int	4-digit year when data was sampled
1001	DAY_OF_YEAR	int	1–366 day when data was sampled
1002	TIME(ms)	long int	Time of day in msec when data was sampled (0–86,400,00)
1004	FREQ	float	System frequency
1006	VDC1	float	Battery 1 voltage
1008	VDC2	float	Battery 2 voltage
100A, 100C	IA1	float[2]	Line phase A current magnitude and phase
100E, 1010	IB1	float[2]	Line phase B current magnitude and phase
1012, 1014	IC1	float[2]	Line phase C current magnitude and phase
1016, 1018	I0_1	float[2]	Line Terminal W 0-sequence current magnitude and phase
101A, 101C	I1_1	float[2]	Line 1-sequence current magnitude and phase
101E, 1020	I2_1	float[2]	Line 2-sequence current magnitude and phase
1022, 1024	IA2	float[2]	Breaker 1 phase A current magnitude and phase
1026, 1028	IB2	float[2]	Breaker 1 phase B current magnitude and phase
102A, 102C	IC2	float[2]	Breaker 1 phase C current magnitude and phase
102E, 1030	IA3	float[2]	Breaker 2 phase A current magnitude and phase
1032, 1034	IB3	float[2]	Breaker 2 phase B current magnitude and phase
1036, 1038	IC3	float[2]	Breaker 2 phase C current magnitude and phase
103A, 103C	VA	float[2]	phase A voltage magnitude and phase
103E, 1040	VB	float[2]	phase B voltage magnitude and phase
1042, 1044	VC	float[2]	phase C voltage magnitude and phase
1046, 1048	V0	float[2]	0-sequence voltage magnitude and phase
104A, 104C	V1	float[2]	1-sequence voltage magnitude and phase
104E, 1050	V2	float[2]	2-sequence voltage magnitude and phase
1052	VP	float	Polarizing voltage magnitude
1054	VS1	float	Synchronizing voltage 1 magnitude
1056	VS2	float	Synchronizing voltage 2 magnitude

Table 4.20 SEL-421 Communications Card Database Structure—METER Region (Sheet 2 of 2)

Address (Hex)	Name	Type	Description
1058	ANG1_DIF	float	VS1 and VP angle difference, in degrees
105A	VS1_SLIP	float	VS1 frequency slip with respect to VP, in HZ
105C	ANG2_DIF	float	VS2 and VP angle difference, in degrees
105E	VS2_SLIP	float	VS2 frequency slip with respect to VP, in HZ
1060	PA	float	phase A real power
1062	PB	float	phase B real power
1064	PC	float	phase C real power
1066	P	float	total real power
1068	QA	float	phase A reactive power
106A	QB	float	phase B reactive power
106C	QC	float	phase C reactive power
106E	Q	float	total reactive power
1070	SA	float	phase A apparent power, if available
1072	SB	float	phase B apparent power, if available
1074	SC	float	phase C apparent power, if available
1076	S	float	total apparent power
1078	PFA	float	phase A power factor
107A	PFB	float	phase power factor
107C	PFC	float	phase power factor
107E	PF	float	3-phase power factor
1080	PEA	float	positive phase A energy in KWh
1082	PEB	float	positive phase B energy in KWh
1084	PEC	float	positive phase C energy in KWh
1086	PE	float	total positive energy in KWh
1088	NEA	float	negative phase A energy in KWh
108A	NEB	float	negative phase B energy in KWh
108C	NEC	float	negative phase C energy in KWh
108E	NE	float	total negative energy in KWh

The DEMAND region contains demand and peak demand information. This region is updated every 15 seconds. See *Table 4.21* for the Map.

Table 4.21 SEL-421 Communications Card Database Structure—DEMAND Region (Sheet 1 of 2)

Address (Hex)	Name	Type	Description
2000	_YEAR	int	4-digit year when data was sampled
2001	DAY_OF_YEAR	int	1–366 day when data was sampled
2002	TIME(ms)	long int	Time of day in msec when data was sampled (0–86,400,00)
2004	IA	float	phase A demand current
2006	IB	float	phase B demand current

Table 4.21 SEL-421 Communications Card Database Structure—DEMAND Region (Sheet 2 of 2)

Address (Hex)	Name	Type	Description
2008	IC	float	phase C demand current
200A	I0	float	0-sequence demand current
200C	I2	float	2-sequence demand current
200E	PA	float	phase A demand real power
2010	PB	float	phase B demand real power
2012	PC	float	phase C demand real power
2014	P	float	total demand real power
2016	SA	float	phase A demand apparent power
2018	SB	float	phase B demand apparent power
201A	SC	float	phase C demand apparent power
201C	S	float	total demand apparent power
201E	PK_IA	float	phase A demand current
2020	PK_IB	float	phase B demand current
2022	PK_IC	float	phase C demand current
2024	PK_I0	float	0-sequence demand current
2026	PK_I2	float	2-sequence demand current
2028	PK_PA	float	phase A demand real power
202A	PK_PB	float	phase B demand real power
202C	PK_PC	float	phase C demand real power
202E	PK_P	float	total demand real power
2030	PK_SA	float	phase A demand apparent power
2032	PK_SB	float	phase B demand apparent power
2034	PK_SC	float	phase C demand apparent power
2036	PK_S	float	total demand apparent power

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 4.22* for the map. See *Appendix A: Relay Word Bits* in the Reference Manual for detailed information on the Relay Word bits.

Table 4.22 SEL-421 Communications Card Database Structure—TARGET Region

Address (Hex)	Name	Type	Description
3000	_YEAR	int	4-digit year when data was sampled
3001	DAY_OF_YEAR	int	1–366 day when data was sampled
3002	TIME(ms)	long int	Time of day in msec when data was sampled (0–86,400,000)
3004	TARGET	char[~240]	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 4.23* for the map.

Table 4.23 SEL-421 Communications Card Database Structure—HISTORY Region

Address (Hex)	Name	Type	Description
4000	_YEAR	int	4-digit year when data was sampled
4001	DAY_OF_YEAR	int	1–366 day when data was sampled
4002	TIME(ms)	long int	Time of day in msec when data was sampled (0–86,400,000)
4004	REF_NUM	int[10]	Event serial number
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[60]	Event type string
4090	GROUP	int[10]	Active group during fault
409A	FREQ	float[10]	System frequency at time of fault
40AE	TARGETS	char[160]	System targets from event
414E	FAULT_LOC	float[10]	Fault location
4162	SHOT	int[10]	Recloser shot counter (sum of 1-pole and 3-pole)
416C	SHOT_1P	int[10]	Single-pole recloser counter
4176	SHOT_3P	int[10]	Three-pole recloser counter
4180	CURR	int[10]	Fault current in primary amps

The BREAKER region contains some of the information available in a summary Breaker report. This region is updated every 15 seconds. See *Table 4.24* for the map.

Table 4.24 SEL-421 Communications Card Database Structure—BREAKER Region (Sheet 1 of 2)

Address (Hex)	Name	Type	Description
5000	_YEAR	int	4-digit year when data was sampled
5001	DAY_OF_YEAR	int	1–366 day when data was sampled
5002	TIME(ms)	long int	Time of day in msec when data was sampled (0–86,400,000)
5004	BCWA1	float	Breaker 1 phase A breaker wear (%)
5006	BCWB1	float	Breaker 1 phase B breaker wear (%)
5008	BCWC1	float	Breaker 1 phase C breaker wear (%)
500A	BCWA2	float	Breaker 2 phase A breaker wear (%)
500C	BCWB2	float	Breaker 2 phase B breaker wear (%)
500E	BCWC2	float	Breaker 2 phase C breaker wear (%)
5010	CURA1	float	Breaker 1 phase A accumulated current (kA)
5012	CURB1	float	Breaker 1 phase B accumulated current (kA)

Table 4.24 SEL-421 Communications Card Database Structure—BREAKER Region (Sheet 2 of 2)

Address (Hex)	Name	Type	Description
5014	CURC1	float	Breaker 1 phase C accumulated current (kA)
5016	CURA2	float	Breaker 2 phase A accumulated current (kA)
5018	CURB2	float	Breaker 2 phase B accumulated current (kA)
501A	CURC2	float	Breaker 2 phase C accumulated current (kA)
501C	NOPA1	long int	Breaker 1 phase A number of operations
501E	NOPB1	long int	Breaker 1 phase B number of operations
5020	NOPC1	long int	Breaker 1 phase C number of operations
5022	NOPA2	long int	Breaker 2 phase A number of operations
5024	NOPB2	long int	Breaker 2 phase B number of operations
5026	NOPC2	long int	Breaker 2 phase C number of operations

The STATUS region contains complete relay status information. This region is updated every 5 seconds. See *Table 4.25* for the map.

Table 4.25 SEL-421 Communications Card Database Structure—STATUS Region (Sheet 1 of 2)

Address (Hex)	Name	Type	Description
6000	_YEAR	int	4-digit year when data was sampled
6001	DAY_OF_YEAR	int	1–366 day when data was sampled
6002	TIME(ms)	long int	Time of day in msec when data was sampled (0–86,400,000)
6004	CH1(mV)	int	Channel 1 offset
6005	CH2(mV)	int	Channel 2 offset
6006	CH3(mV)	int	Channel 3 offset
6007	CH4(mV)	int	Channel 4 offset
6008	CH5(mV)	int	Channel 5 offset
6009	CH6(mV)	int	Channel 6 offset
600A	CH7(mV)	int	Channel 7 offset
600B	CH8(mV)	int	Channel 8 offset
600C	CH9(mV)	int	Channel 9 offset
600D	CH10(mV)	int	Channel 10 offset
600E	CH11(mV)	int	Channel 11 offset
600F	CH12(mV)	int	Channel 12 offset
6010	MOF(mV)	int	Master offset
6011	OFF_WARN	char[8]	Offset warning string
6019	OFF_FAIL	char[8]	Offset failure string
6021	PS3(V)	float	3.3 Volt power supply voltage
6023	PS5(V)	float	5 Volt power supply voltage
6025	PS_N5(V)	float	-5 Volt regulated voltage
6027	PS15(V)	float	15 Volt power supply voltage
6029	PS_N15(V)	float	-15 Volt power supply voltage

Table 4.25 SEL-421 Communications Card Database Structure—STATUS Region (Sheet 2 of 2)

Address (Hex)	Name	Type	Description
602B	PS_WARN	char[8]	Power supply warning string
6033	PS_FAIL	char[8]	Power supply failure string
603B	HW_FAIL	char[40]	Hardware failure strings
6063	CC_STA	char[40]	Comm. card status strings
608B	PORT_STA	char[160]	Serial port status strings
612B	TIME_SRC	char[10]	Time source
6135	LOG_ERR	char[40]	SELOGIC error strings
615D	TEST_MD	char[160]	Test mode string

The ANALOGS region contains protection and automation variables. This region is updated every 0.5 seconds. See *Table 4.26* for the map.

Table 4.26 SEL-421 Communications Card Database Structure—ANALOGS Region

Address (Hex)	Name	Type	Description
7000	_YEAR	int	4-digit year when data was sampled
7001	DAY_OF_YEAR	int	1–366 day when data was sampled
7002	TIME(ms)	long int	Time of day in msec when data was sampled (0–86400000)
7004	PMV01_64	float[64]	PMV01–PMV64
7084	AMV001_256	float[256]	AMV001–AMV256

The STATE region contains elements defined with the **SET R** command and an attached SOE queue that holds up to 100 records. The relay updates this region within 0.5 seconds of any new events. Communications card protocols that require state changes with SOE-quality timestamps must retrieve this data from the STATE region. See *Table 4.27* for the map. See *DNP LAN/WAN Application Example on page R.6.49* for DNP LAN/WAN implementation details.

Table 4.27 SEL-421 Communications Card Database Structure—STATE Region

Address (Hex)	Name	Type	Description
8000	_YEAR	int	4-digit year when data was updated
8001	DAY_OF_YEAR	int	1–366 day when data was updated
8002	TIME(ms)	long int	Time of day in msec when data was updated (0–86,400,00)
8004	ELEMENTS	int[16]	250 Relay Word bits defined to be SER points; SER point 1 goes in first register bit 0,...
8014	CARD_SER	int[8]	128 Relay Word bits defined to be SER points from R CC settings.

The communications card 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 4.18*). An example of the **MAP** command is shown in *Figure 4.4*.

```
=>>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
VDC1          1006h              float
VDC2          1008h              float
IA1           100ah              float[2]
IB1           100eh              float[2]
IC1           1012h              float[2]
I0_1          1016h              float[2]
I1_1          101ah              float[2]

I2_1          101eh              float[2]

IA2           1022h              float[2]
IB2           1026h              float[2]
IC2           102ah              float[2]
IA3           102eh              float[2]
IB3           1032h              float[2]
IC3           1036h              float[2]
VA            103ah              float[2]
VB            103eh              float[2]
VC            1042h              float[2]
V0            1046h              float[2]
V1            104ah              float[2]
V2            104eh              float[2]
VP            1052h              float
VS1           1054h              float
VS2           1056h              float
ANG1_DIF      1058h              float
VS1_SLIP      105ah              float
ANG2_DIF      105ch              float
VS2_SLIP      105eh              float
PA            1060h              float
PB            1062h              float
PC            1064h              float
P             1066h              float
QA            1068h              float
QB            106ah              float
QC            106ch              float
Q             106eh              float
SA            1070h              float
SB            1072h              float
SC            1074h              float
S             1076h              float
PFA           1078h              float
PFB           107ah              float
PFC           107ch              float
PF            107eh              float
PEA           1080h              float
PEB           1082h              float
PEC           1084h              float
PE            1086h              float
NEA           1088h              float
NEB           108ah              float
NEC           108ch              float
NE            108eh              float
```

Figure 4.4 MAP 1:METER Command Example

Section 5

SEL Communications Protocols

This section describes features of the SEL-421 Relay communications protocols and includes the following topics:

Serial Port Hardware Protocol

The serial ports comply with the EIA/TIA-232 Standard, commonly referred to as EIA-232 (formerly known as RS-232). The serial ports support RTS/CTS hardware flow control. See also *Software Flow Control on page R.5.7*.

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 5.1* shows actions the relay takes for the RTSCTS setting values and the conditions relevant to hardware flow control.

Table 5.1 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, 8 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.

Software Protocol Selections

The SEL-421 supports the protocols and command sets shown in *Table 5.2*.

Table 5.2 Supported Serial Command Sets (Sheet 1 of 2)

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 SER	Binary SER commands and responses
MBA or MBB	SEL MIRRORED BITS® communications	Binary high-speed control commands

Table 5.2 Supported Serial Command Sets (Sheet 2 of 2)

PROTO Setting Value	Command Set	Description
PMU	Phasor Measurement Unit	Binary synchrophasor protocol, as selected by Port Setting PMUMODE and Global Setting MFRMT. See *Synchrophasors on page R.7.1*
PMU	SEL Fast Operate	Binary operation commands
RTD	SEL Fast Message protocol for Resistance Temperature Detector (RTD) data	Up to 12 analog temperature readings from the SEL-2600A.
DNP	DNP3 Level 2 Slave	Binary commands and responses. See *Section 6: DNP3 Communications in the Reference Manual*

Virtual Serial Ports

Actual serial ports are described in *Serial Port Hardware Protocol on page R.5.1*. In addition to actual serial ports, the SEL-421 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 SEL-421 to use virtual serial ports encapsulated in SEL MIRRORED BITS communications links, DNP3 links, and through the Telnet mechanism of an installed Ethernet card.

Protocol Active When Setting PROTO := SEL

This subsection 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 9: ASCII Command Reference in the Reference Manual*. *Table 5.3* shows the subset of the ASCII control characters used in this section.

Table 5.3 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 or Compressed 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 using 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 5.4 lists the Compressed ASCII commands and contents of the command responses. The Compressed ASCII commands are described in *Section 9: ASCII Command Reference in the Reference Manual*.

Table 5.4 Compressed ASCII Commands (Sheet 1 of 2)

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
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

Table 5.4 Compressed ASCII Commands (Sheet 2 of 2)

Command	Response	Access Level
ID	Relay identification	0
SNS	ASCII names for SER data reported in Fast Meter	0

CASCII Configuration Message for Compressed Level 0 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 10 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.

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 in order 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 SEL-421 communicates with an SEL Communications Processor. The communications processor performs auto-configuration 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 binary data stream to connect transparently to the SEL-421 and use the ASCII data stream for commands and responses.

Automatic Messages

If you enable automatic messages, AUTO = Y, the SEL-421 issues a message any time the relay powers up, 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: On power up, 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.

Timeout

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.

SEL Fast Meter, Fast Operate, and Fast SER Messages

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 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. Reference the section, *Interleaved ASCII and Binary Messages on page R.5.7* and *Section 6: SEL Communications Processor Applications in the Applications Handbook*.

NOTE: Starting with firmware revision R112, synchrophasor data in the SEL Fast Message format is no longer available when PROTO:= SEL. See Section 7: Synchrophasors for details.

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 SEL-421. To support this type of development, you will also need to contact SEL for Fast Message protocol details.

Table 5.5 lists the two-byte Fast Commands and the actions the relay takes in response to each command.

Table 5.5 Fast Commands and Response Descriptions

Command (Hex)	Name	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, if setting FASTOP :=Y for this port.
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 5.6*. Each Fast Operate command also includes additional bytes that specify a remote bit or circuit breaker bit.

Table 5.6 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 5.7* lists the Fast SER function codes and the actions the relay takes in response to each command.

Table 5.7 Fast Message Command Function Codes Used With Fast SER (A546 Message) and Relay Response Descriptions

Function Code (Hex)	Function	Relay Action
00h	Fast SER message definition block request	Relay transmits Fast SER 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.

The SEL Fast Message Synchrophasor protocol is covered in *Section 7: 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 5.8 lists commands and command usage in the recommended order of execution for automatic configuration.

Table 5.8 Commands in Recommended Sequence for Automatic Configuration (Sheet 1 of 2)

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

Table 5.8 Commands in Recommended Sequence for Automatic Configuration (Sheet 2 of 2)

Command ASCII or hexadecimal (h suffix)	Response	Usage
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

Virtual File Interface

You can retrieve and send data as files through the SEL-421 virtual file interface. 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 a communications card, the file transfer protocol(s) supported by the card can present the file structure and send and receive files.

The SEL-421 has a two-level file structure. There is one file at the root level and three subdirectories or folders. *Table 5.9* shows the directories and the contents of each directory.

Table 5.9 Virtual File Structure

Directory	Usage	Access Level
root	CFG.TXT file, and the SETTINGS, REPORTS, and EVENTS directories (below)	1
SETTINGS	Relay settings	1
REPORTS	SER, circuit breaker, and history reports	1
EVENTS	EVE, CEV, COMTRADE and history reports	1

System Data Format (SDF)

All files use the SDF (System Data Format) unless otherwise specified. The files may contain keywords to aid external support software 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 subdirectories and one file, CFG.TXT.

CFG.TXT File (Read-Only)

The CFG.TXT file contains general configuration information about the relay and each setting class. External support software retrieves the CFG.TXT file to interact automatically with the connected relay.

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 the text files. External settings support software functions by reading settings from all of these files. 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. Changing settings with external support software 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 SEL-421.

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 steps 2–4 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 all of 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 5.10* summarizes the settings files. The settings class is designated by *c*, and the settings instance number is *n*.

ERR.TXT (Read-Only)

The ERR.TXT file contents are based on the most recent SET_*cn*.TXT file you wrote 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.

Table 5.10 Settings Directory Files

Settings Class	Filename	Settings Description	Read Access Level	Write Access Level
S	SET_S*n*.TXT	Group *n*; *n* in range 1–6	1, B, P, A, O, 2	P, 2
G	SET_G1.TXT	Global	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
P	SET_P*n*.TXT	Port; *n* in range 1, 2, 3, 5, F	1, B, P, A, O, 2	P, A, O, 2
D	SET_D1.TXT	DNP remapping (serial)	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
O	SET_O1.TXT	Contact outputs	1, B, P, A, O, 2	O, 2
A	SET_A*n*.TXT	Automation; *n* in range 1–10	1, B, P, A, O, 2	A, 2
L	SET_L*n*.TXT	Protection logic; *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
M	SET_SM.TXT	Circuit breaker monitor	1, B, P, A, O, 2	P, 2
All	SET_ALL.TXT	All instances of all settings classes	1, B, P, A, O, 2	NA
All	ERR.TXT	Error log for most recently written settings file	1, B, P, A, O, 2	NA

Reports Directory

Use the REPORTS directory to retrieve files that contain the reports shown in *Table 5.11*. Note that the relay provides a report file that contains the latest information each time you request the file. You can use the **FILE DIR REPORTS** command to display the contents of the REPORTS directory.

Table 5.11 REPORTS Directory Files

File	Usage: All are read-only files
SER.TXT	ASCII SER report, clears SER when read
CSER.TXT	Compressed ASCII SER report
BRE_1.TXT	BRE 1 H report (Circuit Breaker 1)
BRE_2.TXT	BRE 2 H report (Circuit Breaker 2)
BRE_S1.TXT	BRE 1 report (Circuit Breaker 1)
BRE_S2.TXT	BRE 2 report (Circuit Breaker 2)
CBRE.TXT	Compressed ASCII CBR report for both circuit breakers
HISTORY.TXT	History file
CHISTORY.TXT	Compressed ASCII history file

Events Directory

The relay provides history, event reports, and oscillography files in the EVENTS directory. Event reports are available in the following formats: 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 oscilligraphy is available in binary COMTRADE (IEEE C37.111-1999) format at the sample rate (SRATE) and length (LER) settings in effect at the time the event is triggered. You can use the **FILE DIR EVENTS** command to display the contents of the EVENTS directory.

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_, C4_, C8_, 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 5.12*. Event oscillography in COMTRADE format consists of three files (.CFG, .DAT, and .HDR) that conform to the COMTRADE standard. For an example of retrieving these files see *Retrieving Event Report Data Files: Terminal on page U.4.50*.

Table 5.12 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	8-samples/cycle Compressed ASCII event report; read-only
E4_10001.TXT	4-samples/cycle event report; read-only
E8_10001.TXT	8-samples/cycle event report; read-only
HR_10001.CFG	Sample/second COMTRADE configuration file; read-only
HR_10001.DAT	Sample/second COMTRADE binary data file; read-only
HR_10001.HDR	Sample/second COMTRADE header file; read-only

Ethernet Card Subdirectory

If an Ethernet card with the DNP3 protocol is installed into an SEL-421, the card settings subdirectory (CARD) is accessible as a subdirectory of the SETTINGS directory.

Table 5.13 CARD Subdirectory

Path and Filename	File Description	Read Access Level	Write Access Level
\SETTINGS\CARD\SET_DNPn.TXT	DNP custom remapping (Ethernet); n in range 1–5	1, B, P, A, O, 2	P, A, O, 2
\SETTINGS\CARD\ERR.TXT	List of all error messages from the last write of a settings file (SET_CC1.TXT or SET_DNPn.TXT)	1, B, P, A, O, 2	NA

SEL MIRRORED BITS Communications

Overview

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 POTT and DCB.

SEL products support several variations of MIRRORED BITS communications protocols. Through port settings, you can set the SEL-421 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 5.14* summarizes MIRRORED BITS communications features.

Table 5.14 MIRRORED BITS Communications Features

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
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

NOTE: Complete all of the port settings for a port that you use for MIRRORED BITS communications before you connect an external MIRRORED BITS communications device. If you connect a MIRRORED BITS communications device to a port that is not set for MIRRORED BITS communications operation, the port will be continuously busy.

The SEL-421 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 for MIRRORED BITS communications Channel A or PROTO := MBB 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 through 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 (up to a total of eight) 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.
- Analog Channels. Setting MBNUMAN controls the number of Analog Channels.
  - 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).
- 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.

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

MB8

While the SEL-421 does not have a setting for the MB8 protocol implemented in some SEL products, you can configure the relay to communicate with SEL devices set to MB8A or MB8B. Set the SEL-421 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

Depending on the settings, the SEL-421 transmits a MIRRORED BITS communications message every 1/8 to 1/2 of an electrical cycle (see *Table 5.17*). 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:

NOTE: c represents the MIRRORED BITS channel (A or B), n represents the MIRRORED BITS data channel data number (1–8).

- ➤ 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.

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-421 communicating with another SEL-421 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 5.17* 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-421 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 enable loopback testing. 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 (see *Message Decoding and Integrity Checks on page R.5.17*)

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 using SELOGIC control equations. You can use these alarm conditions to program the relay to take appropriate action when it detects 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

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.

NOTE: You must consider the idle time in calculations of data transfer latency through a Pulsar MBT modem system.

The relay sets RTS to a negative voltage at the EIA-232 connector to signify that Mirrored Bits communications matches this specification. Other relays may set RTS to a positive voltage at the EIA-232 connector to signify usage of the R6 version or the R version of Mirrored Bits communications.

Settings

The SEL-421 Port settings associated with Mirrored Bits communications are shown in *Table 5.15* and *Table 5.16*.

Set PROTO := MBA to enable the Mirrored Bits communications protocol Channel A on this port. Set PROTO := MBB to enable the Mirrored Bits communications protocol Channel B on this port.

Table 5.15 General Port Settings Used With Mirrored Bits Communications

Name	Description	Range	Default
PROTO	Protocol.	None, SEL, DNP[a], MBA, MBB, 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
RTSCTS	Hardware handshaking enable.	Y, N	N

[a] Optional relay feature.

Setting SPEED:= SYNC (available only on the rear-panel serial ports for which PROTO:= MBA or MBB) 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 baud rate up to 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 immediately when it no longer detects a channel error.

The relay uses the CBADPU setting to determine when to assert CBADA and CBADB. If the short-term channel down time ratio exceeds CBADPU, the relay asserts the appropriate CBAD bit.

NOTE: You must use paced transmission mode (set TXMODE := P) when connecting to an SEL product that is not an SEL-400 series relay.

The TXMODE setting provides compatibility with SEL devices that are not SEL-400 series relays. The SEL-421 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 5.17*.

Table 5.16 MIRRORED BITS Communications Protocol Settings

Name	Description	Range	Default
TX_ID	MIRRORED BITS communications ID of this device	1–4	2
RX_ID	MIRRORED BITS communications ID of device connected to this port	1–4; must be different than TX_ID	1
RBADPU	Outage duration to set RBAD	1–10000 seconds	10
CBADPU	Channel unavailability to set CBAD	1–100000 parts per million	20000
TXMODE	Transmission mode[a]	N (normal), P (paced)	N
MBNUM	Number of MIRRORED BITS communications data channels used for logic bits	0–8	8
RMB1FL[b]	RMB1 channel fail state	0, 1, P	P
RMB1PU[b]	RMB1 pickup message count	1–8	1
RMB1DO[b]	RMB1 dropout message count	1–8	1
• • •	• • •		
RMB8FL[b]	RMB8 channel fail state	0, 1, P	P
RMB8PU[b]	RMB8 pickup message count	1–8	1
RMB8DO[b]	RMB8 dropout message count	1–8	1
MBTIME	MIRRORED BITS time synchronize enable	Y, N	N
MBNUMAN	Number of analog data channels. Hidden and set to 0 if MBNUM := 7 or 8.	0–n, n=7–MBNUM	0
MBANA1[c]	Selection for Analog Channel 1	Analog quantity label	LIAFM
MBANA2[c]	Selection for Analog Channel 2	Analog quantity label	LIBFM
MBANA3[c]	Selection for Analog Channel 3	Analog quantity label	LICFM
MBANA4[c]	Selection for Analog Channel 4	Analog quantity label	VAFM
MBANA5[c]	Selection for Analog Channel 5	Analog quantity label	VBFM
MBANA6[c]	Selection for Analog Channel 6	Analog quantity label	VCFM
MBANA7[c]	Selection for Analog Channel 7	Analog quantity label	VABRMS
MBNUMVT	Number of virtual terminal channels	OFF,0–n, n=7–MBNUM–MBNUMAN	OFF

[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 5.17 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 5.18* lists the MIRRORED BITS communications ID settings for Relays X, Y, and Z.

Table 5.18 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)

SEL Distributed Port Switch Protocol (LMD) permits multiple devices to share a common communications channel. This protocol is appropriate for low-cost, low-speed port switching applications where updating a real-time database is not a requirement. The SEL-421 does not have built in LMD protocol, but you can connect an SEL-421 to an SEL-2885 EIA-232/485 Protocol Converter 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. (Contact your local Technical Service Center, the SEL factory, or visit our website at www.selinc.com for a copy of the SEL-2885 product flyer.)

Initialization

For the first 30 seconds after applying power to the relay, the SEL-2885 listens for an initialization string from the relay. The initialization string must be enclosed in square brackets ([ ]). The following table describes the initialization string fields. To send this string automatically, set AUTO to Y and append the initialization string to the relay ID setting so that it is included in the relay power-up header.

Table 5.19 SEL-2885 Initialization String [MODE PREFIX ADDR:SPEED]

Field	Optional or Required	Value	Description
[	Required	[	Opening bracket is start of string
Mode	Optional	Not specified N B	Treat as N, below Addressing for ASCII device Addressing for binary devices
PREFIX	Required	@, #, $, %, or &	Prefix character
ADDR	Required	01–99	Two digit address in the range 01-99
:	Optional; needed if SPEED is specified	Colon “:”	Colon “:”, then one of the following codes to match the port SPEED setting
SPEED	Optional	12 24 48 96	1200 bps 2400 bps 4800 bps 9600 bps
]	Required	]	Closing bracket is end of string

Operation

The following steps describe how to use the LMD operation of the SEL-2885:

Step 1. When you send the prefix and address, the SEL-2885 enables echo and message transmission.

You must wait until you receive a prompt before entering commands to avoid losing echoed characters while the external transmitter is warming up.

Step 2. You can use the commands that are available for the protocol setting of the port where the SEL-2885 is installed.

Step 3. If the port PROTO setting is set to SEL, you can use the **QUIT** command to terminate the connection.

If no data are sent to the relay before the port time-out period, this command automatically terminates the connection.

Step 4. If all relays in the multidrop network do not have the same prefix setting, enter the sequence **<Ctrl+X> QUIT <Enter>** before entering the prefix character to connect to another device.

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.

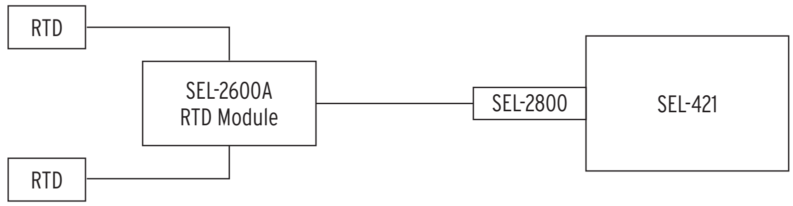

Figure 5.1 SEL-2600A RTD Module and the SEL-421

This protocol supports data acquisition of up to 12 temperature channels and places the results directly into predefined analog quantities (RTD01–RTD12) inside the relay for use in free-form 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 (www.selinc.com) for a copy of the SEL-2600A and SEL-2800 product flyers.

Initialization

Perform the following steps to prepare the SEL-421 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.

Operational Overview

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 through RTD12 for use in free-form 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 5.20* describes how to interpret the status bits.

Table 5.20 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.

To view the temperature measurements received from the SEL-2600A, issue the **MET T** command, as depicted in *Figure 5.2*.

```
=>>MET T <Enter>

Relay 1                                      Date: 05/17/2003  Time: 13:42:13.220
Station A                                    Serial Number: 0000000000

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 5.2 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 5.3*.

```
=>>MET T

SEL-2600 Failure
```

Figure 5.3 MET T Command Response for Status Problem

The three possible messages for status problems, with their interpretation, are indicated in *Table 5.21*.

Table 5.21 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	RTDxxST status bit asserted

Section 6
DNP3 Communications

The SEL-421 Relay provides a DNP3 (Distributed Network Protocol 3) Level 2 Slave interface for direct network connections to the relay. This section covers the following topics:

Introduction to DNP3

A SCADA (Supervisory Control and Data Acquisition) manufacturer developed DNP3 from the lower layers of IEC 60870-5. DNP3 was designed for use in telecontrol applications. The protocol has become popular for both local substation data collection and telecontrol. DNP is one of the protocols included in the IEEE Recommended Practice for Data Communication between Remote Terminal Units and Intelligent Electronic Devices in a Substation.

Rather than individual input and output points wired from the station RTU (remote terminal unit) to the station IEDs (intelligent electronic devices), many stations use DNP to convey measurement and control data to and from the RTU. The RTU then forwards data to the off-site master station. By using data communications 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 DNP standards. See the DNP User's Group web site (www.dnp.org) for more information on DNP standards, implementers of DNP, and tools for working with DNP.

DNP3 Specifications

DNP3 is a protocol with many features and many ways to accomplish tasks. DNP3 is defined in a series of specifications known as the Basic 4. A companion specification called the Subset Definitions simplifies DNP3 implementation by providing three standard interoperable implementation levels. The levels are listed in *Table 6.1*.

Table 6.1 DNP3 Implementation Levels

Level	Description	Equipment Types
1	Simple: limited communication 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 communication requirements	Large RTUs, SCADA masters

Each level is a proper superset of the next lower-numbered level. A higher subset level device can act as a master to a lower subset level device. For example, a typical SCADA master is a Level 3 device and can poll a Level 2 or Level 1 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. For example, a Level 1 device can poll a Level 3 device, but the Level 1 device can only access the features and data available in Level 1.

In addition to the Basic 4 and the Subset Definitions, the protocol is further refined by conformance requirements and a series of technical bulletins. The technical bulletins supplement the specifications with discussion and examples of specific features of DNP.

Data Handling

Objects

DNP3 uses a system of data references called objects, which the Basic 4 standard object library defines. Each subset level specification requires a minimum implementation of object types and also recommends several optional object types. Object types are commonly referred to as objects. DNP 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 DNP device.

If there can be more than one instance of a type of object, then 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.

Each object also includes multiple versions called variations. For example, Object 1 has three variations: 0, 1, and 2. Variation 0 is a shorthand reference used to request all Object 1 data from a DNP device. 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 defines what data or control points correspond with each index.

A master initiates all DNP message exchanges except unsolicited data. DNP terminology describes all points from the perspective of the master. Binary points for control that move from the master to the remote are called Binary Outputs, while binary status points within the remote are called Binary Inputs.

Function Codes

Each DNP 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 6.2*.

Table 6.2 Selected DNP3 Function Codes

Function Code	Function	Description
1	Read	Request data from the remote
2	Write	Send data to the remote
3	Select	First part of a select-before-execute operation
4	Execute	Second part of a select-before-execute operation
5	Direct operate	One-step operation with reply
6	Direct operate, no reply	One-step operation with no reply

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. DNP masters use qualifier codes to compose the shortest, most concise message possible when requesting points from a DNP remote.

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 to 16.

Access Methods

DNP has many features that help it obtain maximum possible message efficiency. Requests are sent with the least number of bytes using special objects, variations, and qualifiers that reduce the message size. Other features eliminate the continual exchange of data values that are not changing. These features optimize use of bandwidth and maximize performance over any speed connection.

DNP event data collection eliminates the need to use bandwidth to transmit values that have not changed. Event data are records of when observed measurements changed. For binary points, the remote 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 dead band. DNP remote devices collect event data in a buffer that the master can either request or the relay can send to the master without a request message. Data sent from the remote to the master without a polling request are called unsolicited data.

DNP data fit into one of four event classes: 0, 1, 2, or 3. Class 0 is reserved for reading the present value data (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.

DNP also supports static polling, simple polling of the present value of data points within the remote. By combining event data, unsolicited polling, and static polling, you can operate your system in one of the four access methods shown in *Table 6.3*.

The access methods listed in *Table 6.3* are in order of increasing communication efficiency. With various tradeoffs, each method is less demanding of communication bandwidth than the previous one. For example, unsolicited report-by-exception consumes less communication 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 in order to properly evaluate which access method provides optimum performance for your application.

Table 6.3 DNP 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

DNP masters use Object 12 control relay output block to perform DNP 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 DNP 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 DNP master implementations.

The control relay output block code selection specifies either a latch or pulse operation on the point. In many cases, DNP remotes have only a limited subset of the possible combinations of the code field. Sometimes, DNP remotes assign special operation characteristics to the latch and pulse selections. *Table 6.15* and *Table 6.16* describe control point operation for the SEL-421.

Conformance Testing

In addition to the protocol specifications, the DNP User's Group has approved conformance testing requirements for Level 1 and Level 2 remote 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 DNP implementers toward a higher level of interoperability. The SEL-421 is certified as having passed DNP3 Level 2 Slave conformance tests by a third-party organization, and the conformance certificate is on file at SEL.

Data Link Layer Operation

DNP 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 DNP device. While this feature helps you recognize a failed device or failed communications link quickly, it also adds significant overhead to the DNP conversation. Consider for your individual application whether you require this link integrity function at the expense of overall system speed and performance.

The DNP technical bulletin *(DNP Confirmation and Retry Guidelines 9804-002)* on confirmation processes 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 due to data collisions.

DNP3 in the SEL-421

The SEL-421 is a DNP3 Level 2 remote (slave) device. Additional implementation documentation describing DNP in the relay is in *DNP3 Documentation on page R.6.12*.

Data Access

NOTE: Because unsolicited messaging only operates properly in some situations, for maximum performance and minimum risk of configuration problems, use the polled report-by-exception access method. Configure the master to perform at least 10 event polls for every integrity poll.

You can use any of the data access methods listed in *Table 6.4*. *Table 6.4* also lists the SEL-421 DNP3 settings. You must configure the DNP master for the data access method you select.

Table 6.4 DNP Access Methods (Sheet 1 of 2)

Access Method	Master Polling	SEL-421 Settings
Polled static	Class 0	Set ECLASSB, ECLASSC, ECLASSA, ECLASSV to Off, UNSOL to No.
Polled report-by-exception	Class 0 occasionally, Class 1, 2, 3 frequently	Set ECLASSB, ECLSSC, ECLASSA, ECLASSV to the desired event class, UNSOL to No.

Table 6.4 DNP Access Methods (Sheet 2 of 2)

Access Method	Master Polling	SEL-421 Settings
Unsolicited report-by-exception	Class 0 occasionally, optional Class 1, 2, 3 less frequently, mainly relies on unsolicited messages	Set ECLASSB, ECLSSC, ECLASSA, ECLASSV to the desired event class, set UNSOL to Yes and PUNSOL to Yes or No.
Quiescent	Class 0, 1, 2, 3 never, relies completely on unsolicited messages	Set ECLASSB, ECLSSC, ECLASSA to the desired event class, set UNSOL and PUNSOL to Yes.

In both the unsolicited report-by-exception and quiescent polling methods shown in *Table 6.4*, you must make a selection for the PUNSOL setting. This setting enables or disables unsolicited data reporting at power up. If your master can send the DNP message to enable unsolicited reporting from the SEL-421, you should set PUNSOL to No.

While automatic unsolicited data transmission on power up is convenient, problems can result if your master is not prepared to start receiving data immediately on power up. 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 relays simultaneously begin sending data and waiting for acknowledgement messages.

Collision Avoidance

If your application uses unsolicited reporting, you must select a polled mode (polled static or polled report-by-exception) or a medium that includes carrier detection to avoid data collisions. EIA-485 two-wire networks are half-duplex. EIA-485 four-wire networks do not provide carrier detection, while EIA-232 systems can support 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 SEL-421 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 SEL-421 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 DNP 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 to 20 ms to change from receive to transmit. If you set the pre-delay to 30 ms, you will avoid data loss resulting from data transmission beginning at the same time as RTS signal assertion.

Event Data

DNP event data objects contain change-of-state and time-stamp information that the SEL-421 collects and stores in a buffer. You can configure the SEL-421 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 DNP 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 SEL-421.

For event data collection you must also consider and enter appropriate settings for dead band and scaling operation on analog points shown in *Table 6.6*. You can either set and use default dead band and scaling according to data type or use a custom data map to select dead bands on a point-by-point basis. See *Configurable Data Mapping on page R.6.10* for a discussion of how to set scaling and dead-band operation on a point-by-point basis.

The settings ANADBA, ANADBV, and ANADBM control default dead-band operation for the specified data type. Because DNP Objects 30 and 32 use integer data, you must use scaling to send digits after the decimal point and avoid rounding to a simple integer value.

With no scaling, the value of 12.632 would be sent as 13. 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 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. Application of event reporting dead bands 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 amps 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 amps) for the relay to report a new event value.

The relay uses the NUMEVE and AGEEVE settings 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 SEL-421 has the buffer capacities listed in *Table 6.5*.

Table 6.5 SEL-421 Event Buffer Capacity

Type	Maximum Number of Events
Binary	1024
Analog	256
Counters	128

Binary Controls

The SEL-421 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. *Table 6.15* and *Table 6.16* list control points and control methods available in the SEL-421.

A DNP 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, Pulse Off, 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 DNP message to specify operation of the points shown in *Control Point Operation on page R.6.24*.

Time Synchronization

The accuracy of DNP time synchronization is insufficient for most protection and oscillography needs. DNP 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 and use Object 50, Variation 1, and Object 52, Variation 2, to set the time via a DNP master.

TIMERQ can be set in one of three ways:

- A numeric setting of 1–32767 minutes specifies the rate at which the SEL-421 shall request a time synchronization.
- A setting of M disables the SEL-421 from requesting a time synchronization, but still allows the SEL-421 to accept and apply time synchronization messages from the master.
- A setting of I disables the SEL-421 from requesting a time synchronization, and sets the SEL-421 to ignore time synchronization messages from the master.

Modem Support

The SEL-421 DNP implementation includes modem support. Your DNP master can dial-in to the SEL-421 and establish a DNP3 connection. The SEL-421 can automatically dial out and deliver unsolicited DNP 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 DNP 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 SEL-421 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_NUM 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_NUM setting when dialing the modem. PH_NUM 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.

DNP3 Settings

The DNP3 protocol settings that become available when you select DNP3 on a serial port are shown in *Table 6.6*. 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** through **PORT 3**, but you can only enable DNP3 on one port at a time.

Table 6.6 SEL-421 Port DNP Protocol Settings (Sheet 1 of 2)

Name	Description	Range	Default
DNPADR	DNP address	0–65519	0
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, M, 1–32767	I
DECPLA	Current value scaling	0–3	1
DECPLV	Voltage value scaling	0–3	1
DECPLM	Miscellaneous data scaling	0–3	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; hidden if DRETRY set to Off	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 from RTS on to TX; Off disables PSTDLY	OFF, 0.00–30.00 seconds	0.00
PSTDLY	Settle time from TX to RTS off; hidden if PREDLY set to Off	0.00–30.00 seconds	0.00
ANADBA	Analog reporting dead band for current; hidden if ECLASSA set to Off	0–32767	100
ANADBV	Analog reporting dead band for voltages; hidden if ECLASSA set to Off	0–32767	100
ANADBM	Analog reporting dead band; hidden if ECLASSC and ECLASSA set to Off	0–32767	100
EVELOCK	Event summary lock period	0–1,000 seconds	0
MINDIST[a]	Minimum fault location to capture	OFF, –10000–10000	OFF
MAXDIST[a]	Maximum fault location to capture	OFF, –10000–10000	OFF
ETIMEO	Event data confirmation time-out	0.1–100.0 seconds	10.0
UNSOL	Enable unsolicited reporting; hidden and set to N if ECLASSB, ECLASSC, ECLASSA, and ECLASSV set to Off	Y, N	N
PUNSOL	Enable unsolicited reporting at power up; hidden if UNSOL set to N	Y, N	N
REPADR	DNP address to which the relay reports unsolicited data; hidden if UNSOL set to N	0–65519	1
NUMEVE	Number of events on which the relay transmits unsolicited data; hidden if UNSOL set to N	1–200	10
AGEEVE	Age of oldest event on which the relay transmits unsolicited data; hidden if UNSOL set to N	0.0–60.0 seconds	2.0
MODEM	Modem connected to port	Y, N	N
MSTR	Modem startup string; hidden if MODEM set to N	Up to 30 characters	“E0X0&D0S0=4”

Table 6.6 SEL-421 Port DNP Protocol Settings (Sheet 2 of 2)

Name	Description	Range	Default
PH_NUM	Phone number for unsolicited reporting dial-out; hidden if MODEM set to N or UNSOL set to N	Up to 30 characters	“”
MDTIME	Time to attempt dial	5–300 seconds	60
MDRET	Time between dial-out attempts	5–3600 seconds	120

[a] MAXDIST must be greater than MINDIST.

Configurable Data Mapping

One of the most powerful features of the SEL-421 DNP3 implementation is the ability to remap DNP data. Remapping is the process of selecting data from the default map and organizing it into a smaller data set optimized for your application.

Use the settings Class D to access the SEL-421 DNP Map settings shown in *Table 6.7*. The SEL-421 provides binary input information with one of two reference maps: binary or extended. When you are remapping points, the new index will be the row number minus one. For example, if you want to remap the power in MW, Object 30 Index 87, to the first, Index 0, set DNPAID to N and enter 87 in the setting for Row 1 of the custom analog map.

Table 6.7 SEL-421 DNP Map Settings (Sheet 1 of 2)

Name	Description	Range	Default
MAPSEL	Reference Map Selection	B, E	B
DNPBID	Default binary input map enable	Y, N	Y
DNPBOD	Default binary output map enable	Y, N	Y
DNPCOD	Default counters map enable	Y, N	Y
DNPAID	Default analog input map enable	Y, N	Y
DNPAOD	Default analog output map enable	Y, N	Y
Row 1[a]	Custom binary input map	Index number from default map	
• • •			
Row 400[a]	Maximum custom binary input map		
Row 1[a]	Custom binary output map	Index number from default map	
• • •			
Row 70[a]	Maximum custom binary output map		
Row 1[a]	Custom counter map, custom counter dead band[b] (Example: 3, 6)	Index number from default map; 1–32767	
• • •			

Table 6.7 SEL-421 DNP Map Settings (Sheet 2 of 2)

Name	Description	Range	Default
Row 10[a]	Last custom counter map; custom counter dead band[b] (Example: 3, 6)	Index number from default map; 1–32767	
Row 1[a]	Custom analog input map; custom analog input scaling[b], custom analog input dead band[b] (Example: 3, 10, 6)	Index number from default map; 0.001–1000.000: 1–32767	
• • •			
Row 200[a]	Last custom analog input map; custom analog input scaling[b] custom analog input dead band	Index number from default map; 0.001–1000.000: 1–32767	
Row 1[a]	Custom analog output map	Index number from default map	
Row 2[a]	Custom analog output map	Index number from default map	

[a] Free-form setting row hidden if corresponding default map is enabled.
[b] Optional. If not specified, defaults to value associated with point in default map.

The settings shown in *Table 6.7* that follow DNPAOD are entered in a line-based free-form format. An example of these settings is shown in the *Application Example on page R.6.27*. You can program a custom scaling and dead band for each point where indicated. If you do not specify a custom scaling or dead band, the relay will use the default for the type of value you are mapping. For example, if you enter 87 in Row 1 of the custom analog map with no other parameters, the power in MW will be available as Object 30 and 32, Index 0 and the relay will use the default scaling DECPLM and default dead band of ANADBM (*Table 6.7*).

Scaling factors allow you to overcome the limitations imposed by the integer nature of Objects 30 and 32. For example, the relay rounds a value of 11.4 amps to 11 amps. Use the scaling to include decimal point values by multiplying by a number larger than one. If you use 10 as a scaling factor, 11.4 amps will be transmitted as 114. You must divide the value by 10 in the master device 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. If you have a value that can reach 157834 you cannot send it using DNP 16-bit analog object variations. Use a scaling factor of 0.1 so that the maximum value reported is 15783. You must multiply the value by 10 in the master to see a value of 157830. You will lose some precision as the last digit is rounded in the scaling process, but you can transmit the scaled value using standard DNP Objects 30 and 32.

Warm Start and Cold Start

The DNP function codes for warm start and cold start reset the SEL-421 serial port. These function codes do not interrupt protection processes within the relay.

Testing

Use the **TEST DNP** command to test the data mapping from the relay to your DNP master. You can use the **TEST DNP** command to force DNP values by object and index number. Although the relay reports forced values to the DNP host, these values do not affect protection processing or other protocol interfaces on the SEL-421. The **TEST DNP** command operates by object and index number, so it works equally well with custom mapping and the default DNP map.

When you are using the **TEST DNP** command to test DNP operation, the Relay Word bit TESTDNP will be asserted to indicate that test mode is active. The DNP status bit will also show forced status for any object variations that include status.

DNP3 Documentation

Device Profile

Table 6.8 contains the standard DNP3 device profile information. Rather than checkboxes in the example Device Profile in the DNP3 Subset Definitions, only the relevant selections are shown.

Table 6.8 SEL-421 DNP3 Device Profile (Sheet 1 of 2)

Parameter	Value
Vendor name	Schweitzer Engineering Laboratories
Device name	SEL-421 Relay
Highest DNP request level	Level 2
Highest DNP response level	Level 2
Device function	Slave
Notable objects, functions, and/or qualifiers supported	Virtual terminal
Maximum data link frame size transmitted/received (octets)	292
Maximum data link retries	Configurable, range 0 to 15
Requires data link layer confirmation	Configurable by setting
Maximum application fragment size transmitted/received (octets)	2048
Maximum application layer retries	None
Requires application layer confirmation	When reporting Event Data
Data link confirm time-out	Configurable
Complete application fragment time-out	None
Application confirm time-out	Configurable
Complete Application response time-out	None
Executes control WRITE binary outputs	Always
Executes control SELECT/OPERATE	Always
Executes control DIRECT OPERATE	Always
Executes control DIRECT OPERATE-NO ACK	Always
Executes control count greater than 1	Never
Executes control Pulse On	Always
Executes control Pulse Off	Always
Executes control Latch Off	Always
Executes control Latch Off	Always
Executes control Queue	Never

Table 6.8 SEL-421 DNP3 Device Profile (Sheet 2 of 2)

Parameter	Value
Executes control Clear Queue	Never
Reports binary input change events when no specific variation requested	Only time-tagged
Reports time-tagged binary input change events when no specific variation requested	Binary Input change with time
Sends unsolicited responses	Configurable with unsolicited message enable settings
Sends static data in unsolicited responses	Never
Default counter object/variation	Object 20, Variation 6
Counter roll-over	16 bits
Sends multifragment responses	No

Object List

Table 6.9 lists the objects and variations with supported function codes and qualifier codes available in the SEL-421. The list of supported objects conforms to the format laid out in the DNP 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 6.9 SEL-421 DNP Object List (Sheet 1 of 4)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
1	0	Binary Input—All Variations	1	0, 1, 6, 7, 8		
1	1	Binary Input	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
1	2[e]	Binary Input With Status	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
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[e]	Binary Input Change With Time	1	6, 7, 8	129, 130	17, 28
2	3[f]	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[e]	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				
12	3	Pattern Mask				
20	0	Binary Counter—All Variations	1	0, 1, 6, 7, 8		
20	1	32-Bit Binary Counter				
20	2	16-Bit Binary Counter				
20	3	32-Bit Delta Counter				
20	4	16-Bit Delta Counter				
20	5	32-Bit Binary Counter Without Flag	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
20	6[e]	16-Bit Binary Counter Without Flag	1	0, 1, 6, 7, 8	129	0, 1, 7, 8

Table 6.9 SEL-421 DNP Object List (Sheet 2 of 4)

Obj.	Var.	Description	Request[a] Funct. Codes[c]	Request[a] Qual. Codes[d]	Response[b] Funct. Codes[c]	Response[b] Qual. Codes[d]
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[e]	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				
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		
30	1	32-Bit Analog Input	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
30	2	16-Bit Analog Input	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
30	3	32-Bit Analog Input Without Flag	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
30	4[e]	16-Bit Analog Input Without Flag	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
31	0	Frozen Analog Input—All Variations				
31	1	32-Bit Frozen Analog Input				

Table 6.9 SEL-421 DNP Object List (Sheet 3 of 4)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
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	32-Bit Analog Change Event Without Time	1	6, 7, 8	129	17, 28
32	2[e]	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
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				
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, 7, 8
40	2[e]	16-Bit Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
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
50	0	Time and Date—All Variations				
50	1	Time and Date	1, 2	7, 8 index=0	129	07, quanity=1
50	2	Time and Date With Interval				
51	0	Time and Date CTO—All Variations				
51	1	Time and Date CTO				
51	2	Unsynchronized Time and Date CTO	07, quanity=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	6		
60	1	Class 0 Data	1	6		
60	2	Class 1 Data	1, 20, 21	6, 7, 8		
60	3	Class 2 Data	1, 20, 21	6, 7, 8		
60	4	Class 3 Data	1, 20, 21	6, 7, 8		
70	1	File Identifier				
80	1	Internal Indications	2	0, 1 index=7		

Table 6.9 SEL-421 DNP Object List (Sheet 4 of 4)

Obj.	Var.	Description	Request[a] Funct. Codes[c]	Request[a] Qual. Codes[d]	Response[b] Funct. Codes[c]	Response[b] Qual. Codes[d]
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, 20, 21	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] Supported in requests from master
[b] May generate in response to master
[c] Decimal
[d] Hexadecimal
[e] Default variation
[f] Supports request, but response contains no data

Default Data Map

Table 6.10 shows the SEL-421 default DNP3 data map. The default data map makes a wide range of data in the relay available. If your DNP3 master does Class 0 polls, polls of all present value points, the response will be quite large. Use the custom DNP mapping functions of the SEL-421 to reduce the data map to the points that your application requires.

The SEL-421 provides binary input information with one of two reference maps: base or extended. The default map selection is base (MAPSEL := B).

With the base reference map, Object 1 and 2 Indices 0–799 and 800–1599 contain the same data but provide different levels of time-stamp accuracy for associated Object 2 DNP events. The SER (sequential events recorder) in the relay controls events for indices 800–1599. The time stamps for these indices have the same accuracy and resolution that the SER provides. The only points available within indices 800–1599 are those that you configure for tracking by the relay SER. Use indices 800–1599 and corresponding SER settings to track each change of bits in the Relay Word and provide SER quality time stamps via DNP,. Event report for indices 0–799 uses a slower, less accurate time-stamping mechanism, but this reporting operates for all points within the range without additional configuration.

With the extended reference map, Object 1 and 2 Indices 16–265 contain the points available for tracking by the relay SER. SER quality time stamps are available for these points and only the SER settings are needed in order to configure the points available. The entire visible Relay Word (*Table A.2*–*Table A.48*) is available starting at Index 272.

The relay scales analog values by the indicated settings or fixed scaling indicated in the description. Analog dead bands for event reporting use the indicated settings, or ANADBM if you have specified no setting.

Table 6.10 SEL-421 DNP3 Default Data Map (Sheet 1 of 4)

Object	Indices	Description
		MAPSEL = B
01, 02	000–799	Relay Word bits, *Table 6.11*
01, 02	800–1599	SER Points, add 800 to indices in *Table 6.11*
01, 02	1600–1615	Relay front panel targets in *Table 6.12*
01, 02	1616	Relay disabled
01, 02	1617	Relay diagnostic failure
01, 02	1618	Relay diagnostic warning
01, 02	1619	New relay event available
01, 02	1620	Settings change or relay restart
01, 02	1621–1623	Reserved for future status points
01, 02	1624–1631	Reserved
01, 02	1632–1635	A-phase, B-phase, C-phase and three-phase power factor leading if this point is on, lagging or zero if off
01, 02	1636–1639	Reserved
		MAPSEL = E
01, 02	0	Relay disabled
01, 02	1	Relay diagnostic failure
01, 02	2	Relay diagnostic warning
01, 02	3	New relay event available
01, 02	4	Settings change or relay restart
01, 02	5–11	Reserved
01, 02	12–15	Power factor leading for A, B, C, and three-phase
01, 02	16–265	SER points 1–250
01, 02	266–271	Reserved
01, 02	272–991	Entire visible Relay Word, starting from bit 0
		MAPSEL = B, MAPSEL = E
10, 12	0–15	Remote bits RB01–RB16
10, 12	16	Pulse Open Circuit Breaker 1 command
10, 12	17	Pulse Close Circuit Breaker 1 command
10, 12	18	Pulse Open Circuit Breaker 2 command
10, 12	19	Pulse Close Circuit Breaker 2 command
10, 12	20–23	Reserved
10, 12	24–31	Remote bit pairs RB01–RB16
10, 12	32	Open/Close pair for Circuit Breaker 1
10, 12	33	Open/Close pair for Circuit Breaker 2
10, 12	34–35	Reserved
10, 12	36	Reset demands
10, 12	37	Reset demand peaks

Table 6.10 SEL-421 DNP3 Default Data Map (Sheet 2 of 4)

Object	Indices	Description
10, 12	38	Reset energies
10, 12	39	Reset breaker monitor
10, 12	40	Reset front panel targets
10, 12	41	Read next relay event
10, 12	42	Reset min/max metering
10, 12	43	Reserved
10, 12	44–59	Remote bits RB17–RB32
10, 12	60–67	Remote bit pairs RB17–RB32
20, 22	00	Active settings group
20, 22	01	Reserved
20, 22	02	Reserved
20, 22	03	Number of unread event reports
20, 22	04	Number of breaker operations on Circuit Breaker 1 A-phase
20, 22	05	Number of breaker operations on Circuit Breaker 1 B-phase
20, 22	06	Number of breaker operations on Circuit Breaker 1 C-phase
20, 22	07	Number of breaker operations on Circuit Breaker 2 A-phase
20, 22	08	Number of breaker operations on Circuit Breaker 2 B-phase
20, 22	09	Number of breaker operations on Circuit Breaker 2 C-phase
30, 32	00, 01[a]	Line A-phase current magnitude (amps) and angle (LIAFM, LIAFA)[b]
30, 32	02, 03[a]	Line B-phase current magnitude (amps) and angle (LIBFM, LIBFA)[b]
30, 32	04, 05[a]	Line C-phase current magnitude (amps) and angle (LICFM, LICFA)[b]
30, 32	06, 07	Reserved
30, 32	08, 09[a]	Circuit Breaker 1 A-phase current magnitude (amps) and angle (B1IAFM, B1IAFA)[b]
30, 32	10, 11[a]	Circuit Breaker 1 B-phase current magnitude (amps) and angle (B1IBFM, B1IBFA)[b]
30, 32	12, 13[a]	Circuit Breaker 1 C-phase current magnitude (amps) and angle (B1ICFM, B1ICFA)[b]
30, 32	14, 15	Reserved
30, 32	16, 17[a]	Circuit Breaker 2 A-phase current magnitude (amps) and angle (B2IAFM, B2IAFA)[b]
30, 32	18, 19[a]	Circuit Breaker 2 B-phase current magnitude (amps) and angle (B2IBFM, B2IBFA)[b]
30, 32	20, 21[a]	Circuit Breaker 2 C-phase current magnitude (amps) and angle (B2ICFM, B2ICFA)[b]
30, 32	22–35	Reserved
30, 32	36, 37[c]	Line A-phase voltage magnitude (kV) and angle (VAFM, VAFA)[b]
30, 32	38, 39[c]	Line B-phase voltage magnitude (kV) and angle (VBFM, VBFA)[b]
30, 32	40, 41[c]	Line C-phase voltage magnitude (kV) and angle (VCFM, VCFA)[b]
30, 32	42[c]	Polarizing voltage magnitude (volts) (VPM)[b]
30, 32	43	Reserved
30, 32	44[c]	Synchronizing voltage 1 magnitude (volts) (NVS1M)[b]
30, 32	45	Reserved
30, 32	46[c]	Synchronizing voltage 2 magnitude (volts) (NVS2M)[b]
30, 32	47	Reserved
30, 32	48, 49[a]	Line zero-sequence current magnitude (3I0) in amps and angle (LIGM, LIGA)[b]
30, 32	50, 51[a]	Line positive-sequence current magnitude in amps and angle (LI1M, LI1A)[b]

Table 6.10 SEL-421 DNP3 Default Data Map (Sheet 3 of 4)

Object	Indices	Description
30, 32	52, 53[a]	Line negative-sequence current magnitude (3I2) in amps and angle (L3I2M, L3I2A)[b]
30, 32	54–71	Reserved
30, 32	72, 73[c]	Zero-sequence voltage magnitude (3V0) in kV and angle (3V0M, 3V0A)[b]
30, 32	74, 75[c]	Positive-sequence voltage magnitude (V1) in kV and angle (V1M, V1A)[b]
30, 32	76, 77[c]	Negative-sequence voltage magnitude (3V2) in kV and angle (3V2M, 3V2A)[b]
30, 32	78–83	Reserved
30, 32	84[d]	A-phase real power in MW (PA_f)[b]
30, 32	85[d]	B-phase real power in MW (PB_f)[b]
30, 32	86[d]	C-phase real power in MW (PC_f)[b]
30, 32	87[d]	Three-phase real power in MW (3P_f)[b]
30, 32	88[d]	A-phase reactive power in MVAR (QA_f)[b]
30, 32	89[d]	B-phase reactive power in MVAR (QB_f)[b]
30, 32	90[d]	C-phase reactive power in MVAR (QC_f)[b]
30, 32	91[d]	Three-phase reactive power in MVAR (3Q_f)[b]
30, 32	92[e]	A-phase power factor (DPFA)[b]
30, 32	93[e]	B-phase power factor (DPFB)[b]
30, 32	94[e]	C-phase power factor (DPFC)[b]
30, 32	95	Power factor (3DPF)[b]
30, 32	96–99	Reserved
30, 32	100[e]	DC Battery 1 voltage (V) (DC1)[b]
30, 32	101	Reserved
30, 32	102[e]	DC Battery 2 voltage (V) (DC2)[b]
30, 32	103	Reserved
30, 32	104[e]	Frequency (Hz) (FREQ)[b]
30, 32	105	Reserved
30, 32	106, 107[d]	A-phase total power in and out (MWh) (MWHAIN, MWHAOUT)[b]
30, 32	108, 109[d]	B-phase total power in and out (MWh) (MWHBIN, MWHBOUT)[b]
30, 32	110, 111[d]	C-phase total power in and out (MWh) (MWHCIN, MWHCOUT)[b]
30, 32	112, 113[d]	Three-phase total power in and out (MWh) (3MWHIN, 3MWHOUT)[b]
30, 32	114, 115	Reserved
30, 32	116, 117	Reserved
30, 32	118, 119	Reserved
30, 32	120, 121	Reserved
30, 32	122[a]	A-phase demand current (amps) (IAD)[b]
30, 32	123[a]	B-phase demand current (amps) (IBD)[b]
30, 32	124[a]	C-phase demand current (amps) (ICD)[b]
30, 32	125[a]	Demand zero-sequence current (amps) (IGD)[b]
30, 32	126[a]	Demand negative-sequence current (amps) (3I2D)[b]
30, 32	127	Reserved
30, 32	128–131[d]	A-phase, B-phase, C-phase, and three-phase demand power (MW) (PAD, PBD, PCD, 3PD)[b]
30, 32	132–135	Reserved

Table 6.10 SEL-421 DNP3 Default Data Map (Sheet 4 of 4)

Object	Indices	Description
30, 32	136–139	Reserved
30, 32	140–143	Reserved
30, 32	144[a]	Peak A-phase demand current (amps) (IAPKD)[b]
30, 32	145[a]	Peak B-phase demand current (amps) (IBPKD)[b]
30, 32	146[a]	Peak C-phase demand current (amps) (ICPKD)[b]
30, 32	147[a]	Peak zero-sequence demand current (amps) (IGPKD)[b]
30, 32	148[a]	Peak negative-sequence demand current (amps) (3I2PKD)[b]
30, 32	149	Reserved
30, 32	150–153[d]	A-phase, B-phase, C-phase and three-phase peak demand power (MW) (PAPKD, PBPKD, PCPKD, 3PPKD)[b]
30, 32	154–157	Reserved
30, 32	158–161	Reserved
30, 32	162–165	Reserved
30, 32	166–168	Circuit Breaker 1 contact wear percentage multiplied by 100 (B1BCWPA, B1BCWPB, B1BCWPC)[b]
30, 32	169–171	Circuit Breaker 2 contact wear percentage multiplied by 100 (B2BCWPA, B2BCWPB, B2BCWPC)[b]
30, 32	172–175	Reserved
30, 32[f]	176	Fault type (*Table 6.13* and *Table 6.14*)
30, 32[f]	177	Fault targets (Relay Word rows 0 and 1)
30, 32[f]	178[e]	Fault location
30, 32[f]	179[a]	Fault current
30, 32[f]	180[e]	Fault frequency (Hz)
30, 32[f]	181	Fault settings group
30, 32[f]	182	Fault targets (Relay Word row 280)
30, 32[f]	183	Reserved
30, 32[f]	184–186	Fault time in DNP format (high, middle, and low 16 bits)
30, 32[f]	187	Reserved
30, 32[f]	188	Three-pole reclose count
30, 32[f]	189–195	Reserved
30, 32	196–227	First 32 automation math variables (AMV001–AMV032)
40, 41	0	Active settings group
40, 41	1	Time-error preload value (TECORR)[g]

[a] Default current scaling DECPLA on magnitudes and scale factor of 100 on angles. Dead band ANADBV on magnitudes and ANADBM on angles.
[b] Analog quantity labels.
[c] Default voltage scaling DECPLV on magnitudes and scale factor of 100 on angles. Dead band ANADBV on magnitudes and ANADBM on angles.
[d] Default miscellaneous scaling DECPLM and dead band ANADBM.
[e] Default scale factor of 100.
[f] Event data shall only be generated for the fault summary information if the relay is operating in single event mode.
[g] In milliseconds, $-30000 \le$ time ≤ 30000. Relay Word bit PLDTE asserts for approximately 1.5 cycles after this value is written.

With the base reference map, the Relay Word bits mapped into Objects 1 and 2 are shown in *Table 6.11*. For non-SER points in the range 0–799, use the Index Range column directly. For SER points in the range 800–1599, add 800 to the indices in *Table 6.11*. The table lists eight bits in each row and the index range for each row. To determine the index for a specific point, add the Relay Word bit number (0 to 7) to the smaller number in the range listed in the first column. For example, the index of TLED_4 is 12 (the bit number, 4, plus the smaller number in the range, 8).

Table 6.11 SEL-421 Object 1, 2 Relay Word Bit Mapping (Sheet 1 of 3)

Index Range	Relay Word Bits[a]							
	7	6	5	4	3	2	1	0
7-0	EN	TRIPLED	*	*	*	*	*	*
15-8	TLED_1	TLED_2	TLED_3	TLED_4	TLED_5	TLED_6	TLED_7	TLED_8
23-16	TLED_9	TLED_10	TLED_11	TLED_12	TLED_13	TLED_14	TLED_15	TLED_16
31-24	3POBK2	3POLINE	3PLSHT	BK1RS	BK2RS	79CY1	79CY3	BK1LO
39-32	BK2LO	BK1CL	BK2CL	LEADBK0	LEADBK1	LEADBK2	FOLBK0	FOLBK1
47-40	B1OPHA	B1OPHB	B1OPHC	B2OPHA	B2OPHB	B2OPHC	LOPHA	LOPHB
55-48	LOPHC	SPOA	SPOB	SPOC	SPO	3PO	27APO	27BPO
63-56	27CPO	*	*	*	*	*	*	*
71-64	52ACL1	52BCL1	52CCL1	52AAL1	52BAL1	52CAL1	52AA1	52AB1
79-72	52AC1	*	52ACL2	52BCL2	52CCL2	52AAL2	52BAL2	52CAL2
87-80	52AA2	52AB2	52AC2	*	*	*	*	*
95-88	*	*	*	*	*	*	*	*
103-96	*	*	*	*	*	*	*	*
111-104	*	*	*	*	*	*	*	*
119-112	*	*	*	*	*	*	*	*
127-120	BM1TRPA	BM1TRPB	BM1TRPC	BM1CLSA	BM1CLSB	BM1CLSC	B1BCWAL	*
135-128	*	B1MSOAL	B1ESOAL	B1PSAL	B1PDAL	B1BITAL	B1MRTAL	B1MRTIN
143-136	BM2TRPA	BM2TRPB	BM2TRPC	BM2CLSA	BM2CLSB	BM2CLSC	B2BCWAL	*
151-144	*	B2MSOAL	B2ESOAL	B2PSAL	B2PDAL	B2BITAL	B2MRTAL	B2MRTIN
159-152	RTD08ST	RTD07ST	RTD06ST	RTD05ST	RTD04ST	RTD03ST	RTD02ST	RTD01ST
167-160	RTDIN	RTDCOMF	RTDFL	*	RTD12ST	RTD11ST	RTD10ST	RTD09ST
175-168	DC1F	DC1W	DC1G	DC1R	DC2F	DC2W	DC2G	DC2R
183-176	PDEM	QDEM	GDEM	*	*	*	*	*
191-184	RB25	RB26	RB27	RB28	RB29	RB30	RB31	RB32
199-192	RB17	RB18	RB19	RB20	RB21	RB22	RB23	RB24
207-200	RB09	RB10	RB11	RB12	RB13	RB14	RB15	RB16
215-208	RB01	RB02	RB03	RB04	RB05	RB06	RB07	RB08
223-216	SG6	SG5	SG4	SG3	SG2	SG1	CHSG	*
231-224	*	IN107	IN106	IN105	IN104	IN103	IN102	IN101
239-232	IN208	IN207	IN206	IN205	IN204	IN203	IN202	IN201
247-240	IN216	IN215	IN214	IN213	IN212	IN211	IN210	IN209
255-248	IN224	IN223	IN222	IN221	IN220	IN219	IN218	IN217
263-256	IN308	IN307	IN306	IN305	IN304	IN303	IN302	IN301
271-264	IN316	IN315	IN314	IN313	IN312	IN311	IN310	IN309
279-272	IN324	IN323	IN322	IN321	IN320	IN319	IN318	IN317
287-280	PSV08	PSV07	PSV06	PSV05	PSV04	PSV03	PSV02	PSV01

Table 6.11 SEL-421 Object 1, 2 Relay Word Bit Mapping (Sheet 2 of 3)

Index Range	Relay Word Bits[a]							
	7	6	5	4	3	2	1	0
295-288	PSV16	PSV15	PSV14	PSV13	PSV12	PSV11	PSV10	PSV09
303-296	PSV24	PSV23	PSV22	PSV21	PSV20	PSV19	PSV18	PSV17
311-304	PSV32	PSV31	PSV30	PSV29	PSV28	PSV27	PSV26	PSV25
319-312	PLT08	PLT07	PLT06	PLT05	PLT04	PLT03	PLT02	PLT01
327-320	PLT16	PLT15	PLT14	PLT13	PLT12	PLT11	PLT10	PLT09
335-328	PCT08Q	PCT07Q	PCT06Q	PCT05Q	PCT04Q	PCT03Q	PCT02Q	PCT01Q
343-336	PCT16Q	PCT15Q	PCT14Q	PCT13Q	PCT12Q	PCT11Q	PCT10Q	PCT09Q
351-344	PST08Q	PST07Q	PST06Q	PST05Q	PST04Q	PST03Q	PST02Q	PST01Q
359-352	PST16Q	PST15Q	PST14Q	PST13Q	PST12Q	PST11Q	PST10Q	PST09Q
367-360	PCN08Q	PCN07Q	PCN06Q	PCN05Q	PCN04Q	PCN03Q	PCN02Q	PCN01Q
375-368	PCN16Q	PCN15Q	PCN14Q	PCN13Q	PCN12Q	PCN11Q	PCN10Q	PCN09Q
383-376	ASV008	ASV007	ASV006	ASV005	ASV004	ASV003	ASV002	ASV001
391-384	ASV016	ASV015	ASV014	ASV013	ASV012	ASV011	ASV010	ASV009
399-392	ASV024	ASV023	ASV022	ASV021	ASV020	ASV019	ASV018	ASV017
407-400	ASV032	ASV031	ASV030	ASV029	ASV028	ASV027	ASV026	ASV025
415-408	ALT08	ALT07	ALT06	ALT05	ALT04	ALT03	ALT02	ALT01
423-416	ALT16	ALT15	ALT14	ALT13	ALT12	ALT11	ALT10	ALT09
431-424	AST08Q	AST07Q	AST06Q	AST05Q	AST04Q	AST03Q	AST02Q	AST01Q
439-432	AST16Q	AST15Q	AST14Q	AST13Q	AST12Q	AST11Q	AST10Q	AST09Q
447-440	ACN08Q	ACN07Q	ACN06Q	ACN05Q	ACN04Q	ACN03Q	ACN02Q	ACN01Q
455-448	ACN16Q	ACN15Q	ACN14Q	ACN13Q	ACN12Q	ACN11Q	ACN10Q	ACN09Q
463-456	PUNRLBL	PFRTEX	MATHERR	*	*	*	*	*
471-464	AUNRLBL	AFRTEXP	AFRTEXA	*	*	*	*	*
479-472	SALARM	HALARM	BADPASS	CCALARM	*	*	*	*
487-480	*	*	*	*	*	*	*	*
495-488	*	*	*	*	*	*	*	*
503-496	*	*	TIRIG	TUPDH	TSYNCA	TSOK	PMDOK	FREQOK
511-504	OUT108	OUT107	OUT106	OUT105	OUT104	OUT103	OUT102	OUT101
519-512	OUT208	OUT207	OUT206	OUT205	OUT204	OUT203	OUT202	OUT201
527-520	OUT216	OUT215	OUT214	OUT213	OUT212	OUT211	OUT210	OUT209
535-528	OUT308	OUT307	OUT306	OUT305	OUT304	OUT303	OUT302	OUT301
543-536	OUT316	OUT315	OUT314	OUT313	OUT312	OUT311	OUT310	OUT309
551-544	PB1_LED	PB2_LED	PB3_LED	PB4_LED	PB5_LED	PB6_LED	PB7_LED	PB8_LED
559-552	RMB8A	RMB7A	RMB6A	RMB5A	RMB4A	RMB3A	RMB2A	RMB1A
567-560	TMB8A	TMB7A	TMB6A	TMB5A	TMB4A	TMB3A	TMB2A	TMB1A
575-568	RMB8B	RMB7B	RMB6B	RMB5B	RMB4B	RMB3B	RMB2B	RMB1B
583-576	TMB8B	TMB7B	TMB6B	TMB5B	TMB4B	TMB3B	TMB2B	TMB1B
591-584	ROKA	RBADA	CBADA	LBOKA	ANOKA	DOKA	*	*
599-592	ROKB	RBADB	CBADB	LBOKB	ANOKB	DOKB	*	*
607-600	TESTDNP	TESTDB	TESTFM	TESTPUL	*	*	*	*

Table 6.11 SEL-421 Object 1, 2 Relay Word Bit Mapping (Sheet 3 of 3)

Index Range	Relay Word Bits[a]							
	7	6	5	4	3	2	1	0
615–608	CCIN025	CCIN026	CCIN027	CCIN028	CCIN029	CCIN030	CCIN031	CCIN032
623–616	CCIN017	CCIN018	CCIN019	CCIN020	CCIN021	CCIN022	CCIN023	CCIN024
631–624	CCIN009	CCIN010	CCIN011	CCIN012	CCIN013	CCIN014	CCIN015	CCIN016
639–632	CCIN001	CCIN002	CCIN003	CCIN004	CCIN005	CCIN006	CCIN007	CCIN008
647–640	CCOUT25	CCOUT26	CCOUT27	CCOUT28	CCOUT29	CCOUT30	CCOUT31	CCOUT32
655–648	CCOUT17	CCOUT18	CCOUT19	CCOUT20	CCOUT21	CCOUT22	CCOUT23	CCOUT24
663–656	CCOUT09	CCOUT10	CCOUT11	CCOUT12	CCOUT13	CCOUT14	CCOUT15	CCOUT16
671–664	CCOUT01	CCOUT02	CCOUT03	CCOUT04	CCOUT05	CCOUT06	CCOUT07	CCOUT08
679–672	CCSTA01	CCSTA02	CCSTA03	CCSTA04	CCSTA05	CCSTA06	CCSTA07	CCSTA08
687–680	CCSTA09	CCSTA10	CCSTA11	CCSTA12	CCSTA13	CCSTA14	CCSTA15	CCSTA16
695–688	CCSTA17	CCSTA18	CCSTA19	CCSTA20	CCSTA21	CCSTA22	CCSTA23	CCSTA24
703–696	CCSTA25	CCSTA26	CCSTA27	CCSTA28	CCSTA29	CCSTA30	CCSTA31	CCSTA32
711–704	FSERP1	FSERP2	FSERP3	FSERPF	*	*	*	*
719–712	ALTI	ALTV	ALTS2	DELAY	*	*	*	*

[a] An * denotes reserved for future use.

Object 1, 2 indices 1600–1615 represent the front-panel target Relay Word bits as listed in *Table 6.12*.

Table 6.12 Object 1, 2 Indices 1600–1615 Front-Panel Targets

Index	Relay Word Bit	Description
1600	TLED_8	Front-panel target 8
1601	TLED_7	Front-panel target 7
1602	TLED_6	Front-panel target 6
1603	TLED_5	Front-panel target 5
1604	TLED_4	Front-panel target 4
1605	TLED_3	Front-panel target 3
1606	TLED_2	Front-panel target 2
1607	TLED_1	Front-panel target 1
1608	TLED_16	Front-panel target 16
1609	TLED_15	Front-panel target 15
1610	TLED_14	Front-panel target 14
1611	TLED_13	Front-panel target 13
1612	TLED_12	Front-panel target 12
1613	TLED_11	Front-panel target 11
1614	TLED_10	Front-panel target 10
1615	TLED_9	Front-panel target 9

Object 30, Index 176 is a 16-bit composite value, where the upper byte value indicates an event cause as shown in *Table 6.13* and a fault type shown in *Table 6.15*.

Reading Relay Event Data

The SEL-421 provides protective relay event history information in one of two modes: single event or with a first-in, first-out (FIFO) multi-event access method. The default mode is single event.

Single event mode provides the most recent tripping event. When a trigger with a trip type (not ER and not TRIG) occurs with a the fault location in the range of MINDIST to MAXDIST, this data shall be made available in the DNP fault summary area, generating appropriate DNP events. (If MINDIST is set OFF, then there is no minimum. Similarly, if MAXDIST is set OFF, there is no maximum.) The relay shall than ignore any subsequent events for EVELOCK (port setting) time. This data shall be reset to 0 on a rising edge of RSTDNPE (global SELogic equation result). The relay element EVELOCK shall be set when the fault is triggered and reset when EVELOCK time expires.

Multi-event mode shall be initiated if the next event control is operated. The master should monitor binary input point 1619 (MAPSEL := B; see *Table 6.10*) or point 3 (MAPSEL := E; see *Table 6.10*), which will be asserted when there is an unread relay event summary. To read the oldest relay event summary, the master should pulse-on binary output point 41 (see *Table 6.15*). This will load the relay event summary analogs (points 176 through 181 *Table 6.10*) with information from the oldest relay event summary, discarding the values from the previous load.

After reading the analogs, the master should again check binary input point 1619 (point 3 when MAPSEL := E), which will be on if there is another unread relay event summary. The master should continue this process until binary input point 1619 (point 3 when MAPSEL := E) is deasserted. If the master attempts to load values using output point 41 when binary input point 1619 (point 3 when MAPSEL := E) is deasserted, the relay event type analog (point 176) will be loaded with zero. With the FIFO method, the relay event summaries will always be collected in chronological order.

Table 6.13 Object 30, 32, Index 176 Upper Byte—Event Cause

Byte Value	Description
1	Trigger command
4	Trip element
8	Event report element

Table 6.14 Object 30, 132, Index 176 Lower Byte—Fault Type

Bit	Description
0	Indeterminate
1	A-phase
2	B-phase
4	C-phase
8	Ground

Control Point Operation

Use the Trip and Close operations with Object 12 control relay output block command messages to operate the points shown in *Table 6.15*. Pulse operations provide a pulse with a duration of one protection processing interval.

Table 6.15 SEL-421 Object 12 Trip/Close Pair Operation

Indices	Close	Trip
0–15	Set remote bits RB1–RB16	Clear remote bits RB1–RB16
16	Open Circuit Breaker 1	No action
17	Close Circuit Breaker 1	No action
18	Open Circuit Breaker 2	No action
19	Close Circuit Breaker 2	No action
20–23	Reserved	Reserved
24	Pulse RB2	Pulse RB1
25	Pulse RB4	Pulse RB3
26	Pulse RB6	Pulse RB5
27	Pulse RB8	Pulse RB7
28	Pulse RB10	Pulse RB9
29	Pulse RB12	Pulse RB11
30	Pulse RB14	Pulse RB13
31	Pulse RB16	Pulse RB15
32	Pulse CC1, Circuit Breaker 1 close command bit	Pulse OC1, Circuit Breaker 1 open command bit
33	Pulse CC2, Circuit Breaker 2 close command bit	Pulse OC2, Circuit Breaker 2 open command bit
34–35	Reserved	Reserved
36	Reset demands	Reset demands
37	Reset demand peaks	Reset demand peaks
38	Reset energy metering	Reset energy metering
39	Reset breaker monitor	Reset breaker monitor
40	Reset front panel targets	Reset front panel targets
41	Read next relay event	Read next relay event
42	Reset min/max metering	Reset min/max metering
43	Reserved	Reserved
44–59	Set remote bits RB17–RB32	Clear remote bits RB17–RB32
60	Pulse RB18	Pulse RB17
61	Pulse RB20	Pulse RB19
62	Pulse RB22	Pulse RB21
63	Pulse RB24	Pulse RB23
64	Pulse RB26	Pulse RB25
65	Pulse RB28	Pulse RB27
66	Pulse RB30	Pulse RB29
67	Pulse RB32	Pulse RB31

The SEL-421 assigns some special operations to the code portion of the control relay output block command. The special operations are shown in *Table 6.16*. Pulse operations provide a pulse duration of one protection-processing interval.

Table 6.16 SEL-421 Object 12 Code Selection Operation

Indices	Latch On	Latch Off	Pulse On	Pulse Off
0–15	Set remote bits RB1–RB16	Clear remote bits RB1–RB16	Pulse remote bits RB1–RB16	Clear remote bits RB1–RB16
16–19	Pulse	No action	Pulse	No action
20–23	Reserved	Reserved	Reserved	Reserved
24	Pulse RB2	Pulse RB1	Pulse RB2	Pulse RB1
25	Pulse RB4	Pulse RB3	Pulse RB4	Pulse RB3
26	Pulse RB6	Pulse RB5	Pulse RB6	Pulse RB5
27	Pulse RB8	Pulse RB7	Pulse RB8	Pulse RB7
28	Pulse RB10	Pulse RB9	Pulse RB10	Pulse RB9
29	Pulse RB12	Pulse RB11	Pulse RB12	Pulse RB11
30	Pulse RB14	Pulse RB13	Pulse RB14	Pulse RB13
31	Pulse RB16	Pulse RB15	Pulse RB16	Pulse RB15
32	Pulse CC1, Circuit Breaker 1 close bit	Pulse OC1, Circuit Breaker 1 open bit	Pulse CC1, Circuit Breaker 1 close bit	Pulse OC1, Circuit Breaker 1 open bit
33	Pulse CC2, Circuit Breaker 2 close bit	Pulse OC2, Circuit Breaker 2 open bit	Pulse CC2, Circuit Breaker 2 close bit	Pulse OC2, Circuit Breaker 2 open bit
34–35	Reserved	Reserved	Reserved	Reserved
36	Reset demands	No action	Reset demands	No action
37	Reset demand peaks	No action	Reset demand peaks	No action
38	Reset energy metering	No action	Reset energy metering	No action
39	Reset breaker monitor	No action	Reset breaker monitor	No action
40	Reset front panel targets	No action	Reset front panel targets	No action
41	Read next relay event	No action	Read next relay event	No action
42	Reset min/max metering	No action	Reset min/max metering	No action
43	Reserved	Reserved	Reserved	Reserved
44–59	Set remote bits RB17–RB32	Clear remote bits RB17–RB32	Pulse remote bits RB17–RB32	Clear remote bits RB17–RB32
60	Pulse RB18	Pulse RB17	Pulse RB18	Pulse RB17
61	Pulse RB20	Pulse RB19	Pulse RB20	Pulse RB19
62	Pulse RB22	Pulse RB21	Pulse RB22	Pulse RB21
63	Pulse RB24	Pulse RB23	Pulse RB24	Pulse RB23
64	Pulse RB26	Pulse RB25	Pulse RB26	Pulse RB25
65	Pulse RB28	Pulse RB27	Pulse RB28	Pulse RB27
66	Pulse RB30	Pulse RB29	Pulse RB30	Pulse RB29
67	Pulse RB32	Pulse RB31	Pulse RB32	Pulse RB31

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. The network for this example is shown in *Figure 6.1*.

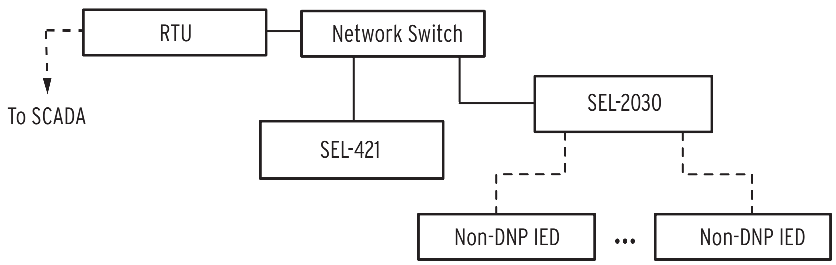

Figure 6.1 DNP Application Network Diagram

The metering and status data that the RTU collects from the relay are listed in *Table 6.17*.

Table 6.17 DNP3 Application Example Data Map (Sheet 1 of 2)

Name	Object	Default Map Index	Custom Map Index	Description
EN	1, 2	7	1	Relay enabled
TRIPLED	1, 2	6	2	Circuit Breaker tripped
IN101	1, 2	1024	3	Relay Discrete Input 1
IN102	1, 2	1025	4	Relay Discrete Input 2
IN103	1, 2	1026	5	Relay Discrete Input 3
IN104	1, 2	1027	6	Relay Discrete Input 4
SALARM	1, 2	479	7	Relay software alarm
HALARM	1, 2	478	8	Relay hardware alarm
TESTDNP	1, 2	607	9	DNP test mode enabled
RB01	10, 12	0	1	General use Control Point 1
RB02	10, 12	1	2	General use Control Point 2
RB03	10, 12	2	3	General use Control Point 3
RB04	10, 12	3	4	General use Control Point 4
RB05	10, 12	4	5	General use Control Point 5
RB06	10, 12	5	6	General use Control Point 5
CC1, OC1	10, 12	32	7	Circuit Breaker manual trip/close
LIAFM[a], LIAFA[b]	30	0, 1	1, 2	IA magnitude and angle
LIBFM[a], LIBFA[b]	30	2, 3	3, 4	IB magnitude and angle

Table 6.17 DNP3 Application Example Data Map (Sheet 2 of 2)

Name	Object	Default Map Index	Custom Map Index	Description
LICFM[a], LICFA[b]	30	4, 5	5, 6	IC magnitude and angle
VAFM[c], VAFA[b]	30	36, 37	7, 8	VAY magnitude and angle
VBFM[c], VBFA[b]	30	38, 39	9, 10	VBY magnitude and angle
VCFM[c], VCFA[b]	30	40, 41	11, 12	VCY magnitude and angle
3P_f[d]	30	87	13	Three-phase real power in MW
3Q_f[d]	30	91	14	Three-phase reactive power in MVAR
DC1[e]	30	100	15	DC1 voltage multiplied by 100
ACTGRP	40	0	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] 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 6.2 shows how to enter the new map into the relay. Use the **SET D** command and enter N at the prompts shown in *Figure 6.2* to allow changes to the existing maps. Press **<Enter>** at the 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.

```
=>>SET D <Enter>
DNP

DNP Reference Map Selection

Reference Map Selection (B,E)                      MAPSEL  := B       ? <Enter>

DNP Object Default Map Enables

Use default DNP map for Binary Inputs (Y/N)        DNPBID  := Y       ?N <Enter>
Use default DNP map for Binary Outputs (Y/N)       DNPBOD  := Y       ?N <Enter>
Use default DNP map for Counters (Y/N)             DNPCOD  := Y       ? <Enter>
Use default DNP map for Analog Inputs (Y/N)        DNPAID  := Y       ?N <Enter>
Use default DNP map for Analog Outputs (Y/N)       DNPAOD  := Y       ? <Enter>

Binary Input Map
(Index Number)
?  7 <Enter>
2:
?  6 <Enter>
3:
?  1024 <Enter>
4:
?  1025 <Enter>
5:
?  1026 <Enter>
6:
?  1027 <Enter>
7:
?  479 <Enter>
8:
?  478 <Enter>
```

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```
9:
?  607 <Enter>
10:
?  <Enter>

Binary Output Map
(Index Number)

1:
?  0 <Enter>
2:
?  1 <Enter>
3:
?  2 <Enter>
4:
?  3 <Enter>
5:
?  4 <Enter>
6:
?  5 <Enter>
7:
?  32 <Enter>
8:
?  <Enter>

Analog Input Map
(Index Number, Scale Factor, Deadband)

1:
?  0 <Enter>
2:
?  1,1,200 <Enter>
3:
?  2 <Enter>
4:
?  3,1,200 <Enter>
5:
?  4 <Enter>
6:
?  5,1,200 <Enter>
7:
?  36 <Enter>
8:
?  37,1,200 <Enter>
9:
?  38 <Enter>
10:
?  39,1,200 <Enter>
11:
?  40 <Enter>
12:
?  41,1,200 <Enter>
13:
?  87,40,40<Enter>
14:
?  91,40,40 <Enter>
15:
?  100,,200 <Enter>
16:
?  <Enter>

Analog Output Map
(Index Number)

1:
?  0 <Enter>
2:
?  <Enter>
DNP

DNP Object Default Map Enables

DNPBID  := N        DNPBOD  := N        DNPCOD  := Y        DNPAID  := N
DNPAOD  := Y

Binary Input Map
(Index Number)

1: 7
2: 6
3: 1024
4: 1025
5: 1026
6: 1027
7: 479
```

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```
8: 478
9: 607


Binary Output Map
(Index Number)

1: 0
2: 1
3: 2
4: 3
5: 4
6: 5
7: 32


Analog Input Map
(Index Number, Scale Factor, Deadband)

1: 0
2: 1, 1.000, 200
3: 2
4: 3, 1.000, 200
5: 4
6: 5, 1.000, 200
7: 36
8: 37, 1.000, 200
9: 38
10: 39, 1.000, 200
11: 40
12: 41, 1.000, 200
13: 87, 40.000, 40
14: 91, 40.000, 40
15: 100, , 200


Analog Output Map
(Index Number)

1: 0

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

=>>
```

Figure 6.2 SEL-421 Example DNP Map Settings

Table 6.18 lists the settings for **PORT 3** for this example. The physical connection between the relay and the DNP 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 6.18 SEL-421 Port 3 Example Settings (Sheet 1 of 2)

Setting Name	Setting	Description
PROTO	DNP	Protocol
SPEED	9600	Data speed; hidden and set to 9600 if MBT set to Y
RTSCTS	N	Hardware handshaking enable
DNPADR	101	DNP address
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 because this feature is not supported by master

Table 6.18 SEL-421 Port 3 Example Settings (Sheet 2 of 2)

Setting Name	Setting	Description
TIMERQ	I	Ignore time-set request because IRIG-B is used for time synchronization
DECPLA	1	Scale current, multiplying by 10 to send amps and tenths of an amp. 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 kilo volts, tenths, and hundredths of a kilo volt.
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	Select/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
ANADBA	50	Analog reporting dead band for currents, 5 amps based on DECPLA scaling factor
ANADBV	100	Analog reporting dead band for voltages, 1 kV based on DECPLV scaling factor
ANADBM	100	Miscellaneous analog value dead band, based on DECPLM scaling factor
EVELOCK	0	Event summary lock period (0–1,000 seconds)
MINDIST[a]	OFF	Minimum fault location to capture (OFF, -10000–10000)
MAXDIST[a]	OFF	Maximum fault location to capture (OFF, -10000–10000)
ETIMEO	10	Event data confirmation time-out in seconds
UNSOL	N	Unsolicited reporting disabled because polling is polled report-by-exception
MODEM	N	No modem connected to port

[a] MAXDIST must be greater than MINDIST.

In this example, the polling method employed by the RTU DNP 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.

Testing

In this example, we can also use the **TEST DNP** command to substitute each measured value with a static value that you can control. You can then examine received values in the RTU or at the SCADA master to verify that each point is reaching the proper destination.

DNP LAN/WAN

The installation of an Ethernet card in an SEL-421 Relay provides a DNP3 Level 2 Slave interface for direct Ethernet network connections to the relay.

Because of the benefits that local- and wide-area networks provide, they have become ubiquitous throughout utilities. Networks are now found in control rooms, substations, and other areas where they were rarely seen until just recently. In line with this trend, the DNP User's Group produced an extension of the DNP3 specification with recommendations for implementing DNP LAN/WAN networks.

The specification contains several key recommendations about DNP3 operation over LAN and Wide Area Network (WAN) links. The most significant recommendations are listed below:

- DNP3 will use the TCP/IP and UDP/IP protocol suite, also known as "The Internet Protocol Suite."
- Ethernet is the recommended physical layer, but the recommended implementation will function over any link where the TCP/IP and UDP/IP protocol suite is present.
- All devices must support messaging through both TCP (connection oriented) and UDP (connectionless) mechanisms.
- The full DNP3 protocol stack is retained. It is supplemented by the network protocol layers so that major restructuring of DNP3 is unnecessary.
- Link layer confirmations, which are optional but discouraged for serial DNP, are specifically not allowed for DNP LAN/WAN. The IP Suite already provides a reliable delivery mechanism that is backed up by confirmations at the application layer when required.

DNP LAN/WAN in the SEL-421

See *Introduction to DNP3 on page R.6.1* for an introduction to DNP3.

Ethernet Card

Installation of the Ethernet card in an SEL-421 provides a high-performance network interface that enables the use of industry-standard SCADA network protocols, including DNP3 Level 2 slave functionality. DNP3 over the SEL-421 Ethernet port incorporates most Serial DNP3 functions, and includes event data reporting with direct time tags, customized data maps and session settings, and operator-initiated control through remote bits.

Configuration and operation of the DNP LAN/WAN interface in the SEL-421 is completely independent of the Serial DNP3 interface, but is just as integrated. In this section, DNP LAN/WAN is discussed as a function of the SEL-421, with the implication that this refers to the operation of an Ethernet card (with the DNP3 option) installed in an SEL-421.

Data Access

The data access methods listed for Serial DNP3 in *Table 6.4* are also available for DNP LAN/WAN, with the exception of Virtual Terminal classes. *Table 6.19* lists the appropriate settings for DNP LAN/WAN. The DNP3 master session must be configured for one of the data access methods below.

Table 6.19 DNP LAN/WAN Access Methods

Access Method	Master Polling	SEL-421 Settings
Polled static	Class 0	Set ECLASSB, ECLASSC, ECLASSA to Off, UNSL*nn* to No (where *nn* is the session number from 01–10).
Polled report-by-exception	Class 0 occasionally, Class 1, 2, 3 frequently	Set ECLASSB, ECLASSC, ECLASSA to the desired event class, UNSL*nn* to No.
Unsolicited report-by-exception	Class 0 occasionally, optional Class 1, 2, 3 less frequently, mainly relies on unsolicited messages	Set ECLASSB, ECLASSC, ECLASSA to the desired event class, set UNSL*nn* to Yes and PUNSL*nn* to Yes or No.
Quiescent	Class 0, 1, 2, 3 never, relies completely on unsolicited messages	Set ECLASSB, ECLASSC, ECLASSA to the desired event class, set UNSL*nn* and PUNSL*nn* to Yes.

As with Serial DNP3, in both the unsolicited report-by-exception and quiescent polling methods shown in *Table 6.19*, you must make a selection for the session's PUNSL*nn* setting. This setting enables or disables unsolicited data reporting at power up for this session. If your master can send the DNP message to enable unsolicited reporting from the SEL-421, you should set the session's PUNSL*nn* to No.

See *DNP3 in the SEL-421 on page R.6.5* for more information on configuring DNP LAN/WAN sessions.

Event Data

The same serial DNP event data objects are available for DNP3 over an Ethernet network. However, configuration is slightly different. You can still configure the SEL-421 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, and ECLASSA, you can set the event class for binary, counter, and analog information. Virtual terminal information is not supported for DNP LAN/WAN since Telnet is available to provide this capability. As with serial DNP3, you can also use the classes as a simple priority system for collecting event data.

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 SEL-421.

For event data collection, you must also consider and enter appropriate settings for dead band and scaling operations on analog points shown in *Table 6.20*. You can set and use either default dead band and scaling according to data type or use a custom data map to select dead bands on a point-by-point basis. See *Custom Data Mapping on page R.6.38* for a discussion of how to set scaling and dead-band operations on a point-by-point basis.

The setting ANADB defines default dead-band operation for analog events. A DNP3 master may also impose its own default dead band that it will use for event data for a specific channel that override the relay's ANADB setting. Because the default variations of DNP Objects 30 and 32 use integer data, you must use scaling to send digits after the decimal point and avoid rounding to a simple integer value. Scaling on the Ethernet DNP3 connection is subject to the same limitations of the serial interface. The master should also be configured to perform the appropriate arithmetic conversion on the incoming value to display it in proper engineering units.

Set the default analog value scaling with the DECPL setting. Application of event reporting dead bands occurs after scaling the incoming value with 10^{DECPL}. For example, if you set DECPL to 2 and ANADB to 10, a measured current of 10.14 amps would be scaled to the value 1014 (10.14×10^2) and would have to increase to more than 1024 or decrease to less than 1004 (a dead band of 0.2 amps) for the relay to report a new event value.

As with the DNP3 serial connection, the NUMEVE and AGEEVE settings are used 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 SEL-421 uses the same buffer capacities with DNP LAN/WAN as through the serial connection, listed in *Table 6.6*.

Time Synchronization

Time synchronization is not supported for DNP3 over the Ethernet port. However, it will accept messages that contain a Record Current Time (Function Code 24) request and return a Null Response.

DNP3 Settings

The DNP3 protocol settings that become available for DNP3 on the SEL-421 Ethernet port are shown in *Table 6.20*. The DNP3 protocol settings are for the port assigned to the Ethernet port: **PORT 5**. Please keep in mind that any settings for the SEL-421 DNP3 Ethernet port will not affect any DNP3 serial port configuration or operation and vice-versa.

It may be useful to note a few parameters that are unique to configuring DNP LAN/WAN:

- The ENDNP setting allows the user to enable or disable all DNP3 sessions on the Ethernet interface.
- The DNPMAP setting enables the usage of custom DNP3 maps to define the data/control maps for the DNP3 sessions. The DNPMAP setting can have one of two values: AUTO or CUSTOM. AUTO is intended for the SEL-2032, SEL-2030, or SEL-2020 Communications Processor applications. With the SEL-421, we recommend that you always use CUSTOM.
- DECPL indicates an exponential scaling factor, 10^{DECPL}, to multiply by the raw value to calculate engineering units. Thus the default value of DECPL, 0, will still result in the raw value being multiplied by 1 (10^0).

Up to 10 sets of unique master station parameters can be configured for implementation when the relay communicates with a specified DNP3 host. These parameters include: DNPIP*xx*, DNPTR*xx*, DNPUP*xx*, UNSL*xx*, PUNSL*xx*, DNPMP*xx*, and DNPCL*xx*, where *xx* is a master station number from 01–10. These allow you to specify, for all communication sessions with a particular master, whether or not to:

- enable or disable unsolicited reporting at power-up,
- enable or disable unsolicited reporting for normal operation,

- indicate which custom DNP3 map is associated with it, and
- enable or disable controls

Note that although 10 masters are supported by the SEL-421, only five unique configuration files are available. These mapping files follow the naming convention SET_DNP*n*.TXT, where *n* indicates the DNP3 map from 1 to 5. These files reside in the SEL-421 card settings subdirectory and are associated with the DNPMP*nn* setting of DNP3 Master *nn*, where *nn* is the master's number from 01 to 10. The DNPMP*nn* setting determines which configuration is used for communication sessions with master *nn*. For example, if DNPMP01 is set to 3, DNP3 LAN/WAN sessions between the SEL-421 and DNP3 Master 01 will employ the custom mapping file named SET_DNP3.TXT. Mapping files may be used by a single session, multiple sessions, or not at all.

See *Custom Data Mapping* for a discussion of how to configure custom DNP3 maps.

Table 6.20 SEL-421 Ethernet Port DNP3 Protocol Settings (Sheet 1 of 4)

Name	Description	Range	Default
ENDNP	Enable DNP3 (Y, N)	Y, N	N
DNPADR	DNP3 Address (0–65519)	0–65519	0
DNPPNUM	DNP3 Port Number for TCP and UDP (1–65534)	1–65534	20000
DNPMAP	DNP3 map Mode (AUTO, CUSTOM)	AUTO, CUSTOM	AUTO
RPADR01	DNP3 Address for Master 1 (0–65519)	0–65519	1
DNPIP01	IP Address for Master 1 (www.xxx.yyy.zzz)	20 Char String	“”
DNPTR01	Transport Protocol for Master 1 (UDP, TCP)	TCP, UDP	TCP
DNPUP01	UDP Response Port Number for Master 1 (1–65534, REQ)	REQ, 1–65534	20000
UNSL01	Enable Unsolicited Reporting for Master 1 (Y,N)	Y,N	N
PUNSL01	Enable Unsolicited Reporting at Powerup for Master 1 (Y, N)	Y,N	N
DNPMP01	CUSTOM Mode: DNP3 map associated with Master 1 (1–5)	1–5	“1”
DNPCL01	Enable Controls for Master 1 (Y, N)	Y, N	N
RPADR02	DNP3 Address for Master 2 (0–65519)	0–65519	1

Table 6.20 SEL-421 Ethernet Port DNP3 Protocol Settings (Sheet 2 of 4)

Name	Description	Range	Default
DNPIP02	IP Address for Master 2 (www.xxx.yyy.zzz)	20 Char String	“”
…			
DNPCL02	Enable Controls for Master 2 (Y, N)	Y,N	N
RPADR03	DNP3 Address for Master 3 (0–65519)	0–65519	1
DNPIP03	IP Address for Master 3 (www.xxx.yyy.zzz)	20 Char String	“”
…			
DNPCL03	Enable Controls for Master 3 (Y,N)	Y,N	N
RPADR04	DNP3 Address for Master 4 (0–65519)	0–65519	1
DNPIP04	IP Address for Master 4 (www.xxx.yyy.zzz)	20 Char String	“”
…			
DNPCL04	Enable Controls for Master 4 (Y, N)	Y,N	N
RPADR05	DNP3 Address for Master 5 (0–65519)	0–65519	1
DNPIP05	IP Address for Master 5 (www.xxx.yyy.zzz)	20 Char String	""
…			
DNPCL05	Enable Controls for Master 5 (Y, N)	Y,N	N
RPADR06	DNP3 Address for Master 6 (0–65519)	0–65519	1
DNPIP06	IP Address for Master 6 (www.xxx.yyy.zzz)	20 Char String	“”
…			
DNPCL06	Enable Controls for Master 4 (Y, N)	Y,N	N
RPADR07	DNP3 Address for Master 7 (0–65519)	0–65519	1
DNPIP07	IP Address for Master 7 (www.xxx.yyy.zzz)	20 Char String	“”
…			
DNPCL07	Enable Controls for Master 7 (Y, N)	Y,N	N
RPADR08	DNP3 Address for Master 8 (0–65519)	0–65519	1

Table 6.20 SEL-421 Ethernet Port DNP3 Protocol Settings (Sheet 3 of 4)

Name	Description	Range	Default
DNPIP08	IP Address for Master 8 (www.xxx.yyy.zzz)	20 Char String	“”
…			
DNPCL08	Enable Controls for Master 8 (Y, N)	Y, N	N
RPADR09	DNP3 Address for Master 9 (0–65519)	0–65519	1
DNPIP09	IP Address for Master 9 (www.xxx.yyy.zzz)	20 Char String	“”
…			
DNPCL09	Enable Controls for Master 9 (Y, N)	Y, N	N
RPADR10	DNP3 Address for Master 10 (0–65519)	0–65519	1
DNPIP10	IP Address for Master 10 (www.xxx.yyy.zzz)	20 Char String	“”
…			
DNPCL10	Enable Controls for Master 10 (Y, N)	Y, N	N
ECLASSA	Class for Analog Event Data (0–3)	0–3	2
ECLASSB	Class for Binary Event Data (0–3)	0–3	1
ECLASSC	Class for Counter Event Data (0–3)	0–3	0
DECPL	Data Scaling Decimal Places (0–3)	0–3	0
ANADB	Data Reporting Deadband Counts (0–32767)	0–32767	100
16BIT	DNP analog input objects default variation size. 16- or 32-bit default variations for analog inputs (16/32)	16, 32	16
STIMEO	Seconds to Select/ Operate Time-out (0.0–30.0)	0.0–30.0	1.0
DNPPAIR	AUTO Mode: Enable Use of DNP3 Trip Close Pairs (Y, N)	Y, N	N
DNPINA	Seconds to send Inactive Heartbeat (0=Off, 1–7200)	0–7200	120

Table 6.20 SEL-421 Ethernet Port DNP3 Protocol Settings (Sheet 4 of 4)

Name	Description	Range	Default
NUMEVE	Number of Events to Transmit On (1–200)	1–200	10
AGEEVE	Age of Oldest Event to Transmit On (0–100000 sec)	0–100000	2
ETIMEO	Event Message Confirm Timeout (1–50 sec)	1–50	2
URETRY	Unsolicited Message Max Retry Attempts (2–10)	2–10	3
UTIMEO	Unsolicited Message Offline Timeout (1–5000 sec)	1–5000	60

Custom Data Mapping

Installing an Ethernet card with DNP3 LAN/WAN into an SEL-421 adds the ability to make relay data available over Ethernet to a properly configured DNP3 Master. However, by default, DNPMAP = AUTO, which includes only the relay Digital and Analog Outputs. If Digital or Analog Inputs or Counters need to be available to DNP3, each point must be specified in a custom data map. Setting DNPMAP = CUSTOM enables you to specify the DNP3 data points available for up to 10 unique master sessions using any of 5 distinct DNP3 data maps.

The SEL-421 relay's DNP LAN/WAN interface also maps incoming control points either to remote bits within the relay or to internal command bits that cause circuit breaker operations. Please see *Table 6.25* for a list of control points and control methods available in the SEL-421.

When the Ethernet port has been configured to use custom DNP3 maps, the SEL-421 will obtain these maps from the Ethernet card Settings subdirectory. Custom setting files have the filename SET_DNP*x*.TXT, where *x* is the map number from 1 to 5.

The settings described in *Table 6.21* below are used to define the custom DNP3 maps. Please note that these settings are only accessible as files in the SETTINGS/CARD subdirectory. The best way to operate on these settings is by using the ACSELERATOR QuickSet settings assistant.

Table 6.21 SEL-421 DNP LAN/WAN Map Settings (Sheet 1 of 2)

Name	Type	Range	Default	Description
BIM0000–BIM1023	Binary Input Point	String of form "1:addr:bit" where addr must be in range 0–65534 and bit must be in range 0–15.	""	These settings correlate specific database bits with binary input indexes.
BIC0000–BIC1023	Binary Input Class	DFLT, 0–3	DFLT	These settings specify the event class for that index. A value of DFLT indicates to use the ECLASSB setting, 0 indicates to not generate events, and 1–3 provide the specific class to place the point events into.
BOM0000–BOM0511	Binary Output Point	OFF, 0–(*MAX* as defined by *Table 6.25*)	OFF	These settings correlate specific control operations from *Table 6.25* to binary output indexes. A value of OFF indicates no object at that index.

Table 6.21 SEL-421 DNP LAN/WAN Map Settings (Sheet 2 of 2)

Name	Type	Range	Default	Description
CIM0000–CIM0127	Counter Input Point	String of form "1:addr" where addr must be in range 0–65534.	“”	These settings correlate specific database registers with counter indexes.
CIC0000–CIC0127	Counter Input Class	DFLT, 0–3	DFLT	These settings specify the event class for that index. A value of DFLT indicates to use the ECLASSC setting, 0 indicates to not generate events, and 1–3 provide the specific class to place the point events into.
AIM0000–AIM0511	Analog Input Point	String of form "1:addr[,t]" where addr must be in range 0–65534 and t must be i, u, il, ul, or f.	“”	These settings correlate specific database registers with analog input indexes. The optional “treat-as” qualifier (t) is used to indicate that the data at the referenced database address is to be treated as if is of this type, rather than the type indicated in the database. i = integer, u = unsigned integer, il = long integer, ul = unsigned long integer, f = floating point
AIC0000–AIC0511	Analog Input Class	DFLT, 0–3	DFLT	These settings specify the event class for that index. A value of DFLT indicates to use the ECLASSA setting, 0 indicates to not generate events, and 1–3 provide the specific class to place the point events into.
AIS0000–AIS0511	Analog Input Scaling	DFLT, 0.000001–1000000.0	DFLT	A value of DFLT indicates to use the DECPL setting for determining the scaling of a point. The given point will be multiplied by this value before being reported through DNP.
AID0000–AID0511	Analog Input Deadband	DFLT, 0–32767	DFLT	This is the deadband to use for the point at the given index. A value of DFLT indicates to use the scaling on the ANADB setting.
AOM0000–AOM0063	Analog Output Point	OFF, 0–255	OFF	These settings correlate addresses within the card-controlled D1 region to analog output indexes. A value of OFF indicates no object at that index.

When DNPMAP = CUSTOM, the points that are included in the DNP3 map are defined by the contents of the custom DNP3 map files. The database capacity for each point type per map and system-wide is discussed below:

- ➤ The total number of Binary Input points allowed per map is 1024. The total system capacity (all custom DNP3 maps) is 2048 Digital Input points with unique references.
- ➤ The total number of Analog Input points allowed per map is 512. The total system capacity is 2048 Analog Inputs with unique references.
- ➤ The total number of Binary Output control points allowed per map is 512.
- ➤ The total number of Analog Output control points allowed per map is 64. The total system capacity, for all the custom DNP3 maps, is 256 Analog Output points with unique references.

Binary Inputs

The DNP index for any data point within a custom DNP3 map is assigned based on the associated setting name (i.e., BIM*xxxx* for a Binary Input, where *xxxx* is the DNP index).

In order for Binary Input points to have SOE-quality timestamps, each point must be listed in the SER and the corresponding STATE region points mapped to DNP (see *DNP LAN/WAN Application Example on page R.6.49*).

Analog Inputs

Analog dead bands and scaling factors may be set for each individual point. Use the AID*xxxx* setting to impose a dead band of 0–32767. This may be used in conjunction with a scaling factor of 0.000001–1000000.0 entered in AIS*xxxx*.

Binary Outputs

NOTE: When DNPMAP = CUSTOM, the DNPPAIR setting is ignored. The user must choose the appropriate CPId(s) to select paired or unpaired points for custom BO maps. For example, you may set BOM000 = 160, BOM001 = 130 to set the first DNP BO point to the remote bit pair RB02/RB01 and the second to RB03.

A Binary Output manipulates a control point, which is associated to the Binary Output by a Control Point Identifier (CPId). The CPId represents either a non-paired (single) control point or a paired (two control points) control point, where the operation selects the control point. The control points correspond to all paired and unpaired remote bits and all breaker controls plus the CCIN*x* bits. CPIds for the SEL-421 Relay, which has 128 CCIN*x* points, 32 Remote Bits, 16 Remote Bit pairs, and controls for 2 Circuit Breakers, are given in *Table 6.22*.

Table 6.22 SEL-421 Binary Output CPId Values

CPId	Description
0–127	CCIN001–CCIN032
128–159	Remote Bits RB01–RB32
160–175	Remote Bit Pairs RB02/RB01–RB32/RB31
176	Open/Close Pair for Circuit Breaker 1 (OC1–CC1)
177	Open/Close Pair for Circuit Breaker 2 (OC2–CC2)

Analog Outputs

Any of the 256 Analog Output Quantities in the D1 Region, RA001–RA256, can be included in a custom data map. Up to 64 Analog Outputs can be assigned to a custom map. Please note that you must subtract 1 from the Analog Quantity number to get the correct index. For example, if you want to specify RA064, use index 63.

DNP Map Command

Use the **POR 5** and Ethernet card **DNPMAP** command to display the data (object types, indices, default variation and source) and controls (object type, indices and destination) that are accessible via DNP LAN/WAN. The output of the **DNPMAP** command documents the DNP3 data map(s) in the Ethernet card to help with the configuration of the DNP3 master.

If the DNPMAP setting is set to CUSTOM, then you can specify an additional integer parameter corresponding to a DNPMAP number (1–5) to view each custom DNP3 data map. For example, the command **DNPMAP 2** would be used to view the custom data map for DNP3 session 2. If a DNPMAP number is not specified, a summary of DNP3 map settings for all configured sessions will be displayed.

Summary and detailed map configurations are also available in the DNPMAP.TXT and DNPMAP*nn*.TXT files from the SEL-421 FTP interface. The individual file names associated with the detailed custom map settings follow the DNPMAP*nn*.TXT naming convention.

Testing

Use the **TEST DB** command to test the communications card relay database. The **TEST DB** command can be used to override any value in the relay database. Since the relay database provides data to the communications card interfaces, the **TEST DB** command can also be used to test the data read operations of any of the protocols on an installed Ethernet card. Use the **MAP 1** command and the **VIEW 1** command to inspect the relay database (see *MAP on page R.9.27*). You must be familiar with the relay database structure to use the **TEST DB** command effectively; see *Communications Card Database on page R.4.18* for more information.

DNP LAN/WAN Documentation

The following section contains information specific to the DNP3 LAN/WAN implementation.

Device Profile

Table 6.23 contains the standard DNP LAN/WAN device profile information. Rather than checkboxes in the example Device Profile in the DNP3 Subset Definitions, only the relevant selections are shown.

Table 6.23 SEL-421 DNP LAN/WAN Device Profile (Sheet 1 of 2)

Parameter	Value
Vendor name	Schweitzer Engineering Laboratories
Device name	SEL-421 Relay with Ethernet card
Highest DNP request level	Level 2
Highest DNP response level	Level 2
Device function	Slave
Notable objects, functions, and/or qualifiers supported	None
Maximum data link frame size transmitted/ received (octets)	292
Maximum data link retries	0
Requires data link layer confirmation	No
Maximum application fragment size transmitted/received (octets)	2048
Maximum application layer retries	None
Requires application layer confirmation	When reporting Event Data
Data link confirm time-out	Configurable
Complete application fragment time-out	None
Application confirm time-out	Configurable
Complete Application response time-out	None
Executes control WRITE binary outputs	Always
Executes control SELECT/OPERATE	Always
Executes control DIRECT OPERATE	Always

Table 6.23 SEL-421 DNP LAN/WAN Device Profile (Sheet 2 of 2)

Parameter	Value
Executes control DIRECT OPERATE-NO ACK	Always
Executes control count greater than 1	Never
Executes control Pulse On	Always
Executes control Pulse Off	Always
Executes control Latch On	Always
Executes control Latch Off	Always
Executes control Queue	Never
Executes control Clear Queue	Never
Reports binary input change events when no specific variation requested	Only time-tagged
Reports time-tagged binary input change events when no specific variation requested	Binary input change with time
Sends unsolicited responses	Configurable with unsolicited message enable settings
Sends static data in unsolicited responses	Never
Default counter object/variation	Object 20, Variation 6
Counter roll-over	N/A
Sends multifragment responses	Yes

Object List

The list of DNP3 objects given in *Table 6.25* lists the supported objects for DNP3 LAN/WAN. Please note the added support of object 34, and removed support of objects 112 and 113.

Table 6.24 SEL-421 DNP3 Object List (Sheet 1 of 6)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
1	0	Binary Input—All Variations	1	0, 1, 6, 7, 8, 17, 28		
1	1[e]	Binary Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
1	2	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[e]	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[e]	Binary Output Status	1	0, 1, 6, 7, 8	129	0, 1

Table 6.24 SEL-421 DNP3 Object List (Sheet 2 of 6)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
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				
12	3	Pattern Mask				
20	0	Binary Counter—All Variations	1	0, 1, 6, 7, 8, 17, 28		
20	1	32-Bit Binary Counter				
20	2	16-Bit Binary Counter				
20	3	32-Bit Delta Counter				
20	4	16-Bit Delta Counter				
20	5	32-Bit Binary Counter Without Flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	6[e]	16-Bit Binary Counter Without Flag	1	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				

Table 6.24 SEL-421 DNP3 Object List (Sheet 3 of 6)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
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[e]	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				
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	32-Bit Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	2	16-Bit Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	3	32-Bit Analog Input Without Flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28

Table 6.24 SEL-421 DNP3 Object List (Sheet 4 of 6)

Obj.	Var.	Description	Request[a] Funct. Codes[c]	Request[a] Qual. Codes[d]	Response[b] Funct. Codes[c]	Response[b] Qual. Codes[d]
30	4[e]	16-Bit Analog Input Without Flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	5	Short Floating Point Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	6	Long Floating Point Analog Input	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	32-Bit Analog Change Event Without Time	1	6, 7, 8	129	17, 28
32	2[e]	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	Short Floating Point Analog Change Event	1	6, 7, 8	129	17, 28
32	6	Long Floating Point Analog Change Event	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 6.24 SEL-421 DNP3 Object List (Sheet 5 of 6)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
34	0	Analog Input Reporting Dead-Band Setting—All Variations	1	1, 6, 7, 8, 17, 28	129	1, 17, 28
34	0	Analog Input Reporting Dead-Band Setting—All Variations	2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
34	1[e]	16-Bit Analog Input Reporting Dead-Band Setting	1	1, 6, 7, 8, 17, 28	129	1, 17, 28
34	1[e]	16-Bit Analog Input Reporting Dead-Band Setting	2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
34	2	32-Bit Analog Input Reporting Dead-Band Setting	1	1, 6, 7, 8, 17, 28	129	1, 17, 28
34	2	32-Bit Analog Input Reporting Dead-Band Setting	2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
34	3	Floating Point Analog Input Reporting Dead-Band Setting	1	1, 6, 7, 8, 17, 28	129	1, 17, 28
34	3	Floating Point Analog Input Reporting Dead-Band Setting	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	139	
40	1	32-Bit Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
40	2[e]	16-Bit 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
50	0	Time and Date—All Variations				
50	1	Time and Date			129	07, quantity=1
50	2	Time and Date With Interval				
50	3	Time and Date at Last Recorded Time	1	7, 8 index=0	129	07, quantity=1
51	0	Time and Date CTO—All Variations				
51	1	Time and Date CTO				

Table 6.24 SEL-421 DNP3 Object List (Sheet 6 of 6)

Obj.	Var.	Description	Request[a] Funct. Codes[c]	Request[a] Qual. Codes[d]	Response[b] Funct. Codes[c]	Response[b] Qual. Codes[d]
51	2	Unsynchronized Time and Date CTO	07, quan-ity=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	6		
60	1	Class 0 Data	1	6	129	0, 1
60	2	Class 1 Data	1, 20, 21	6, 7, 8	129	17, 28
60	3	Class 2 Data	1, 20, 21	6, 7, 8	129	17, 28
60	4	Class 3 Data	1, 20, 21	6, 7, 8	129	17, 28
70	1	File Identifier				
80	1	Internal Indications	2	0, 1 index=7		
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				
113	all	Virtual Terminal Event Data				
N/A		No object required for the following function codes: 13 cold start 14 warm start 24 record current time	13, 14, 24			

[a] Supported in requests from master
[b] May generate in response to master
[c] Decimal
[d] Hexadecimal
[e] Default variation

Control Point Operation

Control point operation for DNP LAN/WAN is functionally identical to Serial DNP3 operation. Use Trip and Close or Code Selection operations with Object 12 control relay output block command messages to operate the points shown in *Table 6.25*. Use the Control Point ID (CPId) shown to select the desired control points to build the Custom Binary Output map. Note that all Binary outputs (paired and non-paired) are available to the DNP LAN/WAN interface. Pulse operations provide a pulse duration of at least one protection-processing interval.

Table 6.25 SEL-421 DNP LAN/WAN Object 12 Control Point Operation (Sheet 1 of 2)

Indices	Control Points	Trip / Close Pairs		Code Selection Operation			
		Close (0x4X)	Trip (0x8X)	Latch On (3)	Latch Off (4)	Pulse On (1)	Pulse Off (2)
0–127	CCIN001–CCIN128	SET Comms Card input 001–128	CLEAR Comms Card input 001–128	SET Comms Card input 001–128	CLEAR Comms Card input 001–128	SET Comms Card input 001–128	CLEAR Comms Card input 001–128
128	RB01	SET remote bit RB01	CLEAR remote bit RB01	SET remote bit RB01	CLEAR remote bit RB01	SET remote bit RB01	CLEAR remote bit RB01
129	RB02	SET remote bit RB02	CLEAR remote bit RB02	SET remote bit RB02	CLEAR remote bit RB02	SET remote bit RB02	CLEAR remote bit RB02
130	RB03	SET remote bit RB03	CLEAR remote bit RB03	SET remote bit RB03	CLEAR remote bit RB03	SET remote bit RB03	CLEAR remote bit RB03
...							
143	RB16	SET remote bit RB16	CLEAR remote bit RB16	SET remote bit RB16	CLEAR remote bit RB16	SET remote bit RB16	CLEAR remote bit RB16
144	RB17	SET remote bit RB17	CLEAR remote bit RB17	SET remote bit RB17	CLEAR remote bit RB17	SETSet remote bit RB17	CLEAR remote bit RB17
...							
159	RB32	SET remote bit RB32	CLEAR remote bit RB32	SET remote bit RB32	CLEAR remote bit RB32	SET remote bit RB32	CLEAR remote bit RB32
160	RB02/RB01	PULSE remote bit RB02	PULSE remote bit RB01	PULSE remote bit RB02	PULSE remote bit RB01	PULSE remote bit RB02	PULSE remote bit RB01
161	RB04/RB03	PULSE remote bit RB04	PULSE remote bit RB03	PULSE remote bit RB04	PULSE remote bit RB03	PULSE remote bit RB04	PULSE remote bit RB03
162	RB06/RB05	PULSE remote bit RB06	PULSE remote bit RB05	PULSE remote bit RB06	PULSE remote bit RB05	PULSE remote bit RB06	PULSE remote bit RB05
...							
167	RB16/RB15	PULSE remote bit RB16	PULSE remote bit RB15	PULSE remote bit RB16	PULSE remote bit RB15	PULSE remote bit RB16	PULSE remote bit RB15
168	RB18/RB17	PULSE remote bit RB18	PULSE remote bit RB17	PULSE remote bit RB18	PULSE remote bit RB17	PULSE remote bit RB18	PULSE remote bit RB17
...							
175	RB32/RB31	PULSE remote bit RB32	PULSE remote bit RB31	PULSE remote bit RB32	PULSE remote bit RB31	PULSE remote bit RB32	PULSE remote bit RB31

Table 6.25 SEL-421 DNP LAN/WAN Object 12 Control Point Operation (Sheet 2 of 2)

Indices	Control Points	Trip / Close Pairs		Code Selection Operation			
		Close (0x4X)	Trip (0x8X)	Latch On (3)	Latch Off (4)	Pulse On (1)	Pulse Off (2)
176	CB1	PULSE CC1, Circuit Breaker 1 close bit	PULSE OC1, Circuit Breaker 1 open bit	PULSE OC1, Circuit Breaker 1 open bit	PULSE CC1, Circuit Breaker 1 close bit	PULSE OC1, Circuit Breaker 1 open bit	PULSE CC1, Circuit Breaker 1 close bit
177	CB2	PULSE CC2, Circuit Breaker 2 close bit	PULSE OC2, Circuit Breaker 2 open bit	PULSE OC2, Circuit Breaker 2 open bit	PULSE CC2, Circuit Breaker 2 close bit	PULSE OC2, Circuit Breaker 2 open bit	PULSE CC2, Circuit Breaker 2 close bit

DNP LAN/WAN Application Example

Application

This example uses an SEL-421 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 6.1*.

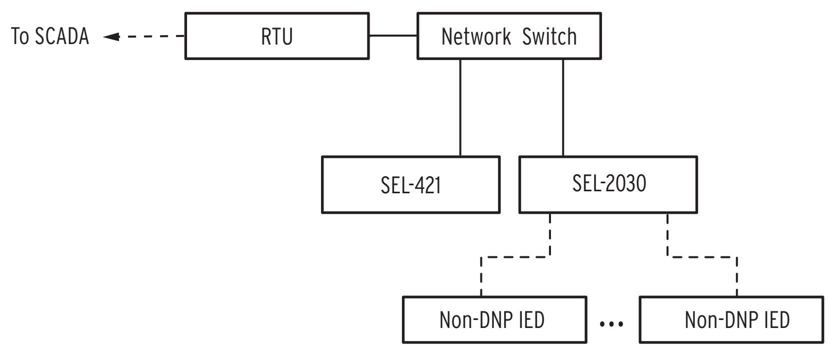

Figure 6.3 DNP LAN/WAN Application Example Ethernet Network

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-421 slave, has an IP address of 192.9.0.1 and a DNP3 address of 12. The SEL-421 should be assigned a DNP3 address of 101.

All event data (analog, binary, counter) should be assigned to CLASS 1.

All Binary Inputs should have SOE-quality timestamps.

The metering, status data and controls that the RTU will receive and/or send to the relay are listed in *Table 6.17*.

Table 6.26 DNP LAN/WAN Application Example Custom Data Map

Name	Object Type	Custom Map Index	Description
EN	Binary Input	0	Relay enabled
TRIPLED	Binary Input	1	
IN101	Binary Input	2	
IN102	Binary Input	3	
IN103	Binary Input	4	
IN104	Binary Input	5	
SALARM	Binary Input	6	
HALARM	Binary Input	7	
TESTDNP	Binary Input	8	
RB01	Binary Output	0	General use Control Point (Remote Bit) 1
RB02	Binary Output	1	General use Control Point (Remote Bit) 2
RB03	Binary Output	2	General use Control Point (Remote Bit) 3
RB04	Binary Output	3	General use Control Point (Remote Bit) 4
RB05	Binary Output	4	General use Control Point (Remote Bit) 5
RB06	Binary Output	5	General use Control Point (Remote Bit) 6
OC1, CC1	Binary Output	6	Circuit Breaker 1 trip/close

Settings

Use the ACSELERATOR QuickSet® SEL-5030 software to enter the DNP3 protocol settings and new data map into the relay.

Table 6.27 DNP LAN/WAN Application Example Protocol Settings (Sheet 1 of 2)

Setting Name	Setting	Description
ENDNP	Y	Enable DNP3
DNPADR	101	DNP3 Address for Relay is 101
DNPPNUM	20000[a]	DNP3 Port Number for TCP
DNPMAP	CUSTOM	CUSTOM DNP3 map Mode
ECLASSA	1	Analog Event Data = Class 1
ECLASSB	1	Binary Event Data = Class 1
ECLASSC	1	Counter Event Data = Class 1
DECPL	2	Scale analog 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. (102=100)
ANADB	200	Analog Deadband Counts, set to 2 engineering units, based on DECPL scaling factor
STIMEO	1.0[a]	1.0 Second to Select/Operate Time-out
DNPPAIR	N[a]	AUTO Mode: Disable Use of DNP3 Trip Close Pairs
DNPINA	120[a]	Wait 120 Seconds to send Inactive Heartbeat
NUMEVE	10[a]	Transmit after 10 Events
AGEEVE	2[a]	Transmit when Age of Oldest Event = 2 sec
ETIMEO	2[a]	Event Message Confirm Timeout (2 sec)

Table 6.27 DNP LAN/WAN Application Example Protocol Settings (Sheet 2 of 2)

Setting Name	Setting	Description
URETRY	3[a]	3 Max Retry Attempts per Unsolicited Message
UTIMEO	60[a]	60 sec for Unsolicited Message Offline Timeout
RPADR01	12	DNP3 Address for Master 1 is 12
DNPIP01	192.9.0.1	IP Address for Master 1 (www.xxx.yyy.zzz)
DNPTR01	TCP	Transport Protocol for Master 1 (UDP, TCP)
DNPUP01	20000[a]	UDP Response Port Number for Master 1
UNSL01	N	Disable Unsolicited Reporting for Master 1
PUNSL01	N	Disable Unsolicited Reporting at Powerup for Master 1
DNPMP01	1	CUSTOM Mode: DNP3 map associated with Master 1 (Map 1)
DNPCL01	Y	Enable Controls for Master 1

[a] Default value

To meet the requirement for SOE-quality timestamps, enter all binary inputs into the SER report. See *Figure 6.4* for a screenshot of the process.

Figure 6.4 Add Binary Inputs to SER Point List

Pass the Binary Input states and timestamps to the DNP master by mapping the SER points from the STATE region, as demonstrated in *Table 6.28*.

Table 6.28 DNP LAN/WAN Application Example Binary Input Map

Setting Name	Setting	Description
BIM0000 Database Address	1:STATE:ELEMENTS:0	SER Point 1 (EN)
BIM0001 Database Address	1:STATE:ELEMENTS:1	SER Point 2 (TRIPLED)
BIM0002 Database Address	1:STATE:ELEMENTS:2	SER Point 3 (IN101)
BIM0003 Database Address	1:STATE:ELEMENTS:3	SER Point 4 (IN102)
BIM0004 Database Address	1:STATE:ELEMENTS:4	SER Point 5 (IN103)
BIM0005 Database Address	1:STATE:ELEMENTS:5	SER Point 6 (IN104)
BIM0006 Database Address	1:STATE:ELEMENTS:6	SER Point 7 (SALARM)
BIM0007 Database Address	1:STATE:ELEMENTS:7	SER Point 8 (HALARM)
BIM0008 Database Address	1:STATE:ELEMENTS:8	SER Point 9 (TESTDNP)

Table 6.29 DNP LAN/WAN Application Example Binary Output Map

Setting Name	Setting	Description
BOM0000 Database Address	128	Custom BO map position for RB01 Control
BOM0001 Database Address	129	Custom BO map position for RB02 Control
BOM0002 Database Address	130	Custom BO map position for RB03 Control
BOM0003 Database Address	131	Custom BO map position for RB04 Control
BOM0004 Database Address	132	Custom BO map position for RB05 Control
BOM0005 Database Address	133	Custom BO map position for RB06 Control
BOM0006 Database Address	176	Custom BO map position for Circuit Breaker 1 trip/close Control

Table 6.30 DNP LAN/WAN Application Example Analog Input Map (Sheet 1 of 2)

Setting Name	Point	Scale Factor	Deadband	Description
AIM0000 Database Address	1:METER:IA1 (Meter Region > IA1)	1	50	Custom map position for IA1 magnitude, scale by 10 and report 5 amp change events
AIM0001 Database Address	1:100Ch			Custom map position for IA1 angle[a], scale by 100 and report 2 degree change events
AIM0002 Database Address	1:METER:IB1 (Meter Region > IB1)	1	50	Custom map position for IB1 magnitude[a], scale by 10 and report 5 amp change events
AIM0003 Database Address	1:1010h			Custom map position for IB1 angle[a], scale by 100 and report 2 degree change events
AIM0004 Database Address	1:METER:IC1 (Meter Region > IC1)	1	50	Custom map position for IC1 magnitude[a], scale by 10 and report 5 amp change events
AIM0005 Database Address	1:1014h			Custom map position for IC1 angle[a], scale by 100 and report 2 degree change events
AIM0006 Database Address	1:METER:VA (Meter Region > VA)	1	10000	Custom map position for VA magnitude, scale by 10 and report 1 kv change events
AIM0007 Database Address	1:103Ch			Custom map position for VA angle[a], scale by 100 and report 2 degree change events
AIM0008 Database Address	1:METER:VB (Meter Region > VB)	1	10000	Custom map position for VB magnitude, scale by 10 and report 1 kv change events
AIM0009 Database Address	1:1040h			Custom map position for VB angle[a], scale by 100 and report 2 degree change events
AIM0010 Database Address	1:METER:VC (Meter Region > VC)	1	10000	Custom map position for VC magnitude, scale by 10 and report 1 kv change events

Table 6.30 DNP LAN/WAN Application Example Analog Input Map (Sheet 2 of 2)

Setting Name	Point	Scale Factor	Deadband	Description
AIM0011 Database Address	1:1044h			Custom map position for VC angle[a], scale by 100 and report 2 degree change events
AIM0012 Database Address	1:METER:P (Meter Region > P)	3	500	Custom map position for three-phase real power in MW scaled by 1000 with an event dead band of 0.5 MW
AIM0013 Database Address	1:METER:Q (Meter Region > Q)	3	500	Custom map position for three-phase real power in MW scaled by 1000 with an event dead band of 0.5 MW
AIM0014 Database Address	1:METER:VDC1 (Meter Region > VDC1)			DC1 voltage[a] multiplied by 100, with a dead band of 2 volts

[a] Uses default scaling and dead band

Table 6.31 DNP LAN/WAN Application Example Analog Output Map

Setting Name	Setting	Description
AOM0000 Database Address	0	Active Settings Group

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Section 7
Synchrophasors

The SEL-421 Relay provides Phasor Measurement Unit (PMU) capabilities when connected to a suitable IRIG-B time source. Synchrophasor is used as a general term that can refer to data or protocols.

This section covers:

See *Configuring High-Accuracy Timekeeping on page U.4.71* for the requirements of the IRIG-B time source. Synchrophasors are still measured if the high-accuracy time source is not connected, however, the data are not time-synchronized to any external reference, as indicated by Relay Word bit TSOK = logical 0.

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-2407 Satellite-Synchronized 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 SEL-421 relays, to synchronize the gathering of power system data. The accurate clock allows precise event report triggering and other off-line analysis functions, which are described in *Section 4: Time-Synchronized Measurements in the Applications Handbook*.

The SEL-421 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 serial port(s) are reserved for synchrophasor protocol use. See *Settings for Synchrophasors on page R.7.9*.

The SEL-421 High-Accuracy Timekeeping function generates status Relay Word bits and time-quality information that is important for synchrophasor measurement. Some protection SELOGIC variables, and programmable digital trigger information (C37.118 protocol only) is also added to the Relay Word bits for synchrophasors—see *Synchrophasor Relay Word Bits on page R.7.18*.

When synchrophasor measurement is enabled, the SEL-421 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 SEL-421. See *Synchrophasor Analog Quantities on page R.7.20*. You can view synchrophasor data over a serial port set to PROTO := SEL, see *View Synchrophasors by Using the MET PM Command on page R.7.24*.

The value of synchrophasor data increases greatly when the data are shared over a communications network in real time. Two synchrophasor protocols are available in the SEL-421 that allow for a centralized device to collect data efficiently from several phasor measurement units (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

Previous SEL-421 relays (firmware version R102 through R111) provided the SEL Fast Message synchrophasor protocol. SEL-421 relays, beginning with firmware version R112, still support this protocol, although the required settings are in a different settings class, and a few message rates are no longer supported—see *SEL-421 Fast Message Synchrophasor Settings on page R.7.32*.

Beginning with firmware version R112, the SEL-421 (and the SEL-421-1) also support IEEE C37.118, Standard for Synchrophasors for Power Systems. In the SEL-421, this protocol is referred to simply as C37.118. See *Settings Affect Message Contents on page R.7.25*.

In any installation, the SEL-421 can transmit synchrophasors using only one of the synchrophasor protocols (SEL Fast Message Synchrophasor or C37.118), as selected by Global setting MFRMT. However, the chosen protocol is available on multiple serial ports when port setting PROTO := PMU and PMUMODE := SERVER.

With either the SEL Fast Message or C37.118 synchrophasor protocol, the SEL-421 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, and Fast SER Messages on page R.5.8*.

Real-Time Control

You can configure the SEL-421 to receive C37.118 protocol synchrophasor data. The SEL-421 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.

Figure 7.1 shows an application example. 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. Alternate 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.

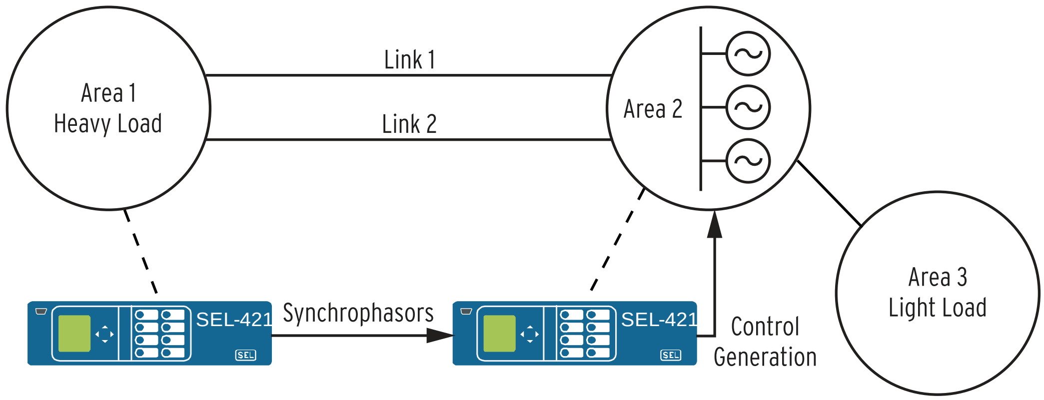

Figure 7.1 Real-Time Control Application

Figure 7.2 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. Lines 4 through 10 unwrap the phase angle when the difference exceeds ±180 degrees.

Line 11 calculates a qualification signal consisting of the local and remote quality indicators. RTCROKA is the local indicator. RTCAD16 is the remote quality indicator. *Figure 7.3* shows its construction at the remote relay.

Line 12 computes absolute value of the angle. Line 13 checks the angle against the reference value. In this case, the reference value is 6 degrees. Lines 14 and 15 build a timer that operates after two successive messages in excess of the threshold. On line 15, the value PSV05 tracks the last result of the angle difference check.

The final result, PSV04, asserts when the SEL-421 receives two successive synchrophasor messages with angle difference exceeding 6 degrees.

```
Protection 1
1: PMV53 := V1LPMAD
2: PMV54 := RTCAP02
3: PMV55 := V1LPMAD - RTCAP01
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: PSV01 := RTCROKA AND RTCAD01
12: PMV56 := ABS(PMV55)
13: PSV03 :=(PMV56 > 10.000000) AND PSV01
14: PSV04 := PSV01 AND PSV03 AND PSV05
15: PSV05 := (NOT PSV01 AND PSV05 OR PSV01 AND PSV03)
```

Figure 7.2 Local Relay SELOGIC Settings

Figure 7.3 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 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 7.2*) contains this remote data quality indicator. A local relay quality indicator also qualifies line 11.

```
1: PSV64 := TSOK AND PMDOK
```

Figure 7.3 Remote Relay SELogic Settings

Set the remote relay Global settings according to *Figure 7.4*. Set the number of digitals (NUMDSW) to one. In this case, the SEL-421 sends SELogic values PSV49 through PSV64 in the 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 7.4 Remote Relay Global Settings

Set the local relay Global settings according to *Figure 7.5*. It is important for synchrophasors to be enabled (EPMU = Y), the application to be fast (PMAPP = F), the compensation settings to be set correctly (VCOMP, IWCOMP, and IXCOMP), and for IRIGC = C37.118.

Set MRTCDLY for the maximum expected communication 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 7.5 Local Relay Global Settings

Set the port settings for the port that sends the synchrophasor data on the remote relay, according to *Figure 7.6*.

```
Protocol Selection

PROTO   := PMU

Communications Settings

SPEED   := 57600    STOPBIT := 1        RTSCTS  := N

SEL Protocol Settings

FASTOP  := N

PMUMODE := SERVER
```

Figure 7.6 Remote Relay Port Settings

Set the port settings for the port that receives the synchrophasor data on the local relay, according to *Figure 7.7*. 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 7.7 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, RTCAP01 in *Figure 7.2*) 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 communication channels with longer transmission delay, but at the cost of increasing the maximum time of operation. A second option is to improve the communication 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 communication channel disruption. In this case, putting RTCDLYA in the SER provides warning.

The **COM RTC** command also provides information for monitoring system status. *Figure 7.8* shows a **COM RTC** command response. Use the maximum packet delay field to monitor the communication 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 7.8 Example COM RTC Command Response

Synchrophasor Measurement

NOTE: The synchrophasor data stream is separate from the other protection and metering functions, as shown in Figure 3.1 on page A.3.3.

The phasor measurement unit in the SEL-421 measures three voltages and six currents on a constant-time basis. These samples are synchronized to the high-accuracy IRIG time source, and occur at a fixed frequency of either 60 Hz or 50 Hz, depending on Global setting NFREQ. The relay then filters the measurement samples according to Global setting PMAPP := F or N—see *PMAPP on page R.7.9*. The phase angle is measured relative to an absolute time reference, which is represented by a cosine function in *Figure 7.9*. The time-of-day is shown for the two time marks.

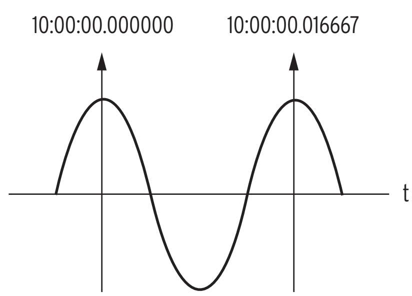

Figure 7.9 High Accuracy Clock Controls Reference Signal (60 Hz System)

The instrumentation transformers (pts or cts) and the interconnecting cables may introduce a time shift in the measured signal. Global settings VCOMP, IWCOMP, and IXCOMP, entered in degrees, are added to the measured phasor angles to create the corrected phasor angles, as shown in *Figure 7.10*, *Figure 7.11*, and *Equation 7.1*. The VCOMP, IWCOMP, and IXCOMP settings may be positive or negative values.

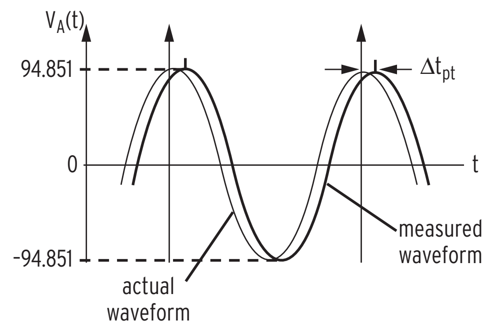

Figure 7.10 Waveform at Relay Terminals May Have a Phase Shift

$$\text{Compensation Angle} = \frac{\Delta t_{pt}}{\left(\frac{1}{\text{freq}_{\text{nominal}}}\right)} \cdot 360° = \Delta t_{pt} \cdot \text{freq}_{\text{nominal}} \cdot 360°$$

Equation 7.1

If the time shift on the pt measurement path Δt_{pt} = 0.784 ms and the nominal frequency, $\text{freq}_{\text{nominal}}$ = 60Hz, use *Equation 7.2* to obtain the correction angle:

$$0.784 \cdot 10^{-3}\text{s} \cdot 60\text{s}^{-1} \cdot 360° = 16.934°$$

Equation 7.2

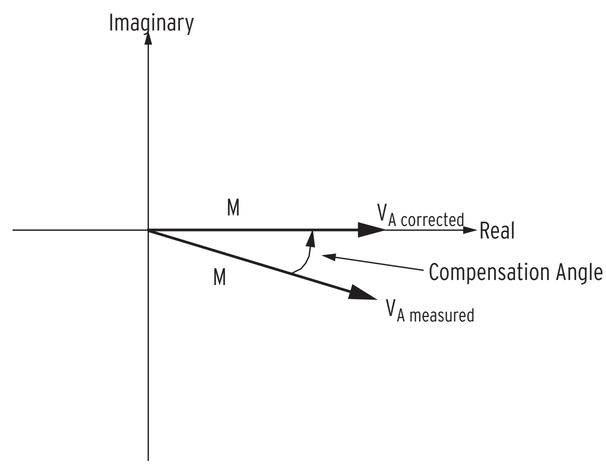

Figure 7.11 Correction of Measured Phase Angle

For a sinusoidal signal, the phasor magnitude is calculated as shown in *Equation 7.3*. The phasors are rms values scaled in primary units, as determined by Group settings PTRY or PTRZ (for the presently selected line voltage source, VY or VZ, respectively), CTRW, and CTRX (for the IW and IX current sources). The SEL-421 then creates the summation quantities IS = IW + IX phase currents, and calculates the positive-sequence voltage V1LPM_ and currents I1WPM_, I1XPM_, and I1SPM_.

$$\text{Magnitude M} = \frac{V_{pk}}{\sqrt{2}} \cdot \text{PTR}_{\text{setting}}$$

Equation 7.3

With PTRY = 2000, and the signal in *Figure 7.10* (with peak voltage V_{pk} = 94.851 V), use *Equation 7.4* to obtain the magnitude, VALPMM:

$$\begin{aligned} \text{VALPMM} &= \frac{94.851}{\sqrt{2}} \cdot 2000 \\ &= 134140 \text{ V} \\ &= 134.140 \text{ kV} \end{aligned}$$

Equation 7.4

Finally, the magnitude and angle pair for each synchrophasor is converted to a real and imaginary pair using *Equation 7.5* and *Equation 7.6*. For example, analog quantities VALPMM and VALPMA are converted to VALPMR and VALPMI. An example phasor with an angle measurement of 104.400° is shown in *Figure 7.11*. *Table 7.13* lists all of the synchrophasor analog quantities available in the SEL-421.

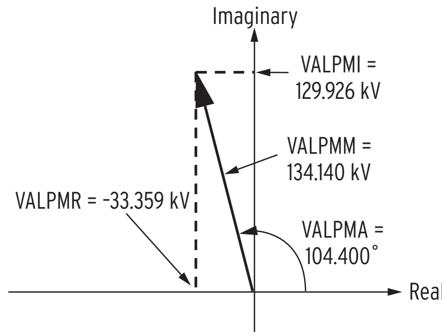

Figure 7.12 Example Calculation of Real and Imaginary Components of Synchrophasor

$$\text{Real part} = \text{M} \cdot \cos(\text{angle})$$

Equation 7.5

$$\text{Imaginary part} = \text{M} \cdot \sin(\text{angle})$$

Equation 7.6

Using the magnitude M from *Equation 7.5*, the real part is given in *Equation 7.7*.

$$\begin{aligned} \text{VALPMR} &= 134.140 \text{ kV} \cdot \cos 104.400° \\ &= -33.359 \text{ kV} \end{aligned}$$

Equation 7.7

Similarly, the imaginary part is calculated in *Equation 7.8*

$$\begin{aligned} \text{VALPMI} &= 134.140 \text{ kV} \cdot \sin 104.400° \\ &= 129.926 \text{ kV} \end{aligned}$$

Equation 7.8

Because the sampling reference is based on the GPS clock (IRIG-B signal) and not synchronized to the power system, an examination of successive synchrophasor data sets will almost always show some angular change between samples of the same signal. This is not a malfunction of the relay or the power system, but is merely a result of viewing data from one system with an instrument with an independent time base. In other words, a power system has a nominal frequency of either 50 or 60 Hz, but on closer examination, it is usually running a little faster or slower than nominal.

Accuracy

The listed SEL-421 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).

See IEEE C37.118 for an explanation of total vector error and for accuracy definitions and conditions.

The SEL-421 synchrophasor measurement accuracy is:

NOTE: When the SEL-421 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:

- Signal Frequency Range: ±5 Hz of nominal (50Hz or 60Hz)
- Voltage Magnitude Range: 30 V – 150 V
- Current Magnitude Range: (0.1 - 2) • I_{nom}, (I_{nom} = 1A or 5A)
- Phase Angle Range: –179.99 to 180°
- Harmonic distortion ≤10% (any harmonic)
- Out of band interfering signals ≤ 10%

The out of band interfering signal frequency (f_i) must satisfy:

$| f_i – \text{NFREQ} | > \text{MRATE}/2$,

where NFREQ is nominal system frequency and MRATE is the message rate, as defined in IEEE C37.118.

Settings for Synchrophasors

The phasor measurement unit (PMU) settings are listed in *Table 7.1*. Make these settings when you want to use the C37.118 synchrophasor protocol, or if you want to use synchrophasor analog quantities.

The Global enable setting EPMU must be set to Y before the remaining SEL-421 synchrophasor settings are available. No synchrophasor data collection can take place when EPMU := N.

You must make the serial port settings in *Table 7.3* to transmit data with a synchrophasor protocol. It is possible to set EPMU := Y without using any serial ports for synchrophasor protocols. For example, the serial port **MET PM** ASCII command can still be used.

The Global settings for the SEL Fast Message synchrophasor protocol are a subset of the *Table 7.1* settings, and are listed separately, see *SEL Fast Message Synchrophasor Protocol on page R.7.31*.

Table 7.1 PMU Settings in the SEL-421 for C37.118 Protocol in Global Setting (Sheet 1 of 2)

Setting	Description	Default
EPMU	Enable Synchronized Phasor Measurement (Y, N)	N[a]
MFRMT	Message Format (C37.118, FM)[b]	C37.118
MRATE	Messages per Second {1, 2, 5, 10, 25, or 50 when NFREQ := 50} {1, 2, 4, 5, 10, 12, 15, 20, 30, or 60 when NFREQ := 60}	2
PMAPP	PMU Application (F = Fast Response, N = Narrow Bandwidth)	N
PHCOMP	Frequency-Based Phasor Compensation (Y, N)	Y

Table 7.1 PMU Settings in the SEL-421 for C37.118 Protocol in Global Setting (Sheet 2 of 2)

Setting	Description	Default
PMSTN	Station Name (16 characters)	STATION A
PMID	PMU Hardware ID (1–65534)	1
PHDATAV	Phasor Data Set, Voltages (V1, ALL, NA)	V1
VCOMP	Voltage Angle Compensation Factor (–179.99 to 180 degrees)	0.00
PHDATAI	Phasor Data Set, Currents (I1, ALL, NA)	NA
PHCURR[c]	Current Source (IW, IX, BOTH, COMB)	IW
IWCOMP	IW Angle Compensation Factor (–179.99 to 180 degrees)	0.00
IXCOMP	IX Angle Compensation Factor (–179.99 to 180 degrees)	0.00
PHNR[d]	Phasor Numeric Representation (I = Integer, F = Floating point)	I
PHFMT[d]	Phasor Format (R = Rectangular coordinates, P = Polar coordinates)	R
FNR	Frequency Numeric Representation (I = Integer, F = Float)	I
NUMANA	Number of Analog Values (0–8)	0
NUMDSW	Number of 16-bit Digital Status Words (0, 1, 2)	1
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
PMTRIG	Trigger (SELOGIC Equation)	NA
MRTCDLY	Maximum RTC Synchrophasor Packet Delay (20–1000 ms)	500
RTCRATE	Remote Messages per Second {1, 2, 5, 10, 25, or 50 when NFREQ := 50} {1, 2, 4, 5, 10, 12, 15, 20, 30, or 60 when NFREQ := 60}	2

[a] Set EPMU := Y to access the remaining settings
[b] C37.118 = IEEE C37.118 Standard; FM := SEL Fast Message—see Table 7.20.
[c] Setting hidden when PHDATAI := NA
[d] Setting hidden when PHDATAV := NA and PHDATAI := NA

Table 7.2 Time and Date Management

Label	Prompt	Default Value
IRIGC[a]	IRIG-B Control Bits Definition (None, C37.118)	None

[a] When MFRMT := C37.118, IRIGC is forced to C37.118.

Certain settings in *Table 7.1* 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 Port settings for PROTO := PMU, shown in *Table 7.3*, do not include the settings DATABIT and PARITY; these two settings are internally fixed as DATABIT := 8, PARITY := N (None). See *Data Frame on page R.5.2* for descriptions of these functions.

Table 7.3 SEL-421 Serial Port Settings for Synchrophasors

Setting	Description	Default
PROTO	Protocol (SEL, DNP, MBA, MBB, RTD, PMU)[a, b]	SEL[c]
SPEED	Data Speed (300 to 57600)	9600
STOPBIT	Stop Bits (1, 2)	1
RTSCTS	Enable Hardware Handshaking (Y, N)	N
FASTOP	Enable Fast Operate Messages (Y, N)	N
PMUMODE	PMU Mode (CLIENTA, CLIENTB, SERVER)	SERVER
RTCID[d]	Remote PMU Hardware ID (1–65534)	1

[a] Some of the other PROTO setting choices may not be available.
[b] Setting choice PMU is not available on PORT 5.
[c] Set PROTO := PMU and PMUMODE := SERVER to enable synchrophasor transmission on this port using the protocol selected by the Global setting MFRMT.
[d] Setting hidden when PMUMODE := SERVER.

PROTO := PMU Does Not Allow Commands on That Serial Port

The PROTO := PMU settings choice in *Table 7.3* 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 making the *Table 7.1* settings, 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.

Table 7.4 SEL-421 Ethernet Port Settings for Synchrophasors

Setting	Description	Default
EPMIP	Enable PMU Processing (Y,N)	N
PMOTS1	PMU Output 1 Transport Scheme (OFF, TCP, UDP_S, UDP_T, UDP_U)	OFF
PMOIPA1	PMU Output 1 Client IP (Remote) Address (www.xxx.yyy.zzz)	OFF
PMOTCP1	PMU Output 1TCP/IP (Local) Port Number (1–65534)	4712
PMOUDP1	PMU Output 1 UDP/IP Data (Remote) Port Number (1–65534)	4713
PMOTS2	PMU Output 2 Transport Scheme (OFF, TCP, UDP_S, UDP_T, UDP_U)	OFF
PMOIPA2	PMU Output 2 Client IP (Remote) Address (www.xxx.yyy.zzz)	OFF
PMOTCP2	PMU Output 2 TCP/IP (Local) Port Number (1–65534)	4722
PMOUDP2	PMU Output 2 UDP/IP Data (Remote) Port Number (1–65534)	4713

Descriptions of Synchrophasor Settings

Definitions for some of the settings in *Table 7.1* are as follows:

MFRMT

Selects the message format for synchrophasor data streaming on serial ports.

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 SEL-421 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 streaming on serial ports.

Choose the MRATE setting that suits the needs of your PMU application. This setting is one of eight settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size. See *Communications Bandwidth on page R.7.26* for detailed information.

PMAPP

Selects the type of digital filters used in the synchrophasor algorithm:

- The Narrow Bandwidth setting (N) represents filters with a cutoff frequency approximately ¼ 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 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.

PHCOMP

Enables or disables frequency-based compensation for 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. Use PHCOMP := N if you are concentrating the SEL-421 synchrophasor data with other PMU data that do not employ frequency compensation.

PMSTN and PMID

Defines the name and number of the PMU.

NOTE: The PMSTN setting is not the same as the SEL-421 Global setting SID (Station Identifier), even though they share the same factory default value.

The PMSTN setting is an ASCII string with as many as 16 characters. The PMID setting is a numeric value. Use your utility or synchrophasor data concentrator naming convention to determine these settings.

PHDATAV and VCOMP

PHDATAV selects which voltage synchrophasors to include in the data packet. Consider the burden on your synchrophasor processor and offline storage requirements when deciding how much data to transmit. This setting is one of eight settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth on page R.7.26* for detailed information.

- PHDATAV := V1 will transmit only positive-sequence voltage, V_1
- PHDATAV := ALL will transmit V_1, V_A, V_B, and V_C
- PHDATAV := NA will not transmit any voltages

NOTE: The SEL-421 only provides one VCOMP setting, which is applied to both the main or alternate voltage sources VY or VZ; respectively. See Voltage Source Switching and Uses on page R.1.6.

Table 7.5 describes the order of synchrophasors inside the data packet.

The VCOMP setting allows correction for any steady-state voltage phase errors (from the potential transformers or wiring characteristics). See *Synchrophasor Measurement on page R.7.6* for details on this setting.

PHDATAI, PHCURR, IWCOMP, and IXCOMP

PHDATAI and PHCURR select which current synchrophasors to include in the data packet. Consider the burden on your synchrophasor processor and offline storage requirements when deciding how much data to transmit. These settings are two of the eight settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth on page R.7.26* for detailed information.

- PHDATAI := I1 will transmit only positive-sequence current, I_1
- PHDATAI := ALL will transmit I_1, I_A, I_B, and I_C
- PHDATAI := NA will not transmit any currents

PHCURR selects the source current(s) for the synchrophasor data selected by PHDATAI.

- PHCURR := IW uses the currents measured on the IAW, IBW, and ICW inputs
- PHCURR := IX uses the currents measured on the IAX, IBX, and ICX inputs
- PHCURR := COMB uses the summation of the currents measured on the inputs: IAS = IAW + IAX, IBS = IBW + IBX, and ICS = ICW + ICX
- PHCURR:= BOTH uses the currents measured on both the I_W inputs and I_X inputs

Table 7.5 describes the order of synchrophasors inside the data packet.

The IWCOMP and IXCOMP settings allow correction for any steady-state phase errors (from the current transformers or wiring characteristics). See *Synchrophasor Measurement on page R.7.6* for details on these settings.

Table 7.5 Synchrophasor Order in Data Stream (Voltages and Currents)

Synchrophasors[a] (Analog Quantity Names)				Included When Global Settings are as follows:
Polar[b]		Rectangular[c]		
Magnitude	Angle	Real	Imaginary	
V1LPMM	V1LPMA	V1LPMR	V1LPMI	PHDATAV := V1 or ALL
VALPMM VBLPMM VCLPMM	VALPMA VBLPMA VCLPMA	VALPMR VBLPMR VCLPMR	VALPMI VBLPMI VCLPMI	PHDATAV := ALL
I1WPMM	I1WPMA	I1WPMR	I1WPMI	PHDATAI := I1 or ALL **AND** (PHCURR := IW or BOTH)
IAWPMM IBWPMM ICWPMM	IAWPMA IBWPMA ICWPMA	IAWPMR IBWPMR ICWPMR	IAWPMI IBWPMI ICWPMI	PHDATAI := ALL **AND** (PHCURR := IW or BOTH)
I1XPMM	I1XPMA	I1XPMR	I1XPMI	(PHDATAI := I1 or ALL) **AND** (PHCURR := IX or BOTH)
IAXPMM IBXPMM ICXPMM	IAXPMA IBXPMA ICXPMA	IAXPMR IBXPMR ICXPMR	IAXPMI IBXPMI ICXPMI	PHDATAI := ALL **AND** (PHCURR := IX or BOTH)
I1SPMM	I1SPMA	I1SPMR	I1SPMI	(PHDATAI := I1 or ALL) **AND** PHCURR := COMB
IASPMM IBSPMM ICSPMM	IASPMA IBSPMA ICSPMA	IASPMR IBSPMR ICSPMR	IASPMI IBSPMI ICSPMI	PHDATAI := ALL **AND** PHCURR := COMB

[a] Synchrophasors are included in the order shown (i.e. Voltages, if selected, will always precede currents).
[b] Polar coordinate values are sent when PHFMT := P.
[c] Rectangular (real and imaginary) values are sent when PHFMT := R.

PHNR

Selects the numeric representation of voltage and current phasor data in the synchrophasor data stream.

This setting is one of eight settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth on page R.7.26* for detailed information.

The choices for this setting depend on synchrophasor processor requirements.

Setting PHNR := I sends each voltage and/or current synchrophasor as 2 two-byte integer values. In this representation, synchrophasor current measurements have an upper limit of 7 • I_{nom}, where I_{nom} = 1 A or 5 A, depending on the current input rating—see *Secondary Circuits on page U.2.4*.

Setting PHNR := F sends each voltage and/or current synchrophasor as 2 four-byte floating-point values.

The PHFMT setting determines the format of the data.

PHFMT

Selects the phasor representation of voltage and current phasor data in the synchrophasor data stream.

The choices for this setting depend on synchrophasor processor requirements.

Setting PHFMT := R (rectangular) sends each voltage and/or current synchrophasor as a pair of signed real and imaginary values.

Setting PHFMT := P (polar) sends each voltage and/or current synchrophasor as a magnitude and angle pair. The angle is in radians when PHNR := F, and in radians • 10^4 when PHNR := I. The range is as follows:

$-\pi < \text{angle} <= \pi$.

In both the rectangular and polar representations, the values are scaled in rms (root mean square) 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. See *Synchrophasor Measurement on page R.7.6* for a sample conversion between polar and rectangular coordinates.

FNR

Selects the numeric representation of the two frequency values in the synchrophasor data stream.

This setting is one of eight settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth on page R.7.26* for detailed information.

The choices for this setting depend on synchrophasor processor requirements.

Setting FNR := I sends the frequency data as a difference from nominal frequency, NFREQ, with the following formula:

$(FREQ_{measured} - NFREQ) \cdot 1000$,

represented as a signed, two-byte value.

Setting FNR := I also sends the rate-of-change of frequency data with scaling.

$DFDT_{measured} \cdot 100$,

represented as a signed, two-byte value.

Setting FNR := F sends the measured frequency data and rate-of-change-of-frequency as two four-byte, floating point values.

NUMANA

Selects the number of user-definable analog values to be included in the synchrophasor data stream.

This setting is one of eight settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth on page R.7.26* for detailed information.

The choices for this setting depend on the synchrophasor system design.

Setting NUMANA := 0 sends no user-definable analog values.

Setting NUMANA := 1–8 sends the user-definable analog values, as listed in *Table 7.6*.

The format of the user-defined analog data is always floating point, and each value occupies four bytes.

Table 7.6 User-Defined Analog Values Selected by the 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

NUMDSW

Selects the number of user-definable digital status words to be included in the synchrophasor data stream.

This setting is one of eight settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth on page R.7.26* for detailed information.

The choices for this setting depend on the synchrophasor system design. The inclusion of binary data can help indicate breaker status or other operational data to the synchrophasor processor. See *PMU Setting Example on page R.7.28* for a suggested use of the digital status word fields.

Setting NUMDSW := 0 sends no user-definable binary status words.

Setting NUMDSW := 1 or 2 sends the user-definable binary status words, as listed in *Table 7.7*.

Table 7.7 User-Defined Digital Status Words Selected by the NUMDSW Setting

NUMDSW Setting	Digital Status Words Sent	Total Number of Bytes Used for Digital Values
0	None	0
1	[PSV64, PSV63.....PSV49]	2
2	[PSV64, PSV63.....PSV49] [PSV48, PSV47.....PSV33]	4

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 in the Global settings class. The SEL-421 evaluates these equations and places the results in Relay Word bits with the same names: TREA1–TREA4, and PMTRIG.

NOTE: The PM Trigger function is not associated with the SEL-421 Event Report Trigger ER, a SELOGIC control equation in the Group settings class.

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 for a reasonable amount of time, to allow the synchrophasor processor to read the TREA1–TREA4 fields.

The IEEE C37.118 standard defines the first eight of 16 binary combinations of these trigger reason bits (bits 0–3).

The remaining eight binary combinations are available for user definition.

Table 7.8 PM Trigger Reason Bits—IEEE C37.118 Assignments

TREA4	TREA3	TREA2	TREA1		Meaning[a]
(bit 3)	(bit 2)	(bit 1)	(bit 0)	Hexadecimal	
0	0	0	0	0x00	Manual
0	0	0	1	0x01	Magnitude Low
0	0	1	0	0x02	Magnitude High
0	0	1	1	0x03	Phase Angle Diff.
0	1	0	0	0x04	Frequency High/Low
0	1	0	1	0x05	df/dt High
0	1	1	0	0x06	Reserved
0	1	1	1	0x07	Digital
1	0	0	0	0x08	User
1	0	0	1	0x09	User
1	0	1	0	0x0A	User
1	0	1	1	0x0B	User
1	1	0	0	0x0C	User
1	1	0	1	0x0D	User
1	1	1	0	0x0E	User
1	1	1	1	0x0F	User

[a] When PMTRIG is asserted. The terminology comes from IEEE C37.118.

The SEL-421 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 SEL-421 synchrophasor processing and protocol transmission are not affected by the status of these bits.

MRTCDLY

Selects the acceptable delay for received synchrophasor messages.

NOTE: The maximum channel delay is available in the **COM RTC** command.

When the SEL-421 is operating as a synchrophasor client (PMUMODE set to CLIENTA or CLIENTB), it 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.

RTCRATE

Rate at which to expect messages from the remote synchrophasor device.

When the SEL-421 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.

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 RTCRATE 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 RTCRATE 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 using the C37.118 format, regardless of the MFRMT setting.

RTCID

Expected synchrophasor ID from remote relay.

When the SEL-421 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.

Synchrophasor Relay Word Bits

Table 7.9 and *Table 7.10* list the SEL-421 Relay Word bits that are related to synchrophasor measurement.

The Synchrophasor Trigger Relay Word bits in *Table 7.9* follow the state of the SELOGIC control equations of the same name, listed at the bottom of *Table 7.1*. These Relay Word bits are included in the IEEE C37.118 synchrophasor data frame STAT field. See *Table 7.7* for standard definitions for these settings.

Table 7.9 Synchrophasor Trigger Relay Word Bits

Name	Description
PMTRIG	Trigger (SELOGIC Equation).
TREA4	Trigger Reason Bit 4 (SELOGIC Equation)
TREA3	Trigger Reason Bit 3 (SELOGIC Equation)
TREA2	Trigger Reason Bit 2 (SELOGIC Equation)
TREA1	Trigger Reason Bit 1 (SELOGIC Equation)

The Time Synchronization Relay Word bits in *Table 7.10* indicate the present status of the high-accuracy timekeeping function of the SEL-421. See *Configuring High-Accuracy Timekeeping on page U.4.71*.

Table 7.10 Time Synchronization Relay Word Bits

Name	Description
TIRIG	Asserts while relay time is based on IRIG-B time source.
TSOK	Time Synchronization OK. Asserts while time is based on high-accuracy IRIG-B time source (HIRIG mode) of sufficient accuracy for synchrophasor measurement.
PMDOK	Phasor Measurement Data OK. Asserts when the SEL-421 is enabled and synchrophasors are enabled (Global setting EPMU := Y).

When using the relay as a synchrophasor client, the Relay Word bits in *Table 7.11* indicate the state of the synchronization.

Table 7.11 Synchrophasor Client Status Bits

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.
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.
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 7.12*.

Table 7.12 Remote Synchrophasor Data Bits

Name	Description
RTCAD01–RTCAD16	First sixteen digitals received in synchrophasor message on channel A. Only valid when RTCROKA is asserted.
RTCBD01–RTCBD16	First sixteen digitals received in synchrophasor message on channel B. Only valid when RTCROKB is asserted.

Synchrophasor Analog Quantities

The synchrophasor measurements in *Table 7.13* are available whenever Global setting EPMU := Y. When EPMU := N, these analog quantities are set to 0.0000.

It is important to note that the synchrophasors are only valid when the relay is in HIRIG timekeeping mode, which can be verified by monitoring the TSOK Relay Word bit. When TSOK = logical 1, the SEL-421 timekeeping is synchronized to the high-accuracy IRIG-B signal, and the synchrophasor data are precisely time-stamped.

Table 7.13 Synchrophasor Analog Quantities (Sheet 1 of 2)

Name	Description	Units
Frequency		
FREQ_PM	Measured system frequency[a]	Hz
DFDT	Rate-of-change of frequency, df/dt[a]	Hz/s
Synchrophasor Measurements		
IAWPMM, IBWPMM, ICWPMM	Synchrophasor current magnitude (I_W terminals)	A[b]
IAWPMA, IBWPMA, ICWPMA	Synchrophasor current angle (I_W terminals)	degrees
IAWPMR, IBWPMR, ICWPMR	Synchrophasor current, real component (I_W terminals)	A[b]
IAWPMI, IBWPMI, ICW-PMI	Synchrophasor current, imaginary component (I_W terminals)	A[b]
IAXPMM, IBXPMM, ICX-PMM	Synchrophasor current magnitude (I_X terminals)	A[b]
IAXPMA, IBXPMA, ICX-PMA	Synchrophasor current angle (I_X terminals)	degrees
IAXPMR, IBXPMR, ICX-PMR	Synchrophasor current, real component (I_X terminals)	A[b]
IAXPMI, IBXPMI, ICXPMI	Synchrophasor current, imaginary component (I_X terminals)	A[b]
IASPMM, IBSPMM, ICSPMM	Synchrophasor current magnitude (I_W + I_X terminals)	A[b]
IASPMA, IBSPMA, ICSPMA	Synchrophasor current angle (I_W + I_X terminals)	degrees
IASPMR, IBSPMR, ICSPMR	Synchrophasor current, real component (I_W + I_X terminals)	A[b]
IASPMI, IBSPMI, ICSPMI	Synchrophasor current, imaginary component (I_W + I_X terminals)	A[b]
I1WPMM	Synchrophasor positive-sequence current magnitude (I_W terminals)	A[b]
I1WPMA	Synchrophasor positive-sequence current angle (I_W terminals)	degrees
I1WPMR	Synchrophasor positive-sequence current, real component (I_W terminals)	A[b]
I1WPMI	Synchrophasor positive-sequence current, imaginary component (I_W terminals)	A[b]

Table 7.13 Synchrophasor Analog Quantities (Sheet 2 of 2)

Name	Description	Units
I1XPMM	Synchrophasor positive-sequence current magnitude (I_X terminals)	A[b]
I1XPMA	Synchrophasor positive-sequence current angle (I_X terminals)	degrees
I1XPMR	Synchrophasor positive-sequence current, real component (I_X terminals)	A[b]
I1XPMI	Synchrophasor positive-sequence current, imaginary component (I_X terminals)	A[b]
I1SPMM	Synchrophasor positive-sequence current magnitude (I_W + I_X terminals)	A[b]
I1SPMA	Synchrophasor positive-sequence current angle (I_W + I_X terminals)	degrees
I1SPMR	Synchrophasor positive-sequence current, real component (I_W + I_X terminals)	A[b]
I1SPMI	Synchrophasor positive-sequence current, imaginary component (I_W + I_X terminals)	A[b]
VALPMM, VBLPMM, VCLPMM	Synchrophasor voltage magnitude	kV[b]
VALPMA, VBLPMA, VCLPMA	Synchrophasor voltage angle	degrees
VALPMR, VBLPMR, VCLPMR	Synchrophasor voltage, real component	kV[b]
VALPMI, VBLPMI, VCLPMI	Synchrophasor voltage, imaginary component	kV[b]
V1LPMM	Synchrophasor positive-sequence voltage magnitude	kV[b]
V1LPMA	Synchrophasor positive-sequence voltage angle	degrees
V1LPMR	Synchrophasor positive-sequence voltage, real component	kV[b]
V1LPMI	Synchrophasor positive-sequence voltage, imaginary component	kV[b]
SODPM	Second-of-day of the synchrophasor data	s
FOSPM	Fraction-of-second of the synchrophasor data	s

[a] Measured value if the voltages are valid and EMPU = Y, otherwise FREQ_PM = nominal frequency setting NFREQ, and DFDT is zero.
[b] Primary value of measurement.

When using the SEL-421 for synchrophasor acquisition, the delayed and aligned analog quantities listed in *Table 7.14* 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 7.14 Synchrophasor Aligned Analog Quantities (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
IAWPMMD, IBWPMMD, ICWPMMD	Aligned local current magnitude (I_W terminal)	A[a]
IAWPMAD, IBWPMAD, ICWPMAD	Aligned local current angle (I_W terminal)	degrees
IAWPMRD, IBWPMRD, ICWPMRD	Aligned local current real component (I_W terminal)	A[a]
IAWPMID, IBWPMID, ICWPMID	Aligned local current imaginary component (I_W terminal)	A[a]
IAXPMMD, IBXPMMD, ICXPMMD	Aligned local current magnitude (I_X terminal)	A[a]
IAXPMAD, IBXPMAD, ICXPMAD	Aligned local current angle (I_X terminal)	degrees
IAXPMRD, IBXPMRD, ICXPMRD	Aligned local current real component (I_X terminal)	A[a]
IAXPMID, IBXPMID, ICXPMID	Aligned local current imaginary component (I_X terminal)	A[a]
IASPMMD, IBSPMMD, ICSPMMD	Aligned local current magnitude (I_W + I_X terminals)	A[a]
IASPMAD, IBSPMAD, ICSPMAD	Aligned local current angle (I_W + I_X terminals)	degrees
IASPMRD, IBSPMRD, ICSPMRD	Aligned local current real component (I_W + I_X terminal)	A[a]
IASPMID, IBSPMID, ICSPMID	Aligned local current imaginary component (I_W + I_X terminal)	A[a]
I1WPMMD	Aligned local positive-sequence current magnitude (I_W terminal)	A[a]
I1WPMAD	Aligned local positive-sequence current angle (I_W terminal)	degrees

Table 7.14 Synchrophasor Aligned Analog Quantities (Sheet 2 of 2)

Name	Description	Units
I1WPMRD	Aligned local positive-sequence current real component (I_W terminal)	A[a]
I1WPMID	Aligned local positive-sequence current imaginary component (I_W terminal)	A[a]
I1XPMMD	Aligned local positive-sequence current magnitude (I_X terminal)	A[a]
I1XPMAD	Aligned local positive-sequence current angle (I_X terminal)	degrees
I1XPMRD	Aligned local positive-sequence current real component (I_X terminal)	A[a]
I1XPMID	Aligned local positive-sequence current imaginary component (I_X terminal)	A[a]
I1SPMMD	Aligned local positive-sequence current magnitude (I_W + I_X terminal)	A[a]
I1SPMAD	Aligned local positive-sequence current angle (I_W + I_X terminal)	degrees
I1SPMRD	Aligned local positive-sequence current real component (I_W + I_X terminal)	A[a]
I1SPMID	Aligned local positive-sequence current imaginary component (I_W + I_X terminal)	A[a]
VALPMMD, VBLPMMD, VCLPMMD	Aligned local voltage magnitude	kV[a]
VALPMAD, VBLPMAD, VCLPMAD	Aligned local voltage angle	degrees
VALPMRD, VBLPMRD, VCLPMRD	Aligned local voltage real component	kV[a]
VALPMID, VBLPMID, VCLPMID	Aligned local voltage imaginary component	kV[a]
V1LPMMD	Aligned local positive-sequence voltage magnitude	kV[a]
V1LPMAD	Aligned local positive-sequence voltage angle	degrees
V1LPMRD	Aligned local positive-sequence voltage real component	kV[a]
V1LPMID	Aligned local positive-sequence voltage imaginary component	kV[a]
SODPMD	Second-of-day for all aligned data	Seconds
FOSPMD	Fraction-of-second for all aligned data	Seconds
FREQPMD	Aligned local system frequency	Hz
DFDTD	Aligned local rate-of-change of frequency	Hz/s

[a] Primary value of measurement.

View Synchrophasors by Using the MET PM Command

The **MET PM** serial port ASCII command may be used to view the SEL-421 synchrophasor measurements. See *METER on page R.9.28* for general information on the **MET** command.

There are multiple ways to use the **MET PM** command:

- ➤ As a test tool, to verify connections, phase rotation, and scaling
- ➤ As an analytical tool, to capture synchrophasor data at an exact time, in order 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

The **MET PM** command displays the same set of analog synchrophasor information, regardless of the Global settings MFRMT, PHDATAV, PHDATAI, and PHCURR. The **MET PM** command can function even when no serial ports are sending synchrophasor data—it is unaffected by serial port setting PROTO.

The **MET PM** command will only operate when the SEL-421 is in the HIRIG timekeeping mode, as indicated by Relay Word bit TSOK = logical 1.

Figure 7.13 shows a sample **MET PM** command response. The synchrophasor data are also available via the **HMI > Meter & Control** menu in ACSELERATOR QuickSet, and has a similar format to *Figure 7.13*.

The **MET PM *time*** command can be used to direct the SEL-421 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 7.13* occurring just after 14:14:12, with the time stamp 14:14:12.000000.

This method of data capture will always report from the exact second, even if the time parameter is entered with fractional seconds. For example, entering **MET PM 14:14:12.200** will result in the same data capture as **MET PM 14:14:12**, because the relay ignores the fractional seconds.

See *MET PM on page R.9.31* for complete command options, and error messages.

```
=>MET PM <Enter>

Relay 1                                     Date: 10/26/2004  Time: 19:18:23.000
Station A                                   Serial Number: 0000000000

Time Quality   Maximum time synchronization error:    0.000 (ms)  TSOK = 1

Synchrophasors
                     Phase Voltages               Pos. Sequence Voltage
                 VA        VB        VC                   V1
MAG (kV)        134.140   131.646   128.600             131.447
ANG (DEG)       129.896    10.262  -111.764             129.477

                     IW Phase Currents            IW Pos. Sequence Current
                 IA        IB        IC                   I1W
MAG (kV)        365.261   359.225   379.917             367.912
ANG (DEG)       114.930    -2.786  -120.238             117.338

                     IX Phase Currents            IX Pos. Sequence Current
                 IA        IB        IC                   I1X
MAG (kV)        617.050   587.237   599.044             600.935
ANG (DEG)       136.345    13.617  -106.733             134.434

                     IS Phase Currents            IS Pos. Sequence Current
                 IA        IB        IC                   I1S
MAG (kV)        966.340   937.347   972.512             958.708
ANG (DEG)       128.412     7.404  -111.967             127.955

FREQ (Hz) 60.029
Rate-of-change of FREQ (Hz/s)    0.00

Digitals

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
  1      0      1      0      0      0      0      0

Analogs

PMV57      0.000  PMV58      0.000  PMV59      0.000  PMV60      0.000
PMV61      0.000  PMV62      0.000  PMV63    127.000  PMV64     23.400


=>
```

Figure 7.13 Sample MET PM Command Response

C37.118 Synchrophasor Protocol

The SEL-421 complies with IEEE C37.118, Standard for Synchrophasors 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 on the Ethernet port when EPMIP := Y.

This subsection 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 SEL-421 allows several options for transmitting synchrophasor data. These are controlled by Global settings described in *Settings for Synchrophasors on page R.7.9*. You can select how often to transmit the synchrophasor messages (MRATE), which synchrophasors to transmit (PHDATAV, PHDATAI, and PHCURR), which numeric representation to use (PHNR), and which coordinate system to use (PHFMT).

The SEL-421 automatically includes the frequency and rate-of-change-of-frequency in the synchrophasor messages. Global setting FNR selects the numeric format to use for these two quantities.

The relay can include up to eight user-programmable analog values in the synchrophasor message, as controlled by Global setting NUMANA, and 0, 16, or 32 digital status values, as controlled by Global setting NUMDSW.

The SEL-421 always includes the results of four synchrophasor trigger reason SELOGIC equations TREA1, TREA2, TREA3, and TREA4, and the trigger SELOGIC equation result PMTRIG, in the synchrophasor message.

Communications Bandwidth

A phasor measurement unit (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 SEL-421 or SEL-5030 software will display an error message and fail to save settings until the error is corrected.

The 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 7.15* can be used to calculate the number of bytes in a synchrophasor message.

Table 7.15 Size of a C37.118 Synchrophasor Message

Item	Possible number of quantities	Bytes per quantity	Minimum number of bytes	Maximum number of bytes
Fixed			18	18
Synchrophasors	0, 1, 2, 3, 4, 5, 6, 8, 9, or 12	4 {PHNR := I} 8 {PHNR := F}	0	96
Frequency	2 (fixed)	2 {FNR := I} 4 {FNR := F}	4	8
Analog Values	0 – 8	4	0	32
Digital Status Words	0 – 2	2	0	4
Total (Minimum and Maximum)			22	158

Table 7.16 lists the baud settings available on any SEL-421 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 7.16 Serial Port Bandwidth for Synchrophasors (in Bytes)

Global setting MRATE	Port setting SPEED								
	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
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 7.15* and *Table 7.16*, 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, up to MRATE := 50 or 30 when SPEED := 19200, and up to 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 up to MRATE := 30 when SPEED := 57600, up to MRATE := 25 when SPEED := 38400, and up to MRATE := 12 when SPEED := 19200.

Protocol Operation

The SEL-421 will only transmit synchrophasor messages over serial ports that have setting PROTO := PMU. The connected device will typically be a synchrophasor processor, such as the SEL-3306. The synchrophasor processor controls the PMU functions of the SEL-421, 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 SEL-421 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 SEL-421 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 SEL-421 will only respond to configuration block request messages when it is in the non-transmitting 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.

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 phasor measurement units (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 SEL-421, an SEL-2600A RTD Module, an SEL-2407 Satellite Synchronized Clock, and an SEL-3306 Synchrophasor Processor in each substation.

This example will cover the PMU settings in one of the SEL-421 relays.

Some system details:

- The nominal frequency is 60 Hz.
- The line is protected by a breaker-and-a-half scheme (similar to *Figure 1.7*).
- 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 baud 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 RTD serial port settings will not be shown.

Determining Settings

The protection engineer performs a bandwidth check, using *Table 7.15*, and determines the required message size. The system requirements, in order of appearance in *Table 7.15*, are:

- 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 7.16*, the engineer verifies that the port baud 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 7.17*.

Table 7.17 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 (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)	F
PHCOMP	Frequency-Based Phasor Compensation (Y, N)	Y
PMSTN	Station Name (16 characters)	SAMPLE1

Table 7.17 Example Synchrophasor Global Settings (Sheet 2 of 2)

Setting	Description	Value
PMID	PMU Hardware ID (1–65534)	14
PHDATAV	Phasor Data Set, Voltages (V1, ALL, NA)	V1
VCOMP	Voltage Angle Compensation Factor (–179.99 to 180 degrees)	4.20
PHDATAI	Phasor Data Set, Currents (I1, ALL, NA)	ALL
PHCURR	Current Source (IW, IX, BOTH, COMB)	COMB
IWCOMP	IW Angle Compensation Factor (–179.99 to 180 degrees)	3.50
IXCOMP	IX Angle Compensation Factor (–179.99 to 180 degrees)	5.50
PHNR	Phasor Numeric Representation (I = Integer, F = Floating point)	F
PHFMT	Phasor Format (R = Rectangular coordinates, P = Polar coordinates)	R
FNR	Frequency Numeric Representation (I = Integer, F = Float)	I
NUMANA	Number of Analog Values (0–8)	2
NUMDSW	Number of 16-bit Digital Status Words (0, 1, 2)	1
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
PMTRIG	Trigger (SELOGIC Equation)	NA

The two analog quantities and three Relay Word bits required in this example must be placed in certain protection math variables and protection SELOGIC variables. Make the Protection Free-Form logic settings in *Table 7.18* in all six settings groups.

Table 7.18 Example Synchrophasor Protection Free-Form Logic Settings

Setting	Value
PSV64	NOT (3PO OR SPO) # Line breaker status
PSV63	LOP # Loss-of-Potential
PMV62	RTD01 # Ambient Temperature
PMV63	DC1 # Station Battery Voltage

Make the *Table 7.19* settings for serial port 3, using the **SET P 3** command.

Table 7.19 Example Synchrophasor Port Settings

Setting	Description	Value
PROTO	Protocol (SEL, DNP, MBA, MBB, 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

The sample **MET PM** capture in *Figure 7.13* shows data that could be measured by this system, including the digital and analog data near the bottom of the figure, that represent the protection free-form logic from *Table 7.18*.

SEL Fast Message Synchrophasor Protocol

SEL Fast Message Unsolicited Write (synchrophasor) messages are general Fast Messages (A546h) that transport measured synchrophasor information. The SEL-421 can send unsolicited write messages as fast as every 50 ms on a 60 Hz system, and 100 ms on a 50 Hz system. Use Global settings PHDATAV, PHDATAI, and PHCURR to select the voltage and current data to include in the Fast Message. *Table 7.22* and *Table 7.23* list analog quantities included in the Fast Message for various Global settings (frequency is included in all messages). 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 7.20 lists the Synchrophasor Fast Message Write function codes and the actions the relay takes in response to each command.

Table 7.20 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 SEL *Application Guide AG2002-08* for more information on the SEL Fast Message Synchrophasor protocol. This application guide refers to previous SEL-421 firmware versions, and the relay-specific portions (pages 1 and 2) should be disregarded.

Differences in New SEL-421 Fast Message Synchrophasor Implementation

One of the differences between the C37.118 and SEL Fast Message formats relates to data transmission speed. When the C37.118 format is used, Global Setting MRATE determines the message rate—the synchrophasor processor cannot request a data rate via the enable message.

In the SEL Fast Message format, the synchrophasor processor must request a particular data message period, which is embedded in the enable message. If the requested message period can be supported, the SEL-421 will acknowledge the request (if an acknowledge was requested) and begin transmitting synchrophasors. If the requested message period is not permitted, the SEL-421 will respond with a bad data message (if an acknowledge was requested), and will not transmit any synchrophasor data.

On a 60 Hz nominal power system (NFREQ := 60), SEL-421 firmware version R112 and above can support the same message periods (1000, 500, 250, 200, 100, and 50 ms) as those supported by prior firmware versions.

On a 50 Hz nominal power system (NFREQ := 50), SEL-421 firmware version R112 and above can support all but two of the same message periods that prior firmware versions supported. Message periods 1000, 500, 200, and 100 ms are supported, while message periods 250 and 50 ms are unavailable.

Another difference is found in the serial port PROTO settings, where a new settings choice, PMU, is available. Beginning with SEL-421 firmware version R112, the SEL Fast Message synchrophasor protocol is only available on ports set to PROTO := PMU. In previous firmware versions, the SEL Fast Message synchrophasor protocol operated on ports set to PROTO := SEL. This separation of general serial port access from the PMU function was designed to enhance security and performance.

Beginning with SEL-421 firmware version R112, the settings for SEL Fast Message format are different than firmware version R102–R111. The new settings are in the Global settings class—see *Upgrading Previous SEL-421 Synchrophasor Settings on page R.7.34*.

SEL-421 Fast Message Synchrophasor Settings

The settings for SEL Fast Message synchrophasors are listed in *Table 7.21*. Many of these settings are identical to the settings for the C37.118 format. See *Settings for Synchrophasors on page R.7.9*.

Table 7.21 PMU Settings in the SEL-421 for SEL Fast Message Protocol, in Global Settings

Setting	Description	Default
EPMU	Enable Synchronized Phasor Measurement (Y, N)	N[a]
MFRMT	Message Format (C37.118, FM)[b]	C37.118
PMAPP	PMU Application (F = Fast Response, N = Narrow Bandwidth)	N
PHCOMP	Frequency-Based Phasor Compensation (Y, N)	Y
PMID	PMU Hardware ID (0x00000000–0xFFFFFFFF)	0x00000001
PHDATAV	Phasor Data Set, Voltages (V1, ALL)	V1
VCOMP	Voltage Angle Compensation Factor (–179.99 to 180 degrees)	0.00
PHDATAI[c]	Phasor Data Set, Currents (ALL, NA)	NA
PHCURR[d]	Current Source (IW, IX, COMB)	IW
IWCOMP	IW Angle Compensation Factor (–179.99 to 180 degrees)	0.00
IXCOMP	IX Angle Compensation Factor (–179.99 to 180 degrees)	0.00

[a] Set EPMU := Y to access the remaining settings
[b] C37.118 = IEEE C37.118 Standard—see Table 7.1; FM := SEL Fast Message. Set MFRMT := FM to enter the Fast Message settings.
[c] When PHDATAV := V1, this setting is forced to NA and cannot be changed.
[d] Setting hidden when PHDATAI := NA

Certain settings in *Table 7.21* 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.

Descriptions of Fast Message Synchrophasor Settings

The SEL Fast Message synchrophasor settings are a subset of the C37.118 settings. See *Descriptions of Synchrophasor Settings on page R.7.12* for details on settings PMAPP, PHCOMP, VCOMP, IWCOMP, and IXCOMP. For the remaining settings, the differences are explained in the following pages.

PMID

Defines the number of the PMU.

The PMID setting is a 32-bit numeric value. Use your utility or synchrophasor data concentrator labeling convention to determine this setting.

PHDATAV, PHDATAI, and PHCURR

These settings define the synchrophasors to be included in the data stream.

There are fewer combinations of synchrophasor data available in the SEL Fast Message synchrophasor format. For example, it is not possible to send only current synchrophasors. You must also send voltages.

See *Table 7.22* for a list of synchrophasors that can be sent in SEL Fast Message format, and the order.

Table 7.22 SEL Fast Message Voltage and Current Selections Based on PHDATAV and PHDATAI

Global Settings	Number of Synchrophasor Magnitude and Angle Pairs Transmitted	Synchrophasor Magnitude and Angle Pairs to Transmit, and the Transmit Order[a]
PHDATAV := V1 PHDATAI := NA	1	V_1
PHDATAV := ALL PHDATAI := NA	4	V_A, V_B, V_C, V_1
PHDATAV := ALL PHDATAI := ALL	8	V_A, V_B, V_C, V_1, I_A, I_B, I_C, I_1

[a] The voltages and currents are defined in Table 7.23.

Table 7.23 SEL Fast Message Voltage and Current Synchrophasor Sources

Synchrophasor Labels From Table 7.22	Synchrophasor Magnitude and Angle Pair Definition (Analog Quantities)	
	Magnitude	**Angle**
V_A	VALPMM	VALPMA
V_B	VBLPMM	VBLPMA
V_C	VCLPMM	VCLPMA
V_1	V1LPMM	V1LPMA
I_A	IA*c*PMM[a]	IA*c*PMA[a]
I_B	IB*c*PMM[a]	IB*c*PMA[a]
I_C	IC*c*PMM[a]	IC*c*PMA[a]
I_1	I1*c*PMM[a]	I1*c*PMA[a]

[a] The letter c is defined in Table 7.24.

Table 7.24 SEL Fast Message Current Channel c Definition

PHCURR Setting	c in Table 7.23
IW	W
IX	X
COMB	S

Other Settings Not Present

The SEL Fast Message format does not require the following settings: PHNR, PHFMT, FNR, NUMANA, NUMDSW, TREA1–TREA4, and PMTRIG.

The SEL Fast Message synchrophasor protocol always includes the frequency information in floating-point representation, and fourteen user-programmable SELOGIC variables PSV51 through PSV64. There are no user-programmable analog quantities in the SEL Fast Message synchrophasor protocol.

Upgrading Previous SEL-421 Synchrophasor Settings

See *Table 7.25* and *Table 7.26* for equivalent settings for your new SEL-421 synchrophasor installation.

Table 7.25 Synchrophasor Voltage and Current Settings Conversion From Previous SEL-421 Firmware Version

Previous Port Setting PMDATA (SEL-421 Firmware Version R102–R111)	Synchrophasors Transmitted	Required Global Settings in SEL-421 Version R112
V1	V1	PHDATAV := V1 PHDATAI := NA
V	VA, VB, VC, V1	PHDATAV := ALL HDATAI := NA
A	VA, VB, VC, V1, IA, IB, IC, I1	PHDATAV := ALL HDATAI := ALL

Table 7.26 Synchrophasor Current Source Settings Conversion From Previous SEL-421 Firmware Version

Global Settings[a]		Required Global Settings in SEL-421 Version R112
ESS := N		PHCURR := IW
ESS ≠ N	LINEI := IW	PHCURR := IW
ESS ≠ N	LINEI := IX	PHCURR := IX
ESS ≠ N	LINEI := COMB	PHCURR := COMB

[a] Starting in SEL-421 firmware version R112, if the SEL-421 ALINEI feature is used to select an alternate line current source, the synchrophasor current measurement data source will not switch over to the new source.

Global settings PMAPP, PHCOMP, VCOMP, IWCOMP, and IXCOMP are new settings (there are no equivalent settings in prior SEL-421 firmware versions) and may be set as needed.

Communications Bandwidth

A phasor measurement unit (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 between successive synchrophasor message time-stamps) in the enable request. If the SEL-421 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 SEL-421 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 SEL-421 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 7.27* can be used to calculate the number of bytes in a synchrophasor message.

Table 7.27 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 7.28 lists the baud settings available on any SEL-421 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 7.28 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 7.27* and *Table 7.28*, it is clear that the lower SPEED settings are very restrictive.

Some observations from *Table 7.28*:

- 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 up to 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 up to 10 messages per second, and any size message at up to 5 messages per second.
- A serial port set with SPEED := 300 cannot be used for Fast Message synchrophasors.

Protocol Operation

The SEL-421 will only transmit synchrophasor messages over serial ports that have setting PROTO := PMU. The connected device will typically be a synchrophasor processor, such as the SEL-3306. The synchrophasor processor controls the PMU functions of the SEL-421, 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 SEL-421 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 SEL-421 will stop synchrophasor transmission on all serial ports when any Global settings change is made.

The SEL-421 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 SEL-421 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.

Synchrophasor Protocols and SEL Fast Operate Commands

The SEL-421 can be configured to process SEL Fast Operate commands received on serial ports that have Port setting PROTO := PMU, when the Port setting FASTOP := Y.

This functionality can allow a host device to initiate control actions in the PMU without the need for a separate communications interface.

If port setting FASTOP:= Y on a serial port set to PROTO := PMU, the SEL-421 will provide Fast Operate support. The host device can request a Fast Operate Configuration Block when the relay is in the nontransmitting mode, and the relay will respond with the message, which includes codes that define the circuit breaker and remote bit control points that are available via Fast Operate commands.

The SEL-421 will process Fast Operate requests regardless of whether synchrophasors are being transmitted, as long as serial port setting FASTOP := Y. When FASTOP := N, the relay will ignore Fast Operate commands. Use the FASTOP := N option to lockout any control actions from that serial port if required by your company operating practices.

The SEL-421 does not acknowledge received Fast Operate commands, however, it is easy to program one or more Relay Word bits in the digital status word to observe the controlled function. For example, a Fast Operate Circuit Breaker 1 close command could be confirmed by monitoring the breaker status bit 52AA1 by assigning SELOGIC free-form protection logic setting PMV64 := 52AA1.

SEL Fast Operate commands are discussed in *SEL Fast Meter, Fast Operate, and Fast SER Messages on page R.5.8*. Note that only the Fast Operate function is available on ports set to PROTO := PMU. The protocols SEL Fast Meter and SEL Fast SER are unavailable on PROTO := PMU ports.

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Section 8

IEC 61850 Communications

Features

The SEL-421 Relay supports the following features using Ethernet and IEC 61850:

- **SCADA**—Connect up to six simultaneous Ethernet client sessions. The SEL-421 also supports up to six buffered and six unbuffered report control blocks.
- **Real-Time Status and Control**—Use GOOSE with as many as 24 incoming (receive) and 8 outgoing (transmit) messages.

NOTE: The SEL-421 supports one CID file, which should be transferred only if a change in the relay configuration is required. If an invalid CID file is transferred, the relay will no longer have a valid IEC 61850 configuration, and the protocol will stop operating. To restart protocol operation, a valid CID must be transferred to the relay.

- **Configuration**—Use FTP client software or ACSELERATOR Architect® SEL-5032 Software to transfer the Substation Configuration Language (SCL) Configured IED Description (CID) file to the relay.
- **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.
- **Firmware Upgrades**—Use FTP client software to transfer the Ethernet port firmware upgrade file to the relay.

This section presents the information you need to use the IEC 61850 features of the SEL-421:

- *Introduction to IEC 61850 on page R.8.2*
- *IEC 61850 Operation on page R.8.3*
- *IEC 61850 Configuration on page R.8.12*
- *Logical Nodes on page R.8.16*
- *ACSI Conformance Statements on page R.8.37*

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 8.1*.

Table 8.1 IEC 61850 Document Set

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
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)
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 the IEC at http://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

Ethernet Networking

IEC 61850 and Ethernet networking model options are available when ordering a new SEL-421 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 SEL-421 Port 5 settings to configure all of the Ethernet settings, including IEC 61850 network settings.

The SEL-421 Ethernet card supports IEC 61850 services, including transport of Logical Node objects, over TCP/IP. The Ethernet card can coordinate a maximum of six concurrent IEC 61850 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 common data class (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), description (DC), and substituted value (SV). Functional constraints, CDCs, and CDC attributes are used as building blocks for defining Logical Nodes.

UCA2 used GOMSFE (Generic Object Models for Substation and Feeder Equipment) to present data from station IEDs as a series of objects called models or bricks. The IEC working group has incorporated GOMSFE concepts into the standard, with some modifications to terminology; one change was the renaming of bricks to logical nodes. Each 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 measurement data and other points associated with three-phase metering including voltages and currents. Each IED may contain many functions such as protection, metering, and control. Multiple logical nodes represent the functions in multifunction devices.

Logical nodes can be organized into logical devices that are similar to directories on a computer disk. As represented in the IEC 61850 network, each physical device can contain many logical devices and each logical device can contain many logical nodes. Many relays, meters, and other IEC 61850 devices contain one primary logical device where all models are organized.

IEC 61850 devices are capable of self-description. You do not need to refer to the specifications for the logical nodes, measurements, and other components to request data from another IEC 61850 device. IEC 61850 clients can request and display a list and description of the data available in an IEC 61850 server device. This process is similar to the autoconfiguration process used within SEL communications processors (SEL-2032 and SEL-2030). Simply run an MMS browser to query devices on an IEC 61850 network and discover what data are available. Self-description also permits 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 simply query an IEC 61850 device and receive a description of all logical devices, logical nodes, and available data.

Unlike other Supervisory Control and Data Acquisition (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 8.2* shows how the A-phase current expressed as MMXUAphsA$cVal is broken down into its component parts.

Table 8.2 Example IEC 61850 Descriptor Components

Component		Description
MMXU	Logical Node	Polyphase measurement unit
A	Data Object	Phase-to-ground amperes
PhsA	Sub-Data Object	Phase A
CVal	Data Attribute	Complex value

Data Mapping

Device data are mapped to IEC 61850 Logical Nodes (LN) according to rules defined by SEL. Refer to IEC 61850-5:2003(E) and IEC 61850-7-4:2003(E) for the mandatory content and usage of these LNs. The SEL-421 logical nodes are grouped under Logical Devices for organization based on function. See *Table 8.3* for descriptions of the Logical Devices in an SEL-421. See *Logical Nodes on page R.8.16* for a description of the LNs that make up these Logical Devices.

Table 8.3 SEL-421 Logical Devices

Logical Device	Description
ANN	Annunciator elements—alarms, status values
CFG	Configuration elements—datasets and report control blocks
CON	Control elements—remote bits
MET	Metering or Measurement elements—currents, voltages, power, etc.
PRO	Protection elements—protection functions and breaker control

MMS

Manufacturing Messaging Specification (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 the IEC chose to keep it for IEC 61850.

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 ACSELERATOR Architect. Also, configure outgoing GOOSE messages for SEL devices in ACSELERATOR Architect. See the ACSELERATOR Architect instruction manual or 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.

CCIN (Communications Card Input) bits are control inputs that you can map to GOOSE receive messages using the ACSELERATOR Architect software. See the CCIN*nn* bits in *Table 8.15* 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 SEL-421 CCIN bits for controls, you must create SELOGIC® equations to define these operations. The CCIN Logical Nodes only contain CCIN status, and only those CCINs that are part of the SER dataset will be able to track CCIN transitions (via reporting) between LN data update scans.

File Services

The Ethernet File System allows reading or writing data as files. The File System supports FTP and, for the SEL-421, the Shared Memory File Transfer service. The File System provides:

- A means for the device to transfer data as files.
- A hierarchal file structure for the device data.

SCL Files

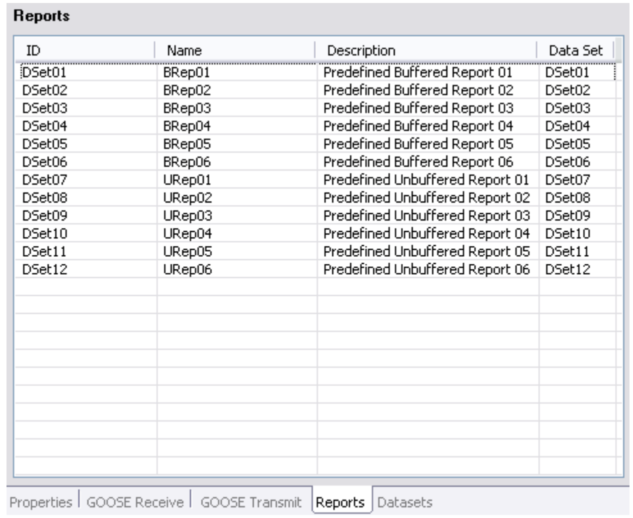
Substation Configuration Language (SCL) is an XML-based configuration language used to support the exchange of database configuration data between different tools, which may come from different manufacturers. There are four types of SCL files:

- IED Capability Description file (.ICD)
- System Specification Description (.SSD) file
- Substation Configuration Description file (.SCD)
- Configured IED Description file (.CID)

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

SEL-421 supports buffered and unbuffered report control blocks in the report model as defined in IEC 61850-8-1:2004(E). The predefined reports shown in *Figure 8.1* are available by default via IEC 61850.



Reports

ID	Name	Description	Data Set
DSet01	BRep01	Predefined Buffered Report 01	DSet01
DSet02	BRep02	Predefined Buffered Report 02	DSet02
DSet03	BRep03	Predefined Buffered Report 03	DSet03
DSet04	BRep04	Predefined Buffered Report 04	DSet04
DSet05	BRep05	Predefined Buffered Report 05	DSet05
DSet06	BRep06	Predefined Buffered Report 06	DSet06
DSet07	URep01	Predefined Unbuffered Report 01	DSet07
DSet08	URep02	Predefined Unbuffered Report 02	DSet08
DSet09	URep03	Predefined Unbuffered Report 03	DSet09
DSet10	URep04	Predefined Unbuffered Report 04	DSet10
DSet11	URep05	Predefined Unbuffered Report 05	DSet11
DSet12	URep06	Predefined Unbuffered Report 06	DSet12

Properties | GOOSE Receive | GOOSE Transmit | Reports | Datasets

Figure 8.1 SEL-421 Predefined Reports

There are twelve report control blocks (six buffered and unbuffered reports). For each report control block, there can be just one client association, i.e., only one client can be associated to a report control block (BRCB or URCB) at any given time. The number of reports (12) and the type of reports (buffered or unbuffered) cannot be changed. However, by using ACSELERATOR Architect, you can reallocate data within each report dataset to present different data attributes for each report beyond the predefined datasets.

For buffered reports, connected clients may edit the report parameters shown in *Table 8.4*.

Table 8.4 Buffered Report Control Block Client Access

RCB Attribute	User Changeable (Report Disabled)	User Changeable (Report Enabled)	Default Values
RptId	YES		FALSE
RptEna	YES	YES	FALSE
OptFlds	YES		segNum
			timeStamp
			dataSet
			reasonCode
			dataRef
BufTm	YES		500
TrgOp	YES		dchg
			qchg
IntgPd	YES		FALSE
GI	YES[a] [b]	YES[a]	FALSE
PurgeBuf	YES[a]		FALSE
EntryId	YES		0

[a] Exhibits a pulse behavior. Write a one to issue the command. Once command is accepted will return to zero. Always read as zero.
[b] When disabled, a GI will be processed and the report buffered if a buffer has been previously established. A buffer is established when the report is enabled for the first time.

Similarly, for unbuffered reports, connected clients may edit the report parameters shown in *Table 8.5*.

Table 8.5 Unbuffered Report Control Block Client Access

RCB Attribute	User Changeable (Report Disabled)	User Changeable (Report Enabled)	Default Values
RptId	YES		FALSE
RptEna	YES	YES	FALSE
Resv	YES		FALSE
OptFlds	YES		segNum
			timeStamp
			dataSet
			reasonCode
			dataRef
BufTm	YES		250
TrgOps	YES		dchg
			qchg
IntgPd	YES		FALSE
GI		YES[a]	0

[a] Exhibits a pulse behavior. Write a one to issue the command. Once command is accepted will return to zero. Always read as zero.

For buffered reports, only one client can enable the RptEna attribute of the BRCB at a time resulting 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 client disables the RptEna attribute. Once enabled, all unassociated clients have read only access to the BRCB.

For unbuffered reports, up to six clients can enable the RptEna attribute of an URCB at a time resulting in multiple client associations for that URCB. Once enabled, each client has independent access to a copy of that URCB.

The Resv attribute is writable, however, the SEL-421 does not support reservations. Writing any field of the URCB causes the client to obtain their own copy of the URCB-in essence, acquiring a reservation.

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 will begin at the time that the current report is serviced.

Datasets

The list of datasets in *Figure 8.2* are the defaults for an SEL-421 device.

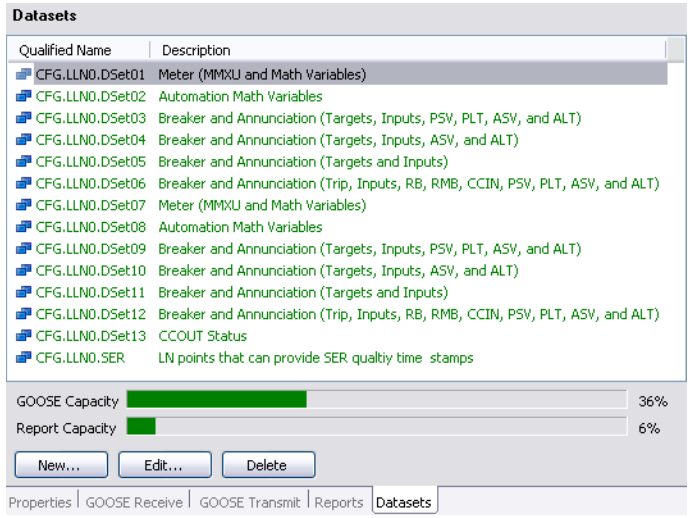


Figure 8.2 SEL-421 Datasets

Within ACSELERATOR Architect, IEC 61850 datasets have two main purposes:

- ➤ GOOSE: You can use predefined or edited datasets, or create new datasets for outgoing GOOSE transmission.
- ➤ Reports: Twelve predefined datasets (DSet01 to DSet12) correspond to the default six buffered and six unbuffered reports. Note that you cannot change the number (12) or type of reports (buffered or unbuffered) within ACSELERATOR Architect. However, you can alter the data attributes that a dataset contains and so define what data an IEC 61850 client receives with a report.

NOTE: Do not edit the dataset names used in reports. Changing or deleting any of those dataset names will cause a failure in generating the corresponding report.

The SER dataset, CFG.LLN0.SER, is a listing of the predetermined LN data attributes that are available with SER quality timestamps in the SEL-421. Modifications to this dataset *do not* modify which data attributes have SER quality timestamps. If your application requires SER quality timestamps for data attributes not in this dataset, contact SEL for possible modification to your device IEC 61850 default configuration.

LN data attributes listed in the SER dataset have SER accurate timestamps of 1 ms 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 timestamp accuracy.

Supplemental Software

Examine the data structure and values of the supported IEC 61850 LNs with an MMS browser such as MMS Object Explorer and AX-S4 MMS from Sisco, Inc.

The settings needed to browse an SEL-421 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 timestamp 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 timestamp 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 that are assigned as SER points, i.e., listed in the SER dataset, the change is detected as the receipt of an SER record (which contains the SER timestamp) from the relay to the card. 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 timestamp. In all cases, these timestamps are used for the reporting model.

The SEL-421 has predetermined LN data attributes that are available with SER quality timestamps. These data attributes are listed in the SER dataset in the default relay ICD file. Modifications to this dataset *do not* modify which data attributes have SER quality timestamps. If your application requires SER quality timestamps on data attributes not in this dataset, contact SEL for possible modification to your relay default configuration.

LN data attributes listed in the SER dataset have SER accurate timestamps of 1 ms 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 timestamp accuracy.

The SEL-421 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 8.3* shows the GOOSE quality attributes available to devices that subscribe to GOOSE messages from SEL-421 datasets 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 SEL-421 will set the Validity attribute to invalid and the Failure attribute to TRUE. Note that the SEL-421 does not set any of the other quality attributes. These attributes will always indicate FALSE (0). See the ACSELERATOR Architect online help for additional information on GOOSE Quality attributes.

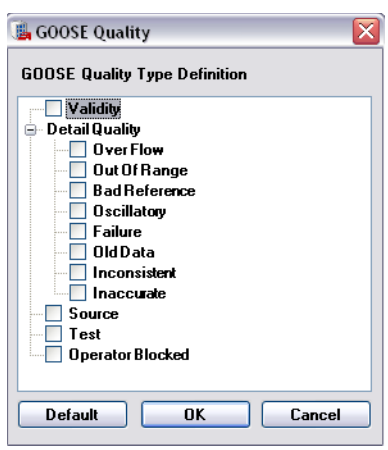


Figure 8.3 GOOSE Quality

GOOSE Processing

SEL devices support GOOSE processing as defined by IEC 61850-7-1:2003(E), IEC 61850-7-2:2003(E), and IEC 61850-8-1:2004(E) via the installed Ethernet card.

Outgoing GOOSE messages are processed in accordance with the following constraints:

- ➤ The user can define up to 8 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, or one or more times within the same outgoing GOOSE. A user can also map a single GOOSE dataset to multiple GOOSE control blocks.
- ➤ High-speed GOOSE messaging (as defined under *GOOSE Performance on page R.8.11*) is only available for CCOUT*n* data.
- ➤ The SEL-421 will transmit all configured GOOSE immediately upon successful initialization. If a GOOSE is not retriggered, then following initial transmission, the SEL-421 will retransmit that GOOSE on a curve. The curve begins at 4 ms and doubles for each retransmission until leveling at the maximum specified in the CID file for that GOOSE. For example, a message with a maximum retransmit interval of 50 ms is retransmitted at intervals of 4 ms, 8 ms, 16 ms, 32 ms and 50 ms, then repeated every 50 ms until a trigger causes the transmission sequence to be repeated. The time-to-live reported in each transmitted message, is three times the current interval, or two times the interval, if the maximum time-to-live has been reached (12 ms, 24 ms, 48 ms, 96 ms and 100 ms for the example above. See IEC 61850-8-1, sec. 18.1).
- ➤ GOOSE transmission is squelched (silenced) if the SEL-421 stops responding to the Ethernet card, or after a permanent (latching) self-test failure.
- ➤ Each outgoing GOOSE includes communication parameters (VLAN, Priority, and Multicast Address) and is transmitted entirely in a single network frame.
- ➤ The SEL-421 will maintain the configuration of outgoing GOOSE through a power cycle and device reset.

Incoming GOOSE messages are processed in accordance with the following constraints:

- ➤ The user can configure the SEL-421 to subscribe to as many as 24 incoming GOOSE messages.
- ➤ Control bits in the SEL-421 get data from incoming GOOSE messages which are mapped to CCIN*n* bits. Note: MMS can independently operate these bits.
- ➤ The SEL-421 will recognize incoming GOOSE messages as valid based on the following content:
  - ➢ Source broadcast MAC address.
  - ➢ Dataset Reference
  - ➢ Application ID
  - ➢ GOOSE Control Reference

  Any GOOSE message that fails these checks shall be rejected.

- 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 dataset 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 SEL-421.
- Reject all DA contained in an incoming GOOSE based on the accumulation of the following error indications created by inspection of the received GOOSE:
  - **Configuration Mismatch.** The configuration number of the incoming GOOSE changes.
  - **Needs Commissioning.** This Boolean parameter of the incoming GOOSE is true.
  - **Test Mode.** This Boolean parameter of the incoming GOOSE is true.
  - **Decode Error.** The format of the incoming GOOSE is not as configured.
- The SEL-421 will discard incoming GOOSE under the following conditions:
  - after a permanent (latching) self-test failure
  - when the host is not responding
  - when EGSE is set to No

Link-layer priority tagging and virtual LAN is supported as described in Annex C of IEC 61850-8-1:2004(E).

GOOSE Performance

For outgoing high-speed data (CCOUT*n* data, as identified under *GOOSE Processing on page R.8.10*), transmission of GOOSE begins within 2 ms of transition of data within the SEL-421. For all other data contained in outgoing GOOSE, transmission of GOOSE begins within 500 ms of transition of data within the SEL-421. Appropriate control commands are issued to the SEL-421 within 2 ms of a GOOSE reception.

IEC 61850 Configuration

Settings

Table 8.6 lists IEC 61850 settings. These settings are only available if your device includes the optional IEC 61850 protocol.

Table 8.6 IEC 61850 Settings

Label	Description	Range	Default
E61850	IEC 61850 interface enable	Y, N	N
EGSE	Outgoing IEC 61850 GSE message enable	Y[a], N	N

[a] Requires E61850 set to Y to send IEC 61850 GSE messages.

Configure all other IEC 61850 settings, including subscriptions to incoming GOOSE messages, with ACSELERATOR Architect software.

ACSELERATOR Architect

The ACSELERATOR Architect software enables protection and integration engineers to design and commission IEC 61850 substations containing SEL IEDs.

Engineers can use ACSELERATOR Architect to:

- Organize and configure all SEL IEDs in a substation project.
- Configure incoming and outgoing GOOSE messages.
- Edit and create GOOSE datasets.
- Read non-SEL IED Capability Description (ICD) and Configured IED Description (CID) files and determine the available IEC 61850 messaging options.
- Use or edit preconfigured datasets for reports.
- Load device settings and 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.
- Configure protection, logic, control, and communication settings of all SEL IEDs in the substation.

ACSELERATOR Architect provides a Graphical User Interface (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. ACSELERATOR 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 ACSELERATOR Architect online help for more information.

SEL ICD File Versions

ACSELERATOR Architect version 1.1.69.0 and higher supports multiple ICD file versions for each IED in a project. Because relays with different Ethernet card 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 ACSELERATOR 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 ACSELERATOR Architect and select the appropriate ICD version(s) for your needs. ACSELERATOR Architect generates CID files from ICD files so the ICD file version ACSELERATOR Architect uses also determines the CID file version generated.

As of this writing, ACSELERATOR Architect comes with two versions of the ICD file for use with the SEL-421-2 or SEL-421-3 on new or existing projects. These versions are:

➤ **002 (SEL-421-2/-3 8-Pushbutton Model):** This file is compatible with Ethernet card firmware R107 to R112 and the 8-pushbutton model of the SEL-421.

➤ **002 (SEL-421-2/-3 12-Pushbutton Model):** Identical in content to the file above, with additional logical nodes for extra pushbuttons made accessible in SEL-421 R123 or higher firmware. Select this file to enable access to these additional logical nodes when using the 12-pushbutton model of the SEL-421.

  Note: Using this file with SEL-421 R122 and lower firmware may cause unexpected behavior.

CID File Conversion

NOTE: If left unmodified, downloading the file will cause CID file parse errors and disable the IEC 61850 protocol.

If you attempt to download a version 001 CID file to a relay with Ethernet card firmware R107 to R112, ACSELERATOR Architect will offer to make the file compatible with version 002. If you agree, ACSELERATOR Architect will modify the existing CID file so that the relay can successfully process it. If you decline, the relay will cancel your request to download the CID file to the relay.

Similarly, if you attempt to download a version 002 CID file to a relay with Ethernet card firmware R113 or higher, ACSELERATOR Architect will offer to convert the file to version 003. Once converted, there will be no difference between version 002 and 003 except for the file version number stored in the CID file. If you agree, ACSELERATOR Architect will change the CID file version so that the relay can successfully process it. If you decline, the relay will cancel your request to download the CID file to the relay. Note that the version 003 file created this way for the SEL-421-2 or SEL-421-3 is completely different from the version 003 file intended for the SEL-421-4 or SEL-421-5 relay with firmware R300 or higher. This conversion is the only method ACSELERATOR Architect supports to download a CID file to a relay with Ethernet card firmware R113 or higher. Do not attempt to download the version 003 file supplied for the SEL-421-4/-5 in the default IED Palette to an SEL-421-2 or SEL-421-3.

ACSELERATOR Architect will only prompt you to perform this conversion when it recognizes that it is trying to download an unsupported CID file to a relay. This is done on a per-file basis. That is, there is no option to do a batch conversion of all CID files in a project.

See *Table 8.7* for a summary of the logical nodes provided with each ICD file version.

Table 8.7 ICD Logical Nodes Summary (Sheet 1 of 3)

Logical Device	Logical Nodes by ICD Version			Description
	Ver 001 Ver 002L	Ver 002	Ver 002 R123+	
PRO	M1PPDIS1	M1PPDIS1	M1PPDIS1	Zone 1 Mho phase element
PRO	Z1GPDIS2	Z1GPDIS2	Z1GPDIS2	Zone 1 ground distance element
PRO	M2PPDIS3	M2PPDIS3	M2PPDIS3	Zone 2 Mho phase element
PRO	Z2GPDIS4	Z2GPDIS4	Z2GPDIS4	Zone 2 ground distance element
PRO	M3PPDIS5	M3PPDIS5	M3PPDIS5	Zone 3 Mho phase element
PRO	Z3GPDIS6	Z3GPDIS6	Z3GPDIS6	Zone 3 ground distance element
PRO	M4PPDIS7	M4PPDIS7	M4PPDIS7	Zone 4 Mho phase element
PRO	Z4GPDIS8	Z4GPDIS8	Z4GPDIS8	Zone 4 ground distance element
PRO	M5PPDIS9	M5PPDIS9	M5PPDIS9	Zone 5 Mho phase element
PRO	Z5GPDIS10	Z5GPDIS10	Z5GPDIS10	Zone 5 ground distance element
PRO	P1PIOC1	P1PIOC1	P1PIOC1	Level 1 phase overcurrent element
PRO	G1PIOC2	G1PIOC2	G1PIOC2	Level 1 residual overcurrent element
PRO	Q1PIOC3	Q1PIOC3	Q1PIOC3	Level 1 negative-sequence overcurrent element
PRO	P2PIOC4	P2PIOC4	P2PIOC4	Level 2 phase overcurrent element
PRO	G2PIOC5	G2PIOC5	G2PIOC5	Level 2 residual overcurrent element
PRO	Q2PIOC6	Q2PIOC6	Q2PIOC6	Level 2 negative-sequence overcurrent element
PRO	P3PIOC7	P3PIOC7	P3PIOC7	Level 3 phase overcurrent element
PRO	G3PIOC8	G3PIOC8	G3PIOC8	Level 3 residual overcurrent element
PRO	Q3PIOC9	Q3PIOC9	Q3PIOC9	Level 3 negative-sequence overcurrent element
PRO	G4PIOC10	G4PIOC10	G4PIOC10	Level 4 residual overcurrent element
PRO	Q4PIOC11	Q4PIOC11	Q4PIOC11	Level 4 negative-sequence overcurrent element
PRO	–	–	P4PIOC12	Level 4 phase overcurrent element (missing in previous versions)
PRO	P1PTOC1	P1PTOC1	P1PTOC1	Level 1 phase directional overcurrent element
PRO	G1PTOC2	G1PTOC2	G1PTOC2	Level 1 residual directional overcurrent element
PRO	Q1PTOC3	Q1PTOC3	Q1PTOC3	Level 1 negative-sequence directional overcurrent element
PRO	P2PTOC4	P2PTOC4	P2PTOC4	Level 2 phase directional overcurrent element
PRO	G2PTOC5	G2PTOC5	G2PTOC5	Level 2 residual directional overcurrent element
PRO	Q2PTOC6	Q2PTOC6	Q2PTOC6	Level 2 negative-sequence directional overcurrent element
PRO	P3PTOC7	P3PTOC7	P3PTOC7	Level 3 phase directional overcurrent element
PRO	G3PTOC8	G3PTOC8	G3PTOC8	Level 3 residual directional overcurrent element
PRO	Q3PTOC9	Q3PTOC9	Q3PTOC9	Level 3 negative-sequence directional overcurrent element
PRO	P4PTOC10	P4PTOC10	P4PTOC10	Level 4 phase directional overcurrent element
PRO	G4PTOC11	G4PTOC11	G4PTOC11	Level 4 residual directional overcurrent element
PRO	Q4PTOC12	Q4PTOC12	Q4PTOC12	Level 4 negative-sequence directional overcurrent element
PRO	S1PTOC13	S1PTOC13	S1PTOC13	Inverse-Time Overcurrent Element 1 pickup
PRO	S2PTOC14	S2PTOC14	S2PTOC14	Inverse-Time Overcurrent Element 2 pickup
PRO	S3PTOC15	S3PTOC15	S3PTOC15	Inverse-Time Overcurrent Element 3 pickup
PRO	POTTPSCH1	POTTPSCH1	POTTPSCH1	POTT Scheme

Table 8.7 ICD Logical Nodes Summary (Sheet 2 of 3)

Logical Device	Logical Nodes by ICD Version			Description
	Ver 001 Ver 002L	Ver 002	Ver 002 R123+	
PRO	DCBPSCH2	DCBPSCH2	DCBPSCH2	DCB Trip Scheme
PRO	DCUBPSCH3	DCUBPSCH3	DCUBPSCH3	DCUB Trip Scheme
PRO	TRIPPTRC1	TRIPPTRC1	TRIPPTRC1	Trip status
PRO	BK1TRPPTRC2	BKR1PTRC2[a]	BKR1PTRC2	Breaker 1 Trip Status
PRO	BK2TRPPTRC3	BKR2PTRC2[a]	BKR2PTRC2	Breaker 2 Trip Status
PRO	F32GRDIR1	F32GRDIR1	F32GRDIR1	Forward ground directional element
PRO	R32GRDIR2	R32GRDIR2	R32GRDIR2	Reverse ground directional element
PRO	F32QRDIR3	F32QRDIR3	F32QRDIR3	Forward negative-sequence phase directional element
PRO	R32QRDIR4	R32QRDIR4	R32QRDIR4	Reverse negative-sequence phase directional element
PRO	F32PRDIR5	F32PRDIR5	F32PRDIR5	Forward phase directional element
PRO	R32PRDIR6	R32PRDIR6	R32PRDIR6	Reverse phase directional element
PRO	BFR1RBRF1	BFR1RBRF1	BFR1RBRF1	Circuit Breaker 1 circuit breaker failure
PRO	BFR2RBRF2	BFR2RBRF2	BFR2RBRF2	Circuit Breaker 2 circuit breaker failure
PRO	OSTRPSB1	OSTRPSB1	OSTRPSB1	Out-of-step tripping
PRO	OSB1RPSB2	OSB1RPSB2	OSB1RPSB2	Block Zone 1 during an out-of-step condition
PRO	OSB2RPSB3	OSB2RPSB3	OSB2RPSB3	Block Zone 2 during an out-of-step condition
PRO	OSB3RPSB4	OSB3RPSB4	OSB3RPSB4	Block Zone 3 during an out-of-step condition
PRO	OSB4RPSB5	OSB4RPSB5	OSB4RPSB5	Block Zone 4 during an out-of-step condition
PRO	OSB5RPSB6	OSB5RPSB6	OSB5RPSB6	Block Zone 5 during an out-of-step condition
PRO	BK1AXCBR1	BK1AXCBR1	BK1AXCBR1	Circuit Breaker 1, Pole A
PRO	BK1BXCBR2	BK1BXCBR2	BK1BXCBR2	Circuit Breaker 1, Pole B
PRO	BK1CXCBR3	BK1CXCBR3	BK1CXCBR3	Circuit Breaker 1, Pole C
PRO	BK2AXCBR4	BK2AXCBR4	BK2AXCBR4	Circuit Breaker 2, Pole A
PRO	BK2BXCBR5	BK2BXCBR5	BK2BXCBR5	Circuit Breaker 2, Pole B
PRO	BK3CXCBR6	BK3CXCBR6	BK3CXCBR6	Circuit Breaker 2, Pole C
PRO	BKR1CSWI1	BKR1CSWI1	BKR1CSWI1	Circuit Breaker 1
PRO	BKR2CSWI2	BKR2CSWI2	BKR2CSWI2	Circuit Breaker 2
MET	METMMXU1	METMMXU1	METMMXU1	Measured Values (Currents and Voltages)
MET	SEQMSQI1	SEQMSQI1	SEQMSQI1	Positive and Zero-sequence currents and voltages
CON	RBGGIO1	RBGGIO1	RBGGIO1	Remote Bits
ANN	PSVGGIO1	PSVGGIO1	PSVGGIO1	Protection SELOGIC Control Variables
ANN	PLTGGIO2	PLTGGIO2	PLTGGIO2	Protection Latches
ANN	PMVGGIO3	PMVGGIO3	PMVGGIO3	Protection SELOGIC Control Equation Math Variables
ANN	ASVGGIO4	ASVGGIO4	ASVGGIO4	Automation SELOGIC Control Equation Variables
ANN	ALTGGIO5	ALTGGIO5	ALTGGIO5	Automation Latches
ANN	AMVGGIO6	AMVGGIO6	AMVGGIO6	Automation SELOGIC Control Equation Math Variables
ANN	TLEDGGIO7	TLEDGGIO7	TLEDGGIO7[b]	Front panel target LEDs
ANN	PBLEDGGIO8	PBLEDGGIO8	PBLEDGGIO8[b]	Pushbutton LEDs
ANN	RMBAGGIO9	RMBAGGIO9	RMBAGGIO9	Channel A Receive MIRRORED BITS

Table 8.7 ICD Logical Nodes Summary (Sheet 3 of 3)

Logical Device	Logical Nodes by ICD Version			Description
	Ver 001 Ver 002L	Ver 002	Ver 002 R123+	
ANN	TMBAGGIO10	TMBAGGIO10	TMBAGGIO10	Channel A Transmit MIRRORED BITS
ANN	RMBAGGIO11	RMBAGGIO11	RMBAGGIO11	Channel B Receive MIRRORED BITS
ANN	TMBAGGIO12	TMBAGGIO12	TMBAGGIO12	Channel B Transmit MIRRORED BITS
ANN	MBOKGGIO13	MBOKGGIO13	MBOKGGIO13	MIRRORED BITS Communications Status
ANN	INPUT1GGIO14	IN1GGIO14[a]	IN1GGIO14	Mainboard inputs
ANN	INPUT2GGIO15	IN2GGIO15[a]	IN2GGIO15	I/O Board 2 inputs, active data only if additional I/O Card(s) installed
ANN	INPUT3GGIO16	IN3GGIO16[a]	IN3GGIO16	I/O Board 3 inputs, active data only if additional I/O Card(s) installed
ANN	OUTPUT1GGIO17	OUT1GGIO17[a]	OUT1GGIO17	Mainboard outputs
ANN	OUTPUT2GGIO18	OUT2GGIO18[a]	OUT2GGIO18	I/O Board 2 outputs, active data only if additional I/O Card(s) installed
ANN	OUTPUT3GGIO19	OUT3GGIO19[a]	OUT3GGIO19	I/O Board 3 outputs, active data only if additional I/O Card(s) installed
ANN	CCINGGIO20	CCINGGIO20	CCINGGIO20	Communications Card Inputs
ANN	CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Communications Card Outputs

[a] Indicates that this logical node name has been changed in this version and differs from the ICD file version in the adjacent left-hand column.
[b] Indicates that this logical node has been modified in this version and differs from the ICD file version in the adjacent left-hand column.

Logical Nodes

Table 8.8 through *Table 8.11* show the logical nodes (LNs) supported in the SEL-421 and the Relay Word bits or Measured Values mapped to those LNs. Any differences between ICD file versions are also indicated in the tables.

Table 8.8 shows the LNs associated with protection elements, defined as Logical Device PRO.

Table 8.8 Logical Device: PRO (Protection) (Sheet 1 of 4)

Logical Nodes by ICD Version		Status	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002 Ver 002 R123+			
P1PIOC1	P1PIOC1	Op.general	50P1	
G1PIOC2	G1PIOC2	Op.general	50G1	
Q1PIOC3	Q1PIOC3	Op.general	50Q1	
P2PIOC4	P2PIOC4	Op.general	50P2	
G2PIOC5	G2PIOC5	Op.general	50G2	
Q2PIOC6	Q2PIOC6	Op.general	50Q2	
P3PIOC7	P3PIOC7	Op.general	50P3	
G3PIOC8	G3PIOC8	Op.general	50G3	
Q3PIOC9	Q3PIOC9	Op.general	50Q3	
G4PIOC10	G4PIOC10	Op.general	50G4	

Table 8.8 Logical Device: PRO (Protection) (Sheet 2 of 4)

Logical Nodes by ICD Version		Status	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002 Ver 002 R123+			
Q4PIOC11	Q4PIOC11	Op.general	50Q4	
P1PTOC1	P1PTOC1	Str.general	67P1	
P1PTOC1	P1PTOC1	Str.dirGeneral	0	unknown
P1PTOC1	P1PTOC1	Opr.general	67P1T	
G1PTOC2	G1PTOC2	Str.general	67G1	
G1PTOC2	G1PTOC2	Str.dirGeneral	1	Always forward
G1PTOC2	G1PTOC2	Op.general	67G1T	
Q1PTOC3	Q1PTOC3	Str.general	67Q1	
Q1PTOC3	Q1PTOC3	Str.dirGeneral	1	Always forward
Q1PTOC3	Q1PTOC3	Op.general	67Q1T	
P2PTOC4	P2PTOC4	Str.general	67P2	
P2PTOC4	P2PTOC4	Str.dirGeneral	0	unknown
P2PTOC4	P2PTOC4	Op.general	67P2T	
G2PTOC5	G2PTOC5	Str.general	67G2	
G2PTOC5	G2PTOC5	Str.dirGeneral	1	Always forward
G2PTOC5	G2PTOC5	Op.general	67G2T	
Q2PTOC6	Q2PTOC6	Str.general	67Q2	
Q2PTOC6	Q2PTOC6	Str.dirGeneral	1	Always forward
Q2PTOC6	Q2PTOC6	Op.general	67Q2T	
P3PTOC7	P3PTOC7	Str.general	67P3	
P3PTOC7	P3PTOC7	Str.dirGeneral	0	unknown
P3PTOC7	P3PTOC7	Op.general	67P3T	
G3PTOC8	G3PTOC8	Str.general	67G3	
G3PTOC8	G3PTOC8	Str.dirGeneral		If DIR3=F: forward (1); If DIR3=R: reverse (2)
G3PTOC8	G3PTOC8	Op.general	67G3T	
Q3PTOC9	Q3PTOC9	Str.general	67Q3	
Q3PTOC9	Q3PTOC9	Str.dirGeneral		If DIR3=F: forward (1); If DIR3=R: reverse (2)
Q3PTOC9	Q3PTOC9	Op.general	67Q3T	
P4PTOC10	P4PTOC10	Str.general	67P4	
P4PTOC10	P4PTOC10	Str.dirGeneral	0	unknown
P4PTOC10	P4PTOC10	Op.general	67P4T	
G4PTOC11	G4PTOC11	Str.general	67G4	
G4PTOC11	G4PTOC11	Str.dirGeneral		If DIR4=F: forward (1); If DIR4=R: reverse (2)
G4PTOC11	G4PTOC11	Op.general	67G4T	
Q4PTOC12	Q4PTOC12	Str.general	67Q4	
Q4PTOC12	Q4PTOC12	Str.dirGeneral		If DIR4=F: forward (1); If DIR4=R: reverse (2)

Table 8.8 Logical Device: PRO (Protection) (Sheet 3 of 4)

Logical Nodes by ICD Version		Status	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002 Ver 002 R123+			
Q4PTOC12	Q4PTOC12	Op.general	67Q4T	
S1PTOC13	S1PTOC13	Str.general	51S1	
S1PTOC13	S1PTOC13	Str.dirGeneral	0	unknown
S1PTOC13	S1PTOC13	Op.general	51S1T	
S2PTOC14	S2PTOC14	Str.general	51S2	
S2PTOC14	S2PTOC14	Str.dirGeneral	0	unknown
S2PTOC14	S2PTOC14	Op.general	51S2T	
S3PTOC15	S3PTOC15	Str.general	51S3	
S3PTOC15	S3PTOC15	Str.dirGeneral	0	unknown
S3PTOC15	S3PTOC15	Op.general	51S3T	
POTTPSCH1	POTTPSCH1	Str.general	KEY	
POTTPSCH1	POTTPSCH1	Op.general	RXPRM	
POTTPSCH1	POTTPSCH1	Echo.general	EKEY	
POTTPSCH1	POTTPSCH1	WeiOp.general	ECTT	
POTTPSCH1	POTTPSCH1	RvABlk.general	Z3RB	
DCBPSCH2	DCBPSCH2	Str.general	DSTRT OR NSTRT	
DCBPSCH2	DCBPSCH2	Op.general	RXPRM	
DBCPSCH2	DBCPSCH2	RvABlk.general	Z3RB	
DCUBPSCH3	DCUBPSCH3	Str.general	KEY	
DCUBPSCH3	DCUBPSCH3	Op.general	RXPRM	
DCUBPSCH3	DCUBPSCH3	Echo.general	EKEY	
DCUBPSCH3	DCUBPSCH3	WeiOp.general	ECTT	
DCUBPSCH3	DCUBPSCH3	RvABlk.general	Z3RB	
TRIPPTRC1	TRIPPTRC1	Tr.general	TRIP	
BK1TRPPTRC2	BKR1PTRC2	Tr.general	TRIP	
BK2TRPPTRC3	BKR2PTRC3	Tr.general	TRIP	
F32GRDIR1	F32GRDIR1	Dir.general	32GF	
R32GRDIR2	R32GRDIR2	Dir.general	32GR	
F32QRDIR3	F32QRDIR3	Dir.general	F32Q	
R32QRDIR4	R32QRDIR4	Dir.general	R32Q	
F32PRDIR5	F32PRDIR5	Dir.general	F32P	
R32PRDIR6	R32PRDIR6	Dir.general	R32P	
BFR1RBRF1	BFR1RBRF1	Str.general	BFI3P1	
BFR1RBRF1	BFR1RBRF1	OpIn.general	FBF1	
BFR2RBRF2	BFR2RBRF2	Str.general	BFI3P2	
BFR2RBRF2	BFR2RBRF2	OpIn.general	FBF2	
BK1XCBR1	BK1XCBR1	Opcnt.stVal	NOPA1	
BK1XCBR1	BK1XCBR1	Pos.stVal	52ACL1	
BK2XCBR2	BK2XCBR2	Opcnt.stVal	NOPA2	

Table 8.8 Logical Device: PRO (Protection) (Sheet 4 of 4)

Logical Nodes by ICD Version		Status	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	**Ver 002 Ver 002 R123+**			
BK2XCBR2	BK2XCBR2	Pos.stVal	52ACL2	
SW1XSWI1[a]	SW1XSWI1[a]	Loc.stVal	LOCAL	
SW1XSWI1[a]	SW1XSWI1[a]	Pos.stVal	89CL1	
SW2XSWI2[a]	SW2XSWI2[a]	Loc.stVal	LOCAL	
SW2XSWI2[a]	SW2XSWI2[a]	Pos.stVal	89CL2	
SW3XSWI3[a]	SW3XSWI3[a]	Loc.stVal	LOCAL	
SW3XSWI3[a]	SW3XSWI3[a]	Pos.stVal	89CL3	
SW2XSWI4[a]	SW2XSWI4[a]	Loc.stVal	LOCAL	
SW2XSWI4[a]	SW2XSWI4[a]	Pos.stVal	89CL4	
SW2XSWI5[a]	SW2XSWI5[a]	Loc.stVal	LOCAL	
SW2XSWI5[a]	SW2XSWI5[a]	Pos.stVal	89CL5	
BKR1CSWI1	BKR1CSWI1	Pos.stVal	52ACL1	
BKR1CSWI1	BKR1CSWI1	OpOpn.general	OC1	
BKR1CSWI1	BKR1CSWI1	OpCls.general	CC1	
BKR2CSWI2	BKR2CSWI2	Pos.stVal	52ACL2	
BKR2CSWI2	BKR2CSWI2	OpOpn.general	OC1	
BKR2CSWI2	BKR2CSWI2	OpCls.general	CC1	
SW1CSWI3[a]	SW1CSWI3[a]	Loc.stVal	LOCAL	
SW1CSWI4[a]	SW1CSWI4[a]	Pos.stVal	89CL1	
SW1CSWI4[a]	SW1CSWI4[a]	OpOpn.general	89OPN1	
SW1CSWI4[a]	SW1CSWI4[a]	OpCls.general	89CLS1	
SW2CSWI5[a]	SW2CSWI5[a]	Loc.stVal	LOCAL	
SW2CSWI5[a]	SW2CSWI5[a]	Pos.stVal	89CL2	
SW2CSWI5[a]	SW2CSWI5[a]	OpOpn.general	89OPN2	
SW2CSWI5[a]	SW2CSWI5[a]	OpCls.general	89CLS2	
SW3CSWI6[a]	SW3CSWI6[a]	Loc.stVal	LOCAL	
SW3CSWI6[a]	SW3CSWI6[a]	Pos.stVal	89CL3	
SW3CSWI6[a]	SW3CSWI6[a]	OpOpn.general	89OPN3	
SW3CSWI6[a]	SW3CSWI6[a]	OpCls.general	89CLS3	
SW2CSWI7[a]	SW2CSWI7[a]	Loc.stVal	LOCAL	
SW2CSWI7[a]	SW2CSWI7[a]	Pos.stVal	89CL4	
SW2CSWI7[a]	SW2CSWI7[a]	OpOpn.general	89OPN4	
SW2CSWI7[a]	SW2CSWI7[a]	OpCls.general	89CLS4	
SW2CSWI8[a]	SW2CSWI8[a]	Loc.stVal	LOCAL	
SW2CSWI8[a]	SW2CSWI8[a]	Pos.stVal	89CL5	
SW2CSWI8[a]	SW2CSWI8[a]	OpOpn.general	89OPN5	
SW2CSWI8[a]	SW2CSWI8[a]	OpCls.general	89CLS5	

[a] Active data only if additional I/O Card(s) installed.

Table 8.9 shows the LNs associated with measuring elements, defined as Logical Device MET.

Table 8.9 Logical Device: MET (Metering) (Sheet 1 of 2)

Logical Node (All ICD Versions)	Measurand	Comment
METMMXU1	TotW.mag	P, Total real power
METMMXU1	TotVAr.mag	Q, Total reactive power
METMMXU1	TotVA.mag	S, Total apparent power
METMMXU1	TotPF.mag	PF, Three-phase power factor
METMMXU1	Hz.mag	FREQ, System frequency
METMMXU1	PhV.phsA.cVal.mag	VA, Phase A voltage magnitude
METMMXU1	PhV.phsA.cVal.ang	VA, Phase A voltage angle
METMMXU1	PhV.phsB.cVal.mag	VB, Phase A voltage magnitude
METMMXU1	PhV.phsB.cVal.ang	VB, Phase A voltage angle
METMMXU1	PhV.phsC.cVal.mag	VC, Phase A voltage magnitude
METMMXU1	PhV.phsC.cVal.ang	VC, Phase A voltage angle
METMMXU1	A1.phsA.cVal.mag	IA1, Line phase A current magnitude
METMMXU1	A1.phsA.cVal.ang	IA1, Line phase A-phase current angle
METMMXU1	A1.phsB.cVal.mag	IB1, Line phase B current magnitude
METMMXU1	A1.phsB.cVal.ang	IB1, Line phase B-phase current angle
METMMXU1	A1.phsC.cVal.mag	IC1, Line phase C current magnitude
METMMXU1	A1.phsC.cVal.ang	IC1, Line phase C-phase current angle
METMMXU1	A2.phsA.cVal.mag	IA2, Breaker 1 A-phase current magnitude
METMMXU1	A2.phsA.cVal.ang	IA2, Breaker 1 A-phase current angle
METMMXU1	A2.phsB.cVal.mag	IB2, Breaker 1 B-phase current magnitude
METMMXU1	A2.phsB.cVal.ang	IB2, Breaker 1 B-phase current angle
METMMXU1	A2.phsC.cVal.mag	IC2, Breaker 1 C-phase current magnitude
METMMXU1	A2.phsC.cVal.ang	IC2, Breaker 1 C-phase current angle
METMMXU1	A3.phsA.cVal.mag	IA3, Breaker 2 A-phase current magnitude
METMMXU1	A3.phsA.cVal.ang	IA3, Breaker 2 A-phase current angle
METMMXU1	A3.phsB.cVal.mag	IB3, Breaker 2 B-phase current magnitude
METMMXU1	A3.phsB.cVal.ang	IB3, Breaker 2 B-phase current angle
METMMXU1	A3.phsC.cVal.mag	IC3, Breaker 2 C-phase current magnitude
METMMXU1	A3.phsC.cVal.ang	IC3, Breaker 2 C-phase current angle
SEQMSQI1	SeqA.c1.cVal.mag	I1_1, Line positive-sequence current magnitude
SEQMSQI1	SeqA.c1.cVal.ang	I1_1, Line positive-sequence current angle
SEQMSQI1	SeqA.c2.cVal.mag	I2_1, Line negative-sequence current magnitude
SEQMSQI1	SeqA.c2.cVal.ang	I2_1, Line negative-sequence current angle
SEQMSQI1	SeqA.c3.cVal.mag	I0_1, Line zero-sequence current magnitude
SEQMSQI1	SeqA.c3.cVal.ang	I0_1, Line zero-sequence current angle
SEQMSQI1	SeqV.c1.cVal.mag	V1, Positive-sequence voltage magnitude

Table 8.9 Logical Device: MET (Metering) (Sheet 2 of 2)

Logical Node (All ICD Versions)	Measurand	Comment
SEQMSQI1	SeqV.c1.cVal.ang	V1, Positive-sequence voltage angle
SEQMSQI1	SeqV.c2.cVal.mag	V2, Negative-sequence voltage magnitude
SEQMSQI1	SeqV.c2.cVal.ang	V2, Negative-sequence voltage angle
SEQMSQI1	SeqV.c3.cVal.mag	V0, Zero-sequence voltage magnitude
SEQMSQI1	SeqV.c3.cVal.ang	V0, Zero-sequence voltage angle

Table 8.10 shows the LNs associated with control elements, defined as Logical Device CON.

Table 8.10 Logical Device: CON (Remote Control) (Sheet 1 of 2)

Logical Node (All ICD Versions)	Control	Relay Word or Database Bit
RBGGIO1	SPCSO01	RB01
RBGGIO1	SPCSO02	RB02
RBGGIO1	SPCSO03	RB03
RBGGIO1	SPCSO04	RB04
RBGGIO1	SPCSO05	RB05
RBGGIO1	SPCSO06	RB06
RBGGIO1	SPCSO07	RB07
RBGGIO1	SPCSO08	RB08
RBGGIO1	SPCSO09	RB09
RBGGIO1	SPCSO10	RB10
RBGGIO1	SPCSO11	RB11
RBGGIO1	SPCSO12	RB12
RBGGIO1	SPCSO13	RB13
RBGGIO1	SPCSO14	RB14
RBGGIO1	SPCSO15	RB15
RBGGIO1	SPCSO16	RB16
RBGGIO1	SPCSO17	RB17
RBGGIO1	SPCSO18	RB18
RBGGIO1	SPCSO19	RB19
RBGGIO1	SPCSO20	RB20
RBGGIO1	SPCSO21	RB21
RBGGIO1	SPCSO22	RB22
RBGGIO1	SPCSO23	RB23
RBGGIO1	SPCSO24	RB24
RBGGIO1	SPCSO25	RB25
RBGGIO1	SPCSO26	RB26
RBGGIO1	SPCSO27	RB27
RBGGIO1	SPCSO28	RB28
RBGGIO1	SPCSO29	RB29
RBGGIO1	SPCSO30	RB30

Table 8.10 Logical Device: CON (Remote Control) (Sheet 2 of 2)

Logical Node (All ICD Versions)	Control	Relay Word or Database Bit
RBGGIO1	SPCSO31	RB31
RBGGIO1	SPCSO32	RB32

Table *Table 8.11* shows the LNs associated with the annunciation element, defined as Logical Device ANN.

Table 8.11 Logical Device: ANN (Annunciation) (Sheet 1 of 9)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R123+			
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind01.stVal	PSV01	
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind02.stVal	PSV02	
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind03.stVal	PSV03	
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind04.stVal	PSV04	
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind05.stVal	PSV05	
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind06.stVal	PSV06	
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind07.stVal	PSV07	
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind08.stVal	PSV08	
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind09.stVal	PSV09	
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind10.stVal	PSV10	
…	…	…	…	…	
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind63.stVal	PSV63	
PSVGGIO1	PSVGGIO1	PSVGGIO1	Ind64.stVal	PSV64	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind01.stVal	PLT01	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind02.stVal	PLT02	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind03.stVal	PLT03	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind04.stVal	PLT04	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind05.stVal	PLT05	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind06.stVal	PLT06	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind07.stVal	PLT07	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind08.stVal	PLT08	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind09.stVal	PLT09	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind10.stVal	PLT10	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind11.stVal	PLT11	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind12.stVal	PLT12	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind13.stVal	PLT13	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind14.stVal	PLT14	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind15.stVal	PLT15	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind16.stVal	PLT16	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind17.stVal	PLT17	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind18.stVal	PLT18	

Table 8.11 Logical Device: ANN (Annunciation) (Sheet 2 of 9)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R123+			
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind19.stVal	PLT19	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind20.stVal	PLT20	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind21.stVal	PLT21	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind22.stVal	PLT22	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind23.stVal	PLT23	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind24.stVal	PLT24	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind25.stVal	PLT25	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind26.stVal	PLT26	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind27.stVal	PLT27	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind28.stVal	PLT28	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind29.stVal	PLT29	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind30.stVal	PLT30	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind31.stVal	PLT31	
PLTGGIO2	PLTGGIO2	PLTGGIO2	Ind32.stVal	PLT32	
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn01.mag	PMV01	
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn02.mag	PMV02	
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn03.mag	PMV03	
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn04.mag	PMV04	
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn05.mag	PMV05	
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn06.mag	PMV06	
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn07.mag	PMV07	
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn08.mag	PMV08	
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn09.mag	PMV09	
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn10.mag	PMV10	
…	…	…	…	…	
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn63.mag	PMV63	
PMVGGIO3	PMVGGIO3	PMVGGIO3	AnIn64.mag	PMV64	
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind001.stVal	ASV001	
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind002.stVal	ASV002	
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind003.stVal	ASV003	
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind004.stVal	ASV004	
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind005.stVal	ASV005	
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind006.stVal	ASV006	
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind007.stVal	ASV007	
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind008.stVal	ASV008	
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind009.stVal	ASV009	
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind010.stVal	ASV010	
…	…	…	…	…	
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind127.stVal	ASV127	

Table 8.11 Logical Device: ANN (Annunciation) (Sheet 3 of 9)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R123+			
ASVGGIO4	ASVGGIO4	ASVGGIO4	Ind128.stVal	ASV128	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind01.stVal	ALT01	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind02.stVal	ALT02	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind03.stVal	ALT03	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind04.stVal	ALT04	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind05.stVal	ALT05	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind06.stVal	ALT06	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind07.stVal	ALT07	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind08.stVal	ALT08	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind09.stVal	ALT09	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind10.stVal	ALT10	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind11.stVal	ALT11	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind12.stVal	ALT12	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind13.stVal	ALT13	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind14.stVal	ALT14	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind15.stVal	ALT15	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind16.stVal	ALT16	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind17.stVal	ALT17	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind18.stVal	ALT18	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind19.stVal	ALT19	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind20.stVal	ALT20	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind21.stVal	ALT21	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind22.stVal	ALT22	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind23.stVal	ALT23	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind24.stVal	ALT24	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind25.stVal	ALT25	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind26.stVal	ALT26	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind27.stVal	ALT27	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind28.stVal	ALT28	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind29.stVal	ALT29	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind30.stVal	ALT30	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind31.stVal	ALT31	
ALTGGIO5	ALTGGIO5	ALTGGIO5	Ind32.stVal	ALT32	
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn01.mag	AMV01	
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn02.mag	AMV02	
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn03.mag	AMV03	
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn04.mag	AMV04	
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn05.mag	AMV05	
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn06.mag	AMV06	

Table 8.11 Logical Device: ANN (Annunciation) (Sheet 4 of 9)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R123+			
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn07.mag	AMV07	
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn08.mag	AMV08	
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn09.mag	AMV09	
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn10.mag	AMV10	
…	…	…	…	…	
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn63.mag	AMV63	
AMVGGIO6	AMVGGIO6	AMVGGIO6	AnIn64.mag	AMV64	
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind01.stVal	EN	Front-panel target LED “EN”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind02.stVal	TRIPLED	Front-panel target LED “TRIPLED”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind03.stVal	TLED_1	Front-panel target LED “TLED_1”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind04.stVal	TLED_2	Front-panel target LED “TLED_2”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind05.stVal	TLED_3	Front-panel target LED “TLED_3”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind06.stVal	TLED_4	Front-panel target LED “TLED_4”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind07.stVal	TLED_5	Front-panel target LED “TLED_5”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind08.stVal	TLED_6	Front-panel target LED “TLED_6”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind09.stVal	TLED_7	Front-panel target LED “TLED_7”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind10.stVal	TLED_8	Front-panel target LED “TLED_8”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind11.stVal	TLED_9	Front-panel target LED “TLED_9”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind12.stVal	TLED_10	Front-panel target LED “TLED_10”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind13.stVal	TLED_11	Front-panel target LED “TLED_11”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind14.stVal	TLED_12	Front-panel target LED “TLED_12”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind15.stVal	TLED_13	Front-panel target LED “TLED_13”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind16.stVal	TLED_14	Front-panel target LED “TLED_14”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind17.stVal	TLED_15	Front-panel target LED “TLED_15”
TLEDGGIO7	TLEDGGIO7	TLEDGGIO7	Ind18.stVal	TLED_16	Front-panel target LED “TLED_16”
-	-	TLEDGGIO7[a]	Ind19.stVal	TLED_17	Front-panel target LED “TLED_17”
-	-	TLEDGGIO7[a]	Ind20.stVal	TLED_18	Front-panel target LED “TLED_18”
-	-	TLEDGGIO7[a]	Ind21.stVal	TLED_19	Front-panel target LED “TLED_19”
-	-	TLEDGGIO7[a]	Ind22.stVal	TLED_20	Front-panel target LED “TLED_20”
-	-	TLEDGGIO7[a]	Ind23.stVal	TLED_21	Front-panel target LED “TLED_21”
-	-	TLEDGGIO7[a]	Ind24.stVal	TLED_22	Front-panel target LED “TLED_22”
-	-	TLEDGGIO7[a]	Ind25.stVal	TLED_23	Front-panel target LED “TLED_23”
-	-	TLEDGGIO7[a]	Ind26.stVal	TLED_24	Front-panel target LED “TLED_24”
PBLEDGGIO8	PBLEDGGIO8	PBLEDGGIO8	Ind01.stVal	PB1_LED	Pushbutton LED “PB1_LED”
PBLEDGGIO8	PBLEDGGIO8	PBLEDGGIO8	Ind02.stVal	PB2_LED	Pushbutton LED “PB2_LED”
PBLEDGGIO8	PBLEDGGIO8	PBLEDGGIO8	Ind03.stVal	PB3_LED	Pushbutton LED “PB3_LED”
PBLEDGGIO8	PBLEDGGIO8	PBLEDGGIO8	Ind04.stVal	PB4_LED	Pushbutton LED “PB4_LED”
PBLEDGGIO8	PBLEDGGIO8	PBLEDGGIO8	Ind05.stVal	PB5_LED	Pushbutton LED “PB5_LED”
PBLEDGGIO8	PBLEDGGIO8	PBLEDGGIO8	Ind06.stVal	PB6_LED	Pushbutton LED “PB6_LED”

Table 8.11 Logical Device: ANN (Annunciation) (Sheet 5 of 9)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R123+			
PBLEDGGIO8	PBLEDGGIO8	PBLEDGGIO8	Ind07.stVal	PB7_LED	Pushbutton LED "PB7_LED"
PBLEDGGIO8	PBLEDGGIO8	PBLEDGGIO8	Ind08.stVal	PB8_LED	Pushbutton LED "PB8_LED"
–	–	PBLEDGGIO8[a]	Ind09.stVal	PB9_LED	Pushbutton LED "PB9_LED"
–	–	PBLEDGGIO8[a]	Ind10.stVal	PB10LED	Pushbutton LED "PB10LED"
–	–	PBLEDGGIO8[a]	Ind11.stVal	PB11LED	Pushbutton LED "PB11LED"
–	–	PBLEDGGIO8[a]	Ind12.stVal	PB12LED	Pushbutton LED "PB12LED"
RMBAGGIO9	RMBAGGIO9	RMBAGGIO9	Ind01.stVal	RMB1A	
RMBAGGIO9	RMBAGGIO9	RMBAGGIO9	Ind02.stVal	RMB2A	
RMBAGGIO9	RMBAGGIO9	RMBAGGIO9	Ind03.stVal	RMB3A	
RMBAGGIO9	RMBAGGIO9	RMBAGGIO9	Ind04.stVal	RMB4A	
RMBAGGIO9	RMBAGGIO9	RMBAGGIO9	Ind05.stVal	RMB5A	
RMBAGGIO9	RMBAGGIO9	RMBAGGIO9	Ind06.stVal	RMB6A	
RMBAGGIO9	RMBAGGIO9	RMBAGGIO9	Ind07.stVal	RMB7A	
RMBAGGIO9	RMBAGGIO9	RMBAGGIO9	Ind08.stVal	RMB8A	
TMBAGGIO10	TMBAGGIO10	TMBAGGIO10	Ind01.stVal	TMB1A	
TMBAGGIO10	TMBAGGIO10	TMBAGGIO10	Ind02.stVal	TMB2A	
TMBAGGIO10	TMBAGGIO10	TMBAGGIO10	Ind03.stVal	TMB3A	
TMBAGGIO10	TMBAGGIO10	TMBAGGIO10	Ind04.stVal	TMB4A	
TMBAGGIO10	TMBAGGIO10	TMBAGGIO10	Ind05.stVal	TMB5A	
TMBAGGIO10	TMBAGGIO10	TMBAGGIO10	Ind06.stVal	TMB6A	
TMBAGGIO10	TMBAGGIO10	TMBAGGIO10	Ind07.stVal	TMB7A	
TMBAGGIO10	TMBAGGIO10	TMBAGGIO10	Ind08.stVal	TMB8A	
RMBAGGIO11	RMBAGGIO11	RMBAGGIO11	Ind01.stVal	RMB1B	
RMBAGGIO11	RMBAGGIO11	RMBAGGIO11	Ind02.stVal	RMB2B	
RMBAGGIO11	RMBAGGIO11	RMBAGGIO11	Ind03.stVal	RMB3B	
RMBAGGIO11	RMBAGGIO11	RMBAGGIO11	Ind04.stVal	RMB4B	
RMBAGGIO11	RMBAGGIO11	RMBAGGIO11	Ind05.stVal	RMB5B	
RMBAGGIO11	RMBAGGIO11	RMBAGGIO11	Ind06.stVal	RMB6B	
RMBAGGIO11	RMBAGGIO11	RMBAGGIO11	Ind07.stVal	RMB7B	
RMBAGGIO11	RMBAGGIO11	RMBAGGIO11	Ind08.stVal	RMB8B	
TMBAGGIO12	TMBAGGIO12	TMBAGGIO12	Ind01.stVal	TMB1B	
TMBAGGIO12	TMBAGGIO12	TMBAGGIO12	Ind02.stVal	TMB2B	
TMBAGGIO12	TMBAGGIO12	TMBAGGIO12	Ind03.stVal	TMB3B	
TMBAGGIO12	TMBAGGIO12	TMBAGGIO12	Ind04.stVal	TMB4B	
TMBAGGIO12	TMBAGGIO12	TMBAGGIO12	Ind05.stVal	TMB5B	
TMBAGGIO12	TMBAGGIO12	TMBAGGIO12	Ind06.stVal	TMB6B	
TMBAGGIO12	TMBAGGIO12	TMBAGGIO12	Ind07.stVal	TMB7B	
TMBAGGIO12	TMBAGGIO12	TMBAGGIO12	Ind08.stVal	TMB8B	
MBOKGGIO13	MBOKGGIO13	MBOKGGIO13	Ind01.stVal	ROKA	

Table 8.11 Logical Device: ANN (Annunciation) (Sheet 6 of 9)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R123+			
MBOKGGIO13	MBOKGGIO13	MBOKGGIO13	Ind02.stVal	RBADA	
MBOKGGIO13	MBOKGGIO13	MBOKGGIO13	Ind03.stVal	CBADA	
MBOKGGIO13	MBOKGGIO13	MBOKGGIO13	Ind04.stVal	LBOKA	
MBOKGGIO13	MBOKGGIO13	MBOKGGIO13	Ind05.stVal	ANOKA	
MBOKGGIO13	MBOKGGIO13	MBOKGGIO13	Ind06.stVal	DOKA	
MBOKGGIO13	MBOKGGIO13	MBOKGGIO13	Ind07.stVal	ROKB	
MBOKGGIO13	MBOKGGIO13	MBOKGGIO13	Ind08.stVal	RBADB	
MBOKGGIO13	MBOKGGIO13	MBOKGGIO13	Ind09.stVal	CBADB	
MBOKGGIO13	MBOKGGIO13	MBOKGGIO13	Ind10.stVal	LBOKB	
MBOKGGIO13	MBOKGGIO13	MBOKGGIO13	Ind11.stVal	ANOKB	
MBOKGGIO13	MBOKGGIO13	MBOKGGIO13	Ind12.stVal	DOKB	
INPUT1GGIO14	IN1GGIO14	IN1GGIO14	Ind01.stVal	IN101	Mainboard input, point 1 value
INPUT1GGIO14	IN1GGIO14	IN1GGIO14	Ind02.stVal	IN102	Mainboard input, point 2 value
INPUT1GGIO14	IN1GGIO14	IN1GGIO14	Ind03.stVal	IN103	Mainboard input, point 3 value
INPUT1GGIO14	IN1GGIO14	IN1GGIO14	Ind04.stVal	IN104	Mainboard input, point 4 value
INPUT1GGIO14	IN1GGIO14	IN1GGIO14	Ind05.stVal	IN105	Mainboard input, point 5 value
INPUT1GGIO14	IN1GGIO14	IN1GGIO14	Ind06.stVal	IN106	Mainboard input, point 6 value
INPUT1GGIO14	IN1GGIO14	IN1GGIO14	Ind07.stVal	IN107	Mainboard input, point 7 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind01.stVal	IN201	I/O Board 2 input, point 1 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind02.stVal	IN202	I/O Board 2 input, point 2 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind03.stVal	IN203	I/O Board 2 input, point 3 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind04.stVal	IN204	I/O Board 2 input, point 4 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind05.stVal	IN205	I/O Board 2 input, point 5 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind06.stVal	IN206	I/O Board 2 input, point 6 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind07.stVal	IN207	I/O Board 2 input, point 7 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind08.stVal	IN208	I/O Board 2 input, point 8 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind09.stVal	IN209	I/O Board 2 input, point 9 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind10.stVal	IN210	I/O Board 2 input, point 10 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind11.stVal	IN211	I/O Board 2 input, point 11 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind12.stVal	IN212	I/O Board 2 input, point 12 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind13.stVal	IN213	I/O Board 2 input, point 13 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind14.stVal	IN214	I/O Board 2 input, point 14 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind15.stVal	IN215	I/O Board 2 input, point 15 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind16.stVal	IN216	I/O Board 2 input, point 16 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind17.stVal	IN217	I/O Board 2 input, point 17 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind18.stVal	IN218	I/O Board 2 input, point 18 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind19.stVal	IN219	I/O Board 2 input, point 19 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind20.stVal	IN220	I/O Board 2 input, point 20 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind21.stVal	IN221	I/O Board 2 input, point 21 value

Table 8.11 Logical Device: ANN (Annunciation) (Sheet 7 of 9)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R123+			
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind22.stVal	IN222	I/O Board 2 input, point 22 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind23.stVal	IN223	I/O Board 2 input, point 23 value
INPUT2GGIO15[b]	IN2GGIO15[b]	IN2GGIO15[b]	Ind24.stVal	IN224	I/O Board 2 input, point 24 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind01.stVal	IN301	I/O Board 3 input, point 1 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind02.stVal	IN302	I/O Board 3 input, point 2 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind03.stVal	IN303	I/O Board 3 input, point 3 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind04.stVal	IN304	I/O Board 3 input, point 4 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind05.stVal	IN305	I/O Board 3 input, point 5 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind06.stVal	IN306	I/O Board 3 input, point 6 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind07.stVal	IN307	I/O Board 3 input, point 7 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind08.stVal	IN308	I/O Board 3 input, point 8 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind09.stVal	IN309	I/O Board 3 input, point 9 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind10.stVal	IN310	I/O Board 3 input, point 10 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind11.stVal	IN311	I/O Board 3 input, point 11 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind12.stVal	IN312	I/O Board 3 input, point 12 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind13.stVal	IN313	I/O Board 3 input, point 13 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind14.stVal	IN314	I/O Board 3 input, point 14 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind15.stVal	IN315	I/O Board 3 input, point 15 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind16.stVal	IN316	I/O Board 3 input, point 16 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind17.stVal	IN317	I/O Board 3 input, point 17 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind18.stVal	IN318	I/O Board 3 input, point 18 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind19.stVal	IN319	I/O Board 3 input, point 19 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind20.stVal	IN320	I/O Board 3 input, point 20 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind21.stVal	IN321	I/O Board 3 input, point 21 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind22.stVal	IN322	I/O Board 3 input, point 22 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind23.stVal	IN323	I/O Board 3 input, point 23 value
INPUT3GGIO16[b]	IN3GGIO16[b]	IN3GGIO16[b]	Ind24.stVal	IN324	I/O Board 3 input, point 24 value
OUTPUT1GGIO17	OUT1GGIO17	OUT1GGIO17	Ind01.stVal	OUT101	Mainboard output, point 1 value
OUTPUT1GGIO17	OUT1GGIO17	OUT1GGIO17	Ind02.stVal	OUT102	Mainboard output, point 2 value
OUTPUT1GGIO17	OUT1GGIO17	OUT1GGIO17	Ind03.stVal	OUT103	Mainboard output, point 3 value
OUTPUT1GGIO17	OUT1GGIO17	OUT1GGIO17	Ind04.stVal	OUT104	Mainboard output, point 4 value
OUTPUT1GGIO17	OUT1GGIO17	OUT1GGIO17	Ind05.stVal	OUT105	Mainboard output, point 5 value
OUTPUT1GGIO17	OUT1GGIO17	OUT1GGIO17	Ind06.stVal	OUT106	Mainboard output, point 6 value
OUTPUT1GGIO17	OUT1GGIO17	OUT1GGIO17	Ind07.stVal	OUT107	Mainboard output, point 7 value
OUTPUT1GGIO17	OUT1GGIO17	OUT1GGIO17	Ind08.stVal	OUT108	Mainboard output, point 8 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind01.stVal	OUT201	I/O Board 2 output, point 1 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind02.stVal	OUT202	I/O Board 2 output, point 2 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind03.stVal	OUT203	I/O Board 2 output, point 3 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind04.stVal	OUT204	I/O Board 2 output, point 4 value

Table 8.11 Logical Device: ANN (Annunciation) (Sheet 8 of 9)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R123+			
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind05.stVal	OUT205	I/O Board 2 output, point 5 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind06.stVal	OUT206	I/O Board 2 output, point 6 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind07.stVal	OUT207	I/O Board 2 output, point 7 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind08.stVal	OUT208	I/O Board 2 output, point 8 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind09.stVal	OUT209	I/O Board 2 output, point 9 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind10.stVal	OUT210	I/O Board 2 output, point 10 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind11.stVal	OUT211	I/O Board 2 output, point 11 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind12.stVal	OUT212	I/O Board 2 output, point 12 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind13.stVal	OUT213	I/O Board 2 output, point 13 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind14.stVal	OUT214	I/O Board 2 output, point 14 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind15.stVal	OUT215	I/O Board 2 output, point 15 value
OUTPUT2GGIO18[b]	OUT2GGIO18[b]	OUT2GGIO18[b]	Ind16.stVal	OUT216	I/O Board 2 output, point 16 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind01.stVal	OUT301	I/O Board 3 output, point 1 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind02.stVal	OUT302	I/O Board 3 output, point 2 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind03.stVal	OUT303	I/O Board 3 output, point 3 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind04.stVal	OUT304	I/O Board 3 output, point 4 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind05.stVal	OUT305	I/O Board 3 output, point 5 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind06.stVal	OUT306	I/O Board 3 output, point 6 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind07.stVal	OUT307	I/O Board 3 output, point 7 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind08.stVal	OUT308	I/O Board 3 output, point 8 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind09.stVal	OUT309	I/O Board 3 output, point 9 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind10.stVal	OUT310	I/O Board 3 output, point 10 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind11.stVal	OUT311	I/O Board 3 output, point 11 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind12.stVal	OUT312	I/O Board 3 output, point 12 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind13.stVal	OUT313	I/O Board 3 output, point 13 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind14.stVal	OUT314	I/O Board 3 output, point 14 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind15.stVal	OUT315	I/O Board 3 output, point 15 value
OUTPUT3GGIO19[b]	OUT3GGIO19[b]	OUT3GGIO19[b]	Ind16.stVal	OUT316	I/O Board 3 output, point 16 value
CCINGGIO20	CCINGGIO20	CCINGGIO20	Ind001.stVal	CCIN001	
CCINGGIO20	CCINGGIO20	CCINGGIO20	Ind002.stVal	CCIN002	
CCINGGIO20	CCINGGIO20	CCINGGIO20	Ind003.stVal	CCIN003	
CCINGGIO20	CCINGGIO20	CCINGGIO20	Ind004.stVal	CCIN004	
CCINGGIO20	CCINGGIO20	CCINGGIO20	Ind005.stVal	CCIN005	
CCINGGIO20	CCINGGIO20	CCINGGIO20	Ind006.stVal	CCIN006	
CCINGGIO20	CCINGGIO20	CCINGGIO20	Ind007.stVal	CCIN007	
CCINGGIO20	CCINGGIO20	CCINGGIO20	Ind008.stVal	CCIN008	
CCINGGIO20	CCINGGIO20	CCINGGIO20	Ind009.stVal	CCIN009	
CCINGGIO20	CCINGGIO20	CCINGGIO20	Ind010.stVal	CCIN010	
…	…	…	…	…	

Table 8.11 Logical Device: ANN (Annunciation) (Sheet 9 of 9)

Logical Nodes by ICD Version			Attribute	Relay Word or Database Bit	Comment
Ver 001 Ver 002L	Ver 002	Ver 002 R123+			
CCINGGIO20	CCINGGIO20	CCINGGIO20	Ind127.stVal	CCIN127	
CCINGGIO20	CCINGGIO20	CCINGGIO20	Ind128.stVal	CCIN128	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind01.stVal	CCOUT001	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind02.stVal	CCOUT002	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind03.stVal	CCOUT003	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind04.stVal	CCOUT004	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind05.stVal	CCOUT005	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind06.stVal	CCOUT006	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind07.stVal	CCOUT007	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind08.stVal	CCOUT008	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind09.stVal	CCOUT009	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind10.stVal	CCOUT010	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind11.stVal	CCOUT011	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind12.stVal	CCOUT012	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind13.stVal	CCOUT013	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind14.stVal	CCOUT014	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind15.stVal	CCOUT015	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind16.stVal	CCOUT016	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind17.stVal	CCOUT017	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind18.stVal	CCOUT018	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind19.stVal	CCOUT019	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind20.stVal	CCOUT020	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind21.stVal	CCOUT021	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind22.stVal	CCOUT022	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind23.stVal	CCOUT023	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind24.stVal	CCOUT024	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind25.stVal	CCOUT025	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind26.stVal	CCOUT026	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind27.stVal	CCOUT027	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind28.stVal	CCOUT028	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind29.stVal	CCOUT029	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind30.stVal	CCOUT030	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind31.stVal	CCOUT031	
CCOUTGGIO21	CCOUTGGIO21	CCOUTGGIO21	Ind32.stVal	CCOUT032	

[a] Active data only if enhanced front-panel installed.
[b] Active data only if additional I/O card(s) installed.

Protocol Implementation Conformance Statement: SEL-400 Series Devices

The tables below are as shown in the IEC 61850 standard, Part 8-1, Section 24. Note that since the standard explicitly dictates which services and functions must be implemented to achieve conformance, only the optional services and functions are listed.

Table 8.12 PICS for A-Profile Support

Profile		Client	Server	Value/Comment
A1	Client/Server	N	Y	
A2	GOOSE/GSE management	Y	Y	Only GOOSE, not GSSE management
A3	GSSE	N	N	
A4	Time Sync	N	N	

Table 8.13 PICS for T-Profile Support

Profile		Client	Server	Value/Comment
T1	TCP/IP	N	Y	
T2	OSI	N	N	
T3	GOOSE/GSE	Y	Y	Only GOOSE, not GSSE
T4	GSSE	N	N	
T5	Time Sync	N	N	

Refer to the *ACSI Conformance Statements on page R.8.37* for information on the supported services.

MMS Conformance

The Manufacturing Message Specification (MMS) stack provides the basis for many IEC 61850 protocol services. *Table 8.14* defines the service support requirement and restrictions of the MMS services in the SEL-400 series devices. Generally, only those services whose implementation is not mandatory are shown. Refer to the IEC 61850 standard Part 8-1 for more information.

Table 8.14 MMS Service Supported Conformance (Sheet 1 of 3)

MMS Service Supported CBB	Client-CR	Server-CR
	Supported	Supported
status		Y
getNameList		Y
identify		Y
rename		
read		Y
write		Y
getVariableAccessAttributes		Y
defineNamedVariable		
defineScatteredAccess		

Table 8.14 MMS Service Supported Conformance (Sheet 2 of 3)

MMS Service Supported CBB	Client-CR Supported	Server-CR Supported
getScatteredAccessAttributes		
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		
defineEventCondition		
deleteEventCondition		
getEventConditionAttributes		

Table 8.14 MMS Service Supported Conformance (Sheet 3 of 3)

MMS Service Supported CBB	Client-CR	Server-CR
	Supported	Supported
reportEventConditionStatus		
alterEventConditionMonitoring		
triggerEvent		
defineEventAction		
deleteEventAction		
alterEventEnrollment		
reportEventEnrollmentStatus		
getEventEnrollmentAttributes		
acknowledgeEventNotification		
getAlarmSummary		
getAlarmEnrollmentSummary		
readJournal		
writeJournal		
initializeJournal		
reportJournalStatus		
createJournal		
deleteJournal		
fileOpen		
fileRead		
fileClose		
fileRename		
fileDelete		
fileDirectory		
unsolicitedStatus		
informationReport		Y
eventNotification		
attachToEventCondition		
attachToSemaphore		
conclude		Y
cancel		Y
getDataExchangeAttributes		
exchangeData		
defineAccessControlList		
getAccessControlListAttributes		
reportAccessControlledObjects		
deleteAccessControlList		
alterAccessControl		
reconfigureProgramInvocation		

Table 8.15 lists specific settings for the MMS parameter Conformance Building Block (CBB).

Table 8.15 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 8.16 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 8.17 VariableAccessSpecification Conformance Statement

VariableAccessSpecification	Client-CR Supported	Server-CR Supported
listOfVariable		Y
variableSpecification		Y
alternateAccess		Y
variableListName		Y

Table 8.18 VariableSpecification Conformance Statement

VariableSpecification	Client-CR	Server-CR
	Supported	Supported
name		Y
address		
variableDescription		
scatteredAccessDescription		
invalidated		

Table 8.19 Read Conformance Statement

Read	Client-CR	Server-CR
	Supported	Supported
Request		
specificationWithResult		
variableAccessSpecification		
Response		
variableAccessSpecification		Y
listOfAccessResult		Y

Table 8.20 GetVariableAccessAttributes Conformance Statement

GetVariableAccessAttributes	Client-CR	Server-CR
	Supported	Supported
Request		
name		
address		
Response		
mmsDeletable		
address		
typeSpecification		

Table 8.21 DefineNamedVariableList Conformance Statement

DefineVariableAccessAttributes	Client-CR	Server-CR
	Supported	Supported
Request		
variableListName		
listOfVariable		
variableSpecification		
alternateAccess		
Response		

Table 8.22 GetNamedVariableListAttributes Conformance Statement

GetNamedVariableListAttributes	Client-CR	Server-CR
	Supported	Supported
Request		
ObjectName		
Response		
mmsDeletable		Y
listOfVariable		Y
variableSpecification		Y
alternateAccess		Y

Table 8.23 DeleteNamedVariableList Conformance Statement

DeleteNamedVariableList	Client-CR	Server-CR
	Supported	Supported
Request		
Scope		
listOfVariableListName		
domainName		
Response		
numberMatched		
numberDeleted		
DeleteNamedVariableList-Error		

GOOSE Services Conformance Statement

Table 8.24 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 8.25 ACSI Basic Conformance Statement

Services		Client/Subscriber	Server/Publisher	SEL-421 Support
Client-Server Roles				
B11	Server side (of Two-Party Application-Association)	–	c1[a]	YES
B12	Client side (of Two-Party Application-Association)	c1[a]	–	
SCMS Supported				
B21	SCSM: IEC 61850-8-1 used			YES
B22	SCSM: IEC 61850-9-1 used			
B23	SCSM: IEC 61850-9-2 used			
B24	SCSM: other			
Generic Substation Event Model (GSE)				
B31	Publisher side	–	O[b]	YES
B32	Subscriber side	O[b]	–	YES
Transmission of Sampled Value Model (SVC)				
B41	Publisher side	–	O[b]	
B42	Subscriber side	O[b]	–	

[a] c1 shall be mandatory if support for LOGICAL-DEVICE model has been declared.
[b] O = optional.

Table 8.26 ACSI Models Conformance Statement (Sheet 1 of 2)

Models		Client/Subscriber	Server/Publisher	SEL-421 Support
If Server Side (B11) Supported				
M1	Logical device	c2[a]	c2[a]	YES
M2	Logical node	c3[b]	c3[b]	YES
M3	Data	c4[c]	c4[c]	YES
M4	Dataset	c5[d]	c5[d]	YES
M5	Substitution	O[e]	O[e]	
M6	Setting group control	O[e]	O[e]	
Reporting				
M7	Buffered report control	O[e]	O[e]	YES
M7-1	sequence-number			YES
M7-2	report-time-stamp			YES
M7-3	reason-for-inclusion			YES
M7-4	data-set-name			YES
M7-5	data-reference			YES
M7-6	buffer-overflow			YES
M7-7	entryID			YES
M7-8	BufTm			YES
M7-9	IntgPd			YES
M7-10	GI			YES

Table 8.26 ACSI Models Conformance Statement (Sheet 2 of 2)

Models		Client/Subscriber	Server/Publisher	SEL-421 Support
M8	Unbuffered report control	O[e]	O[e]	YES
M8-1	sequence-number			YES
M8-2	report-time-stamp			YES
M8-3	reason-for-inclusion			YES
M8-4	data-set-name			YES
M8-5	data-reference			YES
M8-6	BufTm			YES
M8-7	IntgPd			YES
M8-8	GI			
	Logging	O[e]	O[e]	
M9	Log control	O[e]	O[e]	
M9-1	IntgPd			
M10	Log	O[e]	O[e]	
M11	Control	M[f]	M[f]	YES
If GSE (B31/32) Is Supported				
M12	GOOSE	O[e]	O[e]	YES
M12-1	entryID			YES
M12-2	DataReflnc			YES
M13	GSSE	O[e]	O[e]	
If GSE (B41/42) Is Supported				
M14	Multicast SVC	O[e]	O[e]	
M15	Unicast SVC	O[e]	O[e]	
M16	Time	M[f]	M[f]	
M17	File Transfer	O[e]	O[e]	

[a] c2 shall be "M" if support for LOGICAL-NODE model has been declared.
[b] c3 shall be "M" if support for DATA model has been declared.
[c] c4 shall be "M" if support for DATA-SET, Substitution, Report, Log Control, or Time model has been declared.
[d] c5 shall be "M" if support for Report, GSE, or SV models has been declared.
[e] O = optional
[f] M = mandatory

Table 8.27 ACSI Services Conformance Statement (Sheet 1 of 4)

Services		AA: TP/MC	Client/ Subscriber	Server/Publisher	SEL-421 Support
Server (Clause 6)					
S1	ServerDirectory	TP		M[a]	YES
Application Association (Clause 7)					
S2	Associate		M[a]	M[a]	YES
S3	Abort		M[a]	M[a]	YES
S4	Release		M[a]	M[a]	YES
Logical Device (Clause 8)					
S5	LogicalDeviceDirectory	TP	M[a]	M[a]	YES

Table 8.27 ACSI Services Conformance Statement (Sheet 2 of 4)

Services		AA: TP/MC	Client/ Subscriber	Server/Publisher	SEL-421 Support
Logical Node (Clause 9)					
S6	LogicalNodeDirectory	TP	M[a]	M[a]	YES
S7	GetAllDataValues	TP	O[b]	M[a]	YES
Data (Clause 10)					
S8	GetDataValues	TP	M[a]	M[a]	YES
S9	SetDataValues	TP	O[b]	O[b]	YES
S10	GetDataDirectory	TP	O[b]	M[a]	YES
S11	GetDataDefinition	TP	O[b]	M[a]	YES
Dataset (Clause 11)					
S12	GetDataSetValues	TP	O[b]	M[a]	YES
S13	SetDataSetValues	TP	O[b]	O[b]	YES
S14	CreateDataSet	TP	O[b]	O[b]	
S15	DeleteDataSet	TP	O[b]	O[b]	
S16	GetDataSetDirectory	TP	O[b]	O[b]	YES
Substitution (Clause 12)					
S17	SetDataValues	TP	M[a]	M[a]	
Setting Group Control (Clause 13)					
S18	SelectActiveSG	TP	O[b]	O[b]	
S19	SelectEditSG	TP	O[b]	O[b]	
S20	SetSGvalues	TP	O[b]	O[b]	
S21	ConfirmEditSGVal	TP	O[b]	O[b]	
S22	GetSGValues	TP	O[b]	O[b]	
S23	GetSGCBValues	TP	O[b]	O[b]	
Reporting (Clause 14)					
Buffered Report Control Block (BRCB)					
S24	Report	TP	c6[c]	c6[c]	YES
S24-1	data-change (dchg)				YES
S24-2	qchg-change (qchg)				YES
S24-3	data-update (dupd)				
S25	GetBRCBValues	TP	c6[c]	c6[c]	YES
S26	SetBRCBValues	TP	c6[c]	c6[c]	YES
Unbuffered Report Control Block (URCB)					
S27	Report	TP	c6[c]	c6[c]	YES
S27-1	data-change (dchg)				YES
S27-2	qchg-change (qchg)				YES
S27-3	data-update (dupd)				
S28	GetURCBValues	TP	c6[c]	c6[c]	YES
S29	SetURCBValues	TP	c6[c]	c6[c]	YES

Table 8.27 ACSI Services Conformance Statement (Sheet 3 of 4)

Services		AA: TP/MC	Client/ Subscriber	Server/Publisher	SEL-421 Support
Logging (Clause 14)					
Log Control Block					
S30	GetLCBValues	TP	M[a]	M[a]	
S31	SetLCBValues	TP	O[b]	M[a]	
LOG					
S32	QueryLogByTime	TP	c7[d]	M[a]	
S33	QueryLogByEntry	TP	c7[d]	M[a]	
S34	GetLogStatusValues	TP	M[a]	M[a]	
Generic Substation Event Model (GSE) (Clause 14.3.5.3.4.)					
GOOSE-Control-Block					
S35	SendGOOSEMessage	MC	c8[e]	c8[e]	YES
S36	GetReference	TP	O[b]	c9[f]	
S37	GetGOOSEElementNumber	TP	O[b]	c9[f]	
S38	GetGoCBValues	TP	O[b]	O[b]	YES
S39	SetGoCBValues	TP	O[b]	O[b]	Client/Sub ONLY
GSSE-Control-Block					
S40	SendGSSEMessage	MC	c8[e]	c8[e]	
S41	GetReference	TP	O[b]	c9[f]	
S42	GetGSSEElementNumber	TP	O[b]	c9[f]	
S43	GetGsCBValues	TP	O[b]	O[b]	
S44	SetGsCBValues	TP	O[b]	O[b]	
Transmission of Sample Value Model (SVC) (Clause 16)					
Multicast SVC					
S45	SendMSVMessage	MC	c10[g]	c10[g]	
S46	GetMSVCBValues	TP	O[b]	O[b]	
S47	SetMSVCBValues	TP	O[b]	O[b]	
Unicast SVC					
S48	SendUSVMessage	MC	c10[g]	c10[g]	
S49	GetUSVCBValues	TP	O[b]	O[b]	
S50	SetUSVCBValues	TP	O[b]	O[b]	
Control (Clause 16.4.8)					
S51	Select		M[a]	O[b]	
S52	SelectWithValue	TP	M[a]	O[b]	
S53	Cancel	TP	O[b]	M[a]	YES
S54	Operate	TP	M[a]	M[a]	YES
S55	Commmand-Termination	TP	M[a]	M[a]	
S56	TimeActivated-Operate	TP	O[b]	O[b]	

Table 8.27 ACSI Services Conformance Statement (Sheet 4 of 4)

Services		AA: TP/MC	Client/ Subscriber	Server/Publisher	SEL-421 Support
File Transfer (Clause 20)					
S57	GetFile	TP	O[b]	M[a]	
S58	SetFile	TP	O[b]	O[b]	
S59	DeleteFile	TP	O[b]	O[b]	
S60	GetFileAttributeValues	TP	O[b]	M[a]	
Time (Clause 5.5)					
T1	Time resolution of internal clock (nearest negative power of 2 in seconds)			2–10 (1 ms)	T1
T2	Time accuracy of internal clock				10/9
	T1				YES
	T2				YES
	T3				YES
	T4				YES
	T5				YES
T3	Supported TimeStamp resolution (nearest negative power of 2 in seconds)			2–10 (1 ms)	10

[a] M = Mandatory
[b] O = Optional
[c] c6 shall declare support for at least one (BRCB or URCB).
[d] c7 shall declare support for at least one (QueryLogByTime or QueryLogAfter).
[e] c8 shall declare support for at least one (SendGOOSEMessage or SendGSSEMessage).
[f] c9 shall declare support if TP association is available.
[g] c10 shall declare support for at least one (SendMSVMessage or SendUSVMessage).

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Section 9
ASCII Command Reference

This section covers *Description of Commands on page R.9.2*.

You can use a communications terminal or terminal emulation program to set and operate the SEL-421 Relay. This section explains the commands that you send to the SEL-421 using SEL ASCII (American National Standard Code for Information Interchange) communications protocol. The relay responds to commands such as settings, metering, and control operations.

This section lists ASCII commands alphabetically. Commands, command options, and command variables that you enter are shown in bold. Lower case 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 5: SEL Communications Protocols*.

Tables in this section show the access level(s) where the command or command option is active. Access levels in the SEL-421 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 on page U.4.6*.

Description of Commands

2ACCESS

Use the **2AC** command to gain access to Access Level 2 (full relay control). See *Access Levels on page U.4.6* for more information.

Table 9.1 2AC Command

Command	Description	Access Level
2AC	Go to Access Level 2 (full relay control).	1, B, P, A, O, 2

AACCESS

Use the **AAC** command to gain access to Access Level A (automation). See *Access Levels on page U.4.6* for more information.

Table 9.2 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 on page U.4.6* for more information.

Table 9.3 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 on page U.4.6* for more information.

Table 9.4 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 status bits for Fast Meter Compressed ASCII. See *Section 5: SEL Communications Protocols* for more information on Fast Meter and the Compressed ASCII command set.

Table 9.5 BNA Command

Command	Description	Access Level
BNA	Display ASCII names of all relay status bits.	0, 1, B, P, A, O, 2

BREAKER

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 monitor with monitor settings EB1MON := Y and EB2MON :=Y for one and two circuit breaker applications, respectively. See *Circuit Breaker Monitor on page A.2.1* 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 9.6 BRE n Command[a]

Command	Description	Access Level
BRE *n*	Display the breaker report for the most recent Circuit Breaker *n* operation.	1, B, P, A, O, 2

[a] Parameter n = 1 or 2, representing Circuit Breaker 1 or Circuit Breaker 2.

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 9.7 BRE n C and BRE n R Commands[a]

Command	Description	Access Level
BRE *n* 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 = 1 or 2, representing Circuit Breaker 1 or Circuit Breaker 2.

BRE C A and BRE R A

The **BRE C A** and **BRE R A** commands clear all circuit breaker monitor data for both circuit breakers from memory. Options **C A** and **R A** are identical.

Table 9.8 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 9.9 BRE n H Command

Command	Description	Access Level
BRE *n* H[a]	Display history data for the last 128 Circuit Breaker *n* operations.	1, B, P, A, O, 2

[a] Parameter n = 1 or 2, representing Circuit Breaker 1 or Circuit Breaker 2.

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 9.10 BRE n P Command

Command	Description	Access Level
BRE *n* P[a]	Preload previously accumulated Breaker *n* data.	B, P, A, O, 2

[a] Parameter n = 1 or 2, representing Circuit Breaker 1 or Circuit Breaker 2.

CAL

Use the **CAL** command to gain access to Access Level C. See *Access Levels on page U.4.6* 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 9.11 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 *Section 5: SEL Communications Protocols* for an example of the **CAS** command configuration message and for further information on the Compressed ASCII command set.

Table 9.12 CAS Command

Command	Description	Access Level
CAS	Return the Compressed ASCII configuration message.	0, 1, B, P, A, O, 2

CBREAKER

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 either Circuit Breaker 1 or Circuit Breaker 2 to generate the Compressed ASCII report. You can specify Circuit Breaker 1 or Circuit Breaker 2 to retrieve a report for one circuit breaker only. See *Section 5: SEL Communications Protocols* for information on the Compressed ASCII command set.

CBR

Use the **CBR** command to gather the comprehensive circuit breaker report in Compressed ASCII format. For a detailed example, see *Section 2: Monitoring and Metering in the Applications Handbook*.

Table 9.13 CBR Command

Command	Description	Access Level
CBR	Return the most recent circuit breaker reports for Circuit Breaker 1 and Circuit Breaker 2 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 = 1 or 2, representing Circuit Breaker 1 or Circuit Breaker 2.

CBR TERSE

The **CBR TERSE** command omits the breaker report labels.

Table 9.14 CBR TERSE Command

Command	Description	Access Level
CBR TERSE	Return the most recent circuit breaker report for Circuit Breaker 1 and Circuit Breaker 2 in Compressed ASCII format; suppress the labels; transmit only the data lines.	1, B, P, A, O, 2
CBR *n* TERSE[a]	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 = 1 or 2 to represent Circuit Breaker 1 and Circuit Breaker 2.

CEVENT

The **CEVENT** command provides a Compressed ASCII response similar to the **EVENT** command. See *Section 5: SEL Communications Protocols* for information on the Compressed ASCII command set. For detailed examples of the items in the Compressed ASCII event report, see *CEVENT on page A.3.24*.

CEV

Use the **CEV** command to gather relay event reports. When parameter *n* is 1 through 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 through 42767, *n* indicates the absolute serial number of the event report.

Table 9.15 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 9.16 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 9.17 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*[a]	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

[a] Parameter n indicates event order or serial number; see CEV on page R.9.5.

CEV L

Use **CEV L** to return a large resolution (8-samples/cycle) event report in Compressed ASCII format. The **S*x*** option overrides the **L** option (see **CEV S*x***).

Table 9.18 CEV L Command

Command	Description	Access Level
CEV L	Return the most recent event report at full length with 8-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV *n* L[a]	Return particular *n* event report at full length with 8-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 R.9.5.

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 9.19 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* L*yyy*[a]	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 R.9.5.

CEV NEXT

CEV NEXT returns the oldest unacknowledged event report on the present communications port in Compressed ASCII format.

Table 9.20 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 9.21 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* NSET[a]	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; see CEV on page R.9.5.

CEV NSUM

The **CEV NSUM** returns the Compressed ASCII event report with no event summary.

Table 9.22 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* NSUM[a]	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 R.9.5.

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* is either 4 samples/cycle or 8 samples/cycle; the default value is 4 samples/cycle if you do not specify **S*x***. The **S*x*** option overrides the **L** option.

Table 9.23 CEV Sx Command[a]

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* 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 R.9.5.

CEV TERSE

The **CEV TERSE** command returns a Compressed ASCII event report without the event report labels.

Table 9.24 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* TERSE[a]	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; see CEV on page R.9.5.

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 9.25 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 9.25 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 8-samples/cycle 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 8-samples/cycle data.

CHISTORY

The **CHISTORY** command is the **HISTORY** command for the Compressed ASCII command set. See *Section 5: SEL Communications Protocols* for information on the Compressed ASCII command set. For a detailed example of the items in the Compressed ASCII history report, see *Section 3: Analyzing Data in the Applications Handbook*.

CHI

Use the **CHI** command to gather one-line descriptions of event reports.

Table 9.26 CHI Command

Command	Description	Access Level
CHI	Return the data as contained in the History report 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 9.27 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 connector J18C) must be in place. Further, you must set relay setting NUMBK := 2 to issue a **CLOSE 2** command.

The **CLOSE 1** and **CLOSE 2** commands assert Relay Word bits CC1 and CC2, respectively. Relay Word bit CC1 is a variable in the factory default manual close SEL equation BK1MCL Circuit Breaker 1. Typically, you program Relay Word bit CC2 in the manual close SELOGIC control equation BK2MCL for Circuit Breaker 2. The relay uses these equations and additional relay logic to assert a control output (for example, OUT103 := BK1CL) to close a circuit breaker. See *Control Outputs on page U.2.7*, and *Section 2: Auto-Reclosing and Synchronism Check* for more information.

Table 9.28 CLOSE n Command

Command	Description	Access Level
CLOSE 1	Command the relay to close Circuit Breaker 1.	B, P, A, O, 2
CLOSE 2	Command the relay to close Circuit Breaker 2 (if NUMBK := 2).	B, P, A, O, 2

If the circuit breaker control enable jumper J18C is in place, the relay responds, `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 52AAn, 52ABn, 52ACn 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 J18C 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, `Command aborted because relay is disabled`. If setting NUMBK := 1 and you issue the **CLOSE 2** command, the relay responds `Breaker 2 is not available`.

COMMUNICATIONS

The **COMMUNICATIONS** command displays communications statistics for the MIRRORED BITS® communications channels and for synchrophasor client channels. For more information on MIRRORED BITS communications, see *SEL MIRRORED BITS Communications on page R.5.15*. For more information on synchrophasor client communications see *Section 7: Synchrophasors*.

COM c

Use the **COM *c*** command to view records in the communications buffers for specific relay communications channels.

Table 9.29 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 **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 9.30 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. See *Section 10: Settings* for more information.

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 9.31 is a representative list of options for listing records in the communications buffer.

Table 9.31 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 RTC

Use the **COM RTC** to get a report on the status of the configured synchrophasor client channels.

Table 9.32 COM RTC c Command[a]

Command	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 9.33 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

CONTROL nn

Use the **CONTROL *nn*** command to set, clear, or pulse internal Relay Word bits RB01 through RB32 (Remote Bit 1 through Remote Bit 32). 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 *Control Points on page A.6.11* for information on remote bits.

Table 9.34 CON nn Command[a]

Command	Description	Access Level
CON *nn* 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 a number from 01 to 32 representing Remote Bit 01 through Remote Bit 32.

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. Use the command order specified in *Table 9.35*.

Table 9.35 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 *c* 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. The *class* parameter is the class that you can choose from group (S), port (P), and protection SELOGIC control equations (L). 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, `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, `Cannot copy port settings to present port`.

When you enter the **COPY** command with valid parameters, the relay responds, `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.

CSER

The **CSER** command is the **SER** command for the Compressed ASCII command set. See *SEL Compressed ASCII Commands on page R.5.4* for information on the Compressed ASCII command set. 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). For a detailed example of the items in the Compressed ASCII SER report, see *Figure 3.19 on page A.3.36*.

CSE

Use the **CSE** command to gather Sequential Events Recorder records. You can sort these records in numerical or date order.

Table 9.36 CSE Command

Command	Description	Access Level
CSE	Return all records from the Sequential Events Recorder 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 Sequential Events Recorder 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 *m n*[b]	Return the Sequential Events Recorder 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 Sequential Events Recorder records in Compressed ASCII format on date *date1*.	1, B, P, A, O, 2
CSE *date1 date2*[c]	Return the Sequential Events Recorder 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 Sequential Events Recorder 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 9.37 CSE TERSE Command (Sheet 1 of 2)

Command	Description	Access Level
CSE TERSE	Return all Sequential Events Recorder records without the label lines in Compressed ASCII format.	1, B, P, A, O, 2
CSE *k* TERSE[a]	Return the *k* most recent Sequential Events Recorder records without the label lines in Compressed ASCII format.	1, B, P, A, O, 2
CSE *m n* TERSE[b]	Return the Sequential Events Recorder 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.	1, B, P, A, O, 2

Table 9.37 CSE TERSE Command (Sheet 2 of 2)

Command	Description	Access Level
	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.	
CSE *date1* TERSE[c]	Return the Sequential Events Recorder 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 Sequential Events Recorder 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 is the **STATUS** command for the Compressed ASCII command set. The **TERSE** option eliminates the report label lines. See *Section 5: SEL Communications Protocols* for information on the Compressed ASCII command set. For an example of the **CST** command, see *Figure 6.34 on page U.6.41*.

Table 9.38 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** command is the **SUMMARY** command for the Compressed ASCII command set. You can combine the *n*, **ACK**, **MB**, and **TERSE** options. See *SEL Compressed ASCII Commands on page R.5.4* for information on the Compressed ASCII command set. For a detailed example of the items in the Compressed ASCII summary report, see *Figure 3.15 on page A.3.31*.

CSU

Use the **CSU** command to gather event report summaries.

Table 9.39 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 through 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 through 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 9.40 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 9.41 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 9.42 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 9.43 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* TERSE[a]	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 DNP (see *Configuring High-Accuracy Timekeeping on page U.4.71* for information). 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 2-digit form (for dates 2000–2099) or 4-digit form. If you enter the year as **12**, the relay date is 2012. Global setting DATE_F sets the date format (see *Section 10: Settings* for more information).

Table 9.44 DATE Command[a]

Command	Description	Access Level
DATE	Display the internal clock date.	1, B, P, A, O, 2
DATE ***date***	Set the internal clock date (for setting DATE_F set to MDY).	1, B, P, A, O, 2

[a] Enter date setting in the same format 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. See *SEL Fast Meter, Fast Operate, and Fast SER Messages on page R.5.8* for more information on SEL Fast Meter.

Table 9.45 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. Type **DNP <Enter>** to show the relay serial port DNP3 settings beginning at the first setting label. Issue the **DNP** command with any parameter *param* to set the serial port DNP settings; the relay begins at the first DNP3 setting. For more information, see the **SET D** command and *Section 5: SEL Communications Protocols*.

Table 9.46 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

EVENT

Use the **EVENT** command to view the SEL-421 filtered event reports (see *Event Report on page A.3.12* for information on event reports).

EVE

The **EVE** command displays the full-length event reports stored in relay memory. (Set event report length with setting LER; see *Table 10.90*). When parameter *n* is 1 through 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 through 42767, *n* indicates the absolute serial number of the event report.

Table 9.47 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 9.48 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.

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 9.49 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, `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 L*yyy***).

Table 9.50 EVE C Command

Command	Description	Access Level
EVE C	Return the most recent event report at a 15-cycle length with 8-samples/cycle data.	1, B, P, A, O, 2
EVE C *n*[a]	Return a particular *n* event report at a 15-cycle length with 8-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number; see EVE on page R.9.17.

EVE D

Use **EVE D** to return only the digital information in the event report.

Table 9.51 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 R.9.17).

EVE L

Use **EVE L** to return a large resolution (8-samples/cycle) event report. The **S*x*** option overrides the **L** option (see **EVE S*x***).

Table 9.52 EVE L Command

Command	Description	Access Level
EVE L	Return the most recent event report at full length with 8-samples/cycle data.	1, B, P, A, O, 2
EVE *n* L[a]	Return a particular *n* event report at full length with 8-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number (see EVE on page R.9.17).

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 9.53 EVE Lyyy Command

Command	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*[a]	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 R.9.17.

EVE NEXT

EVE NEXT returns the oldest unacknowledged event report on the present communications port.

Table 9.54 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 9.55 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* NSET[a]	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 R.9.17.

EVE NSUM

The **EVE NSUM** returns the event report with no event summary.

Table 9.56 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* NSUM[a]	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; see EVE on page R.9.17.

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 8 samples/cycle; the default value is 4 samples/cycle if you do not specify **S*x***. The **S*x*** option overrides the **L** option.

Table 9.57 EVE Sx Command

Command	Description	Access Level
EVE Sx	Return the most recent event report at full length with *x*-samples/cycle data.	1, B, P, A, O, 2
EVE *n* Sx[a]	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 (see EVE on page R.9.17); x is 4 or 8 to represent data at 4 samples/cycle or 8 samples/cycle, respectively.

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 9.58 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 9.58 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 9.59 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.

FILE

The **FILE** command provides a safe and efficient means of transferring files between intelligent electronic devices (IEDs) and external support software (ESS). The **FILE** commands are especially useful for retrieving high-resolution sampled data in binary COMTRADE format from the relay. For examples of retrieving data captures from the relay, see *Reading Oscillograms, Event Reports, and SER on page U.4.42*. For more information on the **FILE** command, see *Virtual File Interface on page R.5.11*.

Table 9.60 FILE Command

Command	Description	Access Level
FILE DIR *[directory1 [directory2]]*	Returns a list of filenames in specified directory *(directory1)* and subdirectory *(directory2)*. If neither parameter is specified, then the list of files and directories in the root directory is returned.	1, B, P, A, P, O, 2
FILE READ *[directory1 [directory2]] filename*	Initiates a file transfer of the file *filename* (in the folder *directory1*, subdirectory *directory2*) from the relay to external support software. The *filename* parameter is required.	1, B, P, A, P, O, 2
FILE WRITE SETTINGS *[directory1 [directory2]] filename*	Initiates a file transfer of the file *filename* (in the folder *directory1*, subdirectory *directory2*) from external support software 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] indicate optional command line parameters. The **FILE** command allows access to second level subdirectories as the optional *directory2* parameter.

File directories in the SEL-421 are the EVENTS directory, the REPORTS directory, and the SETTINGS directory. For **FILE READ** operations, specify the *directory1* (and *directory2*) parameters as needed. The **FILE WRITE** command is available only for the SETTINGS directory and its second level subdirectories.

GROUP

Use the **GROUP** command to view the present group number or to change the active group.

Table 9.61 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 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 `No group change: SELogic equations SS1-SS6 have priority over GROUP command`. For information on SELOGIC control equations SS1 through SS6, see *Multiple Setting Groups on page R.3.8*.

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. For information about access levels and passwords, see *Access Levels on page U.4.6*.

Table 9.62 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 contain the event serial number, date, time, location, maximum current, active group, and targets. See *Event History on page A.3.31* for the **HISTORY** report format.

HIS

Use the **HIS** command to list one-line descriptions of relay events. You can list event histories by number or by date.

Table 9.63 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 same format as 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 9.64 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, `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 9.65 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, `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 9.66 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 ID string as stored in the relay settings of the IED

DEVCODE: a unique Device Code (for Modus identification purposes)

PARTNO: the Part Number

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, and 3 = SEF.

"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

A sample **ID** command response is shown in *Figure 9.1*.

```
"FID=SEL-421-R108-V0-Z002003-D20021216","089E"
"BFID=SLBT-4xx-R100-V0-Z001001-D20010703","0972"
"CID=8C88","0268"
"DEVID=Relay 1","0467"
"DEVCODE=39","0313"
"PARTNO=042104154225XHX","05D7"
"CONFIG=110022","0389"
"SPECIAL=","02AE"
```

Figure 9.1 Sample ID Command Response

If the device supports IEC 61850 ICD or CID files and the IEC 61850 protocol is enabled, the **ID** command will display the following additional information.

- iedName: the IED name (e.g., SEL-421_OtterTail)
- type: the IED type (e.g., SEL-421)
- configVersion: the CID file configuration version (e.g., ICD-421-R100-V0-Z001001-20060512

The optional Ethernet card provides support for IEC 61850 in the SEL-421. You must first use the **POR 5** command to establish a transparent session to the Ethernet card, then issue the **ID** command to view the IEC 61850 ID data.

A sample **ID** command response from the optional Ethernet card (with IEC 61850 enabled) is shown in *Figure 9.2*.

```
"FID=SEL-2702-R100-V2-Z000000-D20060524","08DA"
"BFID=SLBT-2701-R102-V0-Z000000-D20051107","095B"
"CID=9689h","02C5"
"DEVID=ETHERNET PROCESSOR WITH IEC 61850 AND DNP","0CBE"
"PARTNO=2702C4P","0413"
"CONFIG=000000","0383"
"iedName=SEL_421_OtterTail","05BC"
"type=SEL_421","04A4"
"configVersion=ICD-421-R117-V0-Z001001-D20060524","0698"
```

Figure 9.2 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 on page U.4.71*.

Table 9.67 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

The **IRIG** command was originally provided in the SEL-421 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 Descriptions on page U.4.75*.

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 Communications on page R.5.15* 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 timeout period, the relay provides a 5-minute timeout.

Table 9.68 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 timeout *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 timeout *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 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, `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 9.69 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 9.70 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

MAP

Use the **MAP** command to view the organization of the relay database. The **MAP** command in the SEL-421 is very similar to the **MAP** command in the SEL-2020 and SEL-2030 Communications Processors. See *Section 4: Communications Interfaces* for more information on the relay database regions and data types.

MAP 1

The **MAP 1** command lists the relay database regions. Database region names are LOCAL, METER, DEMAND, TARGET, HISTORY, BREAKER, STATUS, and ANALOGS.

Table 9.71 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. Database region names are LOCAL, METER, DEMAND, TARGET, HISTORY, BREAKER, STATUS, and ANALOGS.

Table 9.72 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. Examples of database bit label names are M1P, 25W1BK2, and ASV256.

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). For more information on power system measurements, see *Section 2: Monitoring and Metering in the Applications Handbook*. For information on math variables, see *Section 3: SELOGIC Control Equation Programming*. Find a discussion of synchronism check in *Section 2: Auto-Reclosing and Synchronism Check*.

LINE, BK1, and BK2 command options generally measure feeder lines parameters and circuit breaker currents, depending on relay configuration (see *Current and Voltage Source Selection on page R.1.2*).

MET

Use the **MET** command to view fundamental metering quantities. The relay filters harmonics and subharmonics to present only measured quantities at the power system fundamental operating frequency.

Table 9.73 MET Command

Command	Description	Access Level
MET	Display Line fundamental metering data.	1, B, P, A, O, 2
MET ***k***	Display Line fundamental metering data successively for *k* times.	1, B, P, A, O, 2
MET BK*n*[a]	Display Circuit Breaker *n* fundamental metering data.	1, B, P, A, O, 2
MET BK*n* *k*	Display Circuit Breaker *n* fundamental metering data successively for *k* times.	1, B, P, A, O, 2

[a] Parameter n is 1 or 2 to indicate Circuit Breaker 1 or Circuit Breaker 2.

The **MET** command without options defaults to the LINE fundamental metering data. Specify Circuit Breaker 1 and Circuit Breaker 2 by using the BK1 and BK2 command options, respectively.

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 AMV

The **MET AMV** command lists automation math variables.

Table 9.74 MET AMV Command

Command	Description	Access Level
MET AMV	Display the last 16 automation math variables.	1, B, P, A, O, 2
MET AMV *k*	Display the last 16 automation math variables successively for *k* times.	1, B, P, A, O, 2
MET AMV A	Display all automation math variables.	1, B, P, A, O, 2
MET AMV A *k*	Display all automation math variables successively for *k* times.	1, B, P, A, O, 2

The last 16 automation math variables are AMV241 through AMV256. 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 9.75 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 sources, 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.

The relay shows the analog quantities with absolute value greater than 99999.999 or less than 0.100 as scientific notation (for example, –1.002E+22).

MET BAT

Use the **MET BAT** command to view the station dc monitor quantities for Vdc1 and Vdc2.

Table 9.76 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, `DC Monitor Is Not Enabled`. (Enable the dc monitor with the Global setting EDCMON; see *Section 10: Settings*.)

The reset command, **MET RBM**, resets the dc monitor maximum/minimum metering quantities. When you issue the **MET RBM** command, the relay responds, `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.

Table 9.77 MET D Command

Command	Description	Access Level
MET D	Display Line demand metering data.	1, B, P, A, O, 2
MET D *k*	Display Line demand metering data successively for *k* times	1, B, P, A, O, 2
MET RD	Reset Line demand metering data.	P, A, O, 2
MET RP	Reset Line peak demand metering data.	P, A, O, 2

The reset command (**MET RD)** resets the Line 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 Line 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 E

Use the **MET E** command to view the energy import and export quantities.

Table 9.78 MET E Command

Command	Description	Access Level
MET E	Display Line energy metering data.	1, B, P, A, O, 2
MET E *k*	Display Line energy metering data successively for *k* times.	1, B, P, A, O, 2
MET RE	Reset Line energy metering data.	P, A, O, 2

The reset command, **MET RE**, resets the Line, BK1, and BK2 energy metering quantities. When you issue the **MET RE** command, the relay responds, `Reset Energy Metering (Y/N)?` If you answer **Y <Enter>**, the relay responds, `Energy Metering Reset`.

MET M

Use the **MET M** command to view power system maximum and minimum quantities.

Table 9.79 MET M Command

Command	Description	Access Level
MET M	Display Line maximum/minimum metering data.	1, B, P, A, O, 2
MET M *k*	Display Line maximum/minimum metering data successively for *k* times.	1, B, P, A, O, 2
MET BK*n* M[a]	Display Breaker *n* maximum/minimum metering data.	1, B, P, A, O, 2
MET BK*n* M *k*[a]	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 1 or 2 to indicate Circuit Breaker 1 or Circuit Breaker 2.

The reset command, **MET RM**, resets the Line, BK1, and BK2 maximum/minimum metering quantities. When you issue the **MET RM** command, the relay responds, `Reset Max/Min Metering (Y/N)?` If you answer **Y <Enter>**, the relay responds, `Max/Min Reset`.

MET PM

Use the **MET PM** command to view the time-synchronized line quantities. The relay must be in the high-accuracy timekeeping HIRIG mode. For more information on high-accuracy timekeeping, see *Configuring High-Accuracy Timekeeping on page U.4.71*.

Table 9.80 MET PM Command

Command	Description	Access Level
MET PM	Display time-synchronized line values.	1, B, P, A, O, 2
MET PM *k*	Display time-synchronized line values successively for *k* times.	1, B, P, A, O, 2
MET PM *time*	Display time-synchronized line values captured at trigger *time*.	1, B, P, A, O, 2
MET PM HIS	Display time-synchronized line 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 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 7: Synchrophasors* for more information on phasor measurement functions, and *View Synchrophasors by Using the MET PM Command on page R.7.24* for sample MET PM responses.

MET PMV

Use the **MET PMV** command to view the protection math variables.

Table 9.81 MET PMV Command

Command	Description	Access Level
MET PMV	Display the last 16 protection math variables.	1, B, P, A, O, 2
MET PMV *k*	Display the last 16 protection math variables successively for *k* times.	1, B, P, A, O, 2
MET PMV A	Display all protection math variables.	1, B, P, A, O, 2
MET PMV A *k*	Display all protection math variables successively for *k* times.	1, B, P, A, O, 2

The last 16 protection math variables are PMV49 through PMV64. 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 RMS

Use the **MET RMS** command to view rms (root mean square) metering quantities. The relay includes power system harmonics and subharmonics in rms quantities.

Table 9.82 MET RMS Command

Command	Description	Access Level
MET RMS	Display Line rms metering data.	1, B, P, A, O, 2
MET RMS *k*	Display Line rms metering data successively for *k* times.	1, B, P, A, O, 2
MET BK*n* RMS[a]	Display Circuit Breaker *n* rms metering data.	1, B, P, A, O, 2
MET BK*n* RMS *k*	Display Circuit Breaker *n* rms metering data successively for *k* times.	1, B, P, A, O, 2

[a] Parameter n is 1 or 2 to indicate Circuit Breaker 1 or Circuit Breaker 2.

MET RTC

Use the **MET RTC** command to view the data received on all active synchrophasor client channels.

Table 9.83 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 SYN

Use the **MET SYN** command to view the synchronism-check reference voltage, normalized source voltages, angles, and slip calculations.

Table 9.84 MET SYN Command

Command	Description	Access Level
MET SYN	Display the synchronism-check values.	1, B, P, A, O, 2
MET SYN *k*	Display the synchronism-check values successively for *k* times.	1, B, P, A, O, 2

If you have not enabled the synchronism-check function, the relay responds, `Synchronism Check Element Is Not Available`. (Enable synchronism check with the Global settings E25BK1, E25BK2, and NUMBK; see *Section 2: Auto-Reclosing and Synchronism Check* and *Section 10: Settings*).

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.

Table 9.85 MET T Command

Command	Description	Access Level
MET T	Display up to 12 temperature analog values from the SEL-2600A RTD Module.	1, B, P, A, O, 2
MET T *k*	Display up to 12 temperature analog values from the SEL-2600A RTD Module successively for *k* times.	1, B, P, A, O, 2

The relay displays the number of 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 RTDxTY Port Settings are set to NA, the relay displays the following for that channel:

```
Channel Not Used
```

If the RTDxxST 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 on page U.4.6* for more information.

Table 9.86 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 1** command pulses Relay Word bit OC1, and the **OPEN 2** command pulses Relay Word bit OC2. Usually, you configure these Relay Word bits as part of the SELOGIC control equations that trip the appropriate circuit breaker. The factory default manual trip SELOGIC control equation, BK1MTR, includes OC1. Typically, you program Relay Word bit OC2 in the manual trip SELOGIC control equation BK2MTR. See *Trip Logic on page R.1.107* for information on trip SELOGIC control equations.

Table 9.87 OPEN n Command

Command	Description	Access Level
OPEN 1	Change Relay Word bit OC1 to logical 1.	B, P, A, O, 2
OPEN 2	Change Relay Word bit OC2 to logical 1.	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 J18C is not in place, the relay aborts the command and responds, `Aborted: the breaker jumper is not installed`. For information on placing relay jumpers, see *Password and Circuit Breaker Jumpers on page U.2.18*.

When you issue the **OPEN 1** 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 OC1 for one processing interval. Circuit Breaker 1 opens if you have programmed Relay Word bit OC1 in the TR SELOGIC control equation.

If you have assigned auxiliary contact 52A inputs for this circuit breaker (based on settings 52AA1, 52AB1, and 52AC1), the relay waits 0.5 seconds, checks the state of the breaker auxiliary contacts, and responds `Breaker OPEN` or `Breaker CLOSED`, as appropriate.

A similar procedure holds for the **OPEN 2** command and Circuit Breaker 2. To successfully issue the **OPEN 2** command, setting NUMBK must be 2. If setting NUMBK is 1, the relay responds, `Breaker 2 is not available`.

PACCESS

Use the **PACCESS** command to gain access to Access Level P (protection). See *Access Levels on page U.4.6* for more information.

Table 9.88 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. For information on access levels and passwords, see *Changing the Default Passwords on page U.4.6*.

PAS level new_password

⚠WARNING
This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.

The relay changes the existing password for the specified access level to a *new_password* that you specify when you issue the **PAS *level new_password*** command.

Table 9.89 PAS level new_password Command

Command	Description	Access Levels
PAS *level new_-password*[a]	Set a password *new_password* for Access Level *level*.	2

[a] Parameter level represents the relay access levels 1, B, P, A, O, or 2.

Relay access levels that have passwords are 1, B, P, A, O, and 2. Valid passwords are character sequences of as many as 12 characters. Valid characters are any printable ASCII character. HMI password entry is limited to upper- and lower-case 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.

All passwords are case sensitive. See *Changing the Default Passwords on page U.4.6* for information on setting strong passwords. When you successfully enter a new password, the relay pulses the Relay Word bit SALARM for one second, and responds, `Set`.

PAS level DISABLE

Issuing the **PAS *level DISABLE*** command disables password checking for the specified access level. You must type **DISABLE** in upper case.

Table 9.90 PAS level DISABLE Command

Command	Description	Access Levels
PAS *level* DISABLE[a]	Disable password protection for the Access Level *level*.	2

[a] Parameter level represents the relay access Levels 1, B, P, A, O, or 2.

When you successfully disable password checking, the relay pulses the SALARM Relay Word bit for one second, and responds, `Password Disabled`. SEL does not recommend disabling passwords (see *Changing the Default Passwords on page U.4.6*).

PORT

The PORT command can be used to connect to either an installed Ethernet card or a remote relay.

PORT p

The **PORT** *p* command connects a relay serial or ethernet port to another device through a virtual terminal session.

In the SEL-421, 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 Communications on page R.5.15* for information on the MIRRORED BITS communications protocol.

If an Ethernet card is installed, you can use the **PORT** command to initiate a virtual terminal session with the communications card by specifying port number *p* as 5.

Table 9.91 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, 5, and F to indicate Communications PORT 1 through PORT 3, PORT 5, and PORT F.

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 ports 1, 2, 3, or F and you have not properly configured the MIRRORED BITS communications port or the MBNUMVT is not set to 1 or larger, then the relay responds, `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 9.92*).

Table 9.92 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, or 5 to indicate Communications PORT 1 through PORT 3, PORT F, or PORT 5; 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`.

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. See *Test Commands on page U.6.5* for information on using the **PULSE OUT*nnn*** command. The control outputs are **OUT*nnn***, where ***nnn*** represents the 100-series, 200-series, and 300-series addresses.

Table 9.93 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 through 30.

If the circuit breaker control enable jumper J18C is not in place, the relay aborts the command and responds, `Aborted: the breaker jumper is not installed`. See *Jumpers on page U.2.18* for more information on relay jumpers.

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 asserts also during any **PUL** command, so you can monitor pulse operation by programming TESTPUL into event triggers and alarm outputs. See *Section 3: Analyzing Data in the Applications Handbook* for more information on pulsing relay outputs.

QUIT

Use the **QUIT** command to revert to Access Level 0 (exit relay control). See *Section 4: Basic Relay Operations in the User's Guide* for more information.

Table 9.94 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 (see *Section 7: Direct Network Communication in the Applications Handbook*).

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.

Table 9.95 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 (Sequential Events Recorder) records. The relay SER captures state changes of Relay Word bit elements and relay conditions. Relay conditions include power up, relay enable/disable, group changes, settings changes, memory queue overflow, and SER autoremoval/reinsertion. For more information on the Sequential Events Recorder, see *Section 3: Analyzing Data in the Applications Handbook*.

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 9.96 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 9.97 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, `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 9.98 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, `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 9.99 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 RV** command, the relay prompts as follows: `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. See *Section 3: Analyzing Data in the Applications Handbook* for more information on SER automatic deletion and reinsertion.

Table 9.100 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 SEL-421 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, DNP, 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. For more information and a tutorial on setting the relay, see *Making Simple Settings Changes on page U.4.13*.

The order that specific settings appear in the relay settings structure is factory programmed. See *Section 10: Settings* for specific settings order, ranges, and default values.

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 9.101 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 each instance.	P, 2
SET *label*	Set the Group relay settings, beginning at the active group setting label *label*.	P, 2
SET *n label*[a]	Set the Group *n* relay settings, beginning at setting label *label*.	P, 2

[a] Parameter n = 1–6, representing Group 1 through Group 6.

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, `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 A

Use the **SET A** command to set the Automation SELOGIC control equations. See *Section 3: SELOGIC Control Equation Programming* for more information on SELOGIC control equations.

NOTE: The SEL-421-1 and the SEL-421-2 have only one 100-line block of automation free-form SELOGIC control equation programming.

Table 9.102 SET A Command

Command	Description	Access Level
SET A	Set the Automation SELOGIC control equation relay settings in Block 1.	A, 2
SET A *n*[a]	Set the Automation SELOGIC control equation relay settings in Block *n*.	A, 2

[a] Parameter n = 1–10 for Block 1 through Block 10.

The relay presents text-edit mode entry format for the free-form SELOGIC control equations you program in the Automation SELOGIC control equations settings area. See *Text-Edit Mode Line Editing on page U.4.18* for information on settings text-edit mode.

SET D

Issue the **SET D** command to remap the serial port DNP3 values. To set the general DNP settings, use the Port settings for the appropriate port (see *SET P on page R.9.43*). There is only one instance of the serial port DNP3 remapping settings. The relay must have the optional serial port DNP3 protocol installed to access these settings. For more information, see *Section 6: DNP3 Communications*.

Table 9.103 SET D Command

Command	Description	Access Level
SET D	Set the serial port DNP3 remapping settings, beginning at the first setting in this class.	P, A, O, 2
SET D *label*	Set the serial port DNP3 remapping settings, beginning at setting *label*.	P, A, O, 2

SET F

Use the **SET F** command to set the relay front-panel settings. There is only one instance for the Front Panel settings. See *Section 5: Front-Panel Operations in the User's Guide* for information about front-panel settings.

Table 9.104 SET F Command

Command	Description	Access Level
SET F	Set the Front Panel relay settings, beginning at the first setting in this class.	P, A, O, 2
SET F *label*	Set the Front Panel relay settings, beginning at the settings label *label*.	P, A, O, 2

SET G

Use the **SET G** command to the Global class settings. There is only one instance for the Global class.

Table 9.105 SET G Command

Command	Description	Access Level
SET G	Set the Global relay settings, beginning at the first setting in this class.	P, A, O, 2
SET G *label*	Set the Global relay settings, beginning at the setting label *label*.	P, A, O, 2

SET L

Use the **SET L** command to set the Protection SELOGIC control equations. See *Section 3: SELOGIC Control Equation Programming* for more information on SELOGIC control equations.

Table 9.106 SET L Command

Command	Description	Access Level
SET L	Set the Protection SELOGIC control equation relay settings for the active settings group.	P, 2
SET L *n*[a]	Set the Protection SELOGIC relay settings for Instance *n*, which is Group *n*.	P, 2

[a] Parameter n is 1–6 for Protection Groups 1 through 6.

The relay presents text-edit mode entry format for the free-form SELOGIC control equations you program in the Protection SELOGIC control equation settings area. See *Text-Edit Mode Line Editing on page U.4.18* for information on settings text-edit mode.

SET M

Use the **SET M** command to set the circuit breaker monitor settings. There is only one instance for the Breaker Monitor class. See *Section 2: Monitoring and Metering in the Applications Handbook* for information on the circuit breaker monitor.

Table 9.107 SET M Command

Command	Description	Access Level
SET M	Set the Breaker Monitor relay settings, beginning at the first setting in this class.	P, 2
SET M *label*	Set the Breaker Monitor relay settings, beginning at the settings label *label*.	P, 2

SET O

Use the **SET O** command to set the Output SELOGIC control equations. See *Control Outputs on page U.2.7* for more information on relay control outputs.

Table 9.108 SET O Command

Command	Description	Access Level
SET O	Set the Output SELOGIC control equation relay settings, beginning at OUT101.	O, 2
SET O *label*	Set the Output SELOGIC control equation relay settings, beginning at the output label *label*.	O, 2

SET P

Use the **SET P** command to configure the relay communications ports; each port is a settings instance. The SEL-421 communications ports include serial ports at PORT F, PORT 1, PORT 2, and PORT 3. PORT 5 is the communications card port into which the optional Ethernet card or other communications cards can be installed.

Table 9.109 SET P Command

Command	Description	Access Level
SET P	Set the port presently in use, beginning at the first setting for this port.	P, A, O, 2
SET P *label*	Set the port presently in use, beginning at the settings label *label*.	P, A, O, 2
SET P *p*[a]	Set the communications Port relay settings for Port *p*, beginning at the first setting for this port.	P, A, O, 2
SET P *p label*	Set the communications Port relay settings for Port *p*, beginning at the settings label *label*.	P, A, O, 2

[a] Parameter p = 1–3, F, or 5, corresponding to PORT 1–PORT 3, PORT F, or PORT 5.

SET R

Use the **SET R** command to set Report settings and to program SER points and aliases. You can also set event report parameters and program event report digital elements. There is only one instance for the Report settings.

Table 9.110 SET R Command

Command	Description	Access Level
SET R	Set the Report relay settings, beginning at the first setting for this class.	P, A, O, 2
SET R *label*	Set the Report relay settings, beginning at the settings label *label*.	P, A, O, 2

Report settings are a mix of traditional settings entry mode and text-edit entry mode. See *Making Simple Settings Changes on page U.4.13* for settings entry methods for these modes.

SET T

Use the **SET T** command to set aliases for Relay Word bits and analog quantities. There is only one instance for the alias settings.

Table 9.111 SET T Command

Command	Description	Access Level
SET T	Set the alias settings.	P, A, O, 2

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 9.112 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 *label*[a]	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* for information on settings organization. The relay displays each setting in the order specified in the settings tables in the *Section 10: Settings*. 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. See *Making Simple Settings Changes on page U.4.13* for more information on entering and viewing relay settings.

SHO

The **SHO** command with no options or parameters accesses the relay settings Group class and the instance corresponding to the active group. To show a different instance, specify the instance number (1–6).

Table 9.113 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 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

[a] Parameter n = 1–6, representing Group 1 through Group 6.

SHO A

Use the **SHO A** command to show the Automation SELOGIC control equations. See *Section 3: SELOGIC Control Equation Programming* for more information on SELOGIC control equations.

Table 9.114 SHO A Command

Command	Description	Access Level
SHO A	Show the Automation SELOGIC control equation relay settings in Block 1.	1, B, P, A, O, 2
SHO A *n*[a]	Show the Automation SELOGIC control equation relay settings in Block *n*.	1, B, P, A, O, 2

[a] Parameter n = 1–10 for Block 1 through Block 10.

SHO D

NOTE: This does not display mapping information for DNP LAN/WAN.

The **SHO D** command shows the serial port DNP3 remapping settings. To view the general serial port DNP3 settings, use the Port settings (see *SHO P on page R.9.47*). There is only one instance of the serial port DNP3 remapping settings. The relay must have the optional serial port DNP3 protocol installed to access these settings. For more information, see *Section 6: DNP3 Communications*.

Table 9.115 SHO D Command

Command	Description	Access Level
SHO D	Show the serial port DNP3 remapping settings.	P, A, O, 2
SHO D ***label***	Show the serial port DNP3 remapping settings, beginning at setting *label*.	P, A, O, 2

SHO F

Use the **SHO F** command to show the relay front-panel settings. There is only one instance for the Front Panel settings. See *Section 5: Front-Panel Operations in the User's Guide* for information on front-panel settings.

Table 9.116 SHO F Command

Command	Description	Access Level
SHO F	Show the Front Panel relay settings, beginning at the first setting in this class.	1, B, P, A, O, 2
SHO F ***label***	Show the Front Panel relay settings, beginning at the settings label *label*.	1, B, P, A, O, 2

SHO G

Use the **SHO G** command to show the Global class settings. There is only one instance for the Global class.

Table 9.117 SHO G Command

Command	Description	Access Level
SHO G	Show the Global relay settings, beginning at the first setting in this class.	1, B, P, A, O, 2
SHO G *label*	Show the Global relay settings, beginning at the settings label *label*.	1, B, P, A, O, 2

SHO L

Use the **SHO L** command to show the Protection SELOGIC control equations. See *Section 3: SELOGIC Control Equation Programming* for more information on SELOGIC control equations.

Table 9.118 SHO L Command

Command	Description	Access Level
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 Instance *n*, which is Group *n*.	1, B, P, A, O, 2

[a] Parameter n is 1–6 for Group 1 through Group 6.

SHO M

Use the **SHO M** command to show the circuit breaker monitor settings. There is only one instance for the Breaker Monitor class. See *Section 2: Monitoring and Metering in the Applications Handbook* for information on the circuit breaker monitor.

Table 9.119 SHO M Command

Command	Description	Access Level
SHO M	Show the Breaker Monitor relay settings, beginning at the first setting in this class.	1, B, P, A, O, 2
SHO M *label*	Show the Breaker Monitor relay settings, beginning at the settings label *label*.	1, B, P, A, O, 2

SHO O

Use the **SHO O** command to show the Output SELOGIC control equations. See *Control Outputs on page U.2.7* for more information on relay control outputs.

Table 9.120 SHO O Command

Command	Description	Access Level
SHO O	Show the Output SELOGIC control equation relay settings, beginning at OUT101.	1, B, P, A, O, 2
SHO O *label*	Show the Output SELOGIC control equation relay settings, beginning at the output label *label*.	1, B, P, A, O, 2

SHO P

Use the **SHO P** command to configure the relay communications ports; each port is a settings instance. The SEL-421 communications ports include serial ports at PORT F, PORT 1, PORT 2, and PORT 3. PORT 5 is the communications card port into which the optional Ethernet card or other communications cards can be installed.

Table 9.121 SHO P Command

Command	Description	Access Level
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 *label*	Show the relay settings for the port presently in use, beginning at the settings label *label.*	1, B, P, A, O, 2
SHO P *p*[a]	Show the communications Port relay settings for Port *p*, beginning at the first setting for this port.	1, B, P, A, O, 2
SHO P *p label*	Show the communications Port relay settings for Port *p*, beginning at the settings label *label*.	1, B, P, A, O, 2

[a] Parameter p = 1–3, F, and 5 which corresponds to PORT 1–PORT 3, PORT F, and PORT 5.

The **SHO P** command with no options and parameters shows the settings for the active port.

SHO R

Use the **SHO R** command to show Report settings and to program SER Points and Aliases. You can also show event report parameters and program Event Report Digital Elements. There is only one instance for the Report settings.

Table 9.122 SHO R Command

Command	Description	Access Level
SHO R	Show the Report relay settings, beginning at the first setting for this class.	1, B, P, A, O, 2
SHO R *label*	Show the Report relay settings, beginning at the settings label *label*.	1, B, P, A, O, 2

SHO T

Use the **SHO T** command to show aliases for Relay Word bits or analog quantities. There is only one instance for the alias settings.

Table 9.123 SHO T Command

Command	Description	Access Level
SHO T	Show the alias settings.	1, B, P, A, O, 2

SNS

In response to the **SNS** command, the relay sends the names of the Sequential Events Recorder elements. This is a comma-delimited string used to support the SEL Fast SER report. See *Section 5: SEL Communications Protocols* for more information.

Table 9.124 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 U.6.38* 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 U.4.10* for information on relay status reports.

Table 9.125 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, `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, and time-source synchronization.

Table 9.126 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 reboot 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 9.127 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 operating errors. See *Section 3: SELOGIC Control Equation Programming* for more information.

Table 9.128 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. See *Section 3: SELOGIC Control Equation Programming* for more information.

Table 9.129 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

SUMMARY

The **SUMMARY** command displays a summary event report. See *Section 3: Analyzing Data in the Applications Handbook* for information on summary event reports.

SUM

Use the **SUM** command to view the event summary reports in the relay memory.

Table 9.130 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 command).

When parameter *n* is 1 through 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 through 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 9.131 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 9.132 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 (see *Appendix A: Relay Word Bits*).

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 9.133 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 power up, 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 9.134 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 9.135 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 *Section 6: Testing and Troubleshooting in the User's Guide* for more information.

Table 9.136 TAR X Command

Command	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*[a]	Display target Row *n* and repeat for *k* times; 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*; do not memorize the row number.	1, B, P, A, O, 2
TAR *name* X *k*	Display the target row with the element name *name* and repeat for *k* times; 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. For more information on the time-error calculation, see *Time-Error Calculation on page R.1.17*.

Table 9.137 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

See *Figure 1.13* for a sample **TEC** command response.

Use the **TEC *n*** command to preload the time-error correction value, TECORR. If the value *n* is within range, the relay will prompt `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. See *Figure 1.14 on page R.1.19* for a sample response.

The TECORR value does not affect the TE (time error) estimate until the LOADTE SELOGIC equation asserts, as explained in *Time-Error Calculation on page R.1.17*.

TEST DB

Use the **TEST DB** command for testing interfaces to a virtual device database. For the SEL-421, the interface is the communications card. The relay contains a database that describes the relay to external devices. When other devices access the relay via the communications card, the relay appears as a virtual device described by the database. The SEL-421 is Virtual Device 1.

The virtual database of any installed Ethernet card is accessible to master stations of supported Ethernet protocols (DNP3, IEC 61850) connected to the Ethernet network. You can, therefore, test the read functionality of all protocols in the 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; see *Section 4: Communications Interfaces* for more information.

TEST DB

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 communications card.

Table 9.138 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 *vdev 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 9.139 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 DNP

The **TEST DNP** command is for testing the serial port DNP3 interface only. For more information on Serial DNP3 and the SEL-421, see *Section 6: DNP3 Communications*.

TEST DNP

Values you enter in the DNP map are override values. Use the **TEST DNP** command to write override values in the DNP map.

Table 9.140 TEST DNP Command

Command	Description	Access Level
TEST DNP	Display present override values.	1, B, P, A, O, 2
TEST DNP *type n value1*[a]	Write new data *value1* of type *type* to the DNP map at DNP point number *n*.	B, P, A, O, 2

[a] Parameter type is A for analog, B for binary, or C for counter inputs.; n is a DNP point number.

When displaying DNP test data overrides with the **TEST DNP** command, the relay shows the report header, then the DNP Object Type, Index, and Override Value for binary inputs, counters, and analog inputs.

To force a value, use the **TEST DNP *type n value1*** command. The type is A for analog inputs, B for binary inputs, or C for counter inputs. The point number *n* is based on the active DNP map. The override value *value1* is a value you specify. The point number and override value must be valid for the given data type (see *Section 6: DNP3 Communications*).

When you have successfully added a new DNP test value (for example, **TEST DNP A 17 -357**), the relay responds, `Override Added`.

The relay asserts Relay Word bit TESTDNP while any DNP test data are present in the relay.

DNP Status Bytes

Whenever a DNP value is overridden and the value is read via DNP, the status byte for the overridden value indicates that the bit is locally forced to a test value.

TEST DNP OFF

Use the **TEST DNP OFF** command to remove override values. The relay returns the database registers to the pretest values.

Table 9.141 TEST DNP Command

Command	Description	Access Level
TEST DNP *type n* OFF[a]	Clear the override testing value of type *type* from the DNP point number *n*.	B, P, A, O, 2
TEST DNP OFF	Clear all override testing values from the DNP map.	B, P, A, O, 2

[a] Parameter n is a DNP point number; type is A for analog, B for binary, or C for counter inputs.

When you have successfully removed a DNP test value (for example, **TEST DNP A 17 OFF**), the relay responds, `Override Removed`. When an attempt to remove a DNP test value fails, the relay responds, `Override Not Found`. When removing all DNP test values (for example, **TEST DNP OFF**), the relay responds, `All Overrides Removed`.

TEST FM

The **TEST FM** command overrides normal Fast Meter quantities for testing purposes. You can override only “reported” Fast Meter values (per-phase voltages and currents). For more information on Fast Meter and the SEL-421, see *Section 5: SEL Communications Protocols*.

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 9.142 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. All meter values are in primary units. 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.

Table 9.143 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 pre-test values.

Table 9.144 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.

Table 9.145 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

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 DNP. See *Configuring High-Accuracy Timekeeping on page U.4.71* for more information on configuring SEL-421 time functions.

TIME

The **TIME** command returns information about the internal relay clock. You can also set the clock if you specify hours and minutes (seconds data are optional). Separate the hours, minutes, and seconds with colons, semicolons, spaces, commas, or slashes.

Table 9.146 TIME Command

Command	Description	Access Level
TIME	Display the present relay internal clock time.	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; 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 9.147 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 *Configuring High-Accuracy Timekeeping on page U.4.71*).

TRIGGER

The **TRIGGER** command initiates data captures for high-resolution oscillography and event reports. For information on high-resolution oscillography and event reports, see *Section 3: Analyzing Data in the Applications Handbook*. See *Reading Oscillograms, Event Reports, and SER on page U.4.42* for examples using the **TRI** command.

TRI

Use the **TRI** command to trigger the SEL-421 to record data for high-resolution oscillography and event reports.

Table 9.148 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`.

VERSION

The **VERSION** command displays the relay hardware and software configuration.

VER

Use the **VER** command to list the part numbers, serial numbers, checksums, software release numbers, and other important relay configuration information.

Table 9.149 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 these items:

- FID
- Part number
- Serial number
- SELBOOT BFID
- Chassis orientation and size
- Mainboard memory types and sizes
- Front-panel hardware
- Analog inputs (W, X, Y, Z) ratings
- Fiber port (installed or absent)
- Interface board inputs and outputs
- Power supply ratings
- Communications card IDs and part number
- Extended relay features list (optional DNP communications capability)

A sample **VER** command response is shown in *Figure 9.3*:

```
=>VER <Enter>
FID=SEL-421-R101-V0-Z001001-D20010315
CID=5EEA
Part Number:  04210415X11XXHX
Serial Number:  2001001234
SELboot:
    BFID= SLBT-4XX-R1XX-V0-Z001001-D20010703
    Checksum:  D507
Mainboard:
    Code FLASH Size:    4 MB
    Data FLASH Size:    8 MB
    RAM Size:           2 MB
    EEPROM Size:       64 kB
Front Panel: installed
Analog Inputs:
    W:  Currents:  5 Amp
    X:  Currents:  5 Amp
    Y:  Voltage:   67 Volts
    Z:  Voltage:   67 Volts
Fiber Port:  not installed
Interface Boards:
    Board 1:  not installed
    Board 2:  not installed
Communications Card:
    not installed
Extended Relay Features:
    None

If the information above is not as expected, contact SEL for assistance.

=>
```

Figure 9.3 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 SEL-421 is very similar to the **VIEW** command in SEL Communications Processors. See *Section 4: Communications Interfaces* for more information on the relay database regions and data types.

SEL-421 regions are LOCAL, METER, DEMAND, TARGET, HISTORY, BREAKER, STATUS, and ANALOGS; view this list with the **MAP 1** command.

The SEL-421 is Virtual Device 1; all commands begin **VIEW 1**. In all database views, if a data item is in test mode, the relay displays an asterisk (*) mark following the data value.

VIEW 1 Commands—Region

Use the commands in *Table 9.150* to view the contents of the database regions.

Table 9.150 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 9.151* to view register items in the relay database. 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 9.151 VIEW 1 Commands—Register Item

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*[a]	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
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*[a]	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 9.152* 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. Other examples of bit labels are M1P, 25W1BK2, and ASV256.

Table 9.152 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 10

Settings

NOTE: When using the **SET** command to configure your SEL-421, enter the settings classes Global, Breaker Monitor, and Group in the order shown.

This section contains tables of relay settings for the SEL-421 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 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 the *Applications Handbook*. The section arranges settings in the following order:

Alias Settings

Assign a valid seven-character alias name to any of the following:

- Relay Word bit (except target LEDs)
- Analog Quantity

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.

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 Trip, for example.

BK1 Trip (including the space) consists of eight characters, one more than the allowable number of seven. Changing the name to BK1 Tr reduces the character count to six, but the alias contains two elements not permitted, a space and one lowercase letter (r). One possible alias for the existing name of OUT101 could be BK1_TR, entered using the following syntax:

primitive name, alias name,

e.g., OUT101, BK1_TR

Figure 10.1 shows the steps using the **SET T** command.

```
=>>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 10.1 Changing a Default Name to an Alias

Table 10.1 Default Alias Settings

Label	Default Value
EN	RLY_EN

Global Settings

Table 10.2 Global Settings Categories

Settings	Reference
General Global Settings	*Table 10.3*
Global Enables	*Table 10.4*
Station DC1 Monitor (and Station DC2 Monitor)	*Table 10.5*
Control Inputs (Global)	*Table 10.6*
Main Board Control Inputs	*Table 10.7*
Interface Board #1 Control Inputs	*Table 10.8*
Interface Board #2 Control Inputs	*Table 10.9*
Settings Group Selection	*Table 10.10*
Data Reset Control	*Table 10.11*
Frequency Estimation	*Table 10.12*
Time-Error Calculation	*Table 10.13*
Current and Voltage Source Selection	*Table 10.14*
Synchronized Phasor Measurement	*Table 10.15*
Time and Date Measurement	*Table 10.16*

NOTE: See corresponding command descriptions SET G on page R.9.41 and SHO G on page R.9.45 to set or show the Global settings.

Table 10.3 General Global Settings

Label	Prompt	Default Value
SID	Station Identifier (40 characters)	Station A
RID	Relay Identifier (40 characters)	Relay 1
NUMBK	Number of Breakers in Scheme (1, 2)	1
BID1	Breaker 1 Identifier (40 characters)	Breaker 1
BID2	Breaker 2 Identifier (40 characters)	Breaker 2
NFREQ	Nominal System Frequency (50, 60 Hz)	60
PHROT	System Phase Rotation (ABC, ACB)	ABC
DATE_F	Date Format (MDY, YMD, DMY)	MDY
FAULT	Fault Condition Equation SELOGIC Equation)	50P1 OR 51S1 OR M2P OR Z2G OR M3P OR Z3G

Table 10.4 Global Enables

Label	Prompt	Default Value
EDCMON	Station DC Battery Monitor (N, 1, 2)	N
EICIS	Independent Control Input Settings (Y, N)	N
EDRSTC	Data Reset Control (Y, N)	N
EGADVS	Advanced Global Settings (Y, N)	N
EPMU	Synchronized Phasor Measurement (Y, N)	N

Make *Table 10.5* settings when Global enable setting EDCMON := 1 or 2. These settings are hidden when EDCMON := N.

Table 10.5 Station DC1 Monitor (and Station DC2 Monitor[a])

Label	Prompt	Default Value
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

[a] Replace 1 with 2 in the setting label.

Make *Table 10.6* settings when Global enable setting EICIS := N.

NOTE: Main Board A I/O, INT1, INT5, and INT6 I/O interface boards have direct coupled contact inputs. Main Board B I/O, INT2, INT4, INT7, and INT8 I/O interface boards have optoisolated contact inputs. SEL-421-0 and SEL-421-1 do not support Main Board B I/O, INT2, INT7, and INT8 I/O interface boards. SEL-421-2 and SEL-421-3 support all the boards.

Table 10.6 Control Inputs

Label	Prompt	Default Value
GINP[a]	Input Pickup Level (15–265 Vdc)	85[b]
GINDF[a,c]	Input Dropout Level (10–100% of pickup level)	80
IN1XXD[d]	Main Board Debounce Time (0.0000–5 cyc)	0.1250
IN2XXD[e]	Int Board #1 Debounce Time (0.0000–5 cyc[f])	0.1250
IN3XXD[g]	Int Board #2 Debounce Time (0.0000–5 cyc[f])	0.1250

[a] Setting applies to all direct coupled contact inputs if available, otherwise, the setting is not available.
[b] Factory set at 18 for 24/48 Vdc nominal power supply, 36 for 48/125 Vdc nominal power supply, and 85 for 125/240 Vdc power supply. See Control Inputs on page U.2.5 for setting guidelines.
[c] Setting applies to all direct coupled contact inputs independent of EICIS set to Y or N.
[d] Setting applies to all the main board input contacts.
[e] Setting applies to all the Interface Board #1 input contacts.
[f] If the interface board has more than eight input contacts, the upper range is 1 cycle.
[g] Setting applies to all the Interface Board #2 input contacts.

Make *Table 10.7* settings when Global enable setting EICIS := Y.

NOTE: Main Board A I/O, INT1, INT5, and INT6 I/O interface boards have direct coupled contact inputs. Main Board B I/O, INT2, INT4, INT7, and INT8 I/O interface boards have optoisolated contact inputs. SEL-421-0 and SEL-421-1 do not support Main Board B I/O, INT2, INT7, and INT8 I/O interface boards. SEL-421-2 and SEL-421-3 support all the boards.

Table 10.7 Main Board Control Inputs

Label	Prompt	Default Value
IN101P[a]	Input IN101 Pickup Level (15–265 Vdc)	85[b]
•	•	•
•	•	•
•	•	•
IN107P[a]	Input IN107 Pickup Level (15–265 Vdc)	85[b]
IN101PU	Input IN101 Pickup Delay (0.0000–5 cyc)	0.1250[c]
IN101DO	Input IN101 Dropout Delay (0.0000–5 cyc)	0.1250[c]
•	•	•
•	•	•
•	•	•
IN107PU	Input IN107 Pickup Delay (0.0000–5 cyc)	0.1250[c]
IN107DO	Input IN107 Dropout Delay (0.0000–5 cyc)	0.1250[c]

[a] Setting is not available for Main Board B. Set to Global setting GINP when EICIS := N.
[b] Factory set at 18 for 24/48 Vdc nominal power supply, 36 for 48/125 Vdc nominal power supply, and 85 for 125/240 Vdc power supply. See Control Inputs on page U.2.5 for setting guidelines.
[c] Set to Global setting IN1XXD when EICIS := N.

Make *Table 10.8* settings for Interface Board #1 when Global enable setting EICIS := Y.

Table 10.8 Interface Board #1 Control Inputs

Label	Prompt	Default Value
IN201P[a]	Input IN201 Pickup Level (15–265 Vdc)	85[b]
•	•	•
•	•	•
•	•	•
IN208P[a]	Input IN208 Pickup Level (15–265 Vdc)	85[b]
IN201PU	Input IN201 Pickup Delay (0.0000–5 cyc[c])	0.1250[d]
IN201DO	Input IN201 Dropout Delay (0.0000–5 cyc[c])	0.1250[d]
•	•	•
•	•	•
•	•	•
IN2*mm*PU[e]	Input IN2*mm*[e] Pickup Delay (0.0000–5 cyc[c])	0.1250[d]
IN2*mm*DO[e]	Input IN2*mm*[e] Dropout Delay (0.0000–5 cyc[c])	0.1250[d]

[a] Setting is not available for interface boards INT2, INT4, INT7, and INT8. Set to Global setting GINP when EICIS := N.
[b] Factory set at 18 for 24/48 Vdc nominal power supply, 36 for 48/125 Vdc nominal power supply, and 85 for 125/240 Vdc power supply. See Control Inputs on page U.2.5 for setting guidelines.
[c] If the interface board has more than eight input contacts, the upper range is 1 cycle.
[d] Set to Global setting IN2XXD when EICIS :-= N
[e] mm is the number of available input contacts on the interface board.

Make *Table 10.9* settings for Interface Board #2 when Global enable setting EICIS := Y.

Table 10.9 Interface Board #2 Control Inputs

Label	Prompt	Default Value
IN301P[a]	Input IN301 Pickup Level (15–265 Vdc)	85[b]
•	•	•
•	•	•
•	•	•
IN308P[a]	Input IN308 Pickup Level (15–265 Vdc)	85[b]
IN301PU	Input IN301 Pickup Delay (0.0000–5 cyc[c])	0.1250[d]
IN301DO	Input IN301 Dropout Delay (0.0000–5 cyc[c])	0.1250[d]
•	•	•
•	•	•
•	•	•
IN3*mm*PU[e]	Input IN3*mm*[e] Pickup Delay (0.0000–5 cyc[c])	0.1250[d]
IN3*mm*DO[e]	Input IN3*mm*[e] Dropout Delay (0.0000–5 cyc[c])	0.1250[d]

[a] Setting is not available for interface boards INT2, INT4, INT7, and INT8. Set to Global setting GINP when EICIS := N.
[b] Factory set at 18 for 24/48 Vdc nominal power supply, 36 for 48/125 Vdc nominal power supply, and 85 for 125/240 Vdc power supply. See Control Inputs on page U.2.5 for setting guidelines.
[c] If the interface board has more than eight input contacts, the upper range is 1 cycle.
[d] Set to Global setting IN3XXD when EICIS := N.
[e] mm is the number of available input contacts on the interface board.

Table 10.10 Settings Group Selection

Label	Prompt	Default Value
SS1	Select Setting Group 1 (SELOGIC Equation)	PB3 AND NOT SG1
SS2	Select Setting Group 2 (SELOGIC Equation)	PB3 AND SG1
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

Make *Table 10.11* settings when Global enable setting EDRSTC := Y.

Table 10.11 Data Reset Control

Label	Prompt	Default Value
RST_DEM	Reset Demand Metering (SELOGIC Equation)	NA
RST_PDM	Reset Peak Demand Metering (SELOGIC Equation)	NA
RST_ENE	Reset Energy Metering (SELOGIC Equation)	NA
RSTMML	Reset Maximum/Minimum Line (SELOGIC Equation)	NA
RSTMMB1	Reset Maximum/Minimum Breaker 1 (SELOGIC Equation)	NA
RSTMMB2	Reset Maximum/Minimum Breaker 2 (SELOGIC Equation)	NA
RST_BK1	Reset Monitoring Breaker 1 (SELOGIC Equation)	NA
RST_BK2	Reset Monitoring Breaker 2 (SELOGIC Equation)	NA
RST_BAT	Reset Battery Monitoring (SELOGIC Equation)	NA
RST_79C	Reset Recloser Shot Count Accumulators (SELOGIC Equation)	NA
RSTTRGT	Target Reset (SELOGIC Equation)	NA
RSTFLOC	Reset Fault Locator (SELOGIC Equation)	NA
RSTDNPE	Reset DNP Fault Summary Data (SELOGIC Equation)	TRGTR

Make *Table 10.12* settings when Global enable setting EGADVS := Y.

Table 10.12 Frequency Estimation (Sheet 1 of 2)

Label	Prompt	Default Value
EAFSRC	Alternate Frequency Source (SELOGIC Equation)	NA
VF01	Local Frequency Source 1 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	VAY
VF02	Local Frequency Source 2 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	VBY
VF03	Local Frequency Source 3 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	VCY
VF11	Alternate Frequency Source 1 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	ZERO

Table 10.12 Frequency Estimation (Sheet 2 of 2)

Label	Prompt	Default Value
VF12	Alternate Frequency Source 2 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	ZERO
VF13	Alternate Frequency Source 3 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	ZERO

NOTE: In firmware version R112, Global Time and Date Management Settings ETPPS and ETIRIG were removed. See Configuring High-Accuracy Timekeeping on page U.4.71 for an explanation.

Table 10.13 Time-Error Calculation

Label	Prompt	Default Value
STALLTE	Stall Time-Error Calculation (SELOGIC Equation)	NA
LOADTE	Load TECORR Factor (SELOGIC Equation)	NA

See *Current and Voltage Source Selection on page R.1.2* for more information on *Table 10.14* settings.

Table 10.14 Current and Voltage Source Selection

Label	Prompt	Default Value
ESS	Current and Voltage Source Selection (Y, N, 1, 2, 3, 4)	N
LINEI	Line Current Source (IW, COMB)	IW
ALINEI	Alternate Line Current Source (IX, NA)	NA
ALTI	Alternate Current Source (SELOGIC Equation)	NA
BK1I	Breaker 1 Current Source (IW, IX, NA)	IW
BK2I	Breaker 2 Current Source (IX, COMB, NA)	NA
IPOL	Polarizing Current (IAX, IBX, ICX, NA)	NA
ALINEV	Alternate Line Voltage Source (VZ, NA)	NA
ALTV	Alternate Voltage Source (SELOGIC Equation)	NA

Make *Table 10.15* settings when Global enable setting EPMU := Y.

Table 10.15 Synchronized Phasor Measurement (Sheet 1 of 2)

Label	Prompt	Default Value
MFRMT	Message Format (C37.118, FM)	C37.118
MRATE[a]	Messages per Second (1, 2, 5, 10, 25, 50) {when NFREQ = 50} (1, 2, 4, 5, 10, 12, 15, 20, 30, 60) {when NFREQ = 60}	2
PMAPP	PMU Application (F = Fast Response, N = Narrow Bandwidth)	N
PHCOMP	Frequency Based Phasor Compensation (Y, N)	Y
PMSTN[a]	Station Name (16 characters)	STATION A
PMID	PMU Hardware ID (1–65534)[b]	1
PHDATAV	Phasor Data Set, Voltages (V1, ALL, NA)[c]	V1
VCOMP	Voltage Angle Compensation Factor (–179.99 to 180 deg)	0.00
PHDATAI	Phasor Data Set, Currents (I1, ALL, NA)[d]	NA
PHCURR	Current Source (IW, IX, BOTH, COMB)[e]	IW

Table 10.15 Synchronized Phasor Measurement (Sheet 2 of 2)

Label	Prompt	Default Value
IWCOMP	IW Angle Compensation Factor (–179.99 to 180 deg)	0.00
IXCOMP	IX Angle Compensation Factor (–179.99 to 180 deg)	0.00
PHNR[a]	Phasor Numerical Representation (I = Integer, F = Floating Point)	I
PHFMT[a]	Phasor Format (R = Rectangular, P = Polar)	R
FNR[a]	Frequency Numerical Representation (I = Integer, F = Floating Point)	I
NUMANA[a]	Number of Analog Values (0–8)	0
NUMDSW[a]	Number of 16-bit Digital Status Words (0, 1, 2)	1
TREA1[a]	Trigger Reason Bit 1 (SELOGIC Equation)	NA
TREA2[a]	Trigger Reason Bit 2 (SELOGIC Equation)	NA
TREA3[a]	Trigger Reason Bit 3 (SELOGIC Equation)	NA
TREA4[a]	Trigger Reason Bit 4 (SELOGIC Equation)	NA
PMTRIG[a]	Trigger (SELOGIC EQUATION)	NA
MRTCDLY	Maximum RTC Synchrophasor Packet Delay (20–1000 ms)	500
RTCRATE	Remote Messages per Second {1, 2, 5, 10, 25, or 50 when NFREQ := 50} {1, 2, 4, 5, 10, 12, 15, 20, 30, or 60 when NFREQ :=60}	2

[a] Setting not available when MFRMT := FM.
[b] When MFRMT := FM, range is 0–0xFFFFFFFF.
[c] When MFRMT := FM, NA setting choice is hidden.
[d] When MFRMT := FM, I1 setting choice is hidden, and the ALL setting choice is only available when PHDATAV := ALL.
[e] When MFRMT := FM, BOTH setting choice is hidden.

Table 10.16 Time and Date Management

Label	Prompt	Default Value
IRIGC[a]	IRIG-B Control Bits Definition (None, C37.118)	None

[a] When MFRMT := C37.118, IRIGC is forced to C37.118.

Breaker Monitor Settings

Label	Prompt	Default Value
IRIGC[a]	IRIG-B Control Bits Definition (None, C37.118)	None

[a] When MFRMT := C37.118, IRIGC is forced to C37.118.

NOTE: If you want to enable the circuit breaker monitor on Circuit Breaker 2, confirm that the relay is set for two-circuit breaker operation; global setting NUMBK must be 2. Once you have set NUMBK := 2, you can set the Circuit Breaker 2 monitor settings, including EB2MON.

Table 10.17 Breaker Monitor Settings Categories

Settings	Reference
Breaker Configuration	*Table 10.18*
Breaker 1 Inputs	*Table 10.19*
Breaker 2 Inputs	*Table 10.20*
Breaker 1 Monitor (and Breaker 2 Monitor)	*Table 10.21*
Breaker 1 Contact Wear (and Breaker 2 Contact Wear)	*Table 10.22*
Breaker 1 Electrical Operating Time (and Breaker 2 Electrical Operating Time)	*Table 10.23*
Breaker 1 Mechanical Operating Time (and Breaker 2 Mechanical Operating Time)	*Table 10.24*
Breaker 1 Pole Scatter and Pole Discrepancy (and Breaker 2 Pole Scatter and Pole Discrepancy)	*Table 10.25*
Breaker 1 Inactivity Time Elapsed (and Breaker 2 Inactivity Time Elapsed)	*Table 10.26*
Breaker 1 Motor Running Time (Breaker 2 Motor Running Time)	*Table 10.27*
Breaker 1 Current Interrupted (Breaker 2 Current Interrupted)	*Table 10.28*

NOTE: See corresponding command descriptions SET M on page R.9.42 and SHO M on page R.9.46 to set or show the Breaker Monitor settings.

Make *Table 10.14* EB1MON and BK1TYP settings when Global setting NUMBK := 1 or 2. make EB2MON and BK2TYP settings when Global setting NUMBK := 2.

Table 10.18 Breaker Configuration

Label	Prompt	Default Value
EB1MON	Breaker 1 Monitoring (Y, N)	N
EB2MON	Breaker 2 Monitoring (Y, N)	N
BK1TYP	Breaker 1 Trip Type (Single Pole = 1, Three Pole = 3)	3
BK2TYP	Breaker 2 Trip Type (Single Pole = 1, Three Pole = 3)	3

Table 10.19 Breaker 1 Inputs

Label	Prompt	Default Value
52AA1	Normally Open Contact Input—BK1 (SELOGIC Equation)[a]	IN101
52AA1	A-Phase Normally Open Contact Input—BK1 (SELOGIC Equation)[b]	IN101
52AB1	B-Phase Normally Open Contact Input—BK1 (SELOGIC Equation)	52AA1
52AC1	C-Phase Normally Open Contact Input—BK1 (SELOGIC Equation)	52AA1

[a] This setting for three-pole trip applications when setting BK1TYP := 3.
[b] This setting for single-pole trip applications when setting BK1TYP := 1.

Make *Table 10.20* settings if Global setting NUMBK := 2.

Table 10.20 Breaker 2 Inputs

Label	Prompt	Default Value
52AA2	Normally Open Contact Input—BK2 (SELOGIC Equation)[a]	NA
52AA2	A-Phase Normally Open Contact Input—BK2 (SELOGIC Equation)[b]	NA
52AB2	B-Phase Normally Open Contact Input—BK2 (SELOGIC Equation)	52AA2
52AC2	C-Phase Normally Open Contact Input—BK2 (SELOGIC Equation)	52AA2

[a] This setting for three-pole trip applications when setting BK1TYP := 3.
[b] This setting for single-pole trip applications when setting BK1TYP := 1.

Make *Table 10.21* through *Table 10.28* settings when Breaker Monitor setting EB1MON := Y or EB2MON := Y.

Table 10.21 Breaker 1 Monitor (and Breaker 2 Monitor[a])

Label	Prompt	Default Value
BM1TRPA	Breaker Monitor Trip—BK1 (SELOGIC Equation)[b]	TPA1
BM1TRPA	Breaker Monitor A-Phase Trip—BK1 (SELOGIC Equation)[c]	TPA1
BM1TRPB	Breaker Monitor B-Phase Trip—BK1 (SELOGIC Equation)	BM1TRPA
BM1TRPC	Breaker Monitor C-Phase Trip—BK1 (SELOGIC Equation)	BM1TRPA
BM1CLSA	Breaker Monitor Close—BK1 (SELOGIC Equation)[b]	BK1CL
BM1CLSA	Breaker Monitor A-Phase Close—BK1 (SELOGIC Equation)[c]	BK1CL
BM1CLSB	Breaker Monitor B-Phase Close—BK1 (SELOGIC Equation)	BM1CLSA
BM1CLSC	Breaker Monitor C-Phase Close—BK1 (SELOGIC Equation)	BM1CLSA

[a] Replace 1 with 2 in the setting label, prompt, and default value.
[b] This setting for three-pole trip applications when setting BK1TYP := 3.
[c] This setting for single-pole trip applications when setting BK1TYP := 1.

Table 10.22 Breaker 1 Contact Wear (and Breaker 2 Contact Wear[a])

Label	Prompt	Default Value
B1COSP1	Close/Open Set Point 1—BK1 (0–65000 operations)	1000
B1COSP2	Close/Open Set Point 2—BK1 (0–65000 operations)	100
B1COSP3	Close/Open Set Point 3—BK1 (0–65000 operations)	10
B1KASP1	kA Interrupted Set Point 1—BK1 (1.0–999 kA)	20.0
B1KASP2	kA Interrupted Set Point 2—BK1 (1.0–999 kA)	60.0
B1KASP3	kA Interrupted Set Point 3—BK1 (1.0–999 kA)	100.0
B1BCWAT	Contact Wear Alarm Threshold—BK1 (0–100%)	90

[a] Replace 1 with 2 in the setting label and prompt.

Table 10.23 Breaker 1 Electrical Operating Time (and Breaker 2 Electrical Operating Time[a])

Label	Prompt	Default Value
B1ESTRT	Electrical Slow Trip Alarm Threshold—BK1 (1–999 ms)	50
B1ESCLT	Electrical Slow Close Alarm Threshold—BK1 (1–999 ms)	120

[a] Replace 1 with 2 in the setting label and prompt.

Table 10.24 Breaker 1 Mechanical Operating Time (and Breaker 2 Mechanical Operating Time[a])

Label	Prompt	Default Value
B1MSTRT	Mechanical Slow Trip Alarm Threshold—BK1 (1–999 ms)	50
B1MSCLT	Mechanical Slow Close Alarm Threshold—BK1 (1–999 ms)	120

[a] Replace 1 with 2 in the setting label and prompt.

Table 10.25 Breaker 1 Pole Scatter and Pole Discrepancy (and Breaker 2 Pole Scatter and Pole Discrepancy[a])

Label	Prompt	Default Value
B1PSTRT	Pole Scatter Trip Alarm Threshold—BK1 (1–999 ms)	20
B1PSCLT	Pole Scatter Close Alarm Threshold—BK1 (1–999 ms)	20
B1PDD	Pole Discrepancy Time Delay—BK1 (1–9999 ms)	1400
E1PDCS	Pole Discrepancy Current Supervision—BK1 (Y, N)	N

[a] Replace 1 with 2 in the setting label and prompt.

Table 10.26 Breaker 1 Inactivity Time Elapsed (and Breaker 2 Inactivity Time Elapsed[a])

Label	Prompt	Default Value
B1ITAT	Inactivity Time Alarm Threshold—BK1 (N, 1–9999 days)	365

[a] Replace 1 with 2 in the setting label and prompt.

Table 10.27 Breaker 1 Motor Running Time (and Breaker 2 Motor Running Time[a])

Label	Prompt	Default Value
B1MRTIN	Motor Run Time Contact Input—BK1 (SELOGIC Equation)	NA
B1MRTAT	Motor Run Time Alarm Threshold—BK1 (1–9999 seconds)	25

[a] Replace 1 with 2 in the setting label and prompt.

Table 10.28 Breaker 1 Current Interrupted (and Breaker 2 Current Interrupted[a])

Label	Prompt	Default Value
B1KAIAT	kA Interrupt Capacity Alarm Threshold—BK1 (N, 1–100%)	90
B1MKAI	Maximum kA Interrupt Rating—BK1 (1–999 kA)	50

[a] Replace 1 with 2 in the setting label and prompt.

Group Settings

Table 10.29 Group Settings Categories (Sheet 1 of 2)

Settings	Reference
Line Configuration	*Table 10.30*
Relay Configuration	*Table 10.31*
Mho Phase Distance Element Reach	*Table 10.32*
Series Compensation	*Table 10.33*
Mho Phase Distance Element Time Delay	*Table 10.34*
Mho Ground Distance Element Reach	*Table 10.35*
Quad Ground Distance Element Reach	*Table 10.36*
Zero-Sequence Compensation Factor	*Table 10.37*
Ground Distance Element Time Delay	*Table 10.38*
Distance Element Common Time Delay	*Table 10.39*
Switch-Onto-Fault Scheme	*Table 10.40*
Out-of-Step Tripping/Blocking	*Table 10.41*
Load Encroachment	*Table 10.42*
Phase Instantaneous Overcurrent Pickup	*Table 10.43*
Phase Definite-Time Overcurrent Time Delay	*Table 10.44*
Phase Instantaneous Definite-Time Overcurrent Torque Control	*Table 10.45*
Residual Ground Instantaneous Overcurrent Pickup	*Table 10.46*
Residual Ground Definite-Time Overcurrent Time Delay	*Table 10.47*
Residual Ground Instantaneous Definite-Time Overcurrent Torque Control	*Table 10.48*
Negative-Sequence Instantaneous Overcurrent Pickup	*Table 10.49*
Negative-Sequence Definite-Time Overcurrent Time Delay	*Table 10.50*
Negative-Sequence Instantaneous Definite-Time Overcurrent Torque Control	*Table 10.51*

Table 10.29 Group Settings Categories (Sheet 2 of 2)

Settings	Reference
Selectable Operating Quantity Inverse Time Overcurrent Element 1	*Table 10.52*
Selectable Operating Quantity Inverse Time Overcurrent Element 2	*Table 10.53*
Selectable Operating Quantity Inverse Time Overcurrent Element 3	*Table 10.54*
Zone/Level Direction	*Table 10.55*
Directional Control Element	*Table 10.56*
Pole Open Detection	*Table 10.57*
POTT Trip Scheme	*Table 10.58*
DCUB Trip Scheme	*Table 10.59*
DCB Trip Scheme	*Table 10.60*
Breaker 1 Failure Logic (and Breaker 2 Failure Logic)	*Table 10.61*
Synchronism Check Element Reference	*Table 10.62*
Breaker 1 Synchronism Check	*Table 10.63*
Breaker 2 Synchronism Check	*Table 10.64*
Recloser and Manual Closing	*Table 10.65*
Single-Pole Reclose Settings	*Table 10.66*
Three-Pole Reclose Settings	*Table 10.67*
Voltage Elements	*Table 10.68*
Demand Metering	*Table 10.69*
Trip Logic	*Table 10.70*

NOTE: See corresponding command descriptions SET on page R.9.40 and SHO on page R.9.44 to set or show the Group settings.

Table 10.30 Line Configuration

Label	Prompt	Default Value 5 A	Default Value 1 A
CTRW	Current Transformer Ratio—Input W (1–50000)	200	200
CTRX	Current Transformer Ratio—Input X (1–50000)	200	200
PTRY	Potential Transformer Ratio—Input Y (1–10000)	2000	2000
VNOMY	PT Nominal Voltage (L-L)—Input Y (60–300 V secondary)	115	115
PTRZ	Potential Transformer Ratio—Input Z (1–10000)	2000	2000
VNOMZ	PT Nominal Voltage (L-L)—Input Z (60–300 V secondary)	115	115
Z1MAG	Positive-Sequence Line Impedance Magnitude (0.05–255 Ω secondary) 5 A (0.25–1275 Ω secondary) 1 A	7.80	39.00
Z1ANG	Positive-Sequence Line Impedance Angle (5.00–90 degrees)	84.00	84.00
Z0MAG	Zero-Sequence Line Impedance Magnitude (0.05–255 Ω secondary) 5 A (0.25–1275 Ω secondary) 1 A	24.80	124.00
Z0ANG	Zero-Sequence Line Impedance Angle (5.00–90 degrees)	81.50	81.50
EFLOC	Fault Location (Y, N)	Y	Y
LL	Line Length (0.10–999)	100.00	100.00

Table 10.31 Relay Configuration

Label	Prompt	Default Value
E21P	Mho Phase Distance Zones (N, 1–5)	3
E21MG	Mho Ground Distance Zones (N, 1–5)	3
E21XG	Quadrilateral Ground Distance Zones (N, 1–5)	N
ECVT	Capacitive Voltage Transformer Transient Detection (Y, N)	N
ESERCMP	Series-Compensated Line Logic (Y, N)	N
ECDTD	Distance Element Common Time Delay (Y, N)	N
ESOTF	Switch-Onto-Fault (Y, N)	Y
EOOS	Out-of-Step (Y, Y2, N)	N
ELOAD	Load Encroachment (Y, N)	Y
E50P	Phase Instantaneous Definite-Time Overcurrent Elements (N, 1–4)	1
E50G	Residual Ground Instantaneous Definite-Time Overcurrent Elements (N, 1–4)	N
E50Q	Negative-Sequence Instantaneous Definite-Time Overcurrent Elements (N, 1–4)	N
E51S	Selectable Operating Quantity Inverse Time Overcurrent Element (N, 1–3)	1
E32	Directional Control (Y, AUTO)	AUTO
ECOMM	Communications-Assisted Tripping (N, DCB, POTT, POTT2, POTT3, DCUB1, DCUB2)	POTT
EBFL1	Breaker 1 Failure Logic (N, 1, 2)	N
EBFL2	Breaker 2 Failure Logic (N, 1, 2)	N
E25BK1	Synchronism Check for Breaker 1 (Y, N)	N
E25BK2	Synchronism Check for Breaker 2 (Y, N)	N
E79	Reclosing (Y, Y1, N)	Y
EMANCL	Manual Closing (Y, N)	Y
ELOP	Loss-of-Potential (Y, Y1, N)	Y1
EDEM	Demand Metering (N, THM, ROL)	N
EADVS	Advanced Settings (Y, N)	N

NOTE: The SEL-421-1 and the SEL-421-2 do not provide series-compensated line protection logic. This setting is unavailable in the SEL-421-1 and the SEL-421-2.

The number of pickup settings in *Table 10.32* is dependent on Group setting E21P := 1–5. When E21P := N, no settings are made for *Table 10.32*.

Table 10.32 Mho Phase Distance Element Reach (Sheet 1 of 2)

Label	Prompt	Default Value 5 A	Default Value 1 A
ZIP	Zone 1 Reach (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	6.24	31.2
Z2P	Zone 2Reach (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	9.36	46.8
Z3P	Zone 3 Reach (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	1.87	9.35

Table 10.32 Mho Phase Distance Element Reach (Sheet 2 of 2)

Label	Prompt	Default Value 5 A	Default Value 1 A
Z4P	Zone 4 Reach (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	OFF	OFF
Z5P	Zone 5 Reach (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	OFF	OFF

Make *Table 10.33* settings when Group setting ESERCMP := Y.

NOTE: The SEL-421-1 and the SEL-421-2 do not provide series-compensated line protection logic. This setting is unavailable in the SEL-421-1 and the SEL-421-2.

Table 10.33 Series Compensation

Label	Prompt	Default Value 5 A	Default Value 1 A
XC	Series Capacitor Reactance (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	OFF	OFF

Make corresponding zone *n* = 1–5 settings in *Table 10.34* for any Z*n*P settings that are made in *Table 10.32*. When E21P := N, no settings are made for *Table 10.34*.

Table 10.34 Mho Phase Distance Element Time Delay

Label	Prompt	Default Value
Z1PD	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	0.000
Z2PD	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	20.000
Z3PD	Zone 3 Time Delay (OFF, 0.000–16000 cycles)	60.000
Z4PD	Zone 4 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z5PD	Zone 5 Time Delay (OFF, 0.000–16000 cycles)	OFF

The number of pickup settings in *Table 10.35* is dependent on Group setting E21MG := 1–5. When E21MG := N, no settings are made for *Table 10.35*.

Table 10.35 Mho Ground Distance Element Reach (Sheet 1 of 2)

Label	Prompt	Default Value 5 A	Default Value 1 A
Z1MG	Zone 1 (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	6.24	31.2
Z2MG	Zone 2 (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	9.36	46.8
Z3MG	Zone 3 (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	1.87	9.35

Table 10.35 Mho Ground Distance Element Reach (Sheet 2 of 2)

Label	Prompt	Default Value 5 A	Default Value 1 A
Z4MG	Zone 4 (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	OFF	OFF
Z5MG	Zone 5 (0.05–64 Ω secondary) 5 A (0.25–320 Ω secondary) 1 A	OFF	OFF

The number of pickup settings in *Table 10.36* is dependent on Group setting E21XG := 1–5. When E21XG := N, no settings are made for *Table 10.36*.

Table 10.36 Quad Ground Distance Element Reach

Label	Prompt	Default Value 5 A	Default Value 1 A
XG1	Zone 1 Reactance (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	OFF	OFF
RG1	Zone 1 Resistance (0.05–50 Ω secondary) 5 A (0.25–250 Ω secondary) 1 A	12.48	62.4
XG2	Zone 2 Reactance (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	OFF	OFF
RG2	Zone 2 Resistance (0.05–50 Ω secondary) 5 A (0.25–250 Ω secondary) 1 A	18.72	93.6
XG3	Zone 3 Reactance (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	OFF	OFF
RG3	Zone 3 Resistance (0.05–50 Ω secondary) 5 A (0.25–250 Ω secondary) 1 A	3.64	18.2
XG4	Zone 4 Reactance (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	OFF	OFF
RG4	Zone 4 Resistance (0.05–50 Ω secondary) 5 A (0.25–250 Ω secondary) 1 A	31.2	156
XG5	Zone 5 Reactance (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	OFF	OFF
RG5	Zone 5 Resistance (0.05–50 Ω secondary) 5 A (0.25–250 Ω secondary) 1 A	50	250
XGPOL[a]	Quad Ground Polarizing Quantity (I2, IG)	I2	I2
TANG[a]	Nonhomogeneous Correction Angle (–40.0 to +40.0 degrees)	–3	–3

[a] Make setting only when Group setting EADVS := Y.

Make *Table 10.37* settings when Group setting E21MG := 1–5 or E21XG := 1–5.

Table 10.37 Zero-Sequence Compensation Factor

Label	Prompt	Default Value
k0M1	Zone 1 Zero-Sequence Compensation Factor Magnitude (AUTO, 0.000–10)	0.726
k0A1	Zone 1 Zero-Sequence Compensation Factor Angle (–180.0 to +180.0 degrees)	–3.69
k0M[a]	Forward Zones Zero-Sequence Compensation Factor Magnitude (0.000–10)	0.726
k0A[a]	Forward Zones Zero-Sequence Compensation Factor Angle (–180.0 to +180.0 degrees)	–3.69
k0MR[a]	Reverse Zones Zero-Sequence Compensation Factor Magnitude (0.000–10)	0.726
k0AR[a]	Reverse Zones Zero-Sequence Compensation Factor Angle (–180.0 to +180.0 degrees)	–3.69

[a] Make setting only when Group setting EADVS := Y.

The number of pickup settings in *Table 10.38* is dependent on Group settings E21G := 1–5 and E21XG := 1–5, and the settings made from *Table 10.35* and *Table 10.36*.

Table 10.38 Ground Distance Element Time Delay

Label	Prompt	Default Value
Z1GD	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	0.000
Z2GD	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	20.000
Z3GD	Zone 3 Time Delay (OFF, 0.000–16000 cycles)	60.000
Z4GD	Zone 4 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z5GD	Zone 5 Time Delay (OFF, 0.000–16000 cycles)	OFF

Make *Table 10.39* settings only when Group setting ECDTD := Y; the number of settings is dependent on Group settings E21P := 1–5, E21G := 1–5, and E21XG := 1–5, and the settings made from *Table 10.32*, *Table 10.35* and *Table 10.36*.

Table 10.39 Distance Element Common Time Delay

Label	Prompt	Default Value
Z1D	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	0.000
Z2D	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	20.000
Z3D	Zone 3 Time Delay (OFF, 0.000–16000 cycles)	60.000
Z4D	Zone 4 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z5D	Zone 5 Time Delay (OFF, 0.000–16000 cycles)	OFF

Make *Table 10.40* settings when Group setting ESOTF := Y.

Table 10.40 Switch-Onto-Fault Scheme

Label	Prompt	Default Value
ESPSTF	Single-Pole Switch-Onto-Fault (Y, N)	N
EVRST	Switch-Onto-Fault Voltage Reset (Y, N)	N
52AEND	52A Pole Open Time Delay (OFF, 0.000–16000 cycles)	10.000
CLOEND	CLSMON or Single Pole Open Delay (OFF, 0.000–16000 cycles)	OFF
SOTFD	Switch-Onto-Fault Enable Duration (0.500–16000 cycles)	10.000
CLSMON	Close Signal Monitor (SELOGIC Equation)	NA

Make *Table 10.41* settings only when Group setting EOOS := Y; the number of settings is dependent on Group settings E21P := 1–5 and E21G := 1–5.

Table 10.41 Out-of-Step Tripping/Blocking (Sheet 1 of 2)

		Default Value	
Label	Prompt	5 A	1 A
OOSB1	Block Zone 1 (Y, N)	Y	Y
OOSB2	Block Zone 2 (Y, N)	Y	Y
OOSB3	Block Zone 3 (Y, N)	Y	Y
OOSB4	Block Zone 4 (Y, N)	N	N
OOSB5	Block Zone 5 (Y, N)	N	N
OSBD	Out-of-Step Block Time Delay (0.500–8000 cycles)	2.000	2.000
OSBLTCH	Latch Out-of-Step Blocking (Y, N)	N	N
EOOST	Out-of-Step Tripping (N, I, O)	N	N
OSTD	Out-of-Step Trip Delay (0.500–8000 cycles)	0.500	0.500
X1T7	Zone 7 Reactance—Top (0.05 to 96 Ω secondary) 5 A (0.25 to 480 Ω secondary) 1 A	23.0	115
X1T6	Zone 6 Reactance—Top (0.05 to 96 Ω secondary) 5 A (0.25 to 480 Ω secondary) 1 A	21.0	105
R1R7	Zone 7 Resistance—Right (0.05 to 70 Ω secondary) 5 A (0.25 to 350 Ω secondary) 1 A	23.0	115
R1R6	Zone 6 Resistance—Right (0.05 to 70 Ω secondary) 5 A (0.25 to 350 Ω secondary) 1 A	21.0	105
X1B7[a]	Zone 7 Reactance—Bottom (–0.05 to–96 Ω secondary) 5 A (–0.25 to–480 Ω secondary) 1 A	–23.0	–115
X1B6[a]	Zone 6 Reactance—Bottom (–0.05 to–96 Ω secondary) 5 A (–0.25 to–480 Ω secondary) 1 A	–21.0	–105

Table 10.41 Out-of-Step Tripping/Blocking (Sheet 2 of 2)

Label	Prompt	Default Value 5 A	Default Value 1 A
R1L7[a]	Zone 7 Resistance—Left (–0.05 to–70 Ω secondary) 5 A (–0.25 to–350 Ω secondary) 1 A	–23.0	–115
R1L6[a]	Zone 6 Resistance—Left (–0.05 to–70 Ω secondary) 5 A (–0.25 to–350 Ω secondary) 1 A	–21.0	–105
50ABCP[a]	Positive-Sequence Current Supervision (1.00–100 A secondary) 5 A (0.20–20 A secondary) 1 A	1	0.2
50QUBP[a]	Negative-Sequence Current Supervision (OFF, 0.50–100 A secondary) 5 A (OFF, 0.10–20 A secondary) 1 A	OFF	OFF
UBD[a]	Negative-Sequence Current Unblock Delay (0.500–120 cycles)	0.500	0.500
UBOSBF[a]	Out-of-Step Angle Unblock Rate (1–10)	4	4

[a] Make setting only when Group setting EADVS := Y.

Make *Table 10.42* settings when Group setting ELOAD := Y.

Table 10.42 Load Encroachment

Label	Prompt	Default Value 5 A	Default Value 1 A
ZLF	Forward Load Impedance (0.05–64 Ω secondary) 5 A (0.25–320 Ω secondary) 1 A	9.22	46.1
ZLR	Reverse Load Impedance (0.05–64 Ω secondary) 5 A (0.25–320 Ω secondary) 1 A	9.22	46.1
PLAF	Forward Load Positive Angle (–90 to +90 degrees)	30.0	30.0
NLAF	Forward Load Negative Angle (–90 to +90 degrees)	–30.0	–30.0
PLAR	Reverse Load Positive Angle (+90 to +270 degrees)	150.0	150.0
NLAR	Reverse Load Negative Angle (+90 to +270 degrees)	210.0	210.0

The number of pickup settings in *Table 10.43* is dependent on Group setting E50P := 1–4. When E50P := N, no settings are made for *Table 10.43* through *Table 10.45*.

Table 10.43 Phase Instantaneous Overcurrent Pickup

Label	Prompt	Default Value	
50P1P	Level 1 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	10.0	2
50P2P	Level 2 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF
50P3P	Level 3 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF
50P4P	Level 4 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF

Make corresponding zone *n* = 1–4 settings in *Table 10.44* and *Table 10.45* for any 50P*n*P settings that are made in *Table 10.43*.

Table 10.44 Phase Definite-Time Overcurrent Time Delay

Label	Prompt	Default Value
67P1D	Level 1 Time Delay (0.000–16000 cycles)	0.000
67P2D	Level 2 Time Delay (0.000–16000 cycles)	0.000
67P3D	Level 3 Time Delay (0.000–16000 cycles)	0.000
67P4D	Level 4 Time Delay (0.000–16000 cycles)	0.000

Table 10.45 Phase Instantaneous Definite-Time Overcurrent Torque Control[a]

Label	Prompt	Default Value
67P1TC	Level 1 Torque Control (SELOGIC Equation)	1
67P2TC	Level 2 Torque Control (SELOGIC Equation)	1
67P3TC	Level 3 Torque Control (SELOGIC Equation)	1
67P4TC	Level 4 Torque Control (SELOGIC Equation)	1

[a] These settings cannot be set to NA or to logical 0.

The number of pickup settings in *Table 10.46* is dependent on Group setting E50G := 1–4. When E50G := N, no settings are made for *Table 10.46* through *Table 10.48*.

Table 10.46 Residual Ground Instantaneous Overcurrent Pickup (Sheet 1 of 2)

Label	Prompt	Default Value 5 A	Default Value 1 A
50G1P	Level 1 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF
50G2P	Level 2 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF

Table 10.46 Residual Ground Instantaneous Overcurrent Pickup (Sheet 2 of 2)

Label	Prompt	Default Value 5 A	Default Value 1 A
50G3P	Level 3 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF
50G4P	Level 4 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF

Make corresponding zone *n* = 1–4 settings in *Table 10.47* and *Table 10.48* for any 50G*n*P settings that are made in *Table 10.46*.

Table 10.47 Residual Ground Definite-Time Overcurrent Time Delay

Label	Prompt	Default Value
67G1D	Level 1 Time Delay (0.000–16000 cycles)	0.000
67G2D	Level 2 Time Delay (0.000–16000 cycles)	0.000
67G3D	Level 3 Time Delay (0.000–16000 cycles)	0.000
67G4D	Level 4 Time Delay (0.000–16000 cycles)	0.000

Table 10.48 Residual Ground Instantaneous Definite-Time Overcurrent Torque Control[a]

Label	Prompt	Default Value
67G1TC	Level 1 Torque Control (SELOGIC Equation)	1
67G2TC	Level 2 Torque Control (SELOGIC Equation)	1
67G3TC	Level 3 Torque Control (SELOGIC Equation)	1
67G4TC	Level 4 Torque Control (SELOGIC Equation)	1

[a] These settings cannot be set to NA or to logical 0.

The number of pickup settings in *Table 10.49* is dependent on Group setting E50Q := 1–4. When E50Q := N, no settings are made for *Table 10.49* through *Table 10.51*.

Table 10.49 Negative-Sequence Instantaneous Overcurrent Pickup

Label	Prompt	Default Value 5 A	Default Value 1 A
50Q1P	Level 1 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF
50Q2P	Level 2 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF
50Q3P	Level 3 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF
50Q4P	Level 4 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF

Make corresponding zone *n* = 1–4 settings in *Table 10.50* and *Table 10.51* for any 50Q*n*P settings that are made in *Table 10.49*.

Table 10.50 Negative-Sequence Definite-Time Overcurrent Time Delay

Label	Prompt	Default Value
67Q1D	Level 1 Time Delay (0.000–16000 cycles)	0.000
67Q2D	Level 2 Time Delay (0.000–16000 cycles)	0.000
67Q3D	Level 3 Time Delay (0.000–16000 cycles)	0.000
67Q4D	Level 4 Time Delay (0.000–16000 cycles)	0.000

Table 10.51 Negative-Sequence Instantaneous Definite-Time Overcurrent Torque Control[a]

Label	Prompt	Default Value
67Q1TC	Level 1 Torque Control (SELOGIC Equation)	1
67Q2TC	Level 2 Torque Control (SELOGIC Equation)	1
67Q3TC	Level 3 Torque Control (SELOGIC Equation)	1
67Q4TC	Level 4 Torque Control (SELOGIC Equation)	1

[a] These settings cannot be set to NA or to logical 0.

Make *Table 10.52* settings if Group setting E51S := 1–3.

Table 10.52 Selectable Operating Quantity Inverse Time Overcurrent Element 1

Label	Prompt	Default Value 5 A	Default Value 1 A
51S1O	51S1 Operating Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0*n*)[a]	3I0L	3I0L
51S1P	51S1 Overcurrent Pickup (0.25–16 A secondary) 5 A (0.05–3.2 A secondary) 1 A	0.75	0.15
51S1C	51S1 Inverse Time Overcurrent Curve (U1–U5) US (C1–C5) IEC	U3	U3
51S1TD	51S1 Inverse Time Overcurrent Time Dial (0.50–15.00) US (0.05–1.00) IEC	1.0	1.0
51S1RS	51S1 Inverse Time Overcurrent Electromagnetic Reset (Y, N)	N	N
51S1TC[b]	51S1 Torque Control (SELOGIC Equation)	32GF	32GF

[a] Parameter n = L for line, 1 for BK1, and 2 for BK2.
[b] This setting cannot be set to NA or to logical 0.

Make *Table 10.53* settings if Group setting E51S := 2 or 3.

Table 10.53 Selectable Operating Quantity Inverse Time Overcurrent Element 2

Label	Prompt	Default Value 5 A	Default Value 1 A
51S2O	51S2 Operating Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0*n*)[a]	3I2L	3I2L
51S2P	51S2 Overcurrent Pickup (0.25–16 A secondary) 5 A (0.05–3.2 A secondary) 1 A	5.00	1.00
51S2C	51S2 Inverse Time Overcurrent Curve (U1–U5) US (C1–C5) IEC	U3	U3
51S2TD	51S2 Inverse Time Overcurrent Time Dial (0.50–15.00) (0.05–1.00) IEC	1.0	1.0
51S2RS	51S2 Inverse Time Overcurrent Electromagnetic Reset (Y, N)	N	N
51S2TC[b]	51S2 Torque Control (SELOGIC Equation)	32QF	32QF

[a] Parameter n = L for line, 1 for BK1, 2 for BK2.
[b] This setting cannot be set to NA or to logical 0.

Make *Table 10.54* settings if Group setting E51S := 3.

Table 10.54 Selectable Operating Quantity Inverse Time Overcurrent Element 3

Label	Prompt	Default Value 5 A	Default Value 1 A
51S3O	51S3 Operating Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0*n*)[a]	IMAXL	IMAXL
51S3P	51S3 Overcurrent Pickup (0.25–16 A secondary) 5 A (0.05–3.2 A secondary) 1 A	5.00	1.00
51S3C	51S3 Inverse Time Overcurrent Curve (U1–U5) US (C1–C5) IEC	U3	U3
51S3TD	51S3 Inverse Time Overcurrent Time Dial (0.50–15.00) US (0.05–1.00) IEC	1.0	1.0
51S3RS	51S3 Inverse Time Overcurrent Electromagnetic Reset (Y, N)	N	N
51S3TC[b]	51S3 Torque Control (SELOGIC Equation)	M2P	M2P

[a] Parameter n = L for line, 1 for BK1, 2 for BK2.
[b] This setting cannot be set to NA or to logical 0.

Make *Table 10.55* settings if any of the Group settings E21P, E21G, E21XG, E50P, E50G or E50Q := 3, 4, or 5.

Table 10.55 Zone/Level Direction

Label	Prompt	Default Value
DIR3	Zone/Level 3 Directional Control (F, R)	R
DIR4	Zone/Level 4 Directional Control (F, R)	F
DIR5	Zone/Level 5 Directional Control (F, R)	F

Table 10.56 Directional Control Element

Label	Prompt	Default Value 5 A	Default Value 1 A
ORDER	Ground Directional Element Priority (combine Q, V, I)	QV	QV
50FP[a]	Forward Directional Overcurrent Pickup (0.25–5 A secondary) 5 A (0.05–1 A secondary) 1 A	0.60	0.12
50RP[a]	Reverse Directional Overcurrent Pickup (0.25–5 A secondary) 5 A (0.05–1 A secondary) 1 A	0.40	0.08
Z2F[a]	Forward Directional Z2 Threshold (–64.00 to +64.00 Ω secondary) 5 A (–320.00 to +320.00 Ω secondary) 1 A	3.90	19.50
Z2R[a]	Reverse Directional Z2 Threshold (–64.00 to +64.00 Ω secondary) 5 A (–320.00 to +320.00 Ω secondary) 1 A	4.00	22.00
a2[a]	Positive-Sequence Restraint Factor, I2/I1 (0.02–0.50)	0.10	0.10
k2[a]	Zero-Sequence Restraint Factor, I2/I0 (0.10–1.20)	0.20	0.20
Z0F[a]	Forward Directional Z0 Threshold (–64.00 to +64.00 Ω secondary) 5 A (–320.00 to +320.00 Ω secondary) 1 A	12.40	62.00
Z0R[a]	Reverse Directional Z0 Threshold (–64.00 to +64.00 Ω secondary) 5 A (–320.00 to +320.00 Ω secondary) 1 A	12.50	62.50
a0[a]	Positive-Sequence Restraint Factor, I0/I1 (0.02–0.5)	0.10	0.10
E32IV	Zero-Sequence Voltage and Current Enable (SELOGIC Equation)	1	1

[a] Make setting only when Group setting E32 := Y. Setting automatically calculated when E32 := AUTO.

Table 10.57 Pole Open Detection

Label	Prompt	Default Value
EPO	Pole Open Detection (52, V)	52
27PO	Undervoltage Pole Open Threshold (1–200 V)	40
SPOD	Single Pole Open Dropout Delay (0.000–60 cycles)	0.500
3POD	Three Pole Open Dropout Delay (0.000–60 cycles)	0.500

Make *Table 10.58* settings if Group setting ECOMM := POTT, POTT2, POTT3, DCUB1, or DCUB2. Some settings are not required for every mode (see *Table 1.67*, *Table 1.69*, and *Table 1.71* for details).

Table 10.58 POTT Trip Scheme

Label	Prompt	Default Value
Z3RBD	Zone 3 Reverse Block Time Delay (0.000–16000 cycles)	5.000
EBLKD	Echo Block Time Delay (OFF, 0.000–16000 cycles)	10.000
ETDPU	Echo Time Delay Pickup (OFF, 0.000–16000 cycles)	2.000
EDURD	Echo Duration Time Delay (0.000–16000 cycles)	4.000
EWFC	Weak Infeed Trip (Y, N, SP)	N
27PWI	Weak Infeed Phase Undervoltage Pickup (1.0–200 V secondary)	47
27PPW	Weak Infeed Phase-to-Phase Undervoltage Pickup (1.0–300 V secondary)	80
59NW	Weak Infeed Zero-Sequence Overvoltage Pickup (1.0–200 V secondary)	5
PT1	General Permissive Trip Received (SELOGIC Equation)	IN102 AND PLT02
PT3	Three-Pole Permissive Trip Received (SELOGIC Equation)	NA
PTA	A-Phase Permissive Trip Received (SELOGIC Equation)	NA
PTB	B-Phase Permissive Trip Received (SELOGIC Equation)	NA
PTC	C-Phase Permissive Trip Received (SELOGIC Equation)	NA

Make *Table 10.59* settings if Group setting ECOMM := DCUB1 or DCUB2.

Table 10.59 DCUB Trip Scheme

Label	Prompt	Default Value
GARD1D	Guard Present Security Delay (0.000–16000 cycles)	120.000
UBDURD	DCUB Disabling Time Delay (0.000–16000 cycles)	180.000
UBEND	DCUB Duration Time Delay (0.000–16000 cycles)	20.000
PT2	Channel 2 Permissive Trip Received (SELOGIC Equation)	NA
LOG1	Channel 1 Loss-of-Guard (SELOGIC Equation)	NA
LOG2	Channel 2 Loss-of-Guard (SELOGIC Equation)	NA

Make *Table 10.60* settings if Group setting ECOMM := DCB.

Table 10.60 DCB Trip Scheme (Sheet 1 of 2)

Label	Prompt	Default Value
Z3XPU	Zone 3 Reverse Pickup Time Delay (0.000–16000 cycles)	1.000
Z3XD	Zone 3 Reverse Dropout Delay (0.000–16000 cycles)	6.000
BTXD	Block Trip Receive Extension Time (0.000–16000 cycles)	1.000
21SD	Zone 2 Distance Short Delay (0.000–16000 cycles)	2.000

Table 10.60 DCB Trip Scheme (Sheet 2 of 2)

Label	Prompt	Default Value
67SD	Level 2 Overcurrent Short Delay (0.000–16000 cycles)	2.000
BT	Block Trip Received (SELOGIC Equation)	NA

Make *Table 10.61* settings if Group settings EBFL1 := 1 or 2, or EBFL2 := 1 or 2.

Table 10.61 Breaker 1 Failure Logic (and Breaker 2 Failure Logic[a]) (Sheet 1 of 2)

Label	Prompt	Default Value 5 A	Default Value 1 A
50FP1	Phase Fault Current Pickup—BK1 (0.50–50 A secondary) 5 A (0.10–10 A secondary) 1 A	6.00	1.20
BFPU1	Breaker Failure Time Delay—BK1 (0.000–6000 cycles)	9.000	9.000
SPBFPU1[b]	Single-Pole Trip Breaker Failure Time Delay—BK1 (0.000–6000 cycles)	6.000	6.000
RTPU1	Retrip Time Delay—BK1 (0.000–6000 cycles)	3.000	3.000
RT3PPU1[b]	Three-Pole Retrip Time Delay—BK1 (0.000–6000 cycles)	3.000	3.000
BFI3P1	Three-Pole Breaker Failure Initiate—BK1 (SELOGIC Equation)	NA	NA
BFIA1	A-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)	NA	NA
BFIB1	B-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)	NA	NA
BFIC1	C-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)	NA	NA
BFIDO1	Breaker Fail Initiate Dropout Delay—BK1 (0.000–1000 cycles)	1.500	1.500
BFISP1	Breaker Fail Initiate Seal-in Delay—BK1 (0.000–1000 cycles)	2.000	2.000
ENCBF1	No Current/Residual Current Logic—BK1 (Y, N)	N	N
50RP1	Residual Current Pickup—BK1 (0.25–50 A secondary) 5 A (0.05–10 A secondary) 1 A	1.00	0.20
NPU1	No Current Breaker Failure Delay—BK1 (0.000–6000 cycles)	12.000	12.000
BFIN1	No Current Breaker Failure Initiate—BK1 (SELOGIC Equation)	NA	NA
ELCBF1	Load Current Breaker Failure Logic—BK1 (Y, N)	N	N
50LP1	Phase Load Current Pickup—BK (0.25–50 A secondary) 5 A (0.05–10 A secondary) 1 A	0.50	0.10
LCPU1	Load Pickup Time Delay—BK1 (0.000–6000 cycles)	9.000	9.000
BFILC1	Breaker Failure Load Current Initiate—BK1 (SELOGIC Equation)	NA	NA

Table 10.61 Breaker 1 Failure Logic (and Breaker 2 Failure Logic[a]) (Sheet 2 of 2)

Label	Prompt	Default Value 5 A	Default Value 1 A
EFOBF1	Flashover Breaker Failure Logic—BK1 (Y, N)	N	N
50FO1	Flashover Current Pickup—BK1 (0.25–50 A secondary) 5 A (0.05–10 A secondary) 1 A	0.50	0.10
FOPU1	Flashover Time Delay—BK1 (0.000–6000 cycles)	9.000	9.000
BLKFOA1	Block A-Phase Flashover—BK1 (SELOGIC Equation)	NA	NA
BLKFOB1	Block B-Phase Flashover—BK1 (SELOGIC Equation)	NA	NA
BLKFOC1	Block C-Phase Flashover—BK1 (SELOGIC Equation)	NA	NA
BFTR1	Breaker Failure Trip—BK1 (SELOGIC Equation)	NA	NA
BFULTR1	Breaker Failure Unlatch Trip—BK1 (SELOGIC Equation)	NA	NA

[a] Replace 1 with 2 in the setting label.
[b] Make setting when EBFL1 := 2 or EBFL2 := 2.

Make *Table 10.62* settings if Group settings E25BK1 := Y or E25BK2 := Y.

Table 10.62 Synchronism Check Element Reference

Label	Prompt	Default Value
SYNCP	Synchronism Reference (VAY, VBY, VCY, VAZ, VBZ, VCZ)	VAY
25VL	Voltage Window Low Threshold (20.0–200 V secondary)	55.0
25VH	Voltage Window High Threshold (20.0–200 V secondary)	70.0

Make *Table 10.63* settings if Group setting E25BK1 := Y.

Table 10.63 Breaker 1 Synchronism Check

Label	Prompt	Default Value
SYNCS1	Synchronism Source 1 (VAY, VBY, VCY, VAZ, VBZ, VCZ)	VAZ
KS1M	Synchronism Source 1 Ratio Factor (0.10–3)	1.00
KS1A	Synchronism Source 1 Angle Shift (0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, 330 degrees)	0
25SFBK1	Maximum Slip Frequency—BK1 (OFF, 0.005–0.5 Hz)	0.050
ANG1BK1	Maximum Angle Difference 1—BK1 (3.0–80 degrees)	10.0
ANG2BK1	Maximum Angle Difference 2—BK1 (3.0–80 degrees)	10.0
TCLSBK1	Breaker 1 Close Time (1.00–30 cycles)[a]	8.00
BSYNBK1	Block Synchronism Check—BK1 (SELOGIC Equation)	NA

[a] Adjust setting TCLSBK1 in 0.25-cycle steps.

Make *Table 10.64* settings if Group setting E25BK2 := Y.

Table 10.64 Breaker 2 Synchronism Check

Label	Prompt	Default Value
SYNCS2	Synchronism Source 2 (VAY, VBY, VCY, VAZ, VBZ, VCZ)	VBZ
KS2M	Synchronism Source 2 Ratio Factor (0.10–3)	1.00
KS2A	Synchronism Source 2 Angle Shift (0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, 330 degrees)	0
ALTS2	Alternative Synchronism Source 2 (SELOGIC Equation)	NA
ASYNCS2	Alternative Synchronism Source 2 (VAY, VBY, VCY, VAZ, VBZ, VCZ)	VCZ
AKS2M	Alternative Synchronism Source 2 Ratio Factor (0.10–3)	1.00
AKS2A	Alternative Synchronism Source 2 Angle Shift (0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, 330 degrees)	0
25SFBK2	Maximum Slip Frequency—BK2 (OFF, 0.005–0.5 Hz)	0.050
ANG1BK2	Maximum Angle Difference 1—BK2 (3.0–80 degrees)	10.0
ANG2BK2	Maximum Angle Difference 2—BK2 (3.0–80 degrees)	10.0
TCLSBK2	Breaker 2 Close Time (1.00–30 cycles)[a]	8.00
BSYNBK2	Block Synchronism Check—BK2 (SELOGIC Equation)	NA

[a] Adjust setting TCLSBK2 in 0.25-cycle steps.

Make *Table 10.65* through *Table 10.67* settings if Group settings E79 := Y or Y1 or EMANCL := Y. The number of settings also depends on the Global settings NUMBK := 1 or 2, BK1TYP := 1 or 3, and BK2TYP := 1 or 3.

Table 10.65 Recloser and Manual Closing[a] (Sheet 1 of 2)

Label	Prompt	Default Value
NSPSHOT	Number of Single-Pole Reclosures (N, 1, 2)	N
ESPR1	Single-Pole Reclose Enable—BK1 (SELOGIC Equation)	NA
ESPR2	Single-Pole Reclose Enable—BK2 (SELOGIC Equation)	NA
N3PSHOT	Number of Three-Pole Reclosures (N, 1–4)	2
E3PR1	Three-Pole Reclose Enable—BK1 (SELOGIC Equation)	PLT06
E3PR2	Three-Pole Reclose Enable—BK2 (SELOGIC Equation)	PLT06
TBBKD	Time Between Breakers for Automatic Reclose (1–99999 cycles)	300
BKCFD	Breaker Close Failure Delay (OFF, 1–99999 cycles)	300
SLBK1	Lead Breaker = Breaker 1 (SELOGIC Equation)	1
SLBK2	Lead Breaker = Breaker 2 (SELOGIC Equation)	NA

Table 10.65 Recloser and Manual Closing[a] (Sheet 2 of 2)

Label	Prompt	Default Value
FBKCEN	Follower Breaker Closing Enable (SELOGIC Equation)	1
ULCL1	Unlatch Closing for Breaker 1 (SELOGIC Equation)	52AA1 AND 52AB1 AND 52AC1
ULCL2	Unlatch Closing for Breaker 2 (SELOGIC Equation)	52AA2 AND 52AB2 AND 52AC2
79DTL	Recloser Drive to Lockout (SELOGIC Equation)	NA
79BRCT	Block Reclaim Timer (SELOGIC Equation)	NA
BK1MCL	Breaker 1 Manual Close (SELOGIC Equation)	
	8 pushbuttons	(CC1 OR PB7_PUL) AND PLT04
	12 pushbuttons	(CC1 OR PB11PUL) AND PLT04
	12 pushbuttons and auxiliary **TRIP/CLOSE** pushbuttons	CC1 AND PLT04
BK2MCL	Breaker 2 Manual Close (SELOGIC Equation)	NA
3PMRCD	Manual Close Reclaim Time Delay (1–99999 cycles)	900
BK1CLSD	BK1 Reclose Supervision Delay (OFF, 1–99999 cycles)	7200
BK2CLSD	BK2 Reclose Supervision Delay (OFF, 1–99999 cycles)	7200

[a] Adjust all timers in 1-cycle steps.

Table 10.66 Single-Pole Reclose Settings[a]

Label	Prompt	Default Value
SPOISC	Single-Pole Open Interval Supervision (SELOGIC Equation)[b]	1
SPOISD	Single-Pole Open Interval Supervision Delay (OFF, 1–99999 cycles)	1
SPOID	Single-Pole Open Interval Delay (1–99999 cycles)	60
SPRCD	Single-Pole Reclaim Time Delay (1–99999 cycles)	900
SPRI	Single-Pole Reclose Initiation (SELOGIC Equation)	SPT
SP1CLS	Single-Pole BK1 Reclose Supervision (SELOGIC Equation)[b]	1
SP2CLS	Single-Pole BK2 Reclose Supervision (SELOGIC Equation)[b]	1

[a] Adjust all timers in 1-cycle steps.
[b] These settings cannot be set to NA or to logical 0.

Table 10.67 Three-Pole Reclose Settings[a]

Label	Prompt	Default Value
3POISC	Three-Pole Open Interval Supervision (SELOGIC Equation)[b]	1
3POISD	Three-Pole Open Interval Supervision Delay (OFF, 1–99999 cycles)	1
3POID1	Three-Pole Open Interval 1 Delay (1–99999 cycles)	180
3POID2	Three-Pole Open Interval 2 Delay (1–99999 cycles)	180
3POID3	Three-Pole Open Interval 3 Delay (1–99999 cycles)	180
3POID4	Three-Pole Open Interval 4 Delay (1–99999 cycles)	180
3PFARC	Three-Pole Fast Automatic Reclose Enable (SELOGIC Equation)	NA
3PFOID	Three-Pole Fast Open Interval Delay (1–99999 cycles)	60
3PRCD	Three-Pole Reclaim Time Delay (1–99999 cycles)	900
3PRI	Three-Pole Reclose Initiation (SELOGIC Equation)	3PT AND NOT (M2PT OR Z2GT OR M3PT OR Z3GT OR SOTFT)
79SKP	Skip Reclosing Shot (SELOGIC Equation)	NA
3PRIH	Three-Pole Line Open Failure Delay (OFF, 1–99999)	15
3P1CLS	Three Pole BK 1 Reclose Supervision (SELOGIC Equation)[b]	1
3P2CLS	Three Pole BK 2 Reclose Supervision (SELOGIC Equation)[b]	1

[a] Adjust all timers in 1-cycle steps.
[b] These settings cannot be set to NA or to logical 0.

Make *Table 10.68* settings if Group settings E79 := Y or Y1 or EMANCL := Y.

Table 10.68 Voltage Elements

Label	Prompt	Default Value
EVCK	Reclosing Voltage Check (Y, N)	N
27LP	Dead Line Voltage (1.0–200 V secondary)	14.0
59LP	Live Line Voltage (1.0–200 V secondary)	53.0
27BK1P	Breaker 1 Dead Busbar Voltage (1.0–200 V secondary)	14.0
59BK1P	Breaker 1 Live Busbar Voltage (1.0–200 V secondary)	53.0
27BK2P	Breaker 2 Dead Busbar Voltage (1.0–200 V secondary)	14.0
59BK2P	Breaker 2 Live Busbar Voltage (1.0–200 V secondary)	53.0

Make *Table 10.69* settings if Group setting EDEM := THM or ROL.

Table 10.69 Demand Metering

Label	Prompt	Default Value 5 A	Default Value 1 A
DMTC	Demand Metering Time Constant (5, 10, . . . , 300 minutes)	15	15
PDEMP	Phase Current Pickup (OFF, 0.50–16 A secondary) 5 A (OFF, 0.10–3.2 A secondary) 1 A	OFF	OFF
GDEMP	Residual Ground Current Pickup (OFF, 0.50–16 A secondary) 5 A (OFF, 0.10–3.2 A secondary) 1 A	OFF	OFF
QDEMP	Negative-Sequence Current Pickup (OFF, 0.50–16 A secondary) 5 A (OFF, 0.10–3.2 A secondary) 1 A	OFF	OFF

Table 10.70 Trip Logic (Sheet 1 of 2)

Label	Prompt	Default Value
TR	Trip (SELOGIC Equation)	M1P OR Z1G OR M2PT OR Z2GT
TRCOMM	Communications-Assisted Trip (SELOGIC Equation)	(M2P OR Z2G) AND PLT02
TRSOTF	Switch-Onto-Fault Trip (SELOGIC Equation)	50P1 OR M2P OR Z2G
DTA	Direct Transfer Trip A-Phase (SELOGIC Equation)	NA
DTB	Direct Transfer Trip B-Phase (SELOGIC Equation)	NA
DTC	Direct Transfer Trip C-Phase (SELOGIC Equation)	NA
BK1MTR	Breaker 1 Manual Trip—BK1 (SELOGIC Equation)	
	8 pushbuttons	OC1 OR PB8_PUL
	12 pushbuttons	OC1 OR PB12PUL
	12 pushbuttons and auxiliary TRIP/CLOSE pushbuttons	OC1
BK2MTR	Breaker 2 Manual Trip—BK2 (SELOGIC Equation)	NA
ULTR	Unlatch Trip (SELOGIC Equation)	TRGTR
ULMTR1	Unlatch Manual Trip—BK1 (SELOGIC Equation)	NOT (52AA1 AND 52AB1 AND 52AC1)
ULMTR2	Unlatch Manual Trip—BK2 (SELOGIC Equation)	1
TOPD	Trip During Open Pole Time Delay (2.000–8000 cycles)	2.000
TULO	Trip Unlatch Option (1, 2, 3, 4)	3
Z2GTSP	Zone 2 Ground Distance Time Delay for Single-Pole Tripping (Y, N)	N
67QGSP	Zone 2 Directional Negative-Sequence/ Residual Overcurrent Single-Pole Trip (Y, N)	N

Table 10.70 Trip Logic (Sheet 2 of 2)

Label	Prompt	Default Value
TDUR1D	Single-Pole Trip Minimum Trip Duration Time Delay (2.000–8000 cycles)	6.000
TDUR3D	Three-Pole Trip Minimum Trip Duration Time Delay (2.000–8000 cycles)	12.000
E3PT	Three-Pole Trip Enable (SELOGIC Equation)	1
E3PT1	Breaker 1 Three-Pole Trip (SELOGIC Equation)	1
E3PT2	Breaker 2 Three-Pole Trip (SELOGIC Equation)	1
ER	Event Report Trigger Equation (SELOGIC Equation)	R_TRIG M2P OR R_TRIG Z2G OR R_TRIG 51S1 OR R_TRIG M3P OR R_TRIG Z3G

Protection Free-Form SELOGIC Control Equations

Protection free-form SELOGIC control equations are in classes 1 through 6 corresponding to settings Groups 1 through Group 6 (see *Section 3: SELOGIC Control Equation Programming*).

Table 10.71 only shows the factory default protection free-form SELOGIC control equations. Up to 250 lines of free-form 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 R.3.11* for more information.

NOTE: See corresponding command descriptions SET L on page R.9.42 and SHO L on page R.9.46 to set or show the free-form Protection SELOGIC control equations.

Table 10.71 Protection Free-Form SELOGIC Control Equations

Label	Default Value
PLT02S	PB2_PUL AND NOT PLT02 # COMM SCHEME ENABLED
PLT02R	PB2_PUL AND PLT02
PLT04S	PB4_PUL AND NOT PLT04 # RELAY TEST MODE
PLT04R	PB4_PUL AND PLT04
PLT05S	PB5_PUL AND NOT PLT05 # MANUAL CLOSE ENABLED
PLT05R	PB5_PUL AND PLT05
PLT06S	PB6_PUL AND NOT PLT06 # RECLOSE ENABLED
PLT06R	PB6_PUL AND PLT06

Automation Free-Form SELOGIC Control Equations

NOTE: See corresponding command descriptions SET A on page R.9.40 and SHO A on page R.9.45 to set or show the Automation settings.

NOTE: The SEL-421-1 and the SEL-421-2 have a capacity of 100 lines of automation free-form SELOGIC control equations in one automation setting block.

Automation free-form SELOGIC control equations are in blocks 1 through 10 (see *Section 3: SELOGIC Control Equation Programming*).

The SEL-421 does not contain any automation free-form SELOGIC settings in the factory default settings.

The SEL-421 has a capacity of 100 lines of automation free-form SELOGIC control equations in each of 10 automation setting blocks. See *SELOGIC Control Equation Capacity on page R.3.11* for more information.

Output Settings

Table 10.72 Output Settings Categories

Settings	Reference
Main Board	*Table 10.73*
Interface Board #1	*Table 10.74*
Interface Board #2	*Table 10.75*
Communications Card Outputs	*Table 10.76*
MIRRORED BITS Transmit Equations	*Table 10.77*

NOTE: See corresponding command descriptions SET O on page R.9.42 and SHO O on page R.9.46 to set or show the Output settings.

Table 10.73 Main Board

Label	Prompt	Default Value
OUT101		(3PT OR TPA1) AND NOT PLT04 #THREE POLE TRIP
OUT102		(3PT OR TPA1) AND NOT PLT04 #THREE POLE TRIP
OUT103		BK1CL AND NOT PLT04#BREAKER CLOSE COMMAND
OUT104		KEY AND PLT02 AND NOT PLT04#KEY TX
OUT105		NA
OUT106		NA
OUT107		PLT04 #RELAY TEST MODE
OUT108		NOT (SALARM OR HALARM)

Make *Table 10.74* settings if interface board #1 is present.

Table 10.74 Interface Board #1

Label	Prompt	Default Value
OUT201		NA
•	•	•
•	•	•
•	•	•
OUT216		NA

Make *Table 10.75* settings if interface board #2 is present.

Table 10.75 Interface Board #2

Label	Prompt	Default Value
OUT301		NA
•	•	•
•	•	•
•	•	•
OUT316		NA

Make *Table 10.76* settings if a communications card is present.

Table 10.76 Communications Card Outputs

Label	Prompt	Default Value
CCOUT01		NA
•	•	•
•	•	•
•	•	•
CCOUT32		NA

Table 10.77 MIRRORED BITS Transmit Equations

Label	Prompt	Default Value
TMB1A		NA
•	•	•
•	•	•
•	•	•
TMB8A		NA
TMB1B		NA
•	•	•
•	•	•
•	•	•
TMB8B		NA

Front-Panel Settings

NOTE: See corresponding command descriptions SET F on page R.9.41 to set or show the Front-Panel settings.

Table 10.78 Front-Panel Settings Categories

Settings	Reference
Front-Panel Settings	*Table 10.79*
Selectable Screens for the Front Panel	*Table 10.80*
Selectable Operator Pushbuttons	*Table 10.81*
Front-Panel Event Display	*Table 10.82*
Local Control and Aliases	*Table 10.85*
Display Points and Aliases	
Boolean Display Points	*Table 10.83*
Analog Display Points	*Table 10.84*

Table 10.79 Front-Panel Settings (Sheet 1 of 5)

Label	Prompt	Default Value
FP_TO	Front-Panel Display Time-Out (OFF, 1–60 min)	15
EN_LEDC	Enable LED Asserted Color (R, G)	G
TR_LEDC	Trip LED Asserted Color (R, G)	R
PB1_LED	Pushbutton LED 1 (SELOGIC Equation)	NOT E3PT #SPT ENABLED
PB1_COL	PB_LED Assert and Deassert Color (Enter 2: R, G, A, O)	AO
PB2_LED	Pushbutton LED 2 (SELOGIC Equation)	PLT02 #COMM SCHEME ENABLED
PB2_COL	PB_LED Assert and Deassert Color (Enter 2: R, G, A, O)	AO
PB3_LED	Pushbutton LED 3 (SELOGIC Equation)	NOT SG1 #ALT SETTINGS
PB3_COL	PB_LED Assert and Deassert Color (Enter 2: R, G, A, O)	AO
PB4_LED	Pushbutton LED 4 (SELOGIC Equation)	PLT04 #RELAY TEST MODE
PB4_COL	PB_LED Assert and Deassert Color (Enter 2: R, G, A, O)	AO
PB5_LED	Pushbutton LED 5 (SELOGIC Equation)	PLT05 #MANUAL CLOSE ENABLED
PB5_COL	PB_LED Assert and Deassert Color (Enter 2: R, G, A, O)	AO
PB6_LED	Pushbutton LED 6 (SELOGIC Equation)	PLT06 #RECLOSE ENABLED
PB6_COL	PB_LED Assert and Deassert Color (Enter 2: R, G, A, O)	AO
PB7_LED	Pushbutton LED 7 (SELOGIC Equation)	52ACL1 AND 52AB1 AND 52AC1 #BREAKER CLOSED (8 Pushbuttons) 0#AUX (12 Pushbuttons)
PB7_COL	PB_LED Assert and Deassert Color (Enter 2: R, G, A, O)	AO

Table 10.79 Front-Panel Settings (Sheet 2 of 5)

Label	Prompt	Default Value
PB8_LED	Pushbutton LED 8 (SELOGIC Equation)	NOT (52ACL1 AND 52AB1 AND 52AC1) #BREAKER OPEN (8 Pushbuttons) 0#AUX (12 Pushbuttons)
PB8_COL	PB_LED Assert and Deassert Color (Enter 2: R, G, A, O)	AO
PB9_LED[a]	Pushbutton LED 9 (SELOGIC Equation)	0 #AUX
PB9_COL[a]	PB_LED Assert and Deassert Color (Enter 2: R, G, A, O)	AO
PB10LED[a]	Pushbutton LED 10 (SELOGIC Equation)	0 #AUX
PB10COL[a]	PB_LED Assert and Deassert Color (Enter 2: R, G, A, O)	AO
PB11LED[a]	Pushbutton LED 11 (SELOGIC Equation)	52ACL1 AND 52AB1 AND 52AC1 #BREAKER CLOSED 0 #AUX (Auxiliary TRIP/CLOSE Pushbuttons)
PB11COL[a]	PB_LED Assert and Deassert Color (Enter 2: R, G, A, O)	AO
PB12LED[a]	Pushbutton LED 12 (SELOGIC Equation)	NOT (52ACL1 AND 52AB1 AND 52AC1) #BREAKER OPEN 0 #AUX (Auxiliary TRIP/ CLOSE Pushbuttons)
PB12COL[a]	PB_LED Assert and Deassert Color (Enter 2: R, G, A, O)	AO
T1_LED	Target LED 1 (SELOGIC Equation)	(M1P OR Z1G) AND NOT (SOTFT OR TLED_3)
T1LEDL	Target LED 1 Latch (Y, N)	Y
T1LEDA	Target LED 1 Alias (8 characters)	INST
T1LEDC	T_LED Assert and Deassert Color (Enter 2: R, G, A, O)	RO
T2_LED	Target LED 2 (SELOGIC Equation)	(M2PT OR Z2GT OR M3PT OR Z3GT OR M4PT OR Z4GT) AND NOT (TLED_1 OR TLED_3 OR TLED_4)
T2LEDL	Target LED 2 Latch (Y, N)	Y
T2LEDA	Target LED 2 Alias (8 characters)	TIME
T2LEDC	T_LED Assert and Deassert Color (Enter 2: R, G, A, O)	RO
T3_LED	Target LED 3 (SELOGIC Equation)	COMPRM AND NOT (M1P OR Z1G OR TLED_1 OR SOTFT)
T3LEDL	Target LED 3 Latch (Y, N)	Y
T3LEDA	Target LED 3 Alias (8 characters)	COMM
T3LEDC	T_LED Assert and Deassert Color (Enter 2: R, G, A, O)	RO
T4_LED	Target LED 4 (SELOGIC Equation)	SOTFT

Table 10.79 Front-Panel Settings (Sheet 3 of 5)

Label	Prompt	Default Value
T4LEDL	Target LED 4 Latch (Y, N)	Y
T4LEDA	Target LED 4 Alias (8 characters)	SOTF
T4LEDC	T_LED Assert and Deassert Color (Enter 2: R, G, A, O)	RO
T5_LED	Target LED 5 (SELOGIC Equation)	(M1P OR Z1G) AND NOT (TLED_6 OR TLED_7 OR TLED_8)
T5LEDL	Target LED 5 Latch (Y, N)	Y
T5LEDA	Target LED 5 Alias (8 characters)	ZONE_1
T5LEDC	T_LED Assert and Deassert Color (Enter 2: R, G, A, O)	RO
T6_LED	Target LED 6 (SELOGIC Equation)	(M2P OR Z2G) AND NOT (M1P OR Z1G OR TLED_5)
T6LEDL	Target LED 6 Latch (Y, N)	N
T6LEDA	Target LED 6 Alias (8 characters)	ZONE_2
T6LEDC	T_LED Assert and Deassert Color (Enter 2: R, G, A, O)	RO
T7_LED	Target LED 7 (SELOGIC Equation)	(M3P OR Z3G) AND NOT (M1P OR M2P OR Z1G OR Z2G OR TLED_5 OR TLED_6)
T7LEDL	Target LED 7 Latch (Y, N)	N
T7LEDA	Target LED 7 Alias (8 characters)	ZONE_3
T7LEDC	T_LED Assert and Deassert Color (Enter 2: R, G, A, O)	RO
T8_LED	Target LED 8 (SELOGIC Equation)	(M4P OR Z4G) AND NOT (M1P OR M2P OR M3P OR Z1G OR Z2G OR Z3G OR TLED_5 OR TLED_6 OR TLED_7)
T8LEDL	Target LED 8 Latch (Y, N)	N
T8LEDA	Target LED 8 Alias (8 characters)	ZONE_4
T8LEDC	T_LED Assert and Deassert Color (Enter 2: R, G, A, O)	RO
T9_LED	Target LED 9 (SELOGIC Equation)	PHASE_A
T9LEDL	Target LED 9 Latch (Y, N)	Y
T9LEDA	Target LED 9 Alias (8 characters)	A_PHASE
T9LEDC	T_LED Assert and Deassert Color (Enter 2: R, G, A, O)	RO
T10_LED	Target LED 10 (SELOGIC Equation)	PHASE_B
T10LEDL	Target LED 10 Latch (Y, N)	Y
T10LEDA	Target LED 10 Alias (8 characters)	B_PHASE
T10LEDC	T_LED Assert and Deassert Color (Enter 2: R, G, A, O)	RO
T11_LED	Target LED 11 (SELOGIC Equation)	PHASE_C
T11LEDL	Target LED 11 Latch (Y, N)	Y

Table 10.79 Front-Panel Settings (Sheet 4 of 5)

Label	Prompt	Default Value
T11LEDA	Target LED 11 Alias (8 characters)	C_PHASE
T11LEDC	T_LED Assert and Deassert Color (Enter 2: R, G, A, O)	RO
T12_LED	Target LED 12 (SELOGIC Equation)	GROUND
T12LEDL	Target LED 12 Latch (Y, N)	Y
T12LEDA	Target LED 12 Alias (8 characters)	GROUND
T12LEDC	T_LED Assert and Deassert Color (Enter 2: R, G, A, O)	RO
T13_LED	Target LED 13 (SELOGIC Equation)	50P1 OR 50P2 OR 50P3 OR 50P4 OR 50Q1 OR 50Q2 OR 50Q3 OR 50Q4 OR 50G1 OR 50G2 OR 50G3 OR 50G4
T13LEDL	Target LED 13 Latch (Y, N)	Y
T13LEDA	Target LED 13 Alias (8 characters)	50
T13LEDC	T_LED Assert and Deassert Color (Enter 2: R, G, A, O)	RO
T14_LED	Target LED 14 (SELOGIC Equation)	51S1T OR 51S2T OR 51S3T
T14LEDL	Target LED 14 Latch (Y, N)	Y
T14LEDA	Target LED 14 Alias (8 characters)	51
T14LEDC	T_LED Assert and Deassert Color (Enter 2: R, G, A, O)	RO
T15_LED	Target LED 15 (SELOGIC Equation)	BK1RS
T15LEDL	Target LED 15 Latch (Y, N)	N
T15LEDA	Target LED 15 Alias (8 characters)	79_RESET
T15LEDC	T_LED Assert and Deassert Color (Enter 2: R, G, A, O)	RO
T16_LED	Target LED 16 (SELOGIC Equation)	BK1LO
T16LEDL	Target LED 16 Latch (Y, N)	N
T16LEDA	Target LED 16 Alias (8 characters)	79_LO
T16LEDC	T_LED Assert and Deassert Color (Enter 2: R, G, A, O)	RO
T17_LED[b]	Target LED 17 (SELOGIC Equation)	79CY1 OR 79CY3
T17LEDL[b]	Target LED 17 Latch (Y, N)	N
T17LEDA[b]	Target LED 17 Alias (8 characters)	79_CYCLE
T17LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R, G, A, O)	RO
T18_LED[b]	Target LED 18 (SELOGIC Equation)	25A1BK1
T18LEDL[b]	Target LED 18 Latch (Y, N)	N
T18LEDA[b]	Target LED 18 Alias (8 characters)	25_SYNCH
T18LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R, G, A, O)	RO

Table 10.79 Front-Panel Settings (Sheet 5 of 5)

Label	Prompt	Default Value
T19_LED[b]	Target LED 19 (SELOGIC Equation)	BK1CL
T19LEDL[b]	Target LED 19 Latch (Y, N)	N
T19LEDA[b]	Target LED 19 Alias (8 characters)	BK1_CLS
T19LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R, G, A, O)	RO
T20_LED[b]	Target LED 20 (SELOGIC Equation)	BFTRIP1
T20LEDL[b]	Target LED 20 Latch (Y, N)	N
T20LEDA[b]	Target LED 20 Alias (8 characters)	BK1_FAIL
T20LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R, G, A, O)	RO
T21_LED[b]	Target LED 21 (SELOGIC Equation)	OSB
T21LEDL[b]	Target LED 21 Latch (Y, N)	N
T21LEDA[b]	Target LED 21 Alias (8 characters)	OSB
T21LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R, G, A, O)	RO
T22_LED[b]	Target LED 22 (SELOGIC Equation)	LOP
T22LEDL[b]	Target LED 22 Latch (Y, N)	N
T22LEDA[b]	Target LED 22 Alias (8 characters)	LOP
T22LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R, G, A, O)	RO
T23_LED[b]	Target LED 23 (SELOGIC Equation)	PMDOK AND TSOK
T23LEDL[b]	Target LED 23 Latch (Y, N)	N
T23LEDA[b]	Target LED 23 Alias (8 characters)	PM_OK
T23LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R, G, A, O)	RO
T24_LED[b]	Target LED 24 (SELOGIC Equation)	TIRIG
T24LEDL[b]	Target LED 24 Latch (Y, N)	N
T24LEDA[b]	Target LED 24 Alias (8 characters)	IRIG_LCK
T24LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R, G, A, O)	RO

[a] PB9–PB12 settings are only available on 12 pushbutton models.
[b] T17–T24 settings are only available on 12 pushbutton models.

Table 10.80 Selectable Screens for the Front Panel (Sheet 1 of 2)

Label	Prompt	Default Value
SCROLD	Front-Panel Display Update Rate (OFF, 1–15 sec)[a]	5
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

Table 10.80 Selectable Screens for the Front Panel (Sheet 2 of 2)

Label	Prompt	Default Value
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

[a] Screens will not rotate when SCROLD := OFF; the first screen in the rotation order remains on the screen.

Table 10.81 Selectable Operator Pushbuttons

Label	Prompt	Default Value
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 10.82 Front-Panel Event Display

Label	Prompt	Default Value
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

[a] Setting is only available if DISP_ER := Y.
[b] Setting is only available if an operator pushbutton has been set to EVE.

Table 10.83 Boolean Display Points[a]

Label	Prompt	Default Value[b]
[Relay Word Bit Name]	Name of any element in element store	None
[Alias]	String of ASCII characters except double quotation marks[c]	None
[Set String]	String of ASCII characters except double quotation marks[c]	None
[Clear String]	String of ASCII characters except double quotation marks[c]	None
[Text Size}	S for single, D for double	S

[a] Relay Word Bit Name, "Alias," "Set String," "Clear String", "Text Size."
[b] The SEL-421 has no default values programmed for these settings.
[c] Total length of Boolean Display Point is 20 characters; 19 characters of ASCII string with 1 character reserved for an "=."

Table 10.84 Analog Display Points[a]

Label	Prompt	Default Value[b]
[Analog Quantity Name]	Name of any element in element store	None
[User Text]	String of ASCII characters except double quotation marks and {}[c]	None
[Formatting]	{total width.characters to right of decimal place, scaling factor}[d]	None
[User Text]	String of ASCII characters except double quotation marks and {}[c]	None
[Text Size]	S for single, D for double	S

[a] Analog Quantity Name, "User Text and Formatting", "Text Size."
[b] The SEL-421 has no default values programmed for these settings.
[c] Total length of Analog Display Point is 20 characters.
[d] See Display Points on page U.5.10 for examples of setting Analog Display Points.

Table 10.85 Local Control and Aliases[a]

Label	Prompt	Default Value
[Local Bit number]	Valid Local Bit number (LB01, for example)	None
[Alias Name]	String up to 20 printable ASCII characters except double quotation marks	None
[Alias for Set State]	String up to 20 printable ASCII characters except double quotation marks	None
[Alias for Clear State]	String up to 20 printable ASCII characters except double quotation marks	None
[Pulse Enable]	Pulse Local Bit (Y, N)	N

[a] Local Bit, Local Name, Local Set State, Local Clear State, Pulse Enable.

Table 10.86 Local Bit SELogic[a]

Label	Prompt	Default Value
LB_SP*mm*	Local Bit Supervision (SELogic Equation, NA)	1
LB_DP*mm*	Local Bit Status Display (SELogic Equation, NA)	LB*mm*

[a] Settings in Table 10.86 appear if the associated local bit is defined. If no local bits are defined, the whole category is hidden.

Report Settings

NOTE: See corresponding command descriptions SET R on page R.9.43 and SHO R on page R.9.47 to set or show the Report settings.

Table 10.87 Report Settings Categories

Settings	Reference
SER Chatter Criteria	*Table 10.88*
SER Points and Aliases	*Table 10.89*
Event Reporting	*Table 10.90*
Event Reporting Digital Elements	*Table 10.91*

Table 10.88 SER Chatter Criteria

Label	Prompt	Default Value
ESERDEL	Automatic Removal of Chattering SER Points (Y, N)	N
SRDLCNT[a]	Number of Counts Before Auto-Removal (2–20)	5
SRDLTIM[a]	Time for Auto-Removal (0.1–30 seconds)	1.0

[a] Setting is only available if ESERDEL := Y.

Table 10.89 SER Points and Aliases

Label	Prompt	Default Value
[Relay Word Bit]	Label of any element in element store	None
[Reporting Name]	Alphanumeric string up to 20 characters[a]	None
[Set State Name]	Alphanumeric string up to 20 characters[a]	Asserted
[Clear State Name]	Alphanumeric string up to 20 characters[a]	Deasserted
[HMI Alarm]	Y,N	N

[a] Allowed characters are all printable ASCII characters except double quotes.

Table 10.90 Event Reporting

Label	Prompt	Default Value
SRATE	Sample Rate of Event Report (1, 2, 4, 8 kHz)	2
LER	Length of Event Report (0.25–2.00 seconds); SRATE := 8	0.50
PRE	Length of Pre-Fault (0.05–1.95 seconds); SRATE := 8	0.10
LER	Length of Event Report (0.25–3.00 seconds); SRATE := 4	0.50
PRE	Length of Pre-Fault (0.05–2.95 seconds); SRATE := 4	0.10
LER	Length of Event Report (0.25–4.00 seconds); SRATE := 2	0.50
PRE	Length of Pre-Fault (0.05–3.95 seconds); SRATE := 2	0.10
LER	Length of Event Report (0.25–5.00 seconds); SRATE := 1	0.50
PRE	Length of Pre-Fault (0.05–4.95 seconds); SRATE := 1	0.10

Table 10.91 Event Reporting Digital Elements[a]

Label	Prompt	Default Value
[Relay Word Bit]	Name of any Relay Word bit, or OFF	Relay Word bits[b]

[a] 800 Relay Word bits maximum from 100 Rows maximum.
[b] See ACSELERATOR QuickSet **Report > Event Report Digitals** in the **Relay Editor Settings** tree view. The rows containing the following elements are always included as part of the 100 rows: 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, SPOA, SPOB, SPOC, FSA, FSB, FSC, M1P, M2P, M3P, M4P, M5P, 67Q1, 67Q2, 67Q3, 67Q4, 51S1, 51S2, 51S3, Z1G, Z2G, Z3G, Z4G, Z5G, 67G1, 67G2, 67G3, 67G4, RMBnA, TMBnA, RMBnB, TMBnB, ROKA, RBADA, CBADA, LBOKA, ROKB, RBADB, CBADB, LBOKB, TRIP TPϕ1, TPϕ2, 52ϕCL1, 52ϕCL2, BK1CL, BK2CL (n = 1–8, ϕ = A,B,C). For row descriptions see Appendix A: Relay Word Bits.

Port Settings

NOTE: See corresponding command descriptions SET P on page R.9.43 and SHO P on page R.9.47 to set or show the Port settings.

Table 10.92 Port Settings Categories

Settings	Reference
Protocol Selection	See *Table 10.93*.
Communications Settings	See *Table 10.94*.
SEL Protocol Settings	See *Table 10.95*.
DNP3 Protocol (Serial) Settings	See *Table 10.96*.
MIRRORED BITS Protocol Settings	See *Table 10.97*.
RTD Protocol Settings	See *Table 10.98*.
Ethernet Settings	See *Ethernet Network Operation Settings on page R.4.5*.
FTP Settings	See *FTP on page R.4.7*.
Telnet Settings	See *Telnet on page R.4.9*.
IEC 61850 Settings	See *Section 8: IEC 61850 Communications in the Reference Manual*.
PMU Protocol Settings	See *Table 10.99*.

Table 10.93 Protocol Selection

Label	Prompt	Default Value
EPORT[a]	Enable Port (Y, N)	Y
MAXACC[a]	Maximum Access Level (1, B, P, A, 0, 2, C)	C
PROTO	Protocol (SEL, DNP, MBA, MBB, RTD, PMU)	SEL

[a] Not available in SEL-421 or SEL-421-1.

Make *Table 10.94* settings if preceding setting PROTO ≠ RTD.

Table 10.94 Communications Settings (Sheet 1 of 2)

Label	Prompt	Default Value
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[d]	Parity (Odd, Even, None)	N

Table 10.94 Communications Settings (Sheet 2 of 2)

Label	Prompt	Default Value
STOPBIT[e]	Stop Bits (1, 2 bits)	1
RTSCTS[f]	Enable Hardware Handshaking (Y, N)	N

[a] For PROTO := MBA or MBB only.
[b] For PROTO := MBA or MBB, 57600 not available.
[c] SYNC option only available for PROTO := MBA or MBB, on rear-panel serial ports.
[d] For PROTO := SEL only
[e] For PROTO := SEL, MBA, MBB, or PMU only.
[f] For PROTO := SEL or PMU only.

Make *Table 10.95* settings if Port setting PROTO := SEL, DNP, or PMU.

Table 10.95 SEL Protocol Settings

Label	Prompt	Default Value
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[a]	Initial Delay-Disconnect Sequence (0–600 seconds)	1
TERSTRN[a]	Termination String-Disconnect Sequence (9 characters maximum)[d]	"\005"
TERTIM2[a]	Final Delay-Disconnect Sequence (0–600 seconds)	0

[a] Not required for PROTO := PMU.
[b] Not required for PROTO := DNP or PMU.
[c] Not required for PROTO := DNP.
[d] TERSTRN set at \005 is <Ctrl+E>.

Make *Table 10.96* settings if Port setting PROTO := DNP.

NOTE: In SEL-421 firmware version R112, Port Synchronized Phasor Measurement settings PMADDR and PMDATA were removed. The new Synchronized Phasor Measurement Settings are contained in Global Settings in Table 10.4 and Table 10.15. See Section 7: Synchrophasors for details.

Table 10.96 DNP3 Serial Port Protocol Settings (Sheet 1 of 2)

Label	Prompt	Default Value
DNPADR	DNP Address (0–65519)	0
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	Miscellaneous 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

Table 10.96 DNP3 Serial Port Protocol Settings (Sheet 2 of 2)

Label	Prompt	Default Value
PSTDLY	Settle Time-TX to RTS Off (0.00–30.00 seconds)	0.00
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
EVELOCK	Event Summary Lock Period (0–1000 seconds)	0
MINDIST[a]	Minimum Fault Location to Capture (OFF, -10000–10000)	OFF
MAXDIST[a]	Maximum Fault Location to Capture (OFF, -10000–10000)	OFF
ETIMEO	Event Data Confirmation Time-Out (0.1–100.0 seconds)	10.0
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 (0.0–60.0 seconds)	2.0
MODEM	Modem Connected to Port (Y, N)	N
MSTR	Modem Startup String (30 characters maximum)	“E0X0&D0S0=4”
PH_NUM	Phone Number for Dial-Out (30 characters maximum)	“”
MDTIME	Time to Attempt Dial (5–300 seconds)	60
MDRET	Time Between Dial-Out Attempts (5–3600 seconds)	120

[a] MAXDIST must be greater than MINDIST.

Make *Table 10.97* settings if Port setting PROTO := MBA or MBB.

Table 10.97 MIRRORED BITS Protocol Settings (Sheet 1 of 2)

Label	Prompt	Default Value
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

Table 10.97 MIRRORED BITS Protocol Settings (Sheet 2 of 2)

Label	Prompt	Default Value
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)	LIAFM
MBANA2	Selection for Analog Channel 2 (analog label)	LIBFM
MBANA3	Selection for Analog Channel 3 (analog label)	LICFM
MBANA4	Selection for Analog Channel 4 (analog label)	VAFM
MBANA5	Selection for Analog Channel 5 (analog label)	VBFM
MBANA6	Selection for Analog Channel 6 (analog label)	VCFM
MBANA7	Selection for Analog Channel 7 (analog label)	VABRMS
MBNUMVT	Number of Virtual Terminal Channels (OFF, 0–7)	OFF

Make *Table 10.98* settings if Port setting PROTO := RTD.

Table 10.98 RTD Protocol Settings

Label	Prompt	Default Value
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 10.99 PMU Protocol Settings

Label	Prompt	Default Value
PMUMODE	PMU Mode (CLIENTA, CLIENTB, SERVER)	SERVER
RTCID[a]	Remote PMU Hardware ID (1–65534)	1

[a] Setting hidden when PMUMODE := SERVER

DNP3 Settings—Serial Port

NOTE: See corresponding command descriptions SET D on page R.9.41 and SHO D on page R.9.45 to set or show the DNP3 settings.

Table 10.100 DNP3 Settings Categories

Settings	Reference
DNP Reference Map Selection	*Table 10.101*
DNP3 Object Default Map Enables	*Table 10.102*
Binary Input Map	*Table 10.103*
Binary Output Map	*Table 10.104*
Counter Map	*Table 10.105*
Analog Input Map	*Table 10.106*
Analog Output Map	*Table 10.107*

Table 10.101 DNP Reference Map Selection

Label	Prompt	Default Value
MAPSEL	Reference Map Selection (B, E)	B

Table 10.102 DNP3 Object Default Map Enables

Label	Prompt	Default Value
DNPBID	Use default DNP map for Binary Inputs (Y, N)	Y
DNPBOD	Use default DNP map for Binary Outputs (Y, N)	Y
DNPCOD	Use default DNP map for Counters (Y, N)	Y
DNPAID	Use default DNP map for Analog Inputs (Y, N)	Y
DNPAOD	Use default DNP map for Analog Outputs (Y, N)	Y

Make *Table 10.103* settings if preceding setting DNPBID := N.

Table 10.103 Binary Input Map

Label	Prompt	Default Value
BI_MAP*n*[a]	Index Number (Valid binary input index number)	

[a] Parameter n indicates the index number for row 1 to 400; see Configurable Data Mapping on page R.6.10.

Make *Table 10.104* settings if preceding setting DNPBOD := N.

Table 10.104 Binary Output Map

Label	Prompt	Default Value
BO_MAP*n*[a]	Index Number (Valid binary output index number)	

[a] Parameter n indicates the index number for row 1 to 70; see Configurable Data Mapping on page R.6.10.

Make *Table 10.105* settings if preceding setting DNPCOD := N.

Table 10.105 Counter Map

Label	Prompt	Default Value
CO_MAP*n*[a]	Index Number (Valid counter index number)	
CO_DBD*n*	Deadband (1–32767)	(ANADB*x*[b] port setting)

[a] Parameter n indicates the index number for row 1 to 10; see Configurable Data Mapping on page R.6.10.
[b] Parameter x is A, V, M representing currents, voltages, and miscellaneous, respectively.

Make *Table 10.106* settings if preceding setting DNPAID := N.

Table 10.106 Analog Input Map

Label	Prompt	Default Value
AI_MAP*n*[a]	Index Number (Valid analog input index number)	
AI_SCA*n*	Scale Factor (0.001–1000.000)	(DECPL*x*[b] port setting)
AI_DBD*n*	Deadband (1–32767)	(ANADB*x* port setting)

[a] Parameter n indicates the index number for row 1 to 200; see Configurable Data Mapping on page R.6.10.
[b] Parameter x is A, V, M representing currents, voltages, and miscellaneous, respectively.

Make *Table 10.107* settings if preceding setting DNPAOD := N.

Table 10.107 Analog Output Map

Label	Prompt	Default Value
AO_MAP*n*[a]	Index Number (Valid analog output index number)	

[a] Parameter n indicates the index number for row 1 or 2; see Configurable Data Mapping on page R.6.10.

Appendix A

Relay Word Bits

This section contains tables of the Relay Word bits available within the SEL-421 Relay. For information on using Relay Word bits in protection and automation, see the *Applications Handbook*.

Alphabetic

Use this appendix as a reference for Relay Word bit labels in this manual and as a resource for elements you use in SELOGIC® control equation relay settings. *Table A.1* lists the Relay Word bits in alphabetic order.

Table A.1 Alphabetic List of Relay Word Bits (Sheet 1 of 21)

Name	Description	Row
*	Reserved	
25A1BK1	Circuit Breaker 1 voltages within Synchronism Angle 1	30
25A1BK2	Circuit Breaker 2 voltages within Synchronism Angle 1	32
25A2BK1	Circuit Breaker 1 voltages within Synchronism Angle 2	31
25A2BK2	Circuit Breaker 2 voltages within Synchronism Angle 2	32
25ENBK1	Circuit Breaker 1 synchronism-check element enable	30
25ENBK2	Circuit Breaker 2 synchronism-check element enable	32
25W1BK1	Circuit Breaker 1 Angle 1 within Window 1	30
25W1BK2	Circuit Breaker 2 Angle 1 within Window 1	32
25W2BK1	Circuit Breaker 1 Angle 2 within Window 2	30
25W2BK2	Circuit Breaker 2 Angle 2 within Window 2	32
27APO	A-phase undervoltage, pole open	70
27AWI	A-phase undervoltage condition	50
27BPO	B-phase undervoltage, pole open	70
27BWI	B-phase undervoltage condition	50
27CPO	C-phase undervoltage, pole open	71
27CWI	C-phase undervoltage condition	50
2POBK1	Two poles open Circuit Breaker 1	40
2POBK2	Two poles open Circuit Breaker 2	40
32GF	Forward ground directional element	22
32GR	Reverse ground directional element	22
32IE	32I internal enable	21
32QE	32Q internal enable	21
32QF	Forward negative-sequence overcurrent directional declaration	20

Table A.1 Alphabetic List of Relay Word Bits (Sheet 2 of 21)

Name	Description	Row
32QGE	32QG internal enable	21
32QR	Reverse negative-sequence overcurrent directional declaration	20
32SPOF	Forward open-pole directional declaration	20
32SPOR	Reverse open-pole directional declaration	20
32VE	32V internal enable	21
3P1CLS	Three-pole Circuit Breaker 1 reclose supervision (SELOGIC control equation)	37
3P2CLS	Three-pole Circuit Breaker 2 reclose supervision (SELOGIC control equation)	37
3PARC	Three-pole reclose initiate qualified	34
3PLSHT	Three-pole reclose last shot	35
3PO	All three poles open	70
3POBK1	Three-pole open Circuit Breaker 1	34
3POBK2	Three-pole open Circuit Breaker 2	35
3POI	Three-pole open interval timing	42
3POISC	Three-pole open supervision condition	42
3POLINE	Three-pole open line	35
3PRCIP	Three-pole reclaim in progress	40
3PRI	Three-pole reclose initiation (SELOGIC control equation)	34
3PS	Trip logic three-phase selected	46
3PSHOT0	Three-pole shot counter =0	41
3PSHOT1	Three-pole shot counter =1	41
3PSHOT2	Three-pole shot counter =2	41
3PSHOT3	Three-pole shot counter =3	41
3PSHOT4	Three-pole shot counter =4	41
3PT	Three-pole trip	47
50ABC	Positive-sequence current above 50ABCP threshold	17
50FA1	Circuit Breaker 1 A-phase current threshold exceeded	58
50FA2	Circuit Breaker 2 A-phase current threshold exceeded	64
50FB1	Circuit Breaker 1 B-phase current threshold exceeded	58
50FB2	Circuit Breaker 2 B-phase current threshold exceeded	64
50FC1	Circuit Breaker 1 C-phase current threshold exceeded	58
50FC2	Circuit Breaker 2 C-phase current threshold exceeded	64
50FOA1	Circuit Breaker 1 A-phase flashover current threshold exceeded	61
50FOA2	Circuit Breaker 2 A-phase flashover current threshold exceeded	67
50FOB1	Circuit Breaker 1 B-phase flashover current threshold exceeded	61
50FOB2	Circuit Breaker 2 B-phase flashover current threshold exceeded	67
50FOC1	Circuit Breaker 1 C-phase flashover current threshold exceeded	61

Table A.1 Alphabetic List of Relay Word Bits (Sheet 3 of 21)

Name	Description	Row
50FOC2	Circuit Breaker 2 C-phase flashover current threshold exceeded	67
50G1	Level 1 residual overcurrent element	24
50G2	Level 2 residual overcurrent element	24
50G3	Level 3 residual overcurrent element	24
50G4	Level 4 residual overcurrent element	24
50GF	Forward zero-sequence supervisory current element	21
50GR	Reverse zero-sequence supervisory current element	21
50LCA1	Circuit Breaker 1 A-phase load current threshold exceeded	60
50LCA2	Circuit Breaker 2 A-phase load current threshold exceeded	66
50LCB1	Circuit Breaker 1 B-phase load current threshold exceeded	60
50LCB2	Circuit Breaker 2 B-phase load current threshold exceeded	66
50LCC1	Circuit Breaker 1 C-phase load current threshold exceeded	60
50LCC2	Circuit Breaker 2 C-phase load current threshold exceeded	66
50P1	Level 1 phase overcurrent element	23
50P2	Level 2 phase overcurrent element	23
50P3	Level 3 phase overcurrent element	23
50P4	Level 4 phase overcurrent element	23
50Q1	Level 1 negative-sequence overcurrent element	26
50Q2	Level 2 negative-sequence overcurrent element	26
50Q3	Level 3 negative-sequence overcurrent element	26
50Q4	Level 4 negative-sequence overcurrent element	26
50QF	Forward negative-sequence supervisory current element	21
50QR	Reverse negative-sequence supervisory current element	21
50R1	Circuit Breaker 1 residual current threshold exceeded	60
50R2	Circuit Breaker 2 residual current threshold exceeded	66
51S1	Inverse-Time Overcurrent Element 1 pickup	28
51S1R	Inverse-Time Overcurrent Element 1 reset	28
51S1T	Inverse-Time Overcurrent Element 1 timed out	28
51S2	Inverse-Time Overcurrent Element 2 pickup	28
51S2R	Inverse-Time Overcurrent Element 2 reset	28
51S2T	Inverse-Time Overcurrent Element 2 timed out	28
51S3	Inverse-Time Overcurrent Element 3 pickup	29
51S3R	Inverse-Time Overcurrent Element 3 reset	29
51S3T	Inverse-Time Overcurrent Element 3 timed out	29
52AA1	Circuit Breaker 1, Pole A status	72
52AA2	Circuit Breaker 2, Pole A status	74
52AAL1	Circuit Breaker 1, Pole A alarm	72
52AAL2	Circuit Breaker 2, Pole A alarm	73
52AB1	Circuit Breaker 1, Pole B status	72
52AB2	Circuit Breaker 2, Pole B status	74

Table A.1 Alphabetic List of Relay Word Bits (Sheet 4 of 21)

Name	Description	Row
52AC1	Circuit Breaker 1, Pole C status	73
52AC2	Circuit Breaker 2, Pole C status	74
52ACL1	Circuit Breaker 1, Pole A closed	72
52ACL2	Circuit Breaker 2, Pole A closed	73
52BAL1	Circuit Breaker 1, Pole B alarm	72
52BAL2	Circuit Breaker 2, Pole B alarm	73
52BCL1	Circuit Breaker 1, Pole B closed	72
52BCL2	Circuit Breaker 2, Pole B closed	73
52CAL1	Circuit Breaker 1, Pole C alarm	72
52CAL2	Circuit Breaker 2, Pole C alarm	73
52CCL1	Circuit Breaker 1, Pole C closed	72
52CCL2	Circuit Breaker 2, Pole C closed	73
59VP	VP within “healthy voltage” window	30
59VS1	VS1 within “healthy voltage” window	30
59VS2	VS2 within “healthy voltage” window	32
67G1	Level 1 residual directional overcurrent element	25
67G1T	Level 1 residual delayed directional overcurrent element	25
67G2	Level 2 residual directional overcurrent element	25
67G2T	Level 2 residual delayed directional overcurrent element	25
67G3	Level 3 residual directional overcurrent element	25
67G3T	Level 3 residual delayed directional overcurrent element	25
67G4	Level 4 residual directional overcurrent element	25
67G4T	Level 4 residual delayed directional overcurrent element	25
67P1	Level 1 phase directional overcurrent element	23
67P1T	Level 1 phase-delayed directional overcurrent element	24
67P2	Level 2 phase directional overcurrent element	23
67P2T	Level 2 phase-delayed directional overcurrent element	24
67P3	Level 3 phase directional overcurrent element	23
67P3T	Level 3 phase-delayed directional overcurrent element	24
67P4	Level 4 phase directional overcurrent element	23
67P4T	Level 4 phase-delayed directional overcurrent element	24
67Q1	Level 1 negative-sequence directional overcurrent element	26
67Q1T	Level 1 negative sequence delayed directional overcurrent element	27
67Q2	Level 2 negative-sequence directional overcurrent element	26
67Q2T	Level 2 negative-sequence delayed directional overcurrent element	27
67Q3	Level 3 negative-sequence directional overcurrent element	26
67Q3T	Level 3 negative-sequence delayed directional overcurrent element	27
67Q4	Level 4 negative-sequence directional overcurrent element	26

Table A.1 Alphabetic List of Relay Word Bits (Sheet 5 of 21)

Name	Description	Row
67Q4T	Level 4 negative-sequence delayed directional overcurrent element	27
67QG2S	Negative-sequence and residual directional overcurrent short delay element	52
67QUBF	Forward direction supervised output from 50QUBP	19
67QUBR	Reverse direction supervised output from 50QUBP	19
79CY1	Relay in single-pole reclose cycle state	35
79CY3	Relay in three-pole reclose cycle state	35
79STRT	Relay in start state	42
A3PT	Assert three-pole trip	46
ACN01Q–ACN32Q	Automation counter outputs	186–189
ACN01R–ACN32R	Automation counter resets	190–193
AFRTEXA	Automation SELOGIC control equation first execution after Automation Settings change	196
AFRTEXP	Automation SELOGIC control equation first execution after Protection Settings Change, Group Switch, or Source Switch Selection.	196
ALT01–ALT32	Automation Latches	174–177
ALTI	Alternate current source (SELOGIC control equation)	261
ALTS2	Alternate synchronism source for Circuit Breaker 2	261
ALTV	Alternate voltage source (SELOGIC control equation)	261
ANOKA	Analog transfer OK on MIRRORED BITS® communications Channel A	233
ANOKB	Analog transfer OK on MIRRORED BITS communications Channel B	234
APS	Trip logic A-phase selected	46
AST01Q–AST32Q	Automation sequencing timer outputs	178–181
AST01R–AST32R	Automation sequencing timer resets	182–185
ASV001–ASV256	Automation SELOGIC control equation variable	142–173
ATPA	Assert Trip A	46
ATPB	Assert Trip B	46
ATPC	Assert Trip C	46
AUNRLBL	Automation SELOGIC control equation unresolved label	196
B1BCWAL	Circuit Breaker 1 contact wear monitor alarm	79
B1BITAL	Circuit Breaker 1 inactivity time alarm	80
B1ESOAL	Circuit Breaker 1 electrical slow operation alarm	80
B1KAIAL	Circuit Breaker 1 interrupted current alarm	80
B1MRTAL	Circuit Breaker 1 motor running time alarm	80
B1MRTIN	Motor run time contact input-Circuit Breaker 1 (SELOGIC control equation)	79

Table A.1 Alphabetic List of Relay Word Bits (Sheet 6 of 21)

Name	Description	Row
B1MSOAL	Circuit Breaker 1 mechanical slow operation alarm	80
B1OPHA	Circuit Breaker 1 A-phase open	69
B1OPHB	Circuit Breaker 1 B-phase open	69
B1OPHC	Circuit Breaker 1 C-phase open	69
B1PDAL	Circuit Breaker 1 pole discrepancy alarm	80
B1PSAL	Circuit Breaker 1 pole scatter alarm	80
B2BCWAL	Circuit Breaker 2 contact wear monitor alarm	81
B2BITAL	Circuit Breaker 2 inactivity time alarm	82
B2ESOAL	Circuit Breaker 2 electrical slow operation alarm	82
B2KAIAL	Circuit Breaker 2 interrupted current alarm	82
B2MRTAL	Circuit Breaker 2 motor running time alarm	82
B2MRTIN	Motor run time contact input-Circuit Breaker 2 (SELOGIC control equation)	81
B2MSOAL	Circuit Breaker 2 mechanical slow operation alarm	82
B2OPHA	Circuit Breaker 2 A-phase open	69
B2OPHB	Circuit Breaker 2 B-phase open	69
B2OPHC	Circuit Breaker 2 C-phase open	69
B2PDAL	Circuit Breaker 2 pole discrepancy alarm	82
B2PSAL	Circuit Breaker 2 pole scatter alarm	82
BADPASS	Invalid password attempt alarm	198
BFI3P1	Circuit Breaker 1 three-pole circuit breaker failure initiation	57
BFI3P2	Circuit Breaker 2 three-pole circuit breaker failure initiation	63
BFI3PT1	Circuit Breaker 1 extended three-pole extended circuit breaker failure initiation	57
BFI3PT2	Circuit Breaker 2 three-pole extended circuit breaker failure initiation	63
BFIA1	Circuit Breaker 1 A-phase circuit breaker failure initiation	57
BFIA2	Circuit Breaker 2 A-phase circuit breaker failure initiation	63
BFIAT1	Circuit Breaker 1 A-phase extended circuit breaker failure initiation	57
BFIAT2	Circuit Breaker 2 A-phase extended circuit breaker failure initiation	63
BFIB1	Circuit Breaker 1 B-phase circuit breaker failure initiation	57
BFIB2	Circuit Breaker 2 B-phase circuit breaker failure initiation	63
BFIBT1	Circuit Breaker 1 B-phase extended circuit breaker failure initiation	57
BFIBT2	Circuit Breaker 2 B-phase extended circuit breaker failure initiation	63
BFIC1	Circuit Breaker 1 C-phase circuit breaker failure initiation	57
BFIC2	Circuit Breaker 2 C-phase circuit breaker failure initiation	63
BFICT1	Circuit Breaker 1 C-phase extended circuit breaker failure initiation	57
BFICT2	Circuit Breaker 2 C-phase extended circuit breaker failure initiation	63

Table A.1 Alphabetic List of Relay Word Bits (Sheet 7 of 21)

Name	Description	Row
BFILC1	Circuit Breaker 1 load current circuit breaker failure initiation	60
BFILC2	Circuit Breaker 2 load current circuit breaker failure initiation	66
BFIN1	Circuit Breaker 1 no current circuit breaker failure initiation	60
BFIN2	Circuit Breaker 2 no current circuit breaker failure initiation	66
BFTR1	Circuit breaker failure trip-Circuit Breaker 1 (SELOGIC control equation)	62
BFTR2	Circuit breaker failure trip-Circuit Breaker 2 (SELOGIC control equation)	68
BFTRIP1	Circuit Breaker 1 failure trip output asserted	62
BFTRIP2	Circuit Breaker 2 failure trip output asserted	68
BFULTR1	Circuit breaker failure unlatch trip-Circuit Breaker 1 (SELOGIC control equation)	62
BFULTR2	Circuit breaker failure unlatch trip-Circuit Breaker 2 (SELOGIC control equation)	68
BK1BFT	Indicates Circuit Breaker 1 breaker failure trip	228
BK1CFT	Circuit Breaker 1 close failure delay timed out	38
BK1CL	Circuit Breaker 1 close command	36
BK1CLSS	Circuit Breaker 1 in close supervision state	38
BK1CLST	Circuit Breaker 1 close supervision timer timed out	38
BK1EXT	Circuit Breaker 1 closed externally	42
BK1LO	Circuit Breaker 1 in lockout state	35
BK1RCIP	Circuit Breaker 1 reclaim in progress (lockout state)	40
BK1RS	Circuit Breaker 1 in ready state	35
BK2BFT	Indicates Circuit Breaker 2 breaker failure trip	228
BK2CFT	Circuit Breaker 2 close failure delay timed out	38
BK2CL	Circuit Breaker 2 close command	36
BK2CLSS	Circuit Breaker 2 in close supervision state	38
BK2CLST	Circuit Breaker 2 close supervision timer timed out	38
BK2EXT	Circuit Breaker 2 closed externally	42
BK2LO	Circuit Breaker 2 in lockout state	36
BK2RCIP	Circuit Breaker 2 reclaim in progress (lockout state)	40
BK2RS	Circuit Breaker 2 in ready state	35
BLKFOA1	Circuit Breaker 1 block A-phase flashover detection	61
BLKFOA2	Circuit Breaker 2 block A-phase flashover detection	67
BLKFOB1	Circuit Breaker 1 block B-phase flashover detection	61
BLKFOB2	Circuit Breaker 2 block B-phase flashover detection	67
BLKFOC1	Circuit Breaker 1 block C-phase flashover detection	61
BLKFOC2	Circuit Breaker 2 block C-phase flashover detection	67
BM1CLSA	Circuit breaker monitor A-phase close-Circuit Breaker 1 (SELOGIC control equation)	79
BM1CLSB	Circuit breaker monitor B-phase close-Circuit Breaker 1 (SELOGIC control equation)	79

Table A.1 Alphabetic List of Relay Word Bits (Sheet 8 of 21)

Name	Description	Row
BM1CLSC	Circuit breaker monitor C-phase close-Circuit Breaker 1 (SELOGIC control equation)	79
BM1TRPA	Circuit breaker monitor A-phase trip-Circuit Breaker 1 (SELOGIC control equation)	79
BM1TRPB	Circuit breaker monitor B-phase trip-Circuit Breaker 1 (SELOGIC control equation)	79
BM1TRPC	Circuit breaker monitor C-phase trip-Circuit Breaker 1 (SELOGIC control equation)	79
BM2CLSA	Circuit breaker monitor A-phase close-Circuit Breaker 2 (SELOGIC control equation)	81
BM2CLSB	Circuit breaker monitor B-phase close-Circuit Breaker 2 (SELOGIC control equation)	81
BM2CLSC	Circuit breaker monitor C-phase close-Circuit Breaker 2 (SELOGIC control equation)	81
BM2TRPA	Circuit breaker monitor A-phase trip-Circuit Breaker 2 (SELOGIC control equation)	81
BM2TRPB	Circuit breaker monitor B-phase trip-Circuit Breaker 2 (SELOGIC control equation)	81
BM2TRPC	Circuit breaker monitor C-phase trip-Circuit Breaker 2 (SELOGIC control equation)	81
BPS	Trip logic B-phase selected	46
BSYNBK1	Block synchronism check for Circuit Breaker 1	31
BSYNBK2	Block synchronism check for Circuit Breaker 2	33
BTX	Block extension picked up	52
CBADA	Unavailability threshold exceeded for MIRRORED BITS communications Channel A	233
CBADB	Unavailability threshold exceeded for MIRRORED BITS communications Channel B	234
CC1	Circuit Breaker 1 close command	87
CC2	Circuit Breaker 2 close command	87
CCALARM	Communications card status alarm	194
CCIN001–CCIN128	Communications card input points	236–251
CCOK	Indicates connected Ethernet card is operating correctly	198
CCOUT01–CCOUT32	Communications card output points	252–255
CCSTA01–CCSTA16	Communications card status word	252–253
CCSTA17–CCSTA32	Communications card self-test status word	258–259
CHSG	Settings Group Change	96
COMPRM	Communications-assisted trip permission	45
CPS	Trip logic C-phase selected	46
CVTBL	CCVT transient blocking logic active	15
CVTBLH[a]	CCVT transient blocking logic active-high-speed elements	15
DC1F	DC Monitor 1 fail alarm	85

Table A.1 Alphabetic List of Relay Word Bits (Sheet 9 of 21)

Name	Description	Row
DC1G	DC Monitor 1 ground fault alarm	85
DC1R	DC Monitor 1 alarm for ac ripple	85
DC1W	DC Monitor 1 warning alarm	85
DC2F	DC Monitor 2 fail alarm	85
DC2G	DC Monitor 2 ground fault alarm	85
DC2R	DC Monitor 2 alarm for ac ripple	85
DC2W	DC Monitor 2 warning alarm	85
DELAY	Local current and voltage source delay logic	261
DFAULT	Disables maximum/minimum metering and demand metering when SELOGIC control equation FAULT asserts	44
DLDB1	Dead Line Dead Bus 1	39
DLDB2	Dead Line Dead Bus 2	39
DLLB1	Dead Line Live Bus 1	39
DLLB2	Dead Line Live Bus 2	39
DOKA	Normal MIRRORED BITS communications Channel A status	233
DOKB	Normal MIRRORED BITS communications Channel B status	234
DST	Daylight Savings Time	274
DSTP	Daylight Savings Time Pending	274
DSTRT	Directional start element picked up	52
DTA	Direct transfer trip A-Phase (SELOGIC control equation)	49
DTB	Direct transfer trip B-Phase (SELOGIC control equation)	49
DTC	Direct transfer trip C-Phase (SELOGIC control equation)	49
DTR	Direct transfer trip received	45
E3PT	Three-pole trip enable	45
E3PT1	Circuit Breaker 1 three-pole trip enable	45
E3PT2	Circuit Breaker 2 three-pole trip enable	45
EAFSRC	Alternate frequency source (SELOGIC control equation)	44
ECTT	Echo conversion to trip signal	50
ECTTA	A-phase echo conversion to trip signal (ECOMM=POTT3)	54
ECTTB	B-phase echo conversion to trip signal (ECOMM=POTT3)	54
ECTTC	C-phase echo conversion to trip signal (ECOMM=POTT3)	54
EKEY	Echo received permissive trip signal	50
EKEYA	A-phase echo received permissive trip signal (ECOMM=POTT3)	54
EKEYB	B-phase echo received permissive trip signal (ECOMM=POTT3)	54
EKEYC	C-phase echo received permissive trip signal (ECOMM=POTT3)	54
EN	Relay Enabled	0
ER	Event report trigger equation (SELOGIC control equation)	44
EVELOCK	Lock DNP Events	270
F32I	Forward current polarized zero-sequence directional element	22

Table A.1 Alphabetic List of Relay Word Bits (Sheet 10 of 21)

Name	Description	Row
F32P	Forward phase directional declaration	20
F32Q	Forward negative-sequence phase directional declaration	20
F32QG	Forward negative-sequence ground directional element	22
F32V	Forward voltage polarized zero-sequence directional element	22
FAST1	fs1 > fp	31
FAST2	fs2 > fp	33
FBF1	Circuit Breaker 1 circuit breaker failure	59
FBF2	Circuit Breaker 2 circuit breaker failure	65
FBFA1	Circuit Breaker 1 A-phase circuit breaker failure	59
FBFA2	Circuit Breaker 2 A-phase circuit breaker failure	65
FBFB1	Circuit Breaker 1 B-phase circuit breaker failure	59
FBFB2	Circuit Breaker 2 B-phase circuit breaker failure	65
FBFC1	Circuit Breaker 1 C-phase circuit breaker failure	59
FBFC2	Circuit Breaker 2 C-phase circuit breaker failure	65
FIDEN	Fault identification logic enabled	43
FOA1	Circuit Breaker 1 A-phase flashover detected	61
FOA2	Circuit Breaker 2 A-phase flashover detected	67
FOB1	Circuit Breaker 1 B-phase flashover detected	61
FOB2	Circuit Breaker 2 B-phase flashover detected	67
FOBF1	Circuit Breaker 1 flashover detected	62
FOBF2	Circuit Breaker 2 flashover detected	68
FOC1	Circuit Breaker 1 C-phase flashover detected	62
FOC2	Circuit Breaker 2 C-phase flashover detected	68
FOLBK0	No follower circuit breaker	36
FOLBK1	Follower circuit breaker = Circuit Breaker 1	36
FOLBK2	Follower circuit breaker = Circuit Breaker 2	37
FOP1_01–FOP1_08	Fast Operate Output Control Bits for Port 1, 01–08	300
FOP1_09–FOP1_16	Fast Operate Output Control Bits for Port 1, 09–16	301
FOP1_17–FOP1_24	Fast Operate Output Control Bits for Port 1, 17–24	302
FOP1_25–FOP1_32	Fast Operate Output Control Bits for Port 1, 25–32	303
FOP2_01–FOP2_08	Fast Operate Output Control Bits for Port 2, 01–08	304
FOP2_09–FOP2_16	Fast Operate Output Control Bits for Port 2, 09–16	305
FOP2_17–FOP2_24	Fast Operate Output Control Bits for Port 2, 17–24	306
FOP2_25–FOP2_32	Fast Operate Output Control Bits for Port 2, 25–32	307
FOP3_01–FOP3_08	Fast Operate Output Control Bits for Port 3, 01–08	308

Table A.1 Alphabetic List of Relay Word Bits (Sheet 11 of 21)

Name	Description	Row
FOP3_09–FOP3_16	Fast Operate Output Control Bits for Port 3, 09–16	309
FOP3_17–FOP3_24	Fast Operate Output Control Bits for Port 3, 17–24	310
FOP3_25–FOP3_32	Fast Operate Output Control Bits for Port 3, 25–32	311
FOPF_01–FOPF_08	Fast Operate Output Control Bits for Port F, 01–08	296
FOPF_09–FOPF_16	Fast Operate Output Control Bits for Port F, 09–16	297
FOPF_17–FOPF_24	Fast Operate Output Control Bits for Port F, 17–24	298
FOPF_25–FOPF_32	Fast Operate Output Control Bits for Port F, 25–32	299
FREQOK	Assert if relay is estimating frequency	217
FSA	A-phase sector fault (AG or BCG fault)	43
FSB	B-phase sector fault (BG or CAG fault)	44
FSC	C-phase sector fault (CG or ABG fault)	44
FSERP1	Fast SER enabled for Serial Port 1	260
FSERP2	Fast SER enabled for Serial Port 2	260
FSERP3	Fast SER enabled for Serial Port 3	260
FSERPF	Fast SER enabled for Serial Port F	260
GDEM	Zero-sequence demand current picked up	86
GROUND	Indicates a ground fault	228
HALARM	Hardware alarm	198
ILOP	Internal loss-of-potential from ELOP setting	43
IN101–IN107	Main board inputs	100
IN201–IN224	First optional I/O board inputs (if installed)	10–103
IN301–IN324	Second optional I/O board inputs (if installed)	104–106
KEY	Transmit permissive trip signal	50
KEY1	Transmit general permissive trip	51
KEY3	Transmit three-phase permissive trip	51
KEYA	Transmit A-phase permissive trip (ECOMM=POTT3)	53
KEYB	Transmit B-phase permissive trip (ECOMM=POTT3)	53
KEYC	Transmit C-phase permissive trip (ECOMM=POTT3)	53
LB01–LB32	Latch bits	88–91
LB_DP01–LB_DP32	Local Bit Status Display (SELOGIC control equation)	288–291
LB_SP01–LB_SP32	Local Bit Supervision (SELOGIC control equation)	284–287
LBOKA	Normal MIRRORED BITS communications Channel A status while in loopback mode	233
LBOKB	Normal MIRRORED BITS communications Channel B status while in loopback mode	234
LCBF1	Circuit Breaker 1 load current circuit breaker failure	60

Table A.1 Alphabetic List of Relay Word Bits (Sheet 12 of 21)

Name	Description	Row
LCBF2	Circuit Breaker 2 load current circuit breaker failure	66
LEADBK0	No lead circuit breaker	36
LEADBK1	Lead circuit breaker = Circuit Breaker 1	36
LEADBK2	Lead circuit breaker = Circuit Breaker 2	36
LLDB1	Live Line Dead Bus 1	39
LLDB2	Live Line Dead Bus 2	39
LOADTE	Load TECORR Factor (SELOGIC control equation). When a rising-edge is detected (greater than one cycle), the accumulated time-error value TE is loaded with the TECORR factor (preload value).	276
LOP	Loss-of-potential detected	43
LOPHA	Line A-phase open	69
LOPHB	Line B-phase open	69
LOPHC	Line C-phase open	70
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.	274
LPSECP	Leap second pending (asserts for up to one minute prior to leap second, deasserts when the change is to occur, at “00”)	274
M1P	Zone 1 Mho phase element	3
M1PT	Zone 1 Mho phase distance, time-delayed	4
M2P	Zone 2 Mho phase element	3
M2PT	Zone 2 Mho phase distance, time-delayed	4
M3P	Zone 3 Mho phase element	3
M3PT	Zone 3 Mho phase distance, time-delayed	4
M4P	Zone 4 Mho phase element	3
M4PT	Zone 4 Mho phase distance, time-delayed	4
M5P	Zone 5 Mho phase element	3
M5PT	Zone 5 Mho phase distance, time-delayed	4
MAB1	Zone 1 Mho A-B phase element	8
MAB1H[a]	High-speed Zone 1 Mho A-B phase element	264
MAB2	Zone 2 Mho A-B phase element	8
MAB2H[a]	High-speed Zone 2 Mho A-B phase element	264
MAB3	Zone 3 Mho A-B phase element	9
MAB3H[a]	High-speed Zone 3 Mho A-B phase element	260
MAB4	Zone 4 Mho A-B phase element	9
MAB5	Zone 5 Mho A-B phase element	10
MAG1	Zone 1 Mho A-phase-to-ground element	10
MAG1H[a]	High-speed Zone 1 Mho A-phase-to-ground element	262
MAG2	Zone 2 Mho A-phase-to-ground element	11
MAG2H[a]	High-speed Zone 2 Mho A-phase-to-ground element	262
MAG3	Zone 3 Mho A-phase-to-ground element	11
MAG3H[a]	High-speed Zone 3 Mho A-phase-to-ground element	262

Table A.1 Alphabetic List of Relay Word Bits (Sheet 13 of 21)

Name	Description	Row
MAG4	Zone 4 Mho A-phase-to-ground element	12
MAG5	Zone 5 Mho A-phase-to-ground element	12
MATHERR	SELOGIC control equation math error	194
MBC1	Zone 1 Mho B-C phase element	8
MBC1H[a]	High-speed Zone 1 Mho B-C phase element	264
MBC2	Zone 2 Mho B-C phase element	8
MBC2H[a]	High-speed Zone 2 Mho B-C phase element	264
MBC3	Zone 3 Mho B-C phase element	9
MBC3H[a]	High-speed Zone 3 Mho B-C phase element	264
MBC4	Zone 4 Mho B-C phase element	9
MBC5	Zone 5 Mho B-C phase element	10
MBG1	Zone 1 Mho B-phase-to-ground element	10
MBG1H[a]	High-speed Zone 1 Mho B-phase-to-ground element	262
MBG2	Zone 2 Mho B-phase-to-ground element	11
MBG2H[a]	High-speed Zone 2 Mho B-phase-to-ground element	262
MBG3	Zone 3 Mho B-phase-to-ground element	11
MBG3H[a]	High-speed Zone 3 Mho B-phase-to-ground element	262
MBG4	Zone 4 Mho B-phase-to-ground element	12
MBG5	Zone 5 Mho B-phase-to-ground element	12
MCA1	Zone 1 Mho C-A phase element	8
MCA1H[a]	High-speed Zone 1 Mho C-A phase element	264
MCA2	Zone 2 Mho C-A phase element	8
MCA2H[a]	High-speed Zone 2 Mho C-A phase element	264
MCA3	Zone 3 Mho C-A phase element	9
MCA3H[a]	High-speed Zone 3 Mho C-A phase element	265
MCA4	Zone 4 Mho C-A phase element	9
MCA5	Zone 5 Mho C-A phase element	10
MCG1	Zone 1 Mho C-phase-to-ground element	10
MCG1H[a]	High-speed Zone 1 Mho C-phase-to-ground element	262
MCG2	Zone 2 Mho C-phase-to-ground element	11
MCG2H[a]	High-speed Zone 2 Mho C-phase-to-ground element	262
MCG3	Zone 3 Mho C-phase-to-ground element	11
MCG3H[a]	High-speed Zone 3 Mho C-phase-to-ground element	263
MCG4	Zone 4 Mho C-phase-to-ground element	12
MCG5	Zone 5 Mho C-phase-to-ground element	12
NBF1	Circuit Breaker 1 no current circuit breaker failure	60
NBF2	Circuit Breaker 2 no current circuit breaker failure	66
NBK0	No circuit breakers active in reclose scheme	37
NBK1	One circuit breaker active in reclose scheme	37
NBK2	Two circuit breakers active in reclose scheme	37
NSTRT	Non-directional start element picked up	52

Table A.1 Alphabetic List of Relay Word Bits (Sheet 14 of 21)

Name	Description	Row
OC1	Circuit Breaker 1 open command	87
OC2	Circuit Breaker 2 open command	87
OOSDET	Out-of-step condition detected	19
OSB	Out-of-step block	18
OSB1	Block Zone 1 during an out-of-step condition	17
OSB2	Block Zone 2 during an out-of-step condition	18
OSB3	Block Zone 3 during an out-of-step condition	18
OSB4	Block Zone 4 during an out-of-step condition	18
OSB5	Block Zone 5 during an out-of-step condition	18
OSBA	A-phase out-of-step block	17
OSBB	B-phase out-of-step block	17
OSBC	C-phase out-of-step block	17
OST	Out-of-step tripping	18
OSTI	Incoming out-of-step tripping	18
OSTO	Outgoing out-of-step tripping	18
OUT101–OUT108	Main board outputs	218
OUT201–OUT216	Optional I/O board 1 outputs	219 –220
OUT301–OUT316	Optional I/O board 2 outputs	221–222
PB1–PB8	Pushbuttons	223
PB9–PB12	Pushbuttons	281
PB1_LED–PB8_LED	Pushbutton LEDs	225
PB9_LED–PB12LED	Pushbutton LEDs	282
PB1_PUL–PB8_PUL	Pushbutton pulse inputs (on for one processing interval when button is pushed)	224
PB9_PUL–PB12PUL	Pushbutton pulse inputs (on for one processing interval when button is pushed)	283
PB_CLSE	Auxiliary CLOSE Pushbutton	281
PB_TRIP	Auxiliary CLOSE Pushbutton	281
PCN01Q–PCN32Q	Protection counter outputs	134–137
PCN01R–PCN32R	Protection counter resets	138–141
PCT01Q–PCT32Q	Protection conditioning timer outputs	120–121
PDEM	Phase current demand picked up	86
PFRTEX	Protection SELOGIC control equation first execution	194
PHASE_A	Indicates an A-phase fault	228
PHASE_B	Indicates a B-phase fault	228
PHASE_C	Indicates a C-phase fault	228

Table A.1 Alphabetic List of Relay Word Bits (Sheet 15 of 21)

Name	Description	Row
PLDTE	Asserts for approximately 1.5 cycles when the TEC command is used to load a new time-error correction factor (preload value) into the TECORR analog quantity.	276
PLT01–PLT32	Protection latches	120–123
PMDOK	Assert if data acquisition system is operating correctly	217
PMTRIG	Trigger (SELOGIC control equation)	268
PST01Q–PST32Q	Protection sequencing timer outputs	126–129
PST01R–PST32R	Protection sequencing timer resets	130–133
PSV01–PSV64	Protection SELOGIC control equation variables	112–119
PT	Permissive trip received	50
PTA	A-phase permissive trip received (ECOMM=POTT3)	55
PTB	B-phase permissive trip received (ECOMM=POTT3)	55
PTC	C-phase permissive trip received (ECOMM=POTT3)	55
PTRX	Permissive trip received Channel 1 and Channel 2	52
PTRX1	Permissive trip received Channel 1	51
PTRX2	Permissive trip received Channel 2	51
PUNRLBL	Protection SELOGIC control equation unresolved label	194
QDEM	Negative-sequence demand current picked up	86
R32I	Reverse current polarized zero-sequence directional element	22
R32P	Reverse phase directional declaration	20
R32Q	Reverse negative-sequence phase directional declaration	20
R32QG	Reverse negative-sequence ground directional element	22
R32V	Reverse voltage polarized zero-sequence directional element	22
R3PTE	Recloser three-pole trip enable	39
R3PTE1	Recloser three-pole trip enable Circuit Breaker 1	39
R3PTE2	Recloser three-pole trip enable Circuit Breaker 2	40
RB01–RB32	Remote bits	92–95
RBADA	Outage too long on MIRRORED BITS communications Channel A	233
RBADB	Outage too long on MIRRORED BITS communications Channel B	234
RMB1A	Channel A Receive MIRRORED BITS 1	229
RMB1B	Channel B Receive MIRRORED BITS 1	231
RMB2A	Channel A Receive MIRRORED BITS 2	229
RMB2B	Channel B Receive MIRRORED BITS 2	231
RMB3A	Channel A Receive MIRRORED BITS 3	229
RMB3B	Channel B Receive MIRRORED BITS 3	231
RMB4A	Channel A Receive MIRRORED BITS 4	229
RMB4B	Channel B Receive MIRRORED BITS 4	231
RMB5A	Channel A Receive MIRRORED BITS 5	229

Table A.1 Alphabetic List of Relay Word Bits (Sheet 16 of 21)

Name	Description	Row
RMB5B	Channel B Receive MIRRORED BITS 5	231
RMB6A	Channel A Receive MIRRORED BITS 6	229
RMB6B	Channel B Receive MIRRORED BITS 6	231
RMB7A	Channel A Receive MIRRORED BITS 7	229
RMB7B	Channel B Receive MIRRORED BITS 7	231
RMB8A	Channel A Receive MIRRORED BITS 8	229
RMB8B	Channel B Receive MIRRORED BITS 8	231
ROKA	Normal MIRRORED BITS communications Channel A status while not in loopback mode	231
ROKB	Normal MIRRORED BITS communications Channel B status while not in loopback mode	234
RST_79C	Reset recloser shot count accumulators (SELOGIC control equation)	40
RST_BAT	Reset battery monitoring (SELOGIC control equation)	227
RST_BK1	Reset Circuit Breaker 1 monitor	226
RST_BK2	Reset Circuit Breaker 2 monitor	226
RST_DEM	Reset demand metering	226
RSTDNPE	Reset DNP Fault Summary Data (SELOGIC control equation)	227
RST_ENE	Reset energy metering data	226
RST_PDM	Reset peak demand metering	226
RSTFLOC	Reset fault locator (SELOGIC control equation)	227
RSTMMB1	Reset max/min Circuit Breaker 1 (SELOGIC control equation)	226
RSTMMB2	Reset max/min Circuit Breaker 2 (SELOGIC control equation)	226
RSTMML	Reset max/min line (SELOGIC control equation)	226
RSTTRGT	Target reset (SELOGIC control equation)	228
RT1	Circuit Breaker 1 retrip	59
RT2	Circuit Breaker 2 retrip	65
RT3P1	Circuit Breaker 1 three-pole retrip	58
RT3P2	Circuit Breaker 2 three-pole retrip	64
RTA1	Circuit Breaker 1 A-phase retrip	58
RTA2	Circuit Breaker 2 A-phase retrip	64
RTB1	Circuit Breaker 1 B-phase retrip	58
RTB2	Circuit Breaker 2 B-phase retrip	64
RTC1	Circuit Breaker 1 C-phase retrip	58
RTC2	Circuit Breaker 2 C-phase retrip	64
RTCAD01–RTCAD08	RTC Remote Data Bits, Channel A, 1–8	292
RTCAD09–RTCAD16	RTC Remote Data Bits, Channel A, 9–16	293
RTCBD01–RTCBD08	RTC Remote Data Bits, Channel B, 1–8	294
RTCBD09–RTCBD16	RTC Remote Data Bits, Channel B, 9–16	295

Table A.1 Alphabetic List of Relay Word Bits (Sheet 17 of 21)

Name	Description	Row
RTCCFGA	RTC Configuration Complete, Channel A	270
RTCCFGB	RTC Configuration Complete, Channel B	270
RTCDLYA	RTC Delay Exceeded, Channel A	271
RTCDLYB	RTC Delay Exceeded, Channel B	271
RTCENA	Valid Remote Synchrophasors Received on Channel A	271
RTCENB	Valid Remote Synchrophasors Received on Channel B	271
RTCROK	Valid Aligned RTC Data Available on All Enabled Channels	271
RTCROKA	Valid Aligned RTC Data Available on Channel A	271
RTCROKB	Valid Aligned RTC Data Available on Channel B	271
RTCSEQA	RTC Data In Sequence on Channel B	270
RTCSEQB	RTC Data In Sequence on Channel B	270
RTD01ST	RTD Status for Channel 1	83
RTD02ST	RTD Status for Channel 2	83
RTD03ST	RTD Status for Channel 3	83
RTD04ST	RTD Status for Channel 4	83
RTD05ST	RTD Status for Channel 5	83
RTD06ST	RTD Status for Channel 6	83
RTD07ST	RTD Status for Channel 7	83
RTD08ST	RTD Status for Channel 8	83
RTD09ST	RTD Status for Channel 9	84
RTD10ST	RTD Status for Channel 10	84
RTD11ST	RTD Status for Channel 11	84
RTD12ST	RTD Status for Channel 12	84
RTDCOMF	RTD Communication Failure	84
RTDFL	RTD device Failure	84
RTDIN	State of RTD contact input	84
RTS3P1	Circuit Breaker 1 current-supervised three-pole retrip	58
RTS3P2	Circuit Breaker 2 current-supervised three-pole retrip	64
RTSA1	Circuit Breaker 1 current-supervised A-phase retrip	59
RTSA2	Circuit Breaker 2 current-supervised A-phase retrip	65
RTSB1	Circuit Breaker 1 current-supervised B-phase retrip	59
RTSB2	Circuit Breaker 2 current-supervised B-phase retrip	65
RTSC1	Circuit Breaker 1 current-supervised C-phase retrip	59
RTSC2	Circuit Breaker 2 current-supervised C-phase retrip	65
RXPRM	Receiver trip permission	45
SALARM	Software alarm	198
SERCA[a]	Series-compensated line A-phase output	16
SERCAB[a]	Series-compensated line AB-phase output	16
SERCB[a]	Series-compensated line B-phase output	16
SERCBC[a]	Series-compensated line BC-phase output	16
SERCC[a]	Series-compensated line C-phase output	16

Table A.1 Alphabetic List of Relay Word Bits (Sheet 18 of 21)

Name	Description	Row
SERCCA[a]	Series-compensated line CA-phase output	16
SFBK1	5 mHz ≤ Circuit Breaker 1 slip frequency < 25 SFBK1	30
SFBK2	5 mHz ≤ Circuit Breaker 2 slip frequency < 25 SFBK2	32
SFZBK1	Circuit Breaker 1 slip frequency less than 5 mHz	30
SFZBK2	Circuit Breaker 2 slip frequency less than 5 mHz	32
SG1	Settings Group 1 active	96
SG2	Settings Group 2 active	96
SG3	Settings Group 3 active	96
SG4	Settings Group 4 active	96
SG5	Settings Group 5 active	96
SG6	Settings Group 6 active	96
SLOW1	fs1 < fp	31
SLOW2	fs2 < fp	33
SOTFE	Switch-onto-fault enable	43
SOTFT	Switch-onto-fault trip	45
SP1CLS	Single-pole Circuit Breaker 1 reclose supervision (SELOGIC control equation)	37
SP2CLS	Single-pole Circuit Breaker 2 reclose supervision (SELOGIC control equation)	37
SPARC	Single-pole reclose initiate qualified	34
SPLSHT	Single-pole reclose last shot	34
SPO	One or two poles open	70
SPOA	A-phase open	70
SPOB	B-phase open	70
SPOBK1	Single-pole open Circuit Breaker 1	34
SPOBK2	Single-pole open Circuit Breaker 2	34
SPOC	C-phase open	70
SPOI	Single-pole open interval timing	42
SPOISC	Single-pole open interval supervision condition	42
SPRCIP	Single-pole reclaim in progress	40
SPRI	Single-pole reclose initiation (SELOGIC control equation)	34
SPSHOT0	Single-pole shot counter =0	41
SPSHOT1	Single-pole shot counter =1	41
SPSHOT2	Single-pole shot counter =2	41
SPT	Single-pole trip	47
STALLTE	Stall Time-Error Calculation (SELOGIC control equation). When asserted, the time-error calculation is stalled, or frozen.	272
STOP	Stop element picked up	52
TBBK	Time between circuit breakers timing	42
TESTDB	Communications card database test bit	235
TESTDNP	DNP test bit	235

Table A.1 Alphabetic List of Relay Word Bits (Sheet 19 of 21)

Name	Description	Row
TESTFM	Fast meter test bit	235
TESTPUL	Pulse test bit	235
TIRIG	Assert while time is based on IRIG for both mark and value	217
TLED_1–TLED_8	Target LED 1–8	1
TLED_9–TLED_16	Target LED 9–16	2
TLED_17–TLED_24	Target LED 17–24	280
TMB1A–TMB8A	Channel A Transmit MIRRORED BITS 1–8	230
TMB1B–TMB8B	Channel B Transmit MIRRORED BITS 1–8	232
TOP	Trip during open pole timer is asserted	48
TPA	Trip A	47
TPA1	Circuit Breaker 1 Trip A	47
TPA2	Circuit Breaker 2 Trip A	48
TPB	Trip B	47
TPB1	Circuit Breaker 1 Trip B	47
TPB2	Circuit Breaker 2 Trip B	48
TPC	Trip C	47
TPC1	Circuit Breaker 1 Trip C	48
TPC2	Circuit Breaker 2 Trip C	48
TQUAL1	Time quality, binary, add 1 when asserted[b]	274
TQUAL2	Time quality, binary, add 2 when asserted[b]	274
TQUAL4	Time quality, binary, add 4 when asserted[b]	274
TQUAL8	Time quality, binary, add 8 when asserted[b]	274
TREA1	Trigger Reason Bit 1 (SELOGIC control equation)	268
TREA2	Trigger Reason Bit 2 (SELOGIC control equation)	268
TREA3	Trigger Reason Bit 3 (SELOGIC control equation)	268
TREA4	Trigger Reason Bit 4 (SELOGIC control equation)	268
TRGTR	Reset all active target relay words	228
TRIP	Trip A or Trip B or Trip C	47
TRIPLED	Trip LED	0
TRPRM	Trip permission	45
TSOK	Assert if current time source accuracy is sufficient for synchronized phasor measurements	217
TSYNCA	Assert while the time mark from time source or fixed internal source is not synchronized	217
TUPDH	Assert if update source is high-accuracy time source	217
TUTC1	Offset hours from UTC time, binary, add 1 if asserted	273
TUTC2	Offset hours from UTC time, binary, add 2 if asserted	273
TUTC4	Offset hours from UTC time, binary, add 4 if asserted	273

Table A.1 Alphabetic List of Relay Word Bits (Sheet 20 of 21)

Name	Description	Row
TUTC8	Offset hours from UTC time, binary, add 8 if asserted	273
TUTCH	Offset half-hour from UTC time, binary, add 0.5 if asserted	273
TUTCS	Offset hours sign from UTC time, subtract the UTC offset if TUTCS is asserted, add otherwise	273
UBB	Block permissive trip received 1 or 2	51
UBB1	Blocks permissive trip Receiver 1	51
UBB2	Blocks permissive trip Receiver 2	51
UBOSB	Unblock out-of-step blocking	17
ULCL1	Unlatch closing for Circuit Breaker 1 (SELOGIC control equation)	38
ULCL2	Unlatch closing for Circuit Breaker 2 (SELOGIC control equation)	38
ULMTR1	Circuit Breaker 1 unlatch manual trip	48
ULMTR2	Circuit Breaker 2 unlatch manual trip	48
ULTR	Unlatch all protection trips	48
ULTRA	Unlatch Trip A	49
ULTRB	Unlatch Trip B	49
ULTRC	Unlatch Trip C	49
VPOLV	Polarizing voltage valid	15
WFC	Weak infeed condition detected	51
X6ABC	Impedance inside Zone 6 out-of-step	17
X7ABC	Impedance inside Zone 7 out-of-step	17
XAG1	Zone 1 quad A phase to-ground element	13
XAG2	Zone 2 quad A-phase-to-ground element	13
XAG3	Zone 3 quad A-phase-to-ground element	14
XAG4	Zone 4 quad A-phase-to-ground element	14
XAG5	Zone 5 quad A-phase-to-ground element	15
XBG1	Zone 1 quad B-phase-to-ground element	13
XBG2	Zone 2 quad B-phase-to-ground element	13
XBG3	Zone 3 quad B-phase-to-ground element	14
XBG4	Zone 4 quad B-phase-to-ground element	14
XBG5	Zone 5 quad B-phase-to-ground element	15
XCG1	Zone 1 quad C-phase-to-ground element	13
XCG2	Zone 2 quad C-phase-to-ground element	13
XCG3	Zone 3 quad C-phase-to-ground element	14
XCG4	Zone 4 quad C-phase-to-ground element	14
XCG5	Zone 5 quad C-phase-to-ground element	15
YEAR1	IRIG-B year information, binary-coded-decimal, add 1 if asserted[c]	272
YEAR10	IRIG-B year information, binary-coded-decimal, add 10 if asserted[c]	272
YEAR2	IRIG-B year information, binary-coded-decimal, add 2 if asserted[c]	272

Table A.1 Alphabetic List of Relay Word Bits (Sheet 21 of 21)

Name	Description	Row
YEAR20	IRIG-B year information, binary-coded-decimal, add 20 if asserted[c]	272
YEAR4	IRIG-B year information, binary-coded-decimal, add 4 if asserted[c]	272
YEAR40	IRIG-B year information, binary-coded-decimal, add 40 if asserted[c]	272
YEAR8	IRIG-B year information, binary-coded-decimal, add 8 if asserted[c]	272
YEAR80	IRIG-B year information, binary-coded-decimal, add 80 if asserted[c]	272
Z1G	Zone 1 ground distance element	5
Z1GT	Zone 1 ground distance, time-delayed	6
Z1T	Zone 1 phase or ground distance, time-delayed	7
Z2G	Zone 2 ground distance element	5
Z2GT	Zone 2 ground distance, time-delayed	6
Z2PGS	Zone 2 phase and ground short delay element	52
Z2T	Zone 2 phase or ground distance, time-delayed	7
Z3G	Zone 3 ground distance element	5
Z3GT	Zone 3 ground distance, time-delayed	6
Z3RB	Current reversal guard asserted	50
Z3RBA	A-Phase Current Reversal Guard asserted (ECOMM=POTT3)	53
Z3RBB	B-Phase Current Reversal Guard asserted (ECOMM=POTT3)	53
Z3RBC	C-Phase Current Reversal Guard asserted (ECOMM=POTT3)	53
Z3T	Zone 3 phase or ground distance, time-delayed	7
Z3XT	Current reversal guard timer picked up	52
Z4G	Zone 4 ground distance element	5
Z4GT	Zone 4 ground distance, time-delayed	6
Z4T	Zone 4 phase or ground distance, time-delayed	7
Z5G	Zone 5 ground distance element	5
Z5GT	Zone 5 ground distance, time-delayed	6
Z5T	Zone 5 phase or ground distance, time-delayed	7
ZLIN	Load-encroachment “load out” element	43
ZLOAD	ZLOUT or ZLIN element picked up	43
ZLOUT	Load-encroachment “load in” element	43

[a] Not in SEL-421-1 nor SEL-421-2.
[b] See IRIG-B on page U.4.71.
[c] The SEL-421 uses the year information obtained from IRIG-B to set the internal clock year value if EPMU := Y.

Row List

Table A.2 through *Table A.51* list every Relay Word bit row and the bits contained within each row

Table A.2 Relay Word Bits: Enable and Target LEDs

Row	Name	Description
0	EN	Relay Enabled
0	TRIPLED	Trip LED
0	*	Reserved
0	*	Reserved
0	*	Reserved
0	*	Reserved
0	*	Reserved
0	*	Reserved
1	TLED_1	Target LED 1
1	TLED_2	Target LED 2
1	TLED_3	Target LED 3
1	TLED_4	Target LED 4
1	TLED_5	Target LED 5
1	TLED_6	Target LED 6
1	TLED_7	Target LED 7
1	TLED_8	Target LED 8
2	TLED_9	Target LED 9
2	TLED_10	Target LED 10
2	TLED_11	Target LED 11
2	TLED_12	Target LED 12
2	TLED_13	Target LED 13
2	TLED_14	Target LED 14
2	TLED_15	Target LED 15
2	TLED_16	Target LED 16

Table A.3 Relay Word Bits: Distance Elements (Sheet 1 of 4)

Row	Name	Description
3	M1P	Zone 1 Mho phase element
3	M2P	Zone 2 Mho phase element
3	M3P	Zone 3 Mho phase element
3	M4P	Zone 4 Mho phase element
3	M5P	Zone 5 Mho phase element
3	*	Reserved
3	*	Reserved
3	*	Reserved

Table A.3 Relay Word Bits: Distance Elements (Sheet 2 of 4)

Row	Name	Description
4	M1PT	Zone 1 Mho phase distance, time-delayed
4	M2PT	Zone 2 Mho phase distance, time-delayed
4	M3PT	Zone 3 Mho phase distance, time-delayed
4	M4PT	Zone 4 Mho phase distance, time-delayed
4	M5PT	Zone 5 Mho phase distance, time-delayed
4	*	Reserved
4	*	Reserved
4	*	Reserved
5	Z1G	Zone 1 ground distance element
5	Z2G	Zone 2 ground distance element
5	Z3G	Zone 3 ground distance element
5	Z4G	Zone 4 ground distance element
5	Z5G	Zone 5 ground distance element
5	*	Reserved
5	*	Reserved
5	*	Reserved
6	Z1GT	Zone 1 ground distance, time-delayed
6	Z2GT	Zone 2 ground distance, time-delayed
6	Z3GT	Zone 3 ground distance, time-delayed
6	Z4GT	Zone 4 ground distance, time-delayed
6	Z5GT	Zone 5 ground distance, time-delayed
6	*	Reserved
6	*	Reserved
6	*	Reserved
7	Z1T	Zone 1 phase or ground distance, time-delayed
7	Z2T	Zone 2 phase or ground distance, time-delayed
7	Z3T	Zone 3 phase or ground distance, time-delayed
7	Z4T	Zone 4 phase or ground distance, time-delayed
7	Z5T	Zone 5 phase or ground distance, time-delayed
7	*	Reserved
7	*	Reserved
7	*	Reserved
8	MAB1	Zone 1 Mho A-B phase element
8	MBC1	Zone 1 Mho B-C phase element
8	MCA1	Zone 1 Mho C-A phase element
8	*	Reserved
8	MAB2	Zone 2 Mho A-B phase element
8	MBC2	Zone 2 Mho B-C phase element
8	MCA2	Zone 2 Mho C-A phase element
8	*	Reserved
9	MAB3	Zone 3 Mho A-B phase element

Table A.3 Relay Word Bits: Distance Elements (Sheet 3 of 4)

Row	Name	Description
9	MBC3	Zone 3 Mho B-C phase element
9	MCA3	Zone 3 Mho C-A phase element
9	*	Reserved
9	MAB4	Zone 4 Mho A-B phase element
9	MBC4	Zone 4 Mho B-C phase element
9	MCA4	Zone 4 Mho C-A phase element
9	*	Reserved
10	MAB5	Zone 5 Mho A-B phase element
10	MBC5	Zone 5 Mho B-C phase element
10	MCA5	Zone 5 Mho C-A phase element
10	*	Reserved
10	MAG1	Zone 1 Mho A-phase-to-ground element
10	MBG1	Zone 1 Mho B-phase-to-ground element
10	MCG1	Zone 1 Mho C-phase-to-ground element
10	*	Reserved
11	MAG2	Zone 2 Mho A-phase-to-ground element
11	MBG2	Zone 2 Mho B-phase-to-ground element
11	MCG2	Zone 2 Mho C-phase-to-ground element
11	*	Reserved
11	MAG3	Zone 3 Mho A-phase-to-ground element
11	MBG3	Zone 3 Mho B-phase-to-ground element
11	MCG3	Zone 3 Mho C-phase-to-ground element
11	*	Reserved
12	MAG4	Zone 4 Mho A-phase-to-ground element
12	MBG4	Zone 4 Mho B-phase-to-ground element
12	MCG4	Zone 4 Mho C-phase-to-ground element
12	*	Reserved
12	MAG5	Zone 5 Mho A-phase-to-ground element
12	MBG5	Zone 5 Mho B-phase-to-ground element
12	MCG5	Zone 5 Mho C-phase-to-ground element
12	*	Reserved
13	XAG1	Zone 1 quad A phase to-ground element
13	XBG1	Zone 1 quad B-phase-to-ground element
13	XCG1	Zone 1 quad C-phase-to-ground element
13	*	Reserved
13	XAG2	Zone 2 quad A-phase-to-ground element
13	XBG2	Zone 2 quad B-phase-to-ground element
13	XCG2	Zone 2 quad C-phase-to-ground element
13	*	Reserved
14	XAG3	Zone 3 quad A-phase-to-ground element
14	XBG3	Zone 3 quad B-phase-to-ground element

Table A.3 Relay Word Bits: Distance Elements (Sheet 4 of 4)

Row	Name	Description
14	XCG3	Zone 3 quad C-phase-to-ground element
14	*	Reserved
14	XAG4	Zone 4 quad A-phase-to-ground element
14	XBG4	Zone 4 quad B-phase-to-ground element
14	XCG4	Zone 4 quad C-phase-to-ground element
14	*	Reserved
15	XAG5	Zone 5 quad A-phase-to-ground element
15	XBG5	Zone 5 quad B-phase-to-ground element
15	XCG5	Zone 5 quad C-phase-to-ground element
15	CVTBLH	CCVT transient blocking logic active—high-speed elements
15	CVTBL	CCVT transient blocking logic active
15	VPOLV	Polarizing voltage valid
15	*	Reserved
15	*	Reserved

NOTE: The SEL-421-1 and the SEL-421-2 do not provide high-speed distance elements, so the CVTBLH Relay Word bit is unavailable.

Table A.4 Relay Word Bits: Series Compensated Line Logic[a]

Row	Name	Description
16	SERCAB	Series-compensated line AB-phase output
16	SERCBC	Series-compensated line BC-phase output
16	SERCCA	Series-compensated line CA-phase output
16	SERCA	Series-compensated line A-phase output
16	SERCB	Series-compensated line B-phase output
16	SERCC	Series-compensated line C-phase output
16	*	Reserved
16	*	Reserved

[a] Not in the SEL-421-1 nor the SEL-421-2.

Table A.5 Relay Word Bits: Out-of-Step Elements (Sheet 1 of 2)

Row	Name	Description
17	X6ABC	Impedance inside Zone 6 out-of-step
17	X7ABC	Impedance inside Zone 7 out-of-step
17	50ABC	Positive-sequence current above 50ABCP threshold
17	UBOSB	Unblock out-of-step blocking
17	OSBA	A-phase out-of-step block
17	OSBB	B-phase out-of-step block
17	OSBC	C-phase out-of-step block
17	OSB1	Block Zone 1 during an out-of-step condition
18	OSB2	Block Zone 2 during an out-of-step condition
18	OSB3	Block Zone 3 during an out-of-step condition
18	OSB4	Block Zone 4 during an out-of-step condition
18	OSB5	Block Zone 5 during an out-of-step condition

Table A.5 Relay Word Bits: Out-of-Step Elements (Sheet 2 of 2)

Row	Name	Description
18	OSB	Out-of-step block
18	OSTI	Incoming out-of-step tripping
18	OSTO	Outgoing out-of-step tripping
18	OST	Out-of-step tripping
19	67QUBF	Forward direction supervised output from 50QUBP
19	67QUBR	Reverse direction supervised output from 50QUBP
19	OOSDET	Out-of-step condition detected
19	*	Reserved
19	*	Reserved
19	*	Reserved
19	*	Reserved
19	*	Reserved

Table A.6 Relay Word Bits: Directional Elements (Sheet 1 of 2)

Row	Name	Description
20	F32P	Forward phase directional declaration
20	R32P	Reverse phase directional declaration
20	F32Q	Forward negative-sequence phase directional declaration
20	R32Q	Reverse negative-sequence phase directional declaration
20	32QF	Forward negative-sequence overcurrent directional declaration
20	32QR	Reverse negative-sequence overcurrent directional declaration
20	32SPOF	Forward open-pole directional declaration
20	32SPOR	Reverse open-pole directional declaration
21	50QF	Forward negative-sequence supervisory current element
21	50QR	Reverse negative-sequence supervisory current element
21	50GF	Forward zero-sequence supervisory current element
21	50GR	Reverse zero-sequence supervisory current element
21	32QE	32Q internal enable
21	32QGE	32QG internal enable
21	32VE	32V internal enable
21	32IE	32I internal enable
22	F32I	Forward current polarized zero-sequence directional element
22	R32I	Reverse current polarized zero-sequence directional element
22	F32V	Forward voltage polarized zero-sequence directional element
22	R32V	Reverse voltage polarized zero-sequence directional element
22	F32QG	Forward negative-sequence ground directional element
22	R32QG	Reverse negative-sequence ground directional element

Table A.6 Relay Word Bits: Directional Elements (Sheet 2 of 2)

Row	Name	Description
22	32GF	Forward ground directional element
22	32GR	Reverse ground directional element

Table A.7 Relay Word Bits: Overcurrent Elements (Sheet 1 of 2)

Row	Name	Description
23	50P1	Level 1 phase overcurrent element
23	50P2	Level 2 phase overcurrent element
23	50P3	Level 3 phase overcurrent element
23	50P4	Level 4 phase overcurrent element
23	67P1	Level 1 phase directional overcurrent element
23	67P2	Level 2 phase directional overcurrent element
23	67P3	Level 3 phase directional overcurrent element
23	67P4	Level 4 phase directional overcurrent element
24	67P1T	Level 1 phase-delayed directional overcurrent element
24	67P2T	Level 2 phase-delayed directional overcurrent element
24	67P3T	Level 3 phase-delayed directional overcurrent element
24	67P4T	Level 4 phase-delayed directional overcurrent element
24	50G1	Level 1 residual overcurrent element
24	50G2	Level 2 residual overcurrent element
24	50G3	Level 3 residual overcurrent element
24	50G4	Level 4 residual overcurrent element
25	67G1	Level 1 residual directional overcurrent element
25	67G2	Level 2 residual directional overcurrent element
25	67G3	Level 3 residual directional overcurrent element
25	67G4	Level 4 residual directional overcurrent element
25	67G1T	Level 1 residual delayed directional overcurrent element
25	67G2T	Level 2 residual delayed directional overcurrent element
25	67G3T	Level 3 residual delayed directional overcurrent element
25	67G4T	Level 4 residual delayed directional overcurrent element
26	50Q1	Level 1 negative-sequence overcurrent element
26	50Q2	Level 2 negative-sequence overcurrent element
26	50Q3	Level 3 negative-sequence overcurrent element
26	50Q4	Level 4 negative-sequence overcurrent element
26	67Q1	Level 1 negative-sequence directional overcurrent element
26	67Q2	Level 2 negative-sequence directional overcurrent element
26	67Q3	Level 3 negative-sequence directional overcurrent element
26	67Q4	Level 4 negative-sequence directional overcurrent element
27	67Q1T	Level 1 negative sequence delayed directional overcurrent element
27	67Q2T	Level 2 negative-sequence delayed directional overcurrent element

Table A.7 Relay Word Bits: Overcurrent Elements (Sheet 2 of 2)

Row	Name	Description
27	67Q3T	Level 3 negative-sequence delayed directional overcurrent element
27	67Q4T	Level 4 negative-sequence delayed directional overcurrent element
27	*	Reserved
27	*	Reserved
27	*	Reserved
27	*	Reserved
28	51S1	Inverse-Time Overcurrent Element 1 pickup
28	51S1T	Inverse-Time Overcurrent Element 1 timed out
28	51S1R	Inverse-Time Overcurrent Element 1 reset
28	*	Reserved
28	51S2	Inverse-Time Overcurrent Element 2 pickup
28	51S2T	Inverse-Time Overcurrent Element 2 timed out
28	51S2R	Inverse-Time Overcurrent Element 2 reset
28	*	Reserved
29	51S3	Inverse-Time Overcurrent Element 3 pickup
29	51S3T	Inverse-Time Overcurrent Element 3 timed out
29	51S3R	Inverse-Time Overcurrent Element 3 reset
29	*	Reserved
29	*	Reserved
29	*	Reserved
29	*	Reserved
29	*	Reserved

Table A.8 Relay Word Bits: Synchronism-Check Elements (Sheet 1 of 2)

Row	Name	Description
30	59VP	VP within "healthy voltage" window
30	59VS1	VS1 within "healthy voltage" window
30	25ENBK1	Circuit Breaker 1 synchronism-check element enable
30	SFZBK1	Circuit Breaker 1 slip frequency less than 5 mHz
30	SFBK1	5 mHz ≤ Circuit Breaker 1 slip frequency < 25 SFBK1
30	25W1BK1	Circuit Breaker 1 Angle 1 within Window 1
30	25W2BK1	Circuit Breaker 1 Angle 2 within Window 2
30	25A1BK1	Circuit Breaker 1 voltages within Synchronism Angle 1
31	25A2BK1	Circuit Breaker 1 voltages within Synchronism Angle 2
31	FAST1	fs1 > fp
31	SLOW1	fs1 < fp
31	BSYNBK1	Block synchronism check for Circuit Breaker 1
31	*	Reserved
31	*	Reserved
31	*	Reserved

Table A.8 **Relay Word Bits: Synchronism-Check Elements** (Sheet 2 of 2)

Row	Name	Description
31	*	Reserved
32	59VS2	VS2 within “healthy voltage” window
32	25ENBK2	Circuit Breaker 2 synchronism-check element enable
32	SFZBK2	Circuit Breaker 2 slip frequency less than 5 mHz
32	SFBK2	5 mHz ≤ Circuit Breaker 2 slip frequency < 25 SFBK2
32	25W1BK2	Circuit Breaker 2 Angle 1 within Window 1
32	25W2BK2	Circuit Breaker 2 Angle 2 within Window 2
32	25A1BK2	Circuit Breaker 2 voltages within Synchronism Angle 1
32	25A2BK2	Circuit Breaker 2 voltages within Synchronism Angle 2
33	FAST2	fs2 > fp
33	SLOW2	fs2 < fp
33	BSYNBK2	Block synchronism check for Circuit Breaker 2
33	*	Reserved
33	*	Reserved
33	*	Reserved
33	*	Reserved
33	*	Reserved

Table A.9 **Relay Word Bits: Reclosing Elements** (Sheet 1 of 3)

Row	Name	Description
34	SPRI	Single-pole reclose initiation (SELOGIC control equation)
34	SPARC	Single-pole reclose initiate qualified
34	SPLSHT	Single-pole reclose last shot
34	SPOBK1	Single-pole open Circuit Breaker 1
34	SPOBK2	Single-pole open Circuit Breaker 2
34	3PRI	Three-pole reclose initiation (SELOGIC control equation)
34	3PARC	Three-pole reclose initiate qualified
34	3POBK1	Three-pole open Circuit Breaker 1
35	3POBK2	Three-pole open Circuit Breaker 2
35	3POLINE	Three-pole open line
35	3PLSHT	Three-pole reclose last shot
35	BK1RS	Circuit Breaker 1 in ready state
35	BK2RS	Circuit Breaker 2 in ready state
35	79CY1	Relay in single-pole reclose cycle state
35	79CY3	Relay in three-pole reclose cycle state
35	BK1LO	Circuit Breaker 1 in lockout state
36	BK2LO	Circuit Breaker 2 in lockout state
36	BK1CL	Circuit Breaker 1 close command
36	BK2CL	Circuit Breaker 2 close command
36	LEADBK0	No lead circuit breaker
36	LEADBK1	Lead circuit breaker = Circuit Breaker 1

Table A.9 Relay Word Bits: Reclosing Elements (Sheet 2 of 3)

Row	Name	Description
36	LEADBK2	Lead circuit breaker = Circuit Breaker 2
36	FOLBK0	No follower circuit breaker
36	FOLBK1	Follower circuit breaker = Circuit Breaker 1
37	FOLBK2	Follower circuit breaker = Circuit Breaker 2
37	NBK0	No circuit breakers active in reclose scheme
37	NBK1	One circuit breaker active in reclose scheme
37	NBK2	Two circuit breakers active in reclose scheme
37	SP1CLS	Single-pole Circuit Breaker 1 reclose supervision (SELOGIC control equation)
37	SP2CLS	Single-pole Circuit Breaker 2 reclose supervision (SELOGIC control equation)
37	3P1CLS	Three-pole Circuit Breaker 1 reclose supervision (SELOGIC control equation)
37	3P2CLS	Three-pole Circuit Breaker 2 reclose supervision (SELOGIC control equation)
38	BK1CFT	Circuit Breaker 1 close failure delay timed out
38	BK2CFT	Circuit Breaker 2 close failure delay timed out
38	BK1CLSS	Circuit Breaker 1 in close supervision state
38	BK2CLSS	Circuit Breaker 2 in close supervision state
38	BK1CLST	Circuit Breaker 1 close supervision timer timed out
38	BK2CLST	Circuit Breaker 2 close supervision timer timed out
38	ULCL1	Unlatch closing for Circuit Breaker 1 (SELOGIC control equation)
38	ULCL2	Unlatch closing for Circuit Breaker 2 (SELOGIC control equation)
39	LLDB1	Live Line Dead Bus 1
39	LLDB2	Live Line Dead Bus 2
39	DLLB1	Dead Line Live Bus 1
39	DLLB2	Dead Line Live Bus 2
39	DLDB1	Dead Line Dead Bus 1
39	DLDB2	Dead Line Dead Bus 2
39	R3PTE	Recloser three-pole trip enable
39	R3PTE1	Recloser three-pole trip enable Circuit Breaker 1
40	R3PTE2	Recloser three-pole trip enable Circuit Breaker 2
40	BK1RCIP	Circuit Breaker 1 reclaim in progress (lockout state)
40	BK2RCIP	Circuit Breaker 2 reclaim in progress (lockout state)
40	SPRCIP	Single-pole reclaim in progress
40	3PRCIP	Three-pole reclaim in progress
40	2POBK1	Two poles open Circuit Breaker 1
40	2POBK2	Two poles open Circuit Breaker 2
40	RST_79C	Reset recloser shot count accumulators (SELOGIC control equation)
41	SPSHOT0	Single-pole shot counter =0

Table A.9 Relay Word Bits: Reclosing Elements (Sheet 3 of 3)

Row	Name	Description
41	SPSHOT1	Single-pole shot counter =1
41	SPSHOT2	Single-pole shot counter =2
41	3PSHOT0	Three-pole shot counter =0
41	3PSHOT1	Three-pole shot counter =1
41	3PSHOT2	Three-pole shot counter =2
41	3PSHOT3	Three-pole shot counter =3
41	3PSHOT4	Three-pole shot counter =4
42	SPOI	Single-pole open interval timing
42	3POI	Three-pole open interval timing
42	79STRT	Relay in start state
42	TBBK	Time between circuit breakers timing
42	BK1EXT	Circuit Breaker 1 closed externally
42	BK2EXT	Circuit Breaker 2 closed externally
42	SPOISC	Single-pole open interval supervision condition
42	3POISC	Three-pole open interval supervision condition

Table A.10 Relay Word Bits: Miscellaneous Elements

Row	Name	Description
43	SOTFE	Switch-onto-fault enable
43	ILOP	Internal loss-of-potential from ELOP setting
43	LOP	Loss-of-potential detected
43	ZLOAD	ZLOUT or ZLIN element picked up
43	ZLIN	Load-encroachment “load out” element
43	ZLOUT	Load-encroachment “load in” element
43	FIDEN	Fault identification logic enabled
43	FSA	A-phase sector fault (AG or BCG fault)
44	FSB	B-phase sector fault (BG or CAG fault)
44	FSC	C-phase sector fault (CG or ABG fault)
44	DFAULT	Disables maximum/minimum metering and demand metering when SELOGIC control equation FAULT asserts
44	ER	Event report trigger equation (SELOGIC control equation)
44	EAFSRC	Alternate frequency source (SELOGIC control equation)
44	*	Reserved
44	*	Reserved
44	*	Reserved

Table A.11 Relay Word Bits: Trip Logic Elements (Sheet 1 of 2)

Row	Name	Description
45	RXPRM	Receiver trip permission
45	COMPRM	Communications-assisted trip permission
45	TRPRM	Trip permission

Table A.11 Relay Word Bits: Trip Logic Elements (Sheet 2 of 2)

Row	Name	Description
45	DTR	Direct transfer trip received
45	SOTFT	Switch-onto-fault trip
45	E3PT	Three-pole trip enable
45	E3PT1	Circuit Breaker 1 three-pole trip enable
45	E3PT2	Circuit Breaker 2 three-pole trip enable
46	APS	Trip logic A-phase selected
46	BPS	Trip logic B-phase selected
46	CPS	Trip logic C-phase selected
46	3PS	Trip logic three-phase selected
46	ATPA	Assert Trip A
46	ATPB	Assert Trip B
46	ATPC	Assert Trip C
46	A3PT	Assert three-pole trip
47	TPA	Trip A
47	TPB	Trip B
47	TPC	Trip C
47	TRIP	Trip A or Trip B or Trip C
47	3PT	Three-pole trip
47	SPT	Single-pole trip
47	TPA1	Circuit Breaker 1 Trip A
47	TPB1	Circuit Breaker 1 Trip B
48	TPC1	Circuit Breaker 1 Trip C
48	TPA2	Circuit Breaker 2 Trip A
48	TPB2	Circuit Breaker 2 Trip B
48	TPC2	Circuit Breaker 2 Trip C
48	TOP	Trip during open pole timer is asserted
48	ULTR	Unlatch all protection trips
48	ULMTR1	Circuit Breaker 1 unlatch manual trip
48	ULMTR2	Circuit Breaker 2 unlatch manual trip
49	ULTRA	Unlatch Trip A
49	ULTRB	Unlatch Trip B
49	ULTRC	Unlatch Trip C
49	DTA	Direct transfer trip A-Phase (SELOGIC control equation)
49	DTB	Direct transfer trip B-Phase (SELOGIC control equation)
49	DTC	Direct transfer trip C-Phase (SELOGIC control equation)
49	*	Reserved
49	*	Reserved

Table A.12 Relay Word Bits: Pilot Tripping Elements (Sheet 1 of 2)

Row	Name	Description
50	PT	Permissive trip received
50	Z3RB	Current reversal guard asserted
50	KEY	Transmit permissive trip signal
50	EKEY	Echo received permissive trip signal
50	ECTT	Echo conversion to trip signal
50	27AWI	A-phase undervoltage condition
50	27BWI	B-phase undervoltage condition
50	27CWI	C-phase undervoltage condition
51	WFC	Weak infeed condition detected
51	KEY1	Transmit general permissive trip
51	KEY3	Transmit three-phase permissive trip
51	UBB1	Blocks permissive trip Receiver 1
51	PTRX1	Permissive trip received Channel 1
51	UBB2	Blocks permissive trip Receiver 2
51	PTRX2	Permissive trip received Channel 2
51	UBB	Block permissive trip received 1 or 2
52	PTRX	Permissive trip received Channel 1 and Channel 2
52	Z3XT	Current reversal guard timer picked up
52	Z2PGS	Zone 2 phase and ground short delay element
52	67QG2S	Negative-sequence and residual directional overcurrent short delay element
52	DSTRT	Directional start element picked up
52	NSTRT	Non-directional start element picked up
52	STOP	Stop element picked up
52	BTX	Block extension picked up
53	Z3RBA	A-Phase Current Reversal Guard asserted (ECOMM=POTT3)
53	Z3RBB	B-Phase Current Reversal Guard asserted (ECOMM=POTT3)
53	Z3RBC	C-Phase Current Reversal Guard asserted (ECOMM=POTT3)
53	KEYA	Transmit A-phase permissive trip (ECOMM=POTT3)
53	KEYB	Transmit B-phase permissive trip (ECOMM=POTT3)
53	KEYC	Transmit C-phase permissive trip (ECOMM=POTT3)
53	*	Reserved
53	*	Reserved
54	EKEYA	A-phase echo received permissive trip signal (ECOMM=POTT3)
54	EKEYB	B-phase echo received permissive trip signal (ECOMM=POTT3)
54	EKEYC	C-phase echo received permissive trip signal (ECOMM=POTT3)
54	ECTTA	A-phase echo conversion to trip signal (ECOMM=POTT3)

Table A.12 Relay Word Bits: Pilot Tripping Elements (Sheet 2 of 2)

Row	Name	Description
54	ECTTB	B-phase echo conversion to trip signal (ECOMM=POTT3)
54	ECTTC	C-phase echo conversion to trip signal (ECOMM=POTT3)
54	*	Reserved
54	*	Reserved
55	PTA	A-phase permissive trip received (ECOMM=POTT3)
55	PTB	B-phase permissive trip received (ECOMM=POTT3)
55	PTC	C-phase permissive trip received (ECOMM=POTT3)
55	*	Reserved
55	*	Reserved
55	*	Reserved
55	*	Reserved
55	*	Reserved
56	*	Reserved
56	*	Reserved
56	*	Reserved
56	*	Reserved
56	*	Reserved
56	*	Reserved
56	*	Reserved
56	*	Reserved

Table A.13 Relay Word Bits: Circuit Breaker 1 Failure (Sheet 1 of 2)

Row	Name	Description
57	BFI3P1	Circuit Breaker 1 three-pole circuit breaker failure initiation
57	BFIA1	Circuit Breaker 1 A-phase circuit breaker failure initiation
57	BFIB1	Circuit Breaker 1 B-phase circuit breaker failure initiation
57	BFIC1	Circuit Breaker 1 C-phase circuit breaker failure initiation
57	BFI3PT1	Circuit Breaker 1 extended three-pole extended circuit breaker failure initiation
57	BFIAT1	Circuit Breaker 1 A-phase extended circuit breaker failure initiation
57	BFIBT1	Circuit Breaker 1 B-phase extended circuit breaker failure initiation
57	BFICT1	Circuit Breaker 1 C-phase extended circuit breaker failure initiation
58	50FA1	Circuit Breaker 1 A-phase current threshold exceeded
58	50FB1	Circuit Breaker 1 B-phase current threshold exceeded
58	50FC1	Circuit Breaker 1 C-phase current threshold exceeded
58	RT3P1	Circuit Breaker 1 three-pole retrip
58	RTA1	Circuit Breaker 1 A-phase retrip

Table A.13 Relay Word Bits: Circuit Breaker 1 Failure (Sheet 2 of 2)

Row	Name	Description
58	RTB1	Circuit Breaker 1 B-phase retrip
58	RTC1	Circuit Breaker 1 C-phase retrip
58	RTS3P1	Circuit Breaker 1 current-supervised three-pole retrip
59	RTSA1	Circuit Breaker 1 current-supervised A-phase retrip
59	RTSB1	Circuit Breaker 1 current-supervised B-phase retrip
59	RTSC1	Circuit Breaker 1 current-supervised C-phase retrip
59	RT1	Circuit Breaker 1 retrip
59	FBFA1	Circuit Breaker 1 A-phase circuit breaker failure
59	FBFB1	Circuit Breaker 1 B-phase circuit breaker failure
59	FBFC1	Circuit Breaker 1 C-phase circuit breaker failure
59	FBF1	Circuit Breaker 1 circuit breaker failure
60	50R1	Circuit Breaker 1 residual current threshold exceeded
60	BFIN1	Circuit Breaker 1 no current circuit breaker failure initiation
60	NBF1	Circuit Breaker 1 no current circuit breaker failure
60	50LCA1	Circuit Breaker 1 A-phase load current threshold exceeded
60	50LCB1	Circuit Breaker 1 B-phase load current threshold exceeded
60	50LCC1	Circuit Breaker 1 C-phase load current threshold exceeded
60	BFILC1	Circuit Breaker 1 load current circuit breaker failure initiation
60	LCBF1	Circuit Breaker 1 load current circuit breaker failure
61	50FOA1	Circuit Breaker 1 A-phase flashover current threshold exceeded
61	50FOB1	Circuit Breaker 1 B-phase flashover current threshold exceeded
61	50FOC1	Circuit Breaker 1 C-phase flashover current threshold exceeded
61	BLKFOA1	Circuit Breaker 1 block A-phase flashover detection
61	BLKFOB1	Circuit Breaker 1 block B-phase flashover detection
61	BLKFOC1	Circuit Breaker 1 block C-phase flashover detection
61	FOA1	Circuit Breaker 1 A-phase flashover detected
61	FOB1	Circuit Breaker 1 B-phase flashover detected
62	FOC1	Circuit Breaker 1 C-phase flashover detected
62	FOBF1	Circuit Breaker 1 flashover detected
62	BFTRIP1	Circuit Breaker 1 failure trip output asserted
62	BFTR1	Circuit breaker failure trip—Circuit Breaker 1 (SELOGIC control equation)
62	BFULTR1	Circuit breaker failure unlatch trip—Circuit Breaker 1 (SELOGIC control equation)
62	*	Reserved
62	*	Reserved
62	*	Reserved

Table A.14 Relay Word Bits: Circuit Breaker 2 Failure Elements (Sheet 1 of 2)

Row	Name	Description
63	BFI3P2	Circuit Breaker 2 three-pole circuit breaker failure initiation
63	BFIA2	Circuit Breaker 2 A-phase circuit breaker failure initiation
63	BFIB2	Circuit Breaker 2 B-phase circuit breaker failure initiation
63	BFIC2	Circuit Breaker 2 C-phase circuit breaker failure initiation
63	BFI3PT2	Circuit Breaker 2 three-pole extended circuit breaker failure initiation
63	BFIAT2	Circuit Breaker 2 A-phase extended circuit breaker failure initiation
63	BFIBT2	Circuit Breaker 2 B-phase extended circuit breaker failure initiation
63	BFICT2	Circuit Breaker 2 C-phase extended circuit breaker failure initiation
64	50FA2	Circuit Breaker 2 A-phase current threshold exceeded
64	50FB2	Circuit Breaker 2 B-phase current threshold exceeded
64	50FC2	Circuit Breaker 2 C-phase current threshold exceeded
64	RT3P2	Circuit Breaker 2 three-pole retrip
64	RTA2	Circuit Breaker 2 A-phase retrip
64	RTB2	Circuit Breaker 2 B-phase retrip
64	RTC2	Circuit Breaker 2 C-phase retrip
64	RTS3P2	Circuit Breaker 2 current-supervised three-pole retrip
65	RTSA2	Circuit Breaker 2 current-supervised A-phase retrip
65	RTSB2	Circuit Breaker 2 current-supervised B-phase retrip
65	RTSC2	Circuit Breaker 2 current-supervised C-phase retrip
65	RT2	Circuit Breaker 2 retrip
65	FBFA2	Circuit Breaker 2 A-phase circuit breaker failure
65	FBFB2	Circuit Breaker 2 B-phase circuit breaker failure
65	FBFC2	Circuit Breaker 2 C-phase circuit breaker failure
65	FBF2	Circuit Breaker 2 circuit breaker failure
66	50R2	Circuit Breaker 2 residual current threshold exceeded
66	BFIN2	Circuit Breaker 2 no current circuit breaker failure initiation
66	NBF2	Circuit Breaker 2 no current circuit breaker failure
66	50LCA2	Circuit Breaker 2 A-phase load current threshold exceeded
66	50LCB2	Circuit Breaker 2 B-phase load current threshold exceeded
66	50LCC2	Circuit Breaker 2 C-phase load current threshold exceeded
66	BFILC2	Circuit Breaker 2 load current circuit breaker failure initiation
66	LCBF2	Circuit Breaker 2 load current circuit breaker failure
67	50FOA2	Circuit Breaker 2 A-phase flashover current threshold exceeded
67	50FOB2	Circuit Breaker 2 B-phase flashover current threshold exceeded

Table A.14 Relay Word Bits: Circuit Breaker 2 Failure Elements (Sheet 2 of 2)

Row	Name	Description
67	50FOC2	Circuit Breaker 2 C-phase flashover current threshold exceeded
67	BLKFOA2	Circuit Breaker 2 block A-phase flashover detection
67	BLKFOB2	Circuit Breaker 2 block B-phase flashover detection
67	BLKFOC2	Circuit Breaker 2 block C-phase flashover detection
67	FOA2	Circuit Breaker 2 A-phase flashover detected
67	FOB2	Circuit Breaker 2 B-phase flashover detected
68	FOC2	Circuit Breaker 2 C-phase flashover detected
68	FOBF2	Circuit Breaker 2 flashover detected
68	BFTRIP2	Circuit Breaker 2 failure trip output asserted
68	BFTR2	Circuit breaker failure trip—Circuit Breaker 2 (SELOGIC control equation)
68	BFULTR2	Circuit breaker failure unlatch trip—Circuit Breaker 2 (SELOGIC control equation)
68	*	Reserved
68	*	Reserved
68	*	Reserved

Table A.15 Relay Word Bits: Circuit Breaker Status and Open Phase Detector (Sheet 1 of 2)

Row	Name	Description
69	B1OPHA	Circuit Breaker 1 A-phase open
69	B1OPHB	Circuit Breaker 1 B-phase open
69	B1OPHC	Circuit Breaker 1 C-phase open
69	B2OPHA	Circuit Breaker 2 A-phase open
69	B2OPHB	Circuit Breaker 2 B-phase open
69	B2OPHC	Circuit Breaker 2 C-phase open
69	LOPHA	Line A-phase open
69	LOPHB	Line B-phase open
70	LOPHC	Line C-phase open
70	SPOA	A-phase open
70	SPOB	B-phase open
70	SPOC	C-phase open
70	SPO	One or two poles open
70	3PO	All three poles open
70	27APO	A-phase undervoltage, pole open
70	27BPO	B-phase undervoltage, pole open
71	27CPO	C-phase undervoltage, pole open
71	*	Reserved
71	*	Reserved
71	*	Reserved
71	*	Reserved

Table A.15 Relay Word Bits: Circuit Breaker Status and Open Phase Detector (Sheet 2 of 2)

Row	Name	Description
71	*	Reserved
71	*	Reserved
71	*	Reserved
72	52ACL1	Circuit Breaker 1, Pole A closed
72	52BCL1	Circuit Breaker 1, Pole B closed
72	52CCL1	Circuit Breaker 1, Pole C closed
72	52AAL1	Circuit Breaker 1, Pole A alarm
72	52BAL1	Circuit Breaker 1, Pole B alarm
72	52CAL1	Circuit Breaker 1, Pole C alarm
72	52AA1	Circuit Breaker 1, Pole A status
72	52AB1	Circuit Breaker 1, Pole B status
73	52AC1	Circuit Breaker 1, Pole C status
73	*	Reserved
73	52ACL2	Circuit Breaker 2, Pole A closed
73	52BCL2	Circuit Breaker 2, Pole B closed
73	52CCL2	Circuit Breaker 2, Pole C closed
73	52AAL2	Circuit Breaker 2, Pole A alarm
73	52BAL2	Circuit Breaker 2, Pole B alarm
73	52CAL2	Circuit Breaker 2, Pole C alarm
74	52AA2	Circuit Breaker 2, Pole A status
74	52AB2	Circuit Breaker 2, Pole B status
74	52AC2	Circuit Breaker 2, Pole C status
74	*	Reserved
74	*	Reserved
74	*	Reserved
74	*	Reserved
74	*	Reserved
75–78	*	Reserved

Table A.16 Relay Word Bits: Circuit Breaker Monitor (Sheet 1 of 2)

Row	Name	Description
79	BM1TRPA	Circuit breaker monitor A-phase trip—Circuit Breaker 1 (SELOGIC control equation)
79	BM1TRPB	Circuit breaker monitor B-phase trip—Circuit Breaker 1 (SELOGIC control equation)
79	BM1TRPC	Circuit breaker monitor C-phase trip—Circuit Breaker 1 (SELOGIC control equation)
79	BM1CLSA	Circuit breaker monitor A-phase close—Circuit Breaker 1 (SELOGIC control equation)
79	BM1CLSB	Circuit breaker monitor B-phase close—Circuit Breaker 1 (SELOGIC control equation)

Table A.16 Relay Word Bits: Circuit Breaker Monitor (Sheet 2 of 2)

Row	Name	Description
79	BM1CLSC	Circuit breaker monitor C-phase close—Circuit Breaker 1 (SELOGIC control equation)
79	B1BCWAL	Circuit Breaker 1 contact wear monitor alarm
79	B1MRTIN	Motor run time contact input—Circuit Breaker 1 (SELOGIC control equation)
80	*	Reserved
80	B1MSOAL	Circuit Breaker 1 mechanical slow operation alarm
80	B1ESOAL	Circuit Breaker 1 electrical slow operation alarm
80	B1PSAL	Circuit Breaker 1 pole scatter alarm
80	B1PDAL	Circuit Breaker 1 pole discrepancy alarm
80	B1BITAL	Circuit Breaker 1 inactivity time alarm
80	B1MRTAL	Circuit Breaker 1 motor running time alarm
80	B1KAIAL	Circuit Breaker 1 interrupted current alarm
81	BM2TRPA	Circuit breaker monitor A-phase trip—Circuit Breaker 2 (SELOGIC control equation)
81	BM2TRPB	Circuit breaker monitor B-phase trip—Circuit Breaker 2 (SELOGIC control equation)
81	BM2TRPC	Circuit breaker monitor C-phase trip—Circuit Breaker 2 (SELOGIC control equation)
81	BM2CLSA	Circuit breaker monitor A-phase close—Circuit Breaker 2 (SELOGIC control equation)
81	BM2CLSB	Circuit breaker monitor B-phase close—Circuit Breaker 2 (SELOGIC control equation)
81	BM2CLSC	Circuit breaker monitor C-phase close—Circuit Breaker 2 (SELOGIC control equation)
81	B2BCWAL	Circuit Breaker 2 contact wear monitor alarm
81	B2MRTIN	Motor run time contact input—Circuit Breaker 2 (SELOGIC control equation)
82	*	Reserved
82	B2MSOAL	Circuit Breaker 2 mechanical slow operation alarm
82	B2ESOAL	Circuit Breaker 2 electrical slow operation alarm
82	B2PSAL	Circuit Breaker 2 pole scatter alarm
82	B2PDAL	Circuit Breaker 2 pole discrepancy alarm
82	B2BITAL	Circuit Breaker 2 inactivity time alarm
82	B2MRTAL	Circuit Breaker 2 motor running time alarm
82	B2KAIAL	Circuit Breaker 2 interrupted current alarm

Table A.17 Relay Word Bits: RTD Status (Sheet 1 of 2)

Row	Name	Description
83	RTD08ST	RTD Status for Channel 8
83	RTD07ST	RTD Status for Channel 7
83	RTD06ST	RTD Status for Channel 6
83	RTD05ST	RTD Status for Channel 5
83	RTD04ST	RTD Status for Channel 4

Table A.17 **Relay Word Bits: RTD Status** (Sheet 2 of 2)

Row	Name	Description
83	RTD03ST	RTD Status for Channel 3
83	RTD02ST	RTD Status for Channel 2
83	RTD01ST	RTD Status for Channel 1
84	RTDIN	State of RTD contact input
84	RTDCOMF	RTD Communication Failure
84	RTDFL	RTD device Failure
84	*	Reserved
84	RTD12ST	RTD Status for Channel 12
84	RTD11ST	RTD Status for Channel 11
84	RTD10ST	RTD Status for Channel 10
84	RTD09ST	RTD Status for Channel 9

Table A.18 **Relay Word Bits: DC Supply Monitor**

Row	Name	Description
85	DC1F	DC Monitor 1 fail alarm
85	DC1W	DC Monitor 1 warning alarm
85	DC1G	DC Monitor 1 ground fault alarm
85	DC1R	DC Monitor 1 alarm for ac ripple
85	DC2F	DC Monitor 2 fail alarm
85	DC2W	DC Monitor 2 warning alarm
85	DC2G	DC Monitor 2 ground fault alarm
85	DC2R	DC Monitor 2 alarm for ac ripple

Table A.19 **Relay Word Bits: Metering Elements**

Row	Name	Description
86	PDEM	Phase current demand picked up
86	QDEM	Negative-sequence demand current picked up
86	GDEM	Zero-sequence demand current picked up
86	*	Reserved
86	*	Reserved
86	*	Reserved
86	*	Reserved
86	*	Reserved

Table A.20 **Relay Word Bits: Open and Close Command** (Sheet 1 of 2)

Row	Name	Description
87	CC2	Circuit Breaker 2 close command
87	OC2	Circuit Breaker 2 open command
87	CC1	Circuit Breaker 1 close command
87	OC1	Circuit Breaker 1 open command
87	*	Reserved

Table A.20 Relay Word Bits: Open and Close Command (Sheet 2 of 2)

Row	Name	Description
87	*	Reserved
87	*	Reserved
87	*	Reserved

Table A.21 Relay Word Bits: Local Bits

Row	Name	Description
88	LB08	Local Bit 8
88	LB07	Local Bit 7
88	LB06	Local Bit 6
88	LB05	Local Bit 5
88	LB04	Local Bit 4
88	LB03	Local Bit 3
88	LB02	Local Bit 2
88	LB01	Local Bit 1
89	LB16	Local Bit 16
89	LB15	Local Bit 15
89	LB14	Local Bit 14
89	LB13	Local Bit 13
89	LB12	Local Bit 12
89	LB11	Local Bit 11
89	LB10	Local Bit 10
89	LB09	Local Bit 9
90	LB24	Local Bit 24
90	LB23	Local Bit 23
90	LB22	Local Bit 22
90	LB21	Local Bit 21
90	LB20	Local Bit 20
90	LB19	Local Bit 19
90	LB18	Local Bit 18
90	LB17	Local Bit 17
91	LB32	Local Bit 32
91	LB31	Local Bit 31
91	LB30	Local Bit 30
91	LB29	Local Bit 29
91	LB28	Local Bit 28
91	LB27	Local Bit 27
91	LB26	Local Bit 26
91	LB25	Local Bit 25

Table A.22 Relay Word Bits: Remote Bits

Row	Name	Description
92	RB25	Remote Bit 25
92	RB26	Remote Bit 26
92	RB27	Remote Bit 27
92	RB28	Remote Bit 28
92	RB29	Remote Bit 29
92	RB30	Remote Bit 30
92	RB31	Remote Bit 31
92	RB32	Remote Bit 32
93	RB17	Remote Bit 17
93	RB18	Remote Bit 18
93	RB19	Remote Bit 19
93	RB20	Remote Bit 20
93	RB21	Remote Bit 21
93	RB22	Remote Bit 22
93	RB23	Remote Bit 23
93	RB24	Remote Bit 24
94	RB09	Remote Bit 9
94	RB10	Remote Bit 10
94	RB11	Remote Bit 11
94	RB12	Remote Bit 12
94	RB13	Remote Bit 13
94	RB14	Remote Bit 14
94	RB15	Remote Bit 15
94	RB16	Remote Bit 16
95	RB01	Remote Bit 1
95	RB02	Remote Bit 2
95	RB03	Remote Bit 3
95	RB04	Remote Bit 4
95	RB05	Remote Bit 5
95	RB06	Remote Bit 6
95	RB07	Remote Bit 7
95	RB08	Remote Bit 8

Table A.23 Relay Word Bits: Active Protection Settings Group (Sheet 1 of 2)

Row	Name	Description
96	SG6	Settings Group 6 active
96	SG5	Settings Group 5 active
96	SG4	Settings Group 4 active
96	SG3	Settings Group 3 active
96	SG2	Settings Group 2 active
96	SG1	Settings Group 1 active

Table A.23 Relay Word Bits: Active Protection Settings Group (Sheet 2 of 2)

Row	Name	Description
96	CHSG	Settings Group Change
96	*	Reserved
97–99	*	Reserved

Table A.24 Relay Word Bits: Input Elements (Sheet 1 of 2)

Row	Name	Description
100	*	Reserved
100	IN107	Main Board Input 7
100	IN106	Main Board Input 6
100	IN105	Main Board Input 5
100	IN104	Main Board Input 4
100	IN103	Main Board Input 3
100	IN102	Main Board Input 2
100	IN101	Main Board Input 1
101	IN208	First Optional I/O Board Input 8 (if installed)
101	IN207	First Optional I/O Board Input 7 (if installed)
101	IN206	First Optional I/O Board Input 6 (if installed)
101	IN205	First Optional I/O Board Input 5 (if installed)
101	IN204	First Optional I/O Board Input 4 (if installed)
101	IN203	First Optional I/O Board Input 3 (if installed)
101	IN202	First Optional I/O Board Input 2 (if installed)
101	IN201	First Optional I/O Board Input 1 (if installed)
102	IN216	First Optional I/O Board Input 16 (if installed)
102	IN215	First Optional I/O Board Input 15 (if installed)
102	IN214	First Optional I/O Board Input 14 (if installed)
102	IN213	First Optional I/O Board Input 13 (if installed)
102	IN212	First Optional I/O Board Input 12 (if installed)
102	IN211	First Optional I/O Board Input 11 (if installed)
102	IN210	First Optional I/O Board Input 10 (if installed)
102	IN209	First Optional I/O Board Input 9 (if installed)
103	IN224	First Optional I/O Board Input 24 (if installed)
103	IN223	First Optional I/O Board Input 23 (if installed)
103	IN222	First Optional I/O Board Input 22 (if installed)
103	IN221	First Optional I/O Board Input 21 (if installed)
103	IN220	First Optional I/O Board Input 20 (if installed)
103	IN219	First Optional I/O Board Input 19 (if installed)
103	IN218	First Optional I/O Board Input 18 (if installed)
103	IN217	First Optional I/O Board Input 17 (if installed)
104	IN308	Second Optional I/O Board Input 8 (if installed)
104	IN307	Second Optional I/O Board Input 7 (if installed)
104	IN306	Second Optional I/O Board Input 6 (if installed)

Table A.24 Relay Word Bits: Input Elements (Sheet 2 of 2)

Row	Name	Description
104	IN305	Second Optional I/O Board Input 5 (if installed)
104	IN304	Second Optional I/O Board Input 4 (if installed)
104	IN303	Second Optional I/O Board Input 3 (if installed)
104	IN302	Second Optional I/O Board Input 2 (if installed)
104	IN301	Second Optional I/O Board Input 1 (if installed)
105	IN316	Second Optional I/O Board Input 16 (if installed)
105	IN315	Second Optional I/O Board Input 15 (if installed)
105	IN314	Second Optional I/O Board Input 14 (if installed)
105	IN313	Second Optional I/O Board Input 13 (if installed)
105	IN312	Second Optional I/O Board Input 12 (if installed)
105	IN311	Second Optional I/O Board Input 11 (if installed)
105	IN310	Second Optional I/O Board Input 10 (if installed)
105	IN309	Second Optional I/O Board Input 9 (if installed)
106	IN324	Second Optional I/O Board Input 24 (if installed)
106	IN323	Second Optional I/O Board Input 23 (if installed)
106	IN322	Second Optional I/O Board Input 22 (if installed)
106	IN321	Second Optional I/O Board Input 21 (if installed)
106	IN320	Second Optional I/O Board Input 20 (if installed)
106	IN319	Second Optional I/O Board Input 19 (if installed)
106	IN318	Second Optional I/O Board Input 18 (if installed)
106	IN317	Second Optional I/O Board Input 17 (if installed)
107	*	Reserved
107	*	Reserved
107	*	Reserved
107	*	Reserved
107	*	Reserved
107	*	Reserved
107	*	Reserved
107	*	Reserved

Table A.25 Relay Word Bits: Protection Variables (Sheet 1 of 3)

Row	Name	Description
108	PSV08	Protection SELOGIC Variable 8
108	PSV07	Protection SELOGIC Variable 7
108	PSV06	Protection SELOGIC Variable 6
108	PSV05	Protection SELOGIC Variable 5
108	PSV04	Protection SELOGIC Variable 4
108	PSV03	Protection SELOGIC Variable 3
108	PSV02	Protection SELOGIC Variable 2
108	PSV01	Protection SELOGIC Variable 1
109	PSV16	Protection SELOGIC Variable 16

Table A.25 Relay Word Bits: Protection Variables (Sheet 2 of 3)

Row	Name	Description
109	PSV15	Protection SELOGIC Variable 15
109	PSV14	Protection SELOGIC Variable 14
109	PSV13	Protection SELOGIC Variable 13
109	PSV12	Protection SELOGIC Variable 12
109	PSV11	Protection SELOGIC Variable 11
109	PSV10	Protection SELOGIC Variable 10
109	PSV09	Protection SELOGIC Variable 9
110	PSV24	Protection SELOGIC Variable 24
110	PSV23	Protection SELOGIC Variable 23
110	PSV22	Protection SELOGIC Variable 22
110	PSV21	Protection SELOGIC Variable 21
110	PSV20	Protection SELOGIC Variable 20
110	PSV19	Protection SELOGIC Variable 19
110	PSV18	Protection SELOGIC Variable 18
110	PSV17	Protection SELOGIC Variable 17
111	PSV32	Protection SELOGIC Variable 32
111	PSV31	Protection SELOGIC Variable 31
111	PSV30	Protection SELOGIC Variable 30
111	PSV29	Protection SELOGIC Variable 29
111	PSV28	Protection SELOGIC Variable 28
111	PSV27	Protection SELOGIC Variable 27
111	PSV26	Protection SELOGIC Variable 26
111	PSV25	Protection SELOGIC Variable 25
112	PSV40	Protection SELOGIC Variable 40
112	PSV39	Protection SELOGIC Variable 39
112	PSV38	Protection SELOGIC Variable 38
112	PSV37	Protection SELOGIC Variable 37
112	PSV36	Protection SELOGIC Variable 36
112	PSV35	Protection SELOGIC Variable 35
112	PSV34	Protection SELOGIC Variable 34
112	PSV33	Protection SELOGIC Variable 33
113	PSV48	Protection SELOGIC Variable 48
113	PSV47	Protection SELOGIC Variable 47
113	PSV46	Protection SELOGIC Variable 46
113	PSV45	Protection SELOGIC Variable 45
113	PSV44	Protection SELOGIC Variable 44
113	PSV43	Protection SELOGIC Variable 43
113	PSV42	Protection SELOGIC Variable 42
113	PSV41	Protection SELOGIC Variable 41
114	PSV56	Protection SELOGIC Variable 56
114	PSV55	Protection SELOGIC Variable 55

Table A.25 Relay Word Bits: Protection Variables (Sheet 3 of 3)

Row	Name	Description
114	PSV54	Protection SELOGIC Variable 54
114	PSV53	Protection SELOGIC Variable 53
114	PSV52	Protection SELOGIC Variable 52
114	PSV51	Protection SELOGIC Variable 51
114	PSV50	Protection SELOGIC Variable 50
114	PSV49	Protection SELOGIC Variable 49
115	PSV64	Protection SELOGIC Variable 64
115	PSV63	Protection SELOGIC Variable 63
115	PSV62	Protection SELOGIC Variable 62
115	PSV61	Protection SELOGIC Variable 61
115	PSV60	Protection SELOGIC Variable 60
115	PSV59	Protection SELOGIC Variable 59
115	PSV58	Protection SELOGIC Variable 58
115	PSV57	Protection SELOGIC Variable 57

Table A.26 Relay Word Bits: Protection Latches (Sheet 1 of 2)

Row	Name	Description
116	PLT08	Protection Latch 8
116	PLT07	Protection Latch 7
116	PLT06	Protection Latch 6
116	PLT05	Protection Latch 5
116	PLT04	Protection Latch 4
116	PLT03	Protection Latch 3
116	PLT02	Protection Latch 2
116	PLT01	Protection Latch 1
117	PLT16	Protection Latch 16
117	PLT15	Protection Latch 15
117	PLT14	Protection Latch 14
117	PLT13	Protection Latch 13
117	PLT12	Protection Latch 12
117	PLT11	Protection Latch 11
117	PLT10	Protection Latch 10
117	PLT09	Protection Latch 9
118	PLT24	Protection Latch 24
118	PLT23	Protection Latch 23
118	PLT22	Protection Latch 22
118	PLT21	Protection Latch 21
118	PLT20	Protection Latch 20
118	PLT19	Protection Latch 19
118	PLT18	Protection Latch 18
118	PLT17	Protection Latch 17

Table A.26 Relay Word Bits: Protection Latches (Sheet 2 of 2)

Row	Name	Description
119	PLT32	Protection Latch 32
119	PLT31	Protection Latch 31
119	PLT30	Protection Latch 30
119	PLT29	Protection Latch 29
119	PLT28	Protection Latch 28
119	PLT27	Protection Latch 27
119	PLT26	Protection Latch 26
119	PLT25	Protection Latch 25

Table A.27 Relay Word Bits: Protection Conditioning Timers (Sheet 1 of 2)

Row	Name	Description
120	PCT08Q	Protection Conditioning Timer 8 output
120	PCT07Q	Protection Conditioning Timer 7 output
120	PCT06Q	Protection Conditioning Timer 6 output
120	PCT05Q	Protection Conditioning Timer 5 output
120	PCT04Q	Protection Conditioning Timer 4 output
120	PCT03Q	Protection Conditioning Timer 3 output
120	PCT02Q	Protection Conditioning Timer 2 output
120	PCT01Q	Protection Conditioning Timer 1 output
121	PCT16Q	Protection Conditioning Timer 16 output
121	PCT15Q	Protection Conditioning Timer 15 output
121	PCT14Q	Protection Conditioning Timer 14 output
121	PCT13Q	Protection Conditioning Timer 13 output
121	PCT12Q	Protection Conditioning Timer 12 output
121	PCT11Q	Protection Conditioning Timer 11 output
121	PCT10Q	Protection Conditioning Timer 10 output
121	PCT09Q	Protection Conditioning Timer 9 output
121	PCT09Q	Protection Conditioning Timer 9 output
122	PCT24Q	Protection Conditioning Timer 24 output
122	PCT23Q	Protection Conditioning Timer 23 output
122	PCT22Q	Protection Conditioning Timer 22 output
122	PCT21Q	Protection Conditioning Timer 21 output
122	PCT20Q	Protection Conditioning Timer 20 output
122	PCT19Q	Protection Conditioning Timer 19 output
122	PCT18Q	Protection Conditioning Timer 18 output
122	PCT17Q	Protection Conditioning Timer 17 output
123	PCT32Q	Protection Conditioning Timer 32 output
123	PCT31Q	Protection Conditioning Timer 31 output
123	PCT30Q	Protection Conditioning Timer 30 output
123	PCT29Q	Protection Conditioning Timer 29 output
123	PCT28Q	Protection Conditioning Timer 28 output

Table A.27 Relay Word Bits: Protection Conditioning Timers (Sheet 2 of 2)

Row	Name	Description
123	PCT27Q	Protection Conditioning Timer 27 output
123	PCT26Q	Protection Conditioning Timer 26 output
123	PCT25Q	Protection Conditioning Timer 25 output
124–125	*	Reserved

Table A.28 Relay Word Bits: Protection Sequencing Timers (Sheet 1 of 2)

Row	Name	Description
126	PST08Q	Protection Sequencing Timer 8 output
126	PST07Q	Protection Sequencing Timer 7 output
126	PST06Q	Protection Sequencing Timer 6 output
126	PST05Q	Protection Sequencing Timer 5 output
126	PST04Q	Protection Sequencing Timer 4 output
126	PST03Q	Protection Sequencing Timer 3 output
126	PST02Q	Protection Sequencing Timer 2 output
126	PST01Q	Protection Sequencing Timer 1 output
127	PST16Q	Protection Sequencing Timer 16 output
127	PST15Q	Protection Sequencing Timer 15 output
127	PST14Q	Protection Sequencing Timer 14 output
127	PST13Q	Protection Sequencing Timer 13 output
127	PST12Q	Protection Sequencing Timer 12 output
127	PST11Q	Protection Sequencing Timer 11 output
127	PST10Q	Protection Sequencing Timer 10 output
127	PST09Q	Protection Sequencing Timer 9 output
128	PST24Q	Protection Sequencing Timer 24 output
128	PST23Q	Protection Sequencing Timer 23 output
128	PST22Q	Protection Sequencing Timer 22 output
128	PST21Q	Protection Sequencing Timer 21 output
128	PST20Q	Protection Sequencing Timer 20 output
128	PST19Q	Protection Sequencing Timer 19 output
128	PST18Q	Protection Sequencing Timer 18 output
128	PST17Q	Protection Sequencing Timer 17 output
129	PST32Q	Protection Sequencing Timer 32 output
129	PST31Q	Protection Sequencing Timer 31 output
129	PST30Q	Protection Sequencing Timer 30 output
129	PST29Q	Protection Sequencing Timer 29 output
129	PST28Q	Protection Sequencing Timer 28 output
129	PST27Q	Protection Sequencing Timer 27 output
129	PST26Q	Protection Sequencing Timer 26 output
129	PST25Q	Protection Sequencing Timer 25 output
130	PST08R	Protection Sequencing Timer 8 reset

Table A.28 Relay Word Bits: Protection Sequencing Timers (Sheet 2 of 2)

Row	Name	Description
130	PST07R	Protection Sequencing Timer 7 reset
130	PST06R	Protection Sequencing Timer 6 reset
130	PST05R	Protection Sequencing Timer 5 reset
130	PST04R	Protection Sequencing Timer 4 reset
130	PST03R	Protection Sequencing Timer 3 reset
130	PST02R	Protection Sequencing Timer 2 reset
130	PST01R	Protection Sequencing Timer 1 reset
131	PST16R	Protection Sequencing Timer 16 reset
131	PST15R	Protection Sequencing Timer 15 reset
131	PST14R	Protection Sequencing Timer 14 reset
131	PST13R	Protection Sequencing Timer 13 reset
131	PST12R	Protection Sequencing Timer 12 reset
131	PST11R	Protection Sequencing Timer 11 reset
131	PST10R	Protection Sequencing Timer 10 reset
131	PST09R	Protection Sequencing Timer 9 reset
132	PST24R	Protection Sequencing Timer 24 reset
132	PST23R	Protection Sequencing Timer 23 reset
132	PST22R	Protection Sequencing Timer 22 reset
132	PST21R	Protection Sequencing Timer 21 reset
132	PST20R	Protection Sequencing Timer 20 reset
132	PST19R	Protection Sequencing Timer 19 reset
132	PST18R	Protection Sequencing Timer 18 reset
132	PST17R	Protection Sequencing Timer 17 reset
133	PST32R	Protection Sequencing Timer 32 reset
133	PST31R	Protection Sequencing Timer 31 reset
133	PST30R	Protection Sequencing Timer 30 reset
133	PST29R	Protection Sequencing Timer 29 reset
133	PST28R	Protection Sequencing Timer 28 reset
133	PST27R	Protection Sequencing Timer 27 reset
133	PST26R	Protection Sequencing Timer 26 reset
133	PST25R	Protection Sequencing Timer 25 reset

Table A.29 Relay Word Bits: Protection Counters (Sheet 1 of 3)

Row	Name	Description
134	PCN08Q	Protection Counter 8 output
134	PCN07Q	Protection Counter 7 output
134	PCN06Q	Protection Counter 6 output
134	PCN05Q	Protection Counter 5 output
134	PCN04Q	Protection Counter 4 output
134	PCN03Q	Protection Counter 3 output
134	PCN02Q	Protection Counter 2 output

Table A.29 Relay Word Bits: Protection Counters (Sheet 2 of 3)

Row	Name	Description
134	PCN01Q	Protection Counter 1 output
135	PCN16Q	Protection Counter 16 output
135	PCN15Q	Protection Counter 15 output
135	PCN14Q	Protection Counter 14 output
135	PCN13Q	Protection Counter 13 output
135	PCN12Q	Protection Counter 12 output
135	PCN11Q	Protection Counter 11 output
135	PCN10Q	Protection Counter 10 output
135	PCN09Q	Protection Counter 9 output
136	PCN24Q	Protection Counter 24 output
136	PCN23Q	Protection Counter 23 output
136	PCN22Q	Protection Counter 22 output
136	PCN21Q	Protection Counter 21 output
136	PCN20Q	Protection Counter 20 output
136	PCN19Q	Protection Counter 19 output
136	PCN18Q	Protection Counter 18 output
136	PCN17Q	Protection Counter 17 output
137	PCN32Q	Protection Counter 32 output
137	PCN31Q	Protection Counter 31 output
137	PCN30Q	Protection Counter 30 output
137	PCN29Q	Protection Counter 29 output
137	PCN28Q	Protection Counter 28 output
137	PCN27Q	Protection Counter 27 output
137	PCN26Q	Protection Counter 26 output
137	PCN25Q	Protection Counter 25 output
138	PCN08R	Protection Counter 8 reset
138	PCN07R	Protection Counter 7 reset
138	PCN06R	Protection Counter 6 reset
138	PCN05R	Protection Counter 5 reset
138	PCN04R	Protection Counter 4 reset
138	PCN03R	Protection Counter 3 reset
138	PCN02R	Protection Counter 2 reset
138	PCN01R	Protection Counter 1 reset
139	PCN16R	Protection Counter 16 reset
139	PCN15R	Protection Counter 15 reset
139	PCN14R	Protection Counter 14 reset
139	PCN13R	Protection Counter 13 reset
139	PCN12R	Protection Counter 12 reset
139	PCN11R	Protection Counter 11 reset
139	PCN10R	Protection Counter 10 reset
139	PCN09R	Protection Counter 9 reset

Table A.29 Relay Word Bits: Protection Counters (Sheet 3 of 3)

Row	Name	Description
140	PCN24R	Protection Counter 24 reset
140	PCN23R	Protection Counter 23 reset
140	PCN22R	Protection Counter 22 reset
140	PCN21R	Protection Counter 21 reset
140	PCN20R	Protection Counter 20 reset
140	PCN19R	Protection Counter 19 reset
140	PCN18R	Protection Counter 18 reset
140	PCN17R	Protection Counter 17 reset
141	PCN32R	Protection Counter 32 reset
141	PCN31R	Protection Counter 31 reset
141	PCN30R	Protection Counter 30 reset
141	PCN29R	Protection Counter 29 reset
141	PCN28R	Protection Counter 28 reset
141	PCN27R	Protection Counter 27 reset
141	PCN26R	Protection Counter 26 reset
141	PCN25R	Protection Counter 25 reset

Table A.30 Relay Word Bits: Automation Variables (Sheet 1 of 7)

Row	Name	Description
142	ASV008	Automation SELOGIC Variable 8
142	ASV007	Automation SELOGIC Variable 7
142	ASV006	Automation SELOGIC Variable 6
142	ASV005	Automation SELOGIC Variable 5
142	ASV004	Automation SELOGIC Variable 4
142	ASV003	Automation SELOGIC Variable 3
142	ASV002	Automation SELOGIC Variable 2
142	ASV001	Automation SELOGIC Variable 1
143	ASV016	Automation SELOGIC Variable 16
143	ASV015	Automation SELOGIC Variable 15
143	ASV014	Automation SELOGIC Variable 14
143	ASV013	Automation SELOGIC Variable 13
143	ASV012	Automation SELOGIC Variable 12
143	ASV011	Automation SELOGIC Variable 11
143	ASV010	Automation SELOGIC Variable 10
143	ASV009	Automation SELOGIC Variable 9
144	ASV024	Automation SELOGIC Variable 24
144	ASV023	Automation SELOGIC Variable 23
144	ASV022	Automation SELOGIC Variable 22
144	ASV021	Automation SELOGIC Variable 21
144	ASV020	Automation SELOGIC Variable 20
144	ASV019	Automation SELOGIC Variable 19

Table A.30 Relay Word Bits: Automation Variables (Sheet 2 of 7)

Row	Name	Description
144	ASV018	Automation SELOGIC Variable 18
144	ASV017	Automation SELOGIC Variable 17
145	ASV032	Automation SELOGIC Variable 32
145	ASV031	Automation SELOGIC Variable 31
145	ASV030	Automation SELOGIC Variable 30
145	ASV029	Automation SELOGIC Variable 29
145	ASV028	Automation SELOGIC Variable 28
145	ASV027	Automation SELOGIC Variable 27
145	ASV026	Automation SELOGIC Variable 26
145	ASV025	Automation SELOGIC Variable 25
146	ASV040	Automation SELOGIC Variable 40
146	ASV039	Automation SELOGIC Variable 39
146	ASV038	Automation SELOGIC Variable 38
146	ASV037	Automation SELOGIC Variable 37
146	ASV036	Automation SELOGIC Variable 36
146	ASV035	Automation SELOGIC Variable 35
146	ASV034	Automation SELOGIC Variable 34
146	ASV033	Automation SELOGIC Variable 33
147	ASV048	Automation SELOGIC Variable 48
147	ASV047	Automation SELOGIC Variable 47
147	ASV046	Automation SELOGIC Variable 46
147	ASV045	Automation SELOGIC Variable 45
147	ASV044	Automation SELOGIC Variable 44
147	ASV043	Automation SELOGIC Variable 43
147	ASV042	Automation SELOGIC Variable 42
147	ASV041	Automation SELOGIC Variable 41
148	ASV056	Automation SELOGIC Variable 56
148	ASV055	Automation SELOGIC Variable 55
148	ASV054	Automation SELOGIC Variable 54
148	ASV053	Automation SELOGIC Variable 53
148	ASV052	Automation SELOGIC Variable 52
148	ASV051	Automation SELOGIC Variable 51
148	ASV050	Automation SELOGIC Variable 50
148	ASV049	Automation SELOGIC Variable 49
149	ASV064	Automation SELOGIC Variable 64
149	ASV063	Automation SELOGIC Variable 63
149	ASV062	Automation SELOGIC Variable 62
149	ASV061	Automation SELOGIC Variable 61
149	ASV060	Automation SELOGIC Variable 60
149	ASV059	Automation SELOGIC Variable 59
149	ASV058	Automation SELOGIC Variable 58

Table A.30 Relay Word Bits: Automation Variables (Sheet 3 of 7)

Row	Name	Description
149	ASV057	Automation SELOGIC Variable 57
150	ASV072	Automation SELOGIC Variable 72
150	ASV071	Automation SELOGIC Variable 71
150	ASV070	Automation SELOGIC Variable 70
150	ASV069	Automation SELOGIC Variable 69
150	ASV068	Automation SELOGIC Variable 68
150	ASV067	Automation SELOGIC Variable 67
150	ASV066	Automation SELOGIC Variable 66
150	ASV065	Automation SELOGIC Variable 65
151	ASV080	Automation SELOGIC Variable 80
151	ASV079	Automation SELOGIC Variable 79
151	ASV078	Automation SELOGIC Variable 78
151	ASV077	Automation SELOGIC Variable 77
151	ASV076	Automation SELOGIC Variable 76
151	ASV075	Automation SELOGIC Variable 75
151	ASV074	Automation SELOGIC Variable 74
151	ASV073	Automation SELOGIC Variable 73
148	ASV088	Automation SELOGIC Variable 88
152	ASV087	Automation SELOGIC Variable 87
152	ASV086	Automation SELOGIC Variable 86
152	ASV085	Automation SELOGIC Variable 85
152	ASV084	Automation SELOGIC Variable 84
152	ASV083	Automation SELOGIC Variable 83
152	ASV082	Automation SELOGIC Variable 82
152	ASV081	Automation SELOGIC Variable 81
153	ASV096	Automation SELOGIC Variable 96
153	ASV095	Automation SELOGIC Variable 95
153	ASV094	Automation SELOGIC Variable 94
153	ASV093	Automation SELOGIC Variable 93
153	ASV092	Automation SELOGIC Variable 92
153	ASV091	Automation SELOGIC Variable 91
153	ASV090	Automation SELOGIC Variable 90
153	ASV089	Automation SELOGIC Variable 89
154	ASV104	Automation SELOGIC Variable 104
154	ASV103	Automation SELOGIC Variable 103
154	ASV102	Automation SELOGIC Variable 102
154	ASV101	Automation SELOGIC Variable 101
154	ASV100	Automation SELOGIC Variable 100
154	ASV099	Automation SELOGIC Variable 99
154	ASV098	Automation SELOGIC Variable 98
154	ASV097	Automation SELOGIC Variable 97

Table A.30 Relay Word Bits: Automation Variables (Sheet 4 of 7)

Row	Name	Description
155	ASV112	Automation SELOGIC Variable 112
155	ASV111	Automation SELOGIC Variable 111
155	ASV110	Automation SELOGIC Variable 110
155	ASV109	Automation SELOGIC Variable 109
155	ASV108	Automation SELOGIC Variable 108
155	ASV107	Automation SELOGIC Variable 107
155	ASV106	Automation SELOGIC Variable 106
155	ASV105	Automation SELOGIC Variable 105
156	ASV120	Automation SELOGIC Variable 120
156	ASV119	Automation SELOGIC Variable 119
156	ASV118	Automation SELOGIC Variable 118
156	ASV117	Automation SELOGIC Variable 117
156	ASV116	Automation SELOGIC Variable 116
156	ASV115	Automation SELOGIC Variable 115
156	ASV114	Automation SELOGIC Variable 114
156	ASV113	Automation SELOGIC Variable 113
157	ASV128	Automation SELOGIC Variable 128
157	ASV127	Automation SELOGIC Variable 127
157	ASV126	Automation SELOGIC Variable 126
157	ASV125	Automation SELOGIC Variable 125
157	ASV124	Automation SELOGIC Variable 124
157	ASV123	Automation SELOGIC Variable 123
157	ASV122	Automation SELOGIC Variable 122
157	ASV121	Automation SELOGIC Variable 121
158	ASV136	Automation SELOGIC Variable 136
158	ASV135	Automation SELOGIC Variable 135
158	ASV134	Automation SELOGIC Variable 134
158	ASV133	Automation SELOGIC Variable 133
158	ASV132	Automation SELOGIC Variable 132
158	ASV131	Automation SELOGIC Variable 131
158	ASV130	Automation SELOGIC Variable 130
158	ASV129	Automation SELOGIC Variable 129
159	ASV144	Automation SELOGIC Variable 144
159	ASV143	Automation SELOGIC Variable 143
159	ASV142	Automation SELOGIC Variable 142
159	ASV141	Automation SELOGIC Variable 141
159	ASV140	Automation SELOGIC Variable 140
159	ASV139	Automation SELOGIC Variable 139
159	ASV138	Automation SELOGIC Variable 138
159	ASV137	Automation SELOGIC Variable 137
160	ASV152	Automation SELOGIC Variable 152

Table A.30 Relay Word Bits: Automation Variables (Sheet 5 of 7)

Row	Name	Description
160	ASV151	Automation SELOGIC Variable 151
160	ASV150	Automation SELOGIC Variable 150
160	ASV149	Automation SELOGIC Variable 149
160	ASV148	Automation SELOGIC Variable 148
160	ASV147	Automation SELOGIC Variable 147
160	ASV146	Automation SELOGIC Variable 146
160	ASV145	Automation SELOGIC Variable 145
161	ASV160	Automation SELOGIC Variable 160
161	ASV159	Automation SELOGIC Variable 159
161	ASV158	Automation SELOGIC Variable 158
161	ASV157	Automation SELOGIC Variable 157
161	ASV156	Automation SELOGIC Variable 156
161	ASV155	Automation SELOGIC Variable 155
161	ASV154	Automation SELOGIC Variable 154
161	ASV153	Automation SELOGIC Variable 153
162	ASV168	Automation SELOGIC Variable 168
162	ASV167	Automation SELOGIC Variable 167
162	ASV166	Automation SELOGIC Variable 166
162	ASV165	Automation SELOGIC Variable 165
162	ASV164	Automation SELOGIC Variable 164
162	ASV163	Automation SELOGIC Variable 163
162	ASV162	Automation SELOGIC Variable 162
162	ASV161	Automation SELOGIC Variable 161
163	ASV176	Automation SELOGIC Variable 176
163	ASV175	Automation SELOGIC Variable 175
163	ASV174	Automation SELOGIC Variable 174
163	ASV173	Automation SELOGIC Variable 173
163	ASV172	Automation SELOGIC Variable 172
163	ASV171	Automation SELOGIC Variable 171
163	ASV170	Automation SELOGIC Variable 170
163	ASV169	Automation SELOGIC Variable 169
164	ASV184	Automation SELOGIC Variable 184
164	ASV183	Automation SELOGIC Variable 183
164	ASV182	Automation SELOGIC Variable 182
164	ASV181	Automation SELOGIC Variable 181
164	ASV180	Automation SELOGIC Variable 180
164	ASV179	Automation SELOGIC Variable 179
164	ASV178	Automation SELOGIC Variable 178
164	ASV177	Automation SELOGIC Variable 177
165	ASV192	Automation SELOGIC Variable 192
165	ASV191	Automation SELOGIC Variable 191

Table A.30 Relay Word Bits: Automation Variables (Sheet 6 of 7)

Row	Name	Description
165	ASV190	Automation SELOGIC Variable 190
165	ASV189	Automation SELOGIC Variable 189
165	ASV188	Automation SELOGIC Variable 188
165	ASV187	Automation SELOGIC Variable 187
165	ASV186	Automation SELOGIC Variable 186
165	ASV185	Automation SELOGIC Variable 185
166	ASV200	Automation SELOGIC Variable 200
166	ASV199	Automation SELOGIC Variable 199
166	ASV198	Automation SELOGIC Variable 198
166	ASV197	Automation SELOGIC Variable 197
166	ASV196	Automation SELOGIC Variable 196
166	ASV195	Automation SELOGIC Variable 195
166	ASV194	Automation SELOGIC Variable 194
166	ASV193	Automation SELOGIC Variable 193
167	ASV208	Automation SELOGIC Variable 208
167	ASV207	Automation SELOGIC Variable 207
167	ASV206	Automation SELOGIC Variable 206
167	ASV205	Automation SELOGIC Variable 205
167	ASV204	Automation SELOGIC Variable 204
167	ASV203	Automation SELOGIC Variable 203
167	ASV202	Automation SELOGIC Variable 202
167	ASV201	Automation SELOGIC Variable 201
168	ASV216	Automation SELOGIC Variable 216
168	ASV215	Automation SELOGIC Variable 215
168	ASV214	Automation SELOGIC Variable 214
168	ASV213	Automation SELOGIC Variable 213
168	ASV212	Automation SELOGIC Variable 212
168	ASV211	Automation SELOGIC Variable 211
168	ASV210	Automation SELOGIC Variable 210
168	ASV209	Automation SELOGIC Variable 209
169	ASV224	Automation SELOGIC Variable 224
169	ASV223	Automation SELOGIC Variable 223
169	ASV222	Automation SELOGIC Variable 222
169	ASV221	Automation SELOGIC Variable 221
169	ASV220	Automation SELOGIC Variable 220
169	ASV219	Automation SELOGIC Variable 219
169	ASV218	Automation SELOGIC Variable 218
169	ASV217	Automation SELOGIC Variable 217
170	ASV232	Automation SELOGIC Variable 232
170	ASV231	Automation SELOGIC Variable 231
170	ASV230	Automation SELOGIC Variable 230

Table A.30 Relay Word Bits: Automation Variables (Sheet 7 of 7)

Row	Name	Description
170	ASV229	Automation SELOGIC Variable 229
170	ASV228	Automation SELOGIC Variable 228
170	ASV227	Automation SELOGIC Variable 227
170	ASV226	Automation SELOGIC Variable 226
170	ASV225	Automation SELOGIC Variable 225
171	ASV240	Automation SELOGIC Variable 240
171	ASV239	Automation SELOGIC Variable 239
171	ASV238	Automation SELOGIC Variable 238
171	ASV237	Automation SELOGIC Variable 237
171	ASV236	Automation SELOGIC Variable 236
171	ASV235	Automation SELOGIC Variable 235
171	ASV234	Automation SELOGIC Variable 234
171	ASV233	Automation SELOGIC Variable 233
172	ASV248	Automation SELOGIC Variable 248
172	ASV247	Automation SELOGIC Variable 247
172	ASV246	Automation SELOGIC Variable 246
172	ASV245	Automation SELOGIC Variable 245
172	ASV244	Automation SELOGIC Variable 244
172	ASV243	Automation SELOGIC Variable 243
172	ASV242	Automation SELOGIC Variable 242
172	ASV241	Automation SELOGIC Variable 241
173	ASV256	Automation SELOGIC Variable 256
173	ASV255	Automation SELOGIC Variable 255
173	ASV254	Automation SELOGIC Variable 254
173	ASV253	Automation SELOGIC Variable 253
173	ASV252	Automation SELOGIC Variable 252
173	ASV251	Automation SELOGIC Variable 251
173	ASV250	Automation SELOGIC Variable 250
173	ASV249	Automation SELOGIC Variable 249

Table A.31 Relay Word Bits: Automation Latches (Sheet 1 of 2)

Row	Name	Description
174	ALT08	Automation Latch 8
174	ALT07	Automation Latch 7
174	ALT06	Automation Latch 6
174	ALT05	Automation Latch 5
174	ALT04	Automation Latch 4
174	ALT03	Automation Latch 3
174	ALT02	Automation Latch 2
174	ALT01	Automation Latch 1
175	ALT16	Automation Latch 16

Table A.31 **Relay Word Bits: Automation Latches** (Sheet 2 of 2)

Row	Name	Description
175	ALT15	Automation Latch 15
175	ALT14	Automation Latch 14
175	ALT13	Automation Latch 13
175	ALT12	Automation Latch 12
175	ALT11	Automation Latch 11
175	ALT10	Automation Latch 10
175	ALT09	Automation Latch 9
176	ALT24	Automation Latch 24
176	ALT23	Automation Latch 23
176	ALT22	Automation Latch 22
176	ALT21	Automation Latch 21
176	ALT20	Automation Latch 20
176	ALT19	Automation Latch 19
176	ALT18	Automation Latch 18
176	ALT17	Automation Latch 17
177	ALT32	Automation Latch 32
177	ALT31	Automation Latch 31
177	ALT30	Automation Latch 30
177	ALT29	Automation Latch 29
177	ALT28	Automation Latch 28
177	ALT27	Automation Latch 27
177	ALT26	Automation Latch 26
177	ALT25	Automation Latch 25

Table A.32 **Relay Word Bits: Automation Sequencing Timers** (Sheet 1 of 3)

Row	Name	Description
178	AST08Q	Automation Sequencing Timer 8 output
178	AST07Q	Automation Sequencing Timer 7 output
178	AST06Q	Automation Sequencing Timer 6 output
178	AST05Q	Automation Sequencing Timer 5 output
178	AST04Q	Automation Sequencing Timer 4 output
178	AST03Q	Automation Sequencing Timer 3 output
178	AST02Q	Automation Sequencing Timer 2 output
178	AST01Q	Automation Sequencing Timer 1 output
179	AST16Q	Automation Sequencing Timer 16 output
179	AST15Q	Automation Sequencing Timer 15 output
179	AST14Q	Automation Sequencing Timer 14 output
179	AST13Q	Automation Sequencing Timer 13 output
179	AST12Q	Automation Sequencing Timer 12 output
179	AST11Q	Automation Sequencing Timer 11 output
179	AST10Q	Automation Sequencing Timer 10 output

Table A.32 Relay Word Bits: Automation Sequencing Timers (Sheet 2 of 3)

Row	Name	Description
179	AST09Q	Automation Sequencing Timer 9 output
180	AST24Q	Automation Sequencing Timer 24 output
180	AST23Q	Automation Sequencing Timer 23 output
180	AST22Q	Automation Sequencing Timer 22 output
180	AST21Q	Automation Sequencing Timer 21 output
180	AST20Q	Automation Sequencing Timer 20 output
180	AST19Q	Automation Sequencing Timer 19 output
180	AST18Q	Automation Sequencing Timer 18 output
180	AST17Q	Automation Sequencing Timer 17 output
180	AST32Q	Automation Sequencing Timer 32 output
180	AST31Q	Automation Sequencing Timer 31 output
180	AST30Q	Automation Sequencing Timer 30 output
180	AST29Q	Automation Sequencing Timer 29 output
180	AST28Q	Automation Sequencing Timer 28 output
180	AST27Q	Automation Sequencing Timer 27 output
180	AST26Q	Automation Sequencing Timer 26 output
180	AST25Q	Automation Sequencing Timer 25 output
181	AST08R	Automation Sequencing Timer 8 reset
181	AST07R	Automation Sequencing Timer 7 reset
181	AST06R	Automation Sequencing Timer 6 reset
181	AST05R	Automation Sequencing Timer 5 reset
181	AST04R	Automation Sequencing Timer 4 reset
181	AST03R	Automation Sequencing Timer 3 reset
181	AST02R	Automation Sequencing Timer 2 reset
181	AST01R	Automation Sequencing Timer 1 reset
183	AST16R	Automation Sequencing Timer 16 reset
183	AST15R	Automation Sequencing Timer 15 reset
183	AST14R	Automation Sequencing Timer 14 reset
183	AST13R	Automation Sequencing Timer 13 reset
183	AST12R	Automation Sequencing Timer 12 reset
183	AST11R	Automation Sequencing Timer 11 reset
183	AST10R	Automation Sequencing Timer 10 reset
183	AST09R	Automation Sequencing Timer 9 reset
184	AST24R	Automation Sequencing Timer 24 reset
184	AST23R	Automation Sequencing Timer 23 reset
184	AST22R	Automation Sequencing Timer 22 reset
184	AST21R	Automation Sequencing Timer 21 reset
184	AST20R	Automation Sequencing Timer 20 reset
184	AST19R	Automation Sequencing Timer 19 reset
184	AST18R	Automation Sequencing Timer 18 reset
184	AST17R	Automation Sequencing Timer 17 reset

Table A.32 Relay Word Bits: Automation Sequencing Timers (Sheet 3 of 3)

Row	Name	Description
185	AST32R	Automation Sequencing Timer 32 reset
185	AST31R	Automation Sequencing Timer 31 reset
185	AST30R	Automation Sequencing Timer 30 reset
185	AST29R	Automation Sequencing Timer 29 reset
185	AST28R	Automation Sequencing Timer 28 reset
185	AST27R	Automation Sequencing Timer 27 reset
185	AST26R	Automation Sequencing Timer 26 reset
185	AST25R	Automation Sequencing Timer 25 reset

Table A.33 Relay Word Bits: Automation Counters (Sheet 1 of 2)

Row	Name	Description
186	ACN08Q	Automation Counter 8 output
186	ACN07Q	Automation Counter 7 output
186	ACN06Q	Automation Counter 6 output
186	ACN05Q	Automation Counter 5 output
186	ACN04Q	Automation Counter 4 output
186	ACN03Q	Automation Counter 3 output
186	ACN02Q	Automation Counter 2 output
186	ACN01Q	Automation Counter 1 output
187	ACN16Q	Automation Counter 16 output
187	ACN15Q	Automation Counter 15 output
187	ACN14Q	Automation Counter 14 output
187	ACN13Q	Automation Counter 13 output
187	ACN12Q	Automation Counter 12 output
187	ACN11Q	Automation Counter 11 output
187	ACN10Q	Automation Counter 10 output
187	ACN09Q	Automation Counter 9 output
188	ACN24Q	Automation Counter 24 output
188	ACN23Q	Automation Counter 23 output
188	ACN22Q	Automation Counter 22 output
188	ACN21Q	Automation Counter 21 output
188	ACN20Q	Automation Counter 20 output
188	ACN19Q	Automation Counter 19 output
188	ACN18Q	Automation Counter 18 output
188	ACN17Q	Automation Counter 17 output
189	ACN32Q	Automation Counter 32 output
189	ACN31Q	Automation Counter 31 output
189	ACN30Q	Automation Counter 30 output
189	ACN29Q	Automation Counter 29 output
189	ACN28Q	Automation Counter 28 output
189	ACN27Q	Automation Counter 27 output

Table A.33 Relay Word Bits: Automation Counters (Sheet 2 of 2)

Row	Name	Description
189	ACN26Q	Automation Counter 26 output
189	ACN25Q	Automation Counter 25 output
190	ACN08R	Automation Counter 8 reset
190	ACN07R	Automation Counter 7 reset
190	ACN06R	Automation Counter 6 reset
190	ACN05R	Automation Counter 5 reset
190	ACN04R	Automation Counter 4 reset
190	ACN03R	Automation Counter 3 reset
190	ACN02R	Automation Counter 2 reset
190	ACN01R	Automation Counter 1 reset
191	ACN16R	Automation Counter 16 reset
191	ACN15R	Automation Counter 15 reset
191	ACN14R	Automation Counter 14 reset
191	ACN13R	Automation Counter 13 reset
191	ACN12R	Automation Counter 12 reset
191	ACN11R	Automation Counter 11 reset
191	ACN10R	Automation Counter 10 reset
191	ACN09R	Automation Counter 9 reset
192	ACN24R	Automation Counter 24 reset
192	ACN23R	Automation Counter 23 reset
192	ACN22R	Automation Counter 22 reset
192	ACN21R	Automation Counter 21 reset
192	ACN20R	Automation Counter 20 reset
192	ACN19R	Automation Counter 19 reset
192	ACN18R	Automation Counter 18 reset
192	ACN17R	Automation Counter 17 reset
193	ACN32R	Automation Counter 32 reset
193	ACN31R	Automation Counter 31 reset
193	ACN30R	Automation Counter 30 reset
193	ACN29R	Automation Counter 29 reset
193	ACN28R	Automation Counter 28 reset
193	ACN27R	Automation Counter 27 reset
193	ACN26R	Automation Counter 26 reset
193	ACN25R	Automation Counter 25 reset

Table A.34 Relay Word Bits: SELOGIC Control Equation Error and Status

Row	Name	Description
194	PUNRLBL	Protection SELOGIC control equation unresolved label
194	PFRTEX	Protection SELOGIC control equation first execution
194	MATHERR	SELOGIC control equation math error
194	*	Reserved
194	*	Reserved
194	*	Reserved
194	*	Reserved
194	*	Reserved
195	*	Reserved
195	*	Reserved
195	*	Reserved
195	*	Reserved
195	*	Reserved
195	*	Reserved
195	*	Reserved
195	*	Reserved
196	AUNRLBL	Automation SELOGIC control equation unresolved label
196	AFRTEXP	Automation SELOGIC control equation first execution after Protection Settings Change, Group Switch, or Source Switch Selection.
196	AFRTEXA	Automation SELOGIC control equation first execution after Automation Settings change
196	*	Reserved
196	*	Reserved
196	*	Reserved
196	*	Reserved
196	*	Reserved
197	*	Reserved
197	*	Reserved
197	*	Reserved
197	*	Reserved
197	*	Reserved
197	*	Reserved
197	*	Reserved
197	*	Reserved

Table A.35 Relay Word Bits: Relay Alarms

Row	Name	Description
198	SALARM	Software alarm
198	HALARM	Hardware alarm
198	BADPASS	Invalid password attempt alarm
198	CCALARM	Communications card status alarm
198	CCOK	Indicates connected Ethernet card is operating correctly
198	*	Reserved
198	*	Reserved
198	*	Reserved
199–216	*	Reserved

Table A.36 Relay Word Bits: Time Synchronization

Row	Name	Description
217	*	Reserved
217	*	Reserved
217	TIRIG	Assert while time is based on IRIG for both mark and value
217	TUPDH	Assert if update source is high-accuracy time source
217	TSYNCA	Assert while the time mark from time source or fixed internal source is not synchronized
217	TSOK	Assert if current time source accuracy is sufficient for synchronized phasor measurements
217	PMDOK	Assert if data acquisition system is operating correctly
217	FREQOK	Assert if relay is estimating frequency

Table A.37 Relay Word Bits: Output Elements (Sheet 1 of 2)

Row	Name	Description
218	OUT108	Main Board Output 8
218	OUT107	Main Board Output 7
218	OUT106	Main Board Output 6
218	OUT105	Main Board Output 5
218	OUT104	Main Board Output 4
218	OUT103	Main Board Output 3
218	OUT102	Main Board Output 2
218	OUT101	Main Board Output 1
219	OUT208	Optional I/O Board 1 Output 8
219	OUT207	Optional I/O Board 1 Output 7
219	OUT206	Optional I/O Board 1 Output 6
219	OUT205	Optional I/O Board 1 Output 5
219	OUT204	Optional I/O Board 1 Output 4
219	OUT203	Optional I/O Board 1 Output 3
219	OUT202	Optional I/O Board 1 Output 2
219	OUT201	Optional I/O Board 1 Output 1

Table A.37 Relay Word Bits: Output Elements (Sheet 2 of 2)

Row	Name	Description
220	OUT216	Optional I/O Board 1 Output 16
220	OUT215	Optional I/O Board 1 Output 15
220	OUT214	Optional I/O Board 1 Output 14
220	OUT213	Optional I/O Board 1 Output 13
220	OUT212	Optional I/O Board 1 Output 12
220	OUT211	Optional I/O Board 1 Output 11
220	OUT210	Optional I/O Board 1 Output 10
220	OUT209	Optional I/O Board 1 Output 9
221	OUT308	Optional I/O Board 2 Output 8
221	OUT307	Optional I/O Board 2 Output 7
221	OUT306	Optional I/O Board 2 Output 6
221	OUT305	Optional I/O Board 2 Output 5
221	OUT304	Optional I/O Board 2 Output 4
221	OUT303	Optional I/O Board 2 Output 3
221	OUT302	Optional I/O Board 2 Output 2
221	OUT301	Optional I/O Board 2 Output 1
222	OUT316	Optional I/O Board 2 Output 16
222	OUT315	Optional I/O Board 2 Output 15
222	OUT314	Optional I/O Board 2 Output 14
222	OUT313	Optional I/O Board 2 Output 13
222	OUT312	Optional I/O Board 2 Output 12
222	OUT311	Optional I/O Board 2 Output 11
222	OUT310	Optional I/O Board 2 Output 10
222	OUT309	Optional I/O Board 2 Output 9

Table A.38 Relay Word Bits: Pushbutton Elements (Sheet 1 of 2)

Row	Name	Description
223	PB1	Pushbutton 1
223	PB2	Pushbutton 2
223	PB3	Pushbutton 3
223	PB4	Pushbutton 4
223	PB5	Pushbutton 5
223	PB6	Pushbutton 6
223	PB7	Pushbutton 7
223	PB8	Pushbutton 8
224	PB1_PUL	Pushbutton 1 pulse (on for one processing interval when button is pushed)
224	PB2_PUL	Pushbutton 2 pulse (on for one processing interval when button is pushed)
224	PB3_PUL	Pushbutton 3 pulse (on for one processing interval when button is pushed)

Table A.38 Relay Word Bits: Pushbutton Elements (Sheet 2 of 2)

Row	Name	Description
224	PB4_PUL	Pushbutton 4 pulse (on for one processing interval when button is pushed)
224	PB5_PUL	Pushbutton 5 pulse (on for one processing interval when button is pushed)
224	PB6_PUL	Pushbutton 6 pulse (on for one processing interval when button is pushed)
224	PB7_PUL	Pushbutton 7 pulse (on for one processing interval when button is pushed)
224	PB8_PUL	Pushbutton 8 pulse (on for one processing interval when button is pushed)
225	PB1_LED	Pushbutton 1 LED
225	PB2_LED	Pushbutton 2 LED
225	PB3_LED	Pushbutton 3 LED
225	PB4_LED	Pushbutton 4 LED
225	PB5_LED	Pushbutton 5 LED
225	PB6_LED	Pushbutton 6 LED
225	PB7_LED	Pushbutton 7 LED
225	PB8_LED	Pushbutton 8 LED

Table A.39 Relay Word Bits: Data Reset Bits

Row	Name	Description
226	RST_DEM	Reset demand metering
226	RST_PDM	Reset peak demand metering
226	RST_ENE	Reset energy metering data
226	RSTMML	Reset max/min line (SELOGIC control equation)
226	RSTMMB1	Reset max/min Circuit Breaker 1 (SELOGIC control equation)
226	RSTMMB2	Reset max/min Circuit Breaker 2 (SELOGIC control equation)
226	RST_BK1	Reset Circuit Breaker 1 monitor
226	RST_BK2	Reset Circuit Breaker 2 monitor
227	RST_BAT	Reset battery monitoring (SELOGIC control equation)
227	RSTFLOC	Reset fault locator (SELOGIC control equation)
227	RSTDNPE	Reset DNP Fault Summary Data (SELOGIC control equation)
227	*	Reserved
227	*	Reserved
227	*	Reserved
227	*	Reserved
227	*	Reserved
227	*	Reserved

Table A.40 Relay Word Bits: Target Logic Bits

Row	Name	Description
228	PHASE_A	Indicates an A-phase fault
228	PHASE_B	Indicates a B-phase fault
228	PHASE_C	Indicates a C-phase fault
228	GROUND	Indicates a ground fault
228	BK1BFT	Indicates Circuit Breaker 1 breaker failure trip
228	BK2BFT	Indicates Circuit Breaker 2 breaker failure trip
228	TRGTR	Reset all active target relay words
228	RSTTRGT	Target reset (SELOGIC control equation)

Table A.41 Relay Word Bits: MIRRORED BITS (Sheet 1 of 2)

Row	Name	Description
229	RMB8A	Channel A Receive MIRRORED BIT 8
229	RMB7A	Channel A Receive MIRRORED BIT 7
229	RMB6A	Channel A Receive MIRRORED BIT 6
229	RMB5A	Channel A Receive MIRRORED BIT 5
229	RMB4A	Channel A Receive MIRRORED BIT 4
229	RMB3A	Channel A Receive MIRRORED BIT 3
229	RMB2A	Channel A Receive MIRRORED BIT 2
229	RMB1A	Channel A Receive MIRRORED BIT 1
230	TMB8A	Channel A Transmit MIRRORED BIT 8
230	TMB7A	Channel A Transmit MIRRORED BIT 7
230	TMB6A	Channel A Transmit MIRRORED BIT 6
230	TMB5A	Channel A Transmit MIRRORED BIT 5
230	TMB4A	Channel A Transmit MIRRORED BIT 4
230	TMB3A	Channel A Transmit MIRRORED BIT 3
230	TMB2A	Channel A Transmit MIRRORED BIT 2
230	TMB1A	Channel A Transmit MIRRORED BIT 1
231	RMB8B	Channel B Receive MIRRORED BIT 8
231	RMB7B	Channel B Receive MIRRORED BIT 7
231	RMB6B	Channel B Receive MIRRORED BIT 6
231	RMB5B	Channel B Receive MIRRORED BIT 5
231	RMB4B	Channel B Receive MIRRORED BIT 4
231	RMB3B	Channel B Receive MIRRORED BIT 3
231	RMB2B	Channel B Receive MIRRORED BIT 2
231	RMB1B	Channel B Receive MIRRORED BIT 1
232	TMB8B	Channel B Transmit MIRRORED BIT 8
232	TMB7B	Channel B Transmit MIRRORED BIT 7
232	TMB6B	Channel B Transmit MIRRORED BIT 6
232	TMB5B	Channel B Transmit MIRRORED BIT 5
232	TMB4B	Channel B Transmit MIRRORED BIT 4
232	TMB3B	Channel B Transmit MIRRORED BIT 3

Table A.41 Relay Word Bits: MIRRORED BITS (Sheet 2 of 2)

Row	Name	Description
232	TMB2B	Channel B Transmit MIRRORED BIT 2
232	TMB1B	Channel B Transmit MIRRORED BIT 1
233	ROKA	Normal MIRRORED BITS communications Channel A status while not in loopback mode
233	RBADA	Outage too long on MIRRORED BITS communications Channel A
233	CBADA	Unavailability threshold exceeded for MIRRORED BITS communications Channel A
233	LBOKA	Normal MIRRORED BITS communications Channel A status while in loopback mode
233	ANOKA	Analog transfer OK on MIRRORED BITS communications Channel A
233	DOKA	Normal MIRRORED BITS communications Channel A status
233	*	Reserved
233	*	Reserved
234	ROKB	Normal MIRRORED BITS communications Channel B status while not in loopback mode
234	RBADB	Outage too long on MIRRORED BITS communications Channel B
234	CBADB	Unavailability threshold exceeded for MIRRORED BITS communications Channel B
234	LBOKB	Normal MIRRORED BITS communications Channel B status while in loopback mode
234	ANOKB	Analog transfer OK on MIRRORED BITS communications Channel B
234	DOKB	Normal MIRRORED BITS communications Channel B status
234	*	Reserved
234	*	Reserved

Table A.42 Relay Word Bits: Test Bits

Row	Name	Description
235	TESTDNP	DNP test bit
235	TESTDB	Communications card database test bit
235	TESTFM	Fast meter test bit
235	TESTPUL	Pulse test bit
235	*	Reserved
235	*	Reserved
235	*	Reserved
235	*	Reserved

Table A.43 Relay Word Bits: Communications Card Input Points (Sheet 1 of 4)

Row	Name	Description
236	CCIN121	Communications Card Input Point 121
236	CCIN122	Communications Card Input Point 122
236	CCIN123	Communications Card Input Point 123
236	CCIN124	Communications Card Input Point 124
236	CCIN125	Communications Card Input Point 125
236	CCIN126	Communications Card Input Point 126
236	CCIN127	Communications Card Input Point 127
236	CCIN128	Communications Card Input Point 128
237	CCIN113	Communications Card Input Point 113
237	CCIN114	Communications Card Input Point 114
237	CCIN115	Communications Card Input Point 115
237	CCIN116	Communications Card Input Point 116
237	CCIN117	Communications Card Input Point 117
237	CCIN118	Communications Card Input Point 118
237	CCIN119	Communications Card Input Point 119
237	CCIN120	Communications Card Input Point 120
238	CCIN105	Communications Card Input Point 105
238	CCIN106	Communications Card Input Point 106
238	CCIN107	Communications Card Input Point 107
238	CCIN108	Communications Card Input Point 108
238	CCIN109	Communications Card Input Point 109
238	CCIN110	Communications Card Input Point 110
238	CCIN111	Communications Card Input Point 111
238	CCIN112	Communications Card Input Point 112
239	CCIN097	Communications Card Input Point 97
239	CCIN098	Communications Card Input Point 98
239	CCIN099	Communications Card Input Point 99
239	CCIN100	Communications Card Input Point 100
239	CCIN101	Communications Card Input Point 101
239	CCIN102	Communications Card Input Point 102
239	CCIN103	Communications Card Input Point 103
239	CCIN104	Communications Card Input Point 104
240	CCIN089	Communications Card Input Point 89
240	CCIN090	Communications Card Input Point 90
240	CCIN091	Communications Card Input Point 91
240	CCIN092	Communications Card Input Point 92
240	CCIN093	Communications Card Input Point 93
240	CCIN094	Communications Card Input Point 94
240	CCIN095	Communications Card Input Point 95
240	CCIN096	Communications Card Input Point 96

Table A.43 Relay Word Bits: Communications Card Input Points
(Sheet 2 of 4)

Row	Name	Description
241	CCIN081	Communications Card Input Point 81
241	CCIN082	Communications Card Input Point 82
241	CCIN083	Communications Card Input Point 83
241	CCIN084	Communications Card Input Point 84
241	CCIN085	Communications Card Input Point 85
241	CCIN086	Communications Card Input Point 86
241	CCIN087	Communications Card Input Point 87
241	CCIN088	Communications Card Input Point 88
242	CCIN073	Communications Card Input Point 73
242	CCIN074	Communications Card Input Point 74
242	CCIN075	Communications Card Input Point 75
242	CCIN076	Communications Card Input Point 76
242	CCIN077	Communications Card Input Point 77
242	CCIN078	Communications Card Input Point 78
242	CCIN079	Communications Card Input Point 79
242	CCIN080	Communications Card Input Point 80
243	CCIN065	Communications Card Input Point 65
243	CCIN066	Communications Card Input Point 66
243	CCIN067	Communications Card Input Point 67
243	CCIN068	Communications Card Input Point 68
243	CCIN069	Communications Card Input Point 69
243	CCIN070	Communications Card Input Point 70
243	CCIN071	Communications Card Input Point 71
243	CCIN072	Communications Card Input Point 72
244	CCIN057	Communications Card Input Point 57
244	CCIN058	Communications Card Input Point 58
244	CCIN059	Communications Card Input Point 59
244	CCIN060	Communications Card Input Point 60
244	CCIN061	Communications Card Input Point 61
244	CCIN062	Communications Card Input Point 62
244	CCIN063	Communications Card Input Point 63
244	CCIN064	Communications Card Input Point 64
245	CCIN049	Communications Card Input Point 49
245	CCIN050	Communications Card Input Point 50
245	CCIN051	Communications Card Input Point 51
245	CCIN052	Communications Card Input Point 52
245	CCIN053	Communications Card Input Point 53
245	CCIN054	Communications Card Input Point 54
245	CCIN055	Communications Card Input Point 55
245	CCIN056	Communications Card Input Point 56

Table A.43 Relay Word Bits: Communications Card Input Points (Sheet 3 of 4)

Row	Name	Description
246	CCIN041	Communications Card Input Point 41
246	CCIN042	Communications Card Input Point 42
246	CCIN043	Communications Card Input Point 43
246	CCIN044	Communications Card Input Point 44
246	CCIN045	Communications Card Input Point 45
246	CCIN046	Communications Card Input Point 46
246	CCIN047	Communications Card Input Point 47
246	CCIN048	Communications Card Input Point 48
247	CCIN033	Communications Card Input Point 33
247	CCIN034	Communications Card Input Point 34
247	CCIN035	Communications Card Input Point 35
247	CCIN036	Communications Card Input Point 36
247	CCIN037	Communications Card Input Point 37
247	CCIN038	Communications Card Input Point 38
247	CCIN039	Communications Card Input Point 39
247	CCIN040	Communications Card Input Point 40
248	CCIN025	Communications Card Input Point 25
248	CCIN026	Communications Card Input Point 26
248	CCIN027	Communications Card Input Point 27
248	CCIN028	Communications Card Input Point 28
248	CCIN029	Communications Card Input Point 29
248	CCIN030	Communications Card Input Point 30
248	CCIN031	Communications Card Input Point 31
248	CCIN032	Communications Card Input Point 32
249	CCIN017	Communications Card Input Point 17
249	CCIN018	Communications Card Input Point 18
249	CCIN019	Communications Card Input Point 19
249	CCIN020	Communications Card Input Point 20
249	CCIN021	Communications Card Input Point 21
249	CCIN022	Communications Card Input Point 22
249	CCIN023	Communications Card Input Point 23
249	CCIN024	Communications Card Input Point 24
250	CCIN009	Communications Card Input Point 9
250	CCIN010	Communications Card Input Point 10
250	CCIN011	Communications Card Input Point 11
250	CCIN012	Communications Card Input Point 12
250	CCIN013	Communications Card Input Point 13
250	CCIN014	Communications Card Input Point 14
250	CCIN015	Communications Card Input Point 15
250	CCIN016	Communications Card Input Point 16

Table A.43 Relay Word Bits: Communications Card Input Points (Sheet 4 of 4)

Row	Name	Description
251	CCIN001	Communications Card Input Point 1
251	CCIN002	Communications Card Input Point 2
251	CCIN003	Communications Card Input Point 3
251	CCIN004	Communications Card Input Point 4
251	CCIN005	Communications Card Input Point 5
251	CCIN006	Communications Card Input Point 6
251	CCIN007	Communications Card Input Point 7
251	CCIN008	Communications Card Input Point 8

Table A.44 Relay Word Bits: Communications Card Output Points (Sheet 1 of 2)

Row	Name	Description
252	CCOUT25	Communications Card Output Point 25
252	CCOUT26	Communications Card Output Point 26
252	CCOUT27	Communications Card Output Point 27
252	CCOUT28	Communications Card Output Point 28
252	CCOUT29	Communications Card Output Point 29
252	CCOUT30	Communications Card Output Point 30
252	CCOUT31	Communications Card Output Point 31
252	CCOUT32	Communications Card Output Point 32
253	CCOUT17	Communications Card Output Point 17
253	CCOUT18	Communications Card Output Point 18
253	CCOUT19	Communications Card Output Point 19
253	CCOUT20	Communications Card Output Point 20
253	CCOUT21	Communications Card Output Point 21
253	CCOUT22	Communications Card Output Point 22
253	CCOUT23	Communications Card Output Point 23
253	CCOUT24	Communications Card Output Point 24
254	CCOUT09	Communications Card Output Point 9
254	CCOUT10	Communications Card Output Point 10
254	CCOUT11	Communications Card Output Point 11
254	CCOUT12	Communications Card Output Point 12
254	CCOUT13	Communications Card Output Point 13
254	CCOUT14	Communications Card Output Point 14
254	CCOUT15	Communications Card Output Point 15
254	CCOUT16	Communications Card Output Point 16
255	CCOUT01	Communications Card Output Point 1
255	CCOUT02	Communications Card Output Point 2
255	CCOUT03	Communications Card Output Point 3
255	CCOUT04	Communications Card Output Point 4
255	CCOUT05	Communications Card Output Point 5

Table A.44 Relay Word Bits: Communications Card Output Points (Sheet 2 of 2)

Row	Name	Description
255	CCOUT06	Communications Card Output Point 6
255	CCOUT07	Communications Card Output Point 7
255	CCOUT08	Communications Card Output Point 8

Table A.45 Relay Word Bits: Communications Card Status Points

Row	Name	Description
256	CCSTA01	Communications Card Status Register Bit 16
256	CCSTA02	Communications Card Status Register Bit 15
256	CCSTA03	Communications Card Status Register Bit 14
256	CCSTA04	Communications Card Status Register Bit 13
256	CCSTA05	Communications Card Status Register Bit 12
256	CCSTA06	Communications Card Status Register Bit 11
256	CCSTA07	Communications Card Status Register Bit 10
256	CCSTA08	Communications Card Status Register Bit 9
257	CCSTA09	Communications Card Status Register Bit 8
257	CCSTA10	Communications Card Status Register Bit 7
257	CCSTA11	Communications Card Status Register Bit 6
257	CCSTA12	Communications Card Status Register Bit 5
257	CCSTA13	Communications Card Status Register Bit 4
257	CCSTA14	Communications Card Status Register Bit 3
257	CCSTA15	Communications Card Status Register Bit 2
257	CCSTA16	Communications Card Status Register Bit 1
258	CCSTA17	Communications Card Self-Test Status Register Bit 16
258	CCSTA18	Communications Card Self-Test Status Register Bit 15
258	CCSTA19	Communications Card Self-Test Status Register Bit 14
258	CCSTA20	Communications Card Self-Test Status Register Bit 13
258	CCSTA21	Communications Card Self-Test Status Register Bit 12
258	CCSTA22	Communications Card Self-Test Status Register Bit 11
258	CCSTA23	Communications Card Self-Test Status Register Bit 10
258	CCSTA24	Communications Card Self-Test Status Register Bit 9
259	CCSTA25	Communications Card Self-Test Status Register Bit 8
259	CCSTA26	Communications Card Self-Test Status Register Bit 7
259	CCSTA27	Communications Card Self-Test Status Register Bit 6
259	CCSTA28	Communications Card Self-Test Status Register Bit 5
259	CCSTA29	Communications Card Self-Test Status Register Bit 4
259	CCSTA30	Communications Card Self-Test Status Register Bit 3
259	CCSTA31	Communications Card Self-Test Status Register Bit 2
259	CCSTA32	Communications Card Self-Test Status Register Bit 1

Table A.46 Relay Word Bits: Fast SER Enable Bits

Row	Bit Name	Description
260	FSERP1	Fast SER enabled for Serial Port 1
260	FSERP2	Fast SER enabled for Serial Port 2
260	FSERP3	Fast SER enabled for Serial Port 3
260	FSERPF	Fast SER enabled for Serial Port F
260	*	Reserved
260	*	Reserved
260	*	Reserved
260	*	Reserved

Table A.47 Relay Word Bits: Source Selection Elements

Row	Bit Name	Description
261	ALTI	Alternate current source (SELOGIC control equation)
261	ALTV	Alternate voltage source (SELOGIC control equation)
261	ALTS2	Alternate synchronism source for Circuit Breaker 2
261	DELAY	Local current and voltage source delay logic
261	*	Reserved
261	*	Reserved
261	*	Reserved
261	*	Reserved

Table A.48 Relay Word Bits: High-Speed Distance Elements[a] (Sheet 1 of 2)

Row	Bit Name	Description
262	MBG3H	High-speed Zone 3 Mho B-phase-to-ground element
262	MAG3H	High-speed Zone 3 Mho A-phase-to-ground element
262	MCG2H	High-speed Zone 2 Mho C-phase-to-ground element
262	MBG2H	High-speed Zone 2 Mho B-phase-to-ground element
262	MAG2H	High-speed Zone 2 Mho A-phase-to-ground element
262	MCG1H	High-speed Zone 1 Mho C-phase-to-ground element
262	MBG1H	High-speed Zone 1 Mho B-phase-to-ground element
262	MAG1H	High-speed Zone 1 Mho A-phase-to-ground element
263	*	Reserved
263	*	Reserved
263	*	Reserved
263	*	Reserved
263	*	Reserved
263	*	Reserved
263	*	Reserved
263	MCG3H	High-speed Zone 3 Mho C-phase-to-ground element
264	MBC3H	High-speed Zone 3 Mho B-C phase element
264	MAB3H[a]	High-speed Zone 3 Mho A-B phase element
264	MCA2H	High-speed Zone 2 Mho C-A phase element

Table A.48 Relay Word Bits: High-Speed Distance Elements[a] (Sheet 2 of 2)

Row	Bit Name	Description
264	MBC2H	High-speed Zone 2 Mho B-C phase element
264	MAB2H	High-speed Zone 2 Mho A-B phase element
264	MCA1H	High-speed Zone 1 Mho C-A phase element
264	MBC1H	High-speed Zone 1 Mho B-C phase element
264	MAB1H	High-speed Zone 1 Mho A-B phase element
265	*	Reserved
265	*	Reserved
265	*	Reserved
265	*	Reserved
265	*	Reserved
265	*	Reserved
265	*	Reserved
265	MCA3H	High-speed Zone 3 Mho C-A phase element
266–267	*	Reserved

[a] Not in SEL-421-1 nor SEL-421-2.

Table A.49 Synchrophasor Trigger SELogic Equations/RTC Synchrophasor Status Bits[a] (Sheet 1 of 2)

Row	Bit Name	Description
268	PMTRIG	Trigger (SELogic control equation)
268	TREA4	Trigger Reason Bit 4 (SELogic control equation)
268	TREA3	Trigger Reason Bit 3 (SELogic control equation)
268	TREA2	Trigger Reason Bit 2 (SELogic control equation)
268	TREA1	Trigger Reason Bit 1 (SELogic control equation)
268	*	Reserved
268	*	Reserved
268	*	Reserved
269	*	Reserved
269	*	Reserved
269	*	Reserved
269	*	Reserved
269	*	Reserved
269	*	Reserved
269	*	Reserved
269	*	Reserved
270	EVELOCK	Lock DNP Events
270	*	Reserved
270	*	Reserved
270	*	Reserved
270	*	Reserved
270	RTCCFGB	RTC Configuration Complete, Channel B

Table A.49 Synchrophasor Trigger SELOGIC Equations/RTC Synchrophasor Status Bits[a] (Sheet 2 of 2)

Row	Bit Name	Description
270	RTCCFGA	RTC Configuration Complete, Channel A
270	RTCSEQB	RTC Data In Sequence, Channel B
270	RTCSEQA	RTC Data In Sequence, Channel A
271	*	Reserved
271	RTCDLYB	RTC Delay Exceeded, Channel B
271	RTCDLYA	RTC Delay Exceeded, Channel A
271	RTCROK	Valid Aligned RTC Data Available on All Enabled Channels
271	RTCROKB	Valid Aligned RTC Data Available on Channel B
271	RTCROKA	Valid Aligned RTC Data Available on Channel A
271	RTCENB	Valid Remote Synchrophasors Received on Channel B
271	RTCENA	Valid Remote Synchrophasors Received on Channel A

[a] These bits are sent as part of the IEEE C37.118 format synchrophasor data frame.

Table A.50 Time and Synchronization Control Bits[a] (Sheet 1 of 2)

Row	Bit Name	Description
272	YEAR80	IRIG-B year information, binary-coded-decimal, add 80 if asserted[b]
272	YEAR40	IRIG-B year information, binary-coded-decimal, add 40 if asserted[b]
272	YEAR20	IRIG-B year information, binary-coded-decimal, add 20 if asserted[b]
272	YEAR10	IRIG-B year information, binary-coded-decimal, add 10 if asserted[b]
272	YEAR8	IRIG-B year information, binary-coded-decimal, add 8 if asserted[b]
272	YEAR4	IRIG-B year information, binary-coded-decimal, add 4 if asserted[b]
272	YEAR2	IRIG-B year information, binary-coded-decimal, add 2 if asserted[b]
272	YEAR1	IRIG-B year information, binary-coded-decimal, add 1 if asserted[b]
273	*	
273	*	
273	TUTCH	Offset half-hour from UTC time, binary, add 0.5 if asserted
273	TUTC8	Offset hours from UTC time, binary, add 8 if asserted
273	TUTC4	Offset hours from UTC time, binary, add 4 if asserted
273	TUTC2	Offset hours from UTC time, binary, add 2 if asserted
273	TUTC1	Offset hours from UTC time, binary, add 1 if asserted
273	TUTCS	Offset hours sign from UTC time, subtract the UTC offset if TUTCS is asserted, add otherwise
274	DST	Daylight Savings Time
274	DSTP	Daylight Savings Time Pending

Table A.50 Time and Synchronization Control Bits[a] (Sheet 2 of 2)

Row	Bit Name	Description
274	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.
274	LPSECP	Leap second pending
274	TQUAL8	Time quality, binary, add 8 when asserted[c]
274	TQUAL4	Time quality, binary, add 4 when asserted[c]
274	TQUAL2	Time quality, binary, add 2 when asserted[c]
274	TQUAL1	Time quality, binary, add 1 when asserted[c]
275	*	Reserved
275	*	Reserved
275	*	Reserved
275	*	Reserved
275	*	Reserved
275	*	Reserved
275	*	Reserved
275	*	Reserved

[a] These Relay Word bits are valid when an IRIG-B timekeeping source is connected that includes the IEEE C37.118 IRIG-B control bits in the data stream. Otherwise, these Relay Word bits are indeterminate. When the SEL-421 is not connected to an IRIG source, these Relay Word bits are deasserted, except for TQUAL8–TQUAL1, which are asserted.
[b] The SEL-421 uses the year information obtained from IRIG-B to set the internal clock year value if EPMU := Y.
[c] See IRIG-B on page U.4.71.

Table A.51 Time-Error Calculation (Sheet 1 of 2)

Row	Bit Name	Description
276	LOADTE	Load TECORR Factor (SELOGIC control equation). When a rising-edge is detected, the accumulated time-error value TE is loaded with the TECORR factor (preload value).[a]
276	STALLTE	Stall Time-Error Calculation (SELOGIC control equation). When asserted, the time-error calculation is stalled, or frozen.
276	PLDTE	Asserts for approximately 1.5 cycles when the TEC command is used to load a new time-error correction factor (preload value) into the TECORR analog quantity.
276	*	Reserved
276	*	Reserved
276	*	Reserved
276	*	Reserved
276	*	Reserved
277	*	Reserved
277	*	Reserved
277	*	Reserved
277	*	Reserved
277	*	Reserved
277	*	Reserved

Table A.51 Time-Error Calculation (Sheet 2 of 2)

Row	Bit Name	Description
277	*	Reserved
277–279	*	Reserved

[a] The time-error calculation logic runs once per cycle. Condition the LOADTE equation logic expression to assert for at least one cycle to ensure recognition. (Do not use a rising edge operator, R_TRIG, in the LOADTE setting.)

Table A.52 Pushbuttons, Pushbutton LEDs, and Target LEDs for new HMI (Sheet 1 of 2)

Row	Bit Name	Description
280	TLED_17	Target LED 17
280	TLED_18	Target LED 18
280	TLED_19	Target LED 19
280	TLED_20	Target LED 20
280	TLED_21	Target LED 21
280	TLED_22	Target LED 22
280	TLED_23	Target LED 23
280	TLED_24	Target LED 24
281	PB9	Pushbutton 9
281	PB10	Pushbutton 10
281	PB11	Pushbutton 11
281	PB12	Pushbutton 12
281	*	Reserved
281	*	Reserved
281	PB_TRIP	Auxiliary **TRIP** Pushbutton
281	PB_CLSE	Auxiliary **CLOSE** Pushbutton
282	PB9_LED	Pushbutton 9 LED
282	PB10LED	Pushbutton 10 LED
282	PB11LED	Pushbutton 11 LED
282	PB12LED	Pushbutton 12 LED
282	*	Reserved
282	*	Reserved
282	*	Reserved
282	*	Reserved
283	PB9_PUL	Pushbutton 9 pulse (on for one processing interval when button is pushed)
283	PB10PUL	Pushbutton 10 pulse (on for one processing interval when button is pushed)
283	PB11PUL	Pushbutton 11 pulse (on for one processing interval when button is pushed)
283	PB12PUL	Pushbutton 12 pulse (on for one processing interval when button is pushed)
283	*	Reserved
283	*	Reserved

Table A.52 Pushbuttons, Pushbutton LEDs, and Target LEDs for new HMI (Sheet 2 of 2)

Row	Bit Name	Description
283	*	Reserved
283	*	Reserved

Table A.53 Relay Word Bits: Local Bit Supervision and Status (Sheet 1 of 2)

Row	Bit Name	Description
284	LB_SP08	Local Bit 08 Supervision (SELOGIC control equation)
284	LB_SP07	Local Bit 07 Supervision (SELOGIC control equation)
284	LB_SP06	Local Bit 06 Supervision (SELOGIC control equation)
284	LB_SP05	Local Bit 05 Supervision (SELOGIC control equation)
284	LB_SP04	Local Bit 04 Supervision (SELOGIC control equation)
284	LB_SP03	Local Bit 03 Supervision (SELOGIC control equation)
284	LB_SP02	Local Bit 02 Supervision (SELOGIC control equation)
284	LB_SP01	Local Bit 01 Supervision (SELOGIC control equation)
285	LB_SP16	Local Bit 16 Supervision (SELOGIC control equation)
285	LB_SP15	Local Bit 15 Supervision (SELOGIC control equation)
285	LB_SP14	Local Bit 14 Supervision (SELOGIC control equation)
285	LB_SP13	Local Bit 13 Supervision (SELOGIC control equation)
285	LB_SP12	Local Bit 12 Supervision (SELOGIC control equation)
285	LB_SP11	Local Bit 11 Supervision (SELOGIC control equation)
285	LB_SP10	Local Bit 10 Supervision (SELOGIC control equation)
285	LB_SP09	Local Bit 09 Supervision (SELOGIC control equation)
286	LB_SP24	Local Bit 24 Supervision (SELOGIC control equation)
286	LB_SP23	Local Bit 23 Supervision (SELOGIC control equation)
286	LB_SP22	Local Bit 22 Supervision (SELOGIC control equation)
286	LB_SP21	Local Bit 21 Supervision (SELOGIC control equation)
286	LB_SP20	Local Bit 20 Supervision (SELOGIC control equation)
286	LB_SP19	Local Bit 19 Supervision (SELOGIC control equation)
286	LB_SP18	Local Bit 18 Supervision (SELOGIC control equation)
286	LB_SP17	Local Bit 17 Supervision (SELOGIC control equation)
287	LB_SP32	Local Bit 32 Supervision (SELOGIC control equation)
287	LB_SP31	Local Bit 31 Supervision (SELOGIC control equation)
287	LB_SP30	Local Bit 30 Supervision (SELOGIC control equation)
287	LB_SP29	Local Bit 29 Supervision (SELOGIC control equation)
287	LB_SP28	Local Bit 28 Supervision (SELOGIC control equation)
287	LB_SP27	Local Bit 27 Supervision (SELOGIC control equation)
287	LB_SP26	Local Bit 26 Supervision (SELOGIC control equation)
287	LB_SP25	Local Bit 25 Supervision (SELOGIC control equation)
288	LB_DP08	Local Bit 08 Status Display (SELOGIC control equation)
288	LB_DP07	Local Bit 07 Status Display (SELOGIC control equation)
288	LB_DP06	Local Bit 06 Status Display (SELOGIC control equation)

Table A.53 Relay Word Bits: Local Bit Supervision and Status (Sheet 2 of 2)

Row	Bit Name	Description
288	LB_DP05	Local Bit 05 Status Display (SELOGIC control equation)
288	LB_DP04	Local Bit 04 Status Display (SELOGIC control equation)
288	LB_DP03	Local Bit 03 Status Display (SELOGIC control equation)
288	LB_DP02	Local Bit 02 Status Display (SELOGIC control equation)
288	LB_DP01	Local Bit 01 Status Display (SELOGIC control equation)
289	LB_DP16	Local Bit 16 Status Display (SELOGIC control equation)
289	LB_DP15	Local Bit 15 Status Display (SELOGIC control equation)
289	LB_DP14	Local Bit 14 Status Display (SELOGIC control equation)
289	LB_DP13	Local Bit 13 Status Display (SELOGIC control equation)
289	LB_DP12	Local Bit 12 Status Display (SELOGIC control equation)
289	LB_DP11	Local Bit 11 Status Display (SELOGIC control equation)
289	LB_DP10	Local Bit 10 Status Display (SELOGIC control equation)
289	LB_DP09	Local Bit 09 Status Display (SELOGIC control equation)
290	LB_DP24	Local Bit 24 Status Display (SELOGIC control equation)
290	LB_DP23	Local Bit 23 Status Display (SELOGIC control equation)
290	LB_DP22	Local Bit 22 Status Display (SELOGIC control equation)
290	LB_DP21	Local Bit 21 Status Display (SELOGIC control equation)
290	LB_DP20	Local Bit 20 Status Display (SELOGIC control equation)
290	LB_DP19	Local Bit 19 Status Display (SELOGIC control equation)
290	LB_DP18	Local Bit 18 Status Display (SELOGIC control equation)
290	LB_DP17	Local Bit 17 Status Display (SELOGIC control equation)
291	LB_DP32	Local Bit 32 Status Display (SELOGIC control equation)
291	LB_DP31	Local Bit 31 Status Display (SELOGIC control equation)
291	LB_DP30	Local Bit 30 Status Display (SELOGIC control equation)
291	LB_DP29	Local Bit 29 Status Display (SELOGIC control equation)
291	LB_DP28	Local Bit 28 Status Display (SELOGIC control equation)
291	LB_DP27	Local Bit 27 Status Display (SELOGIC control equation)
291	LB_DP26	Local Bit 26 Status Display (SELOGIC control equation)
291	LB_DP25	Local Bit 25 Status Display (SELOGIC control equation)

Table A.54 RTC Remote Digital Status (Sheet 1 of 2)

Row	Bit Name	Description
292	RTCAD08	RTC Remote Data Bits, Channel A, bit 8
292	RTCAD07	RTC Remote Data Bits, Channel A, bit 7
292	RTCAD06	RTC Remote Data Bits, Channel A, bit 6
292	RTCAD05	RTC Remote Data Bits, Channel A, bit 5
292	RTCAD04	RTC Remote Data Bits, Channel A, bit 4
292	RTCAD03	RTC Remote Data Bits, Channel A, bit 3
292	RTCAD02	RTC Remote Data Bits, Channel A, bit 2
292	RTCAD01	RTC Remote Data Bits, Channel A, bit 1

Table A.54 RTC Remote Digital Status (Sheet 2 of 2)

Row	Bit Name	Description
293	RTCAD16	RTC Remote Data Bits, Channel A, bit 16
293	RTCAD15	RTC Remote Data Bits, Channel A, bit 15
293	RTCAD14	RTC Remote Data Bits, Channel A, bit 14
293	RTCAD13	RTC Remote Data Bits, Channel A, bit 13
293	RTCAD12	RTC Remote Data Bits, Channel A, bit 12
293	RTCAD11	RTC Remote Data Bits, Channel A, bit 11
293	RTCAD10	RTC Remote Data Bits, Channel A, bit 10
293	RTCAD09	RTC Remote Data Bits, Channel A, bit 9
294	RTCBD08	RTC Remote Data Bits, Channel B, bit 8
294	RTCBD07	RTC Remote Data Bits, Channel B, bit 7
294	RTCBD06	RTC Remote Data Bits, Channel B, bit 6
294	RTCBD05	RTC Remote Data Bits, Channel B, bit 5
294	RTCBD04	RTC Remote Data Bits, Channel B, bit 4
294	RTCBD03	RTC Remote Data Bits, Channel B, bit 3
294	RTCBD02	RTC Remote Data Bits, Channel B, bit 2
294	RTCBD01	RTC Remote Data Bits, Channel B, bit 1
295	RTCBD16	RTC Remote Data Bits, Channel B, bit 16
295	RTCBD15	RTC Remote Data Bits, Channel B, bit 15
295	RTCBD14	RTC Remote Data Bits, Channel B, bit 14
295	RTCBD13	RTC Remote Data Bits, Channel B, bit 13
295	RTCBD12	RTC Remote Data Bits, Channel B, bit 12
295	RTCBD11	RTC Remote Data Bits, Channel B, bit 11
295	RTCBD10	RTC Remote Data Bits, Channel B, bit 10
295	RTCBD09	RTC Remote Data Bits, Channel B, bit 9

Table A.55 Fast Operate Transmit Bits (Sheet 1 of 4)

Row	Bit Name	Description
296	FOPF_08	Fast Operate Output Control Bits for Port F, bit 8
296	FOPF_07	Fast Operate Output Control Bits for Port F, bit 7
296	FOPF_06	Fast Operate Output Control Bits for Port F, bit 6
296	FOPF_05	Fast Operate Output Control Bits for Port F, bit 5
296	FOPF_04	Fast Operate Output Control Bits for Port F, bit 4
296	FOPF_03	Fast Operate Output Control Bits for Port F, bit 3
296	FOPF_02	Fast Operate Output Control Bits for Port F, bit 2
296	FOPF_01	Fast Operate Output Control Bits for Port F, bit 1
297	FOPF_16	Fast Operate Output Control Bits for Port F, bit 16
297	FOPF_15	Fast Operate Output Control Bits for Port F, bit 15
297	FOPF_14	Fast Operate Output Control Bits for Port F, bit 14
297	FOPF_13	Fast Operate Output Control Bits for Port F, bit 13
297	FOPF_12	Fast Operate Output Control Bits for Port F, bit 12
297	FOPF_11	Fast Operate Output Control Bits for Port F, bit 11

Table A.55 Fast Operate Transmit Bits (Sheet 2 of 4)

Row	Bit Name	Description
297	FOPF_10	Fast Operate Output Control Bits for Port F, bit 10
297	FOPF_09	Fast Operate Output Control Bits for Port F, bit 9
298	FOPF_24	Fast Operate Output Control Bits for Port F, bit 24
298	FOPF_23	Fast Operate Output Control Bits for Port F, bit 23
298	FOPF_22	Fast Operate Output Control Bits for Port F, bit 22
298	FOPF_21	Fast Operate Output Control Bits for Port F, bit 21
298	FOPF_20	Fast Operate Output Control Bits for Port F, bit 20
298	FOPF_19	Fast Operate Output Control Bits for Port F, bit 19
298	FOPF_18	Fast Operate Output Control Bits for Port F, bit 18
298	FOPF_17	Fast Operate Output Control Bits for Port F, bit 17
299	FOPF_32	Fast Operate Output Control Bits for Port F, bit 32
299	FOPF_31	Fast Operate Output Control Bits for Port F, bit 31
299	FOPF_30	Fast Operate Output Control Bits for Port F, bit 30
299	FOPF_29	Fast Operate Output Control Bits for Port F, bit 29
299	FOPF_28	Fast Operate Output Control Bits for Port F, bit 28
299	FOPF_27	Fast Operate Output Control Bits for Port F, bit 27
299	FOPF_26	Fast Operate Output Control Bits for Port F, bit 26
299	FOPF_25	Fast Operate Output Control Bits for Port F, bit 25
300	FOP1_08	Fast Operate Output Control Bits for Port 1, bit 8
300	FOP1_07	Fast Operate Output Control Bits for Port 1, bit 7
300	FOP1_06	Fast Operate Output Control Bits for Port 1, bit 6
300	FOP1_05	Fast Operate Output Control Bits for Port 1, bit 5
300	FOP1_04	Fast Operate Output Control Bits for Port 1, bit 4
300	FOP1_03	Fast Operate Output Control Bits for Port 1, bit 3
300	FOP1_02	Fast Operate Output Control Bits for Port 1, bit 2
300	FOP1_01	Fast Operate Output Control Bits for Port 1, bit 1
301	FOP1_16	Fast Operate Output Control Bits for Port 1, bit 16
301	FOP1_15	Fast Operate Output Control Bits for Port 1, bit 15
301	FOP1_14	Fast Operate Output Control Bits for Port 1, bit 14
301	FOP1_13	Fast Operate Output Control Bits for Port 1, bit 13
301	FOP1_12	Fast Operate Output Control Bits for Port 1, bit 12
301	FOP1_11	Fast Operate Output Control Bits for Port 1, bit 11
301	FOP1_10	Fast Operate Output Control Bits for Port 1, bit 10
301	FOP1_09	Fast Operate Output Control Bits for Port 1, bit 9
302	FOP1_24	Fast Operate Output Control Bits for Port 1, bit 24
302	FOP1_23	Fast Operate Output Control Bits for Port 1, bit 23
302	FOP1_22	Fast Operate Output Control Bits for Port 1, bit 22
302	FOP1_21	Fast Operate Output Control Bits for Port 1, bit 21
302	FOP1_20	Fast Operate Output Control Bits for Port 1, bit 20
302	FOP1_19	Fast Operate Output Control Bits for Port 1, bit 19
302	FOP1_18	Fast Operate Output Control Bits for Port 1, bit 18

Table A.55 Fast Operate Transmit Bits (Sheet 3 of 4)

Row	Bit Name	Description
302	FOP1_17	Fast Operate Output Control Bits for Port 1, bit 17
303	FOP1_32	Fast Operate Output Control Bits for Port 1, bit 32
303	FOP1_31	Fast Operate Output Control Bits for Port 1, bit 31
303	FOP1_30	Fast Operate Output Control Bits for Port 1, bit 30
303	FOP1_29	Fast Operate Output Control Bits for Port 1, bit 29
303	FOP1_28	Fast Operate Output Control Bits for Port 1, bit 28
303	FOP1_27	Fast Operate Output Control Bits for Port 1, bit 27
303	FOP1_26	Fast Operate Output Control Bits for Port 1, bit 26
303	FOP1_25	Fast Operate Output Control Bits for Port 1, bit 25
304	FOP2_08	Fast Operate Output Control Bits for Port 2, bit 8
304	FOP2_07	Fast Operate Output Control Bits for Port 2, bit 7
304	FOP2_06	Fast Operate Output Control Bits for Port 2, bit 6
304	FOP2_05	Fast Operate Output Control Bits for Port 2, bit 5
304	FOP2_04	Fast Operate Output Control Bits for Port 2, bit 4
304	FOP2_03	Fast Operate Output Control Bits for Port 2, bit 3
304	FOP2_02	Fast Operate Output Control Bits for Port 2, bit 2
304	FOP2_01	Fast Operate Output Control Bits for Port 2, bit 1
305	FOP2_16	Fast Operate Output Control Bits for Port 2, bit 16
305	FOP2_15	Fast Operate Output Control Bits for Port 2, bit 15
305	FOP2_14	Fast Operate Output Control Bits for Port 2, bit 14
305	FOP2_13	Fast Operate Output Control Bits for Port 2, bit 13
305	FOP2_12	Fast Operate Output Control Bits for Port 2, bit 12
305	FOP2_11	Fast Operate Output Control Bits for Port 2, bit 11
305	FOP2_10	Fast Operate Output Control Bits for Port 2, bit 10
305	FOP2_09	Fast Operate Output Control Bits for Port 2, bit 9
306	FOP2_24	Fast Operate Output Control Bits for Port 2, bit 24
306	FOP2_23	Fast Operate Output Control Bits for Port 2, bit 23
306	FOP2_22	Fast Operate Output Control Bits for Port 2, bit 22
306	FOP2_21	Fast Operate Output Control Bits for Port 2, bit 21
306	FOP2_20	Fast Operate Output Control Bits for Port 2, bit 20
306	FOP2_19	Fast Operate Output Control Bits for Port 2, bit 19
306	FOP2_18	Fast Operate Output Control Bits for Port 2, bit 18
306	FOP2_17	Fast Operate Output Control Bits for Port 2, bit 17
307	FOP2_32	Fast Operate Output Control Bits for Port 2, bit 32
307	FOP2_31	Fast Operate Output Control Bits for Port 2, bit 31
307	FOP2_30	Fast Operate Output Control Bits for Port 2, bit 30
307	FOP2_29	Fast Operate Output Control Bits for Port 2, bit 29
307	FOP2_28	Fast Operate Output Control Bits for Port 2, bit 28
307	FOP2_27	Fast Operate Output Control Bits for Port 2, bit 27
307	FOP2_26	Fast Operate Output Control Bits for Port 2, bit 26
307	FOP2_25	Fast Operate Output Control Bits for Port 2, bit 25

Table A.55 Fast Operate Transmit Bits (Sheet 4 of 4)

Row	Bit Name	Description
308	FOP3_08	Fast Operate Output Control Bits for Port 3, bit 8
308	FOP3_07	Fast Operate Output Control Bits for Port 3, bit 7
308	FOP3_06	Fast Operate Output Control Bits for Port 3, bit 6
308	FOP3_05	Fast Operate Output Control Bits for Port 3, bit 5
308	FOP3_04	Fast Operate Output Control Bits for Port 3, bit 4
308	FOP3_03	Fast Operate Output Control Bits for Port 3, bit 3
308	FOP3_02	Fast Operate Output Control Bits for Port 3, bit 2
308	FOP3_01	Fast Operate Output Control Bits for Port 3, bit 1
309	FOP3_16	Fast Operate Output Control Bits for Port 3, bit 16
309	FOP3_15	Fast Operate Output Control Bits for Port 3, bit 15
309	FOP3_14	Fast Operate Output Control Bits for Port 3, bit 14
309	FOP3_13	Fast Operate Output Control Bits for Port 3, bit 13
309	FOP3_12	Fast Operate Output Control Bits for Port 3, bit 12
309	FOP3_11	Fast Operate Output Control Bits for Port 3, bit 11
309	FOP3_10	Fast Operate Output Control Bits for Port 3, bit 10
309	FOP3_09	Fast Operate Output Control Bits for Port 3, bit 9
310	FOP3_24	Fast Operate Output Control Bits for Port 3, bit 24
310	FOP3_23	Fast Operate Output Control Bits for Port 3, bit 23
310	FOP3_22	Fast Operate Output Control Bits for Port 3, bit 22
310	FOP3_21	Fast Operate Output Control Bits for Port 3, bit 21
310	FOP3_20	Fast Operate Output Control Bits for Port 3, bit 20
310	FOP3_19	Fast Operate Output Control Bits for Port 3, bit 19
310	FOP3_18	Fast Operate Output Control Bits for Port 3, bit 18
310	FOP3_17	Fast Operate Output Control Bits for Port 3, bit 17
311	FOP3_32	Fast Operate Output Control Bits for Port 3, bit 32
311	FOP3_31	Fast Operate Output Control Bits for Port 3, bit 31
311	FOP3_30	Fast Operate Output Control Bits for Port 3, bit 30
311	FOP3_29	Fast Operate Output Control Bits for Port 3, bit 29
311	FOP3_28	Fast Operate Output Control Bits for Port 3, bit 28
311	FOP3_27	Fast Operate Output Control Bits for Port 3, bit 27
311	FOP3_26	Fast Operate Output Control Bits for Port 3, bit 26
311	FOP3_25	Fast Operate Output Control Bits for Port 3, bit 25

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Appendix B
Analog Quantities

This section contains a table of the analog quantities available within the SEL-421 Relay. For information on using analog quantities in protection and automation, see *Applications Handbook*.

Use *Table B.2* as a reference for labels in this manual and as a resource for quantities you use in SELOGIC® control equation relay settings. *Table B.1* groups the analog quantities alphanumerically; *Table B.2* groups the analog quantities by function.

Quantities Listed Alphabetically

Table B.1 Analog Quantities Sorted Alphabetically (Sheet 1 of 7)

Label	Description	Units
3DPF	Three-phase displacement power factor	NA
3I2D	Negative-sequence demand current	A[a]
3I2PKD	Negative-sequence peak demand current	A[a]
3MWH3T	Three-phase total energy	MWh[a]
3MWHIN	Three-phase negative (import) energy	MWh[a]
3MWHOUT	Three-phase positive (export) energy	MWh[a]
3P	Three-phase real power	MW[a]
3P_f	Three-phase fundamental real power	MW[a]
3PD	Three-phase demand real power	MW[a]
3PF	Three-phase power factor	NA
3PPKD	Three-phase peak demand real power	MW[a]
3PSHOT	Present value of three-pole shot counter	NA
3Q_f	Three-phase fundamental reactive power	MVAr[a]
3QD	Three-phase demand reactive power	MVAr[a]
3QPKD	Three-phase peak demand reactive power	MVAr[a]
3S_f	Three-phase fundamental apparent power	MVA[a]
3U	Three-phase apparent power	MVA[a]
3UD	Three-phase demand apparent power	MVA[a]
3UPKD	Three-phase peak demand apparent power	MVA[a]
3V0A	Zero-sequence 10-cycle average voltage angle	degrees
3V0FIA	Zero-sequence instantaneous voltage angle	degrees
3V0FIM	Zero-sequence instantaneous voltage magnitude	V
3V0M	Zero-sequence 10-cycle average voltage magnitude	kV[a]
3V2A	Negative-sequence 10-cycle average voltage angle	degrees

Table B.1 Analog Quantities Sorted Alphabetically (Sheet 2 of 7)

Label	Description	Units
3V2FIA	Negative-sequence instantaneous voltage angle	degrees
3V2FIM	Negative-sequence instantaneous voltage magnitude	V
3V2M	Negative-sequence 10-cycle average voltage magnitude	kV[a]
ACN01CV–ACN32CV	Automation counter current value	NA
ACN01PV–ACN32PV	Automation counter preset value	NA
ACTGRP	Active group setting	NA
AMV001–AMV256	Automation SELOGIC control equation math variable	NA
ANG1DIF	Synchronizing angle difference 1	degrees
ANG2DIF	Synchronizing angle difference 2	degrees
AST01ET–AST32ET	Automation sequencing timer elapsed time	seconds
AST01PT–AST32PT	Automation sequencing timer preset time	seconds
B1BCWPA, B1BCWPB, B1BCWPC	Circuit Breaker 1 contact wear	percent
B1IAFA, B1IBFA, B1ICFA	Circuit Breaker 1 phase 10-cycle average fundamental current angle	degrees
B1IAFIM, B1IBFIM, B1ICFIM	Circuit Breaker 1 phase filtered instantaneous current magnitude	A
B1IAFM, B1IBFM, B1ICFM	Circuit Breaker 1 phase 10-cycle average fundamental current magnitude	A[a]
B1IARMS, B1IBRMS, B1ICRMS	Circuit Breaker 1 phase 10-cycle average rms current	A[a]
B1IGFIM	Circuit Breaker 1 zero-sequence instantaneous current magnitude	A
B2BCWPA, B2BCWPB, B2BCWPC	Circuit Breaker 2 contact wear	percent
B2IAFA, B2IBFA, B2ICFA	Circuit Breaker 2 phase 10-cycle average fundamental current angle	degrees
B2IAFIM, B2IBFIM, B2ICFIM	Circuit Breaker 2 phase filtered instantaneous current magnitude	A
B2IAFM, B2IBFM, B2ICFM	Circuit Breaker 2 phase 10-cycle average fundamental current magnitude	A[a]
B2IARMS, B2IBRMS, B2ICRMS	Circuit Breaker 2 phase 10-cycle average rms current	A[a]
B2IGFIM	Circuit Breaker 2 zero-sequence instantaneous current magnitude	A
CTRW	CTRW setting from active group	NA
CTRX	CTRX setting from active group	NA
DC1, DC2	Filtered dc monitor voltage	V
DC1MAX, DC2MAX	Maximum dc voltage	V
DC1MIN, DC2MIN	Minimum dc voltage	V
DC1NE, DC2NE	Average negative-to-ground dc voltage	V
DC1PO, DC2PO	Average positive-to-ground dc voltage	V
DC1RI, DC2RI	AC ripple of dc voltage	V
DDOM	Day of the month	NA
DDOW	Day of the week[b]	NA
DDOY	Day of the year (1–365)	NA
DFDT	Rate-of-change of frequency, df/dt[c]	Hz/s
DFDTD	Aligned rate-of-change of frequency, df/dt	Hz/s
DMON	Month	NA
DPFA, DPFB, DPFC	Phase displacement power factor	NA
DYEAR	Year	NA
FLOC	Fault location[d]	per-unit
FOSPM	Fraction-of-second of the synchrophasor data	seconds

Table B.1 Analog Quantities Sorted Alphabetically (Sheet 3 of 7)

Label	Description	Units
FOSPMD	Aligned synchrophasor fraction-of-second	seconds
FREQ	Measured system frequency[c]	Hz
FREQPM	System Frequency from Synchrophasors[c]	Hz
FREQPMD	Aligned system frequency	Hz
I1SPMA	Synchrophasor positive-sequence current angle (I_W + I_X terminals)	degrees
I1SPMAD	Aligned synchrophasor positive-sequence current angle (I_W + I_X terminals)	degrees
I1SPMI	Synchrophasor positive-sequence current, imaginary component (I_W + I_X terminals)	A[a]
I1SPMID	Aligned synchrophasor positive-sequence current imaginary component (I_W + I_X terminals)	A[a]
I1SPMM	Synchrophasor positive-sequence current magnitude (I_W + I_X terminals)	A[a]
I1SPMMD	Aligned synchrophasor positive-sequence current magnitude (I_W + I_X terminals)	A[a]
I1SPMR	Synchrophasor positive-sequence current, real component (I_W + I_X terminals)	A[a]
I1SPMRD	Aligned synchrophasor positive-sequence current real component (I_W + I_X terminals)	A[a]
I1WPMA	Synchrophasor positive-sequence current angle (I_W terminals)	degrees
I1WPMAD	Aligned synchrophasor positive-sequence current angle (I_W terminal)	degrees
I1WPMI	Synchrophasor positive-sequence current, imaginary component (I_W terminals)	A[a]
I1WPMID	Aligned synchrophasor positive-sequence current imaginary component (I_W terminal)	A[a]
I1WPMM	Synchrophasor positive-sequence current magnitude (I_W terminals)	A[a]
I1WPMMD	Aligned synchrophasor positive-sequence current magnitude (I_W terminal)	A[a]
I1WPMR	Synchrophasor positive-sequence current, real component (I_W terminals)	A[a]
I1WPMRD	Aligned synchrophasor positive-sequence current real component (I_W terminal)	A[a]
I1XPMA	Synchrophasor positive-sequence current angle (I_X terminals)	degrees
I1XPMAD	Aligned synchrophasor positive-sequence current angle (I_X terminal)	degrees
I1XPMI	Synchrophasor positive-sequence current, imaginary component (I_X terminals)	A[a]
I1XPMID	Aligned synchrophasor positive-sequence current imaginary component (I_X terminal)	A[a]
I1XPMM	Synchrophasor positive-sequence current magnitude (I_X terminals)	A[a]
I1XPMMD	Aligned synchrophasor positive-sequence current magnitude (I_X terminal)	A[a]
I1XPMR	Synchrophasor positive-sequence current, real component (I_X terminals)	A[a]
I1XPMRD	Aligned synchrophasor positive-sequence current real component (I_X terminal)	A[a]
IAD, IBD, ICD	Phase demand current	A[a]
IAPKD, IBPKD, ICPKD	Phase peak demand current	A[a]

Table B.1 Analog Quantities Sorted Alphabetically (Sheet 4 of 7)

Label	Description	Units
IASPMA, IBSPMA, ICSPMA	Synchrophasor current angle (I_W + I_X terminals)	degrees
IASPMAD, IBSPMAD, ICSPMAD	Aligned synchrophasor current angle (I_W + I_X terminals)	degrees
IASPMI, IBSPMI, ICSPMI	Synchrophasor current, imaginary component (I_W + I_X terminals)	A[a]
IASPMID, IBSPMID, ICSPMID	Aligned synchrophasor current imaginary component (I_W + I_X terminals)	A[a]
IASPMM, IBSPMM, ICSPMM	Synchrophasor current magnitude (I_W + I_X terminals)	A[a]
IASPMMD, IBSPMMD, ICSPMMD	Aligned synchrophasor current magnitude (I_W + I_X terminals)	A[a]
IASPMR, IBSPMR, ICSPMR	Synchrophasor current, real component (I_W + I_X terminals)	A[a]
IASPMRD, IBSPMRD, ICSPMRD	Aligned synchrophasor current real component (I_W + I_X terminals)	A[a]
IAWM, IBWM, ICWM	Phase filtered instantaneous current magnitude (I_W terminals)	A
IAWPMA, IBWPMA, ICWPMA	Synchrophasor current angle (I_W terminals)	degrees
IAWPMAD, IBWPMAD, ICWPMAD	Aligned synchrophasor current angle (I_W terminal)	degrees
IAWPMI, IBWPMI, ICWPMI	Synchrophasor current, imaginary component (I_W terminals)	A[a]
IAWPMID, IBWPMID, ICWPMID	Aligned synchrophasor current imaginary component (I_W terminal)	A[a]
IAWPMM, IBWPMM, ICWPMM	Synchrophasor current magnitude (I_W terminals)	A[a]
IAWPMMD, IBWPMMD, ICWPMMD	Aligned synchrophasor current magnitude (I_W terminal)	A[a]
IAWPMR, IBWPMR, ICWPMR	Synchrophasor current, real component (I_W terminals)	A[a]
IAWPMRD, IBWPMRD, ICWPMRD	Aligned synchrophasor current real component (I_W terminal)	A[a]
IAXM, IBXM, ICXM	Phase filtered instantaneous current magnitude (I_X terminals)	A
IAXPMA, IBXPMA, ICXPMA	Synchrophasor current angle (I_X terminals)	degrees
IAXPMAD, IBXPMAD, ICXPMAD	Aligned synchrophasor current angle (I_X terminal)	degrees
IAXPMI, IBXPMI, ICXPMI	Synchrophasor current, imaginary component (I_X terminals)	A[a]
IAXPMID, IBXPMID, ICXPMID	Aligned synchrophasor current imaginary component (I_X terminal)	A[a]
IAXPMM, IBXPMM, ICXPMM	Synchrophasor current magnitude (I_X terminals)	A[a]
IAXPMMD, IBXPMMD, ICXPMMD	Aligned synchrophasor current magnitude (I_X terminal)	A[a]
IAXPMR, IBXPMR, ICXPMR	Synchrophasor current, real component (I_X terminals)	A[a]
IAXPMRD, IBXPMRD, ICXPMRD	Aligned synchrophasor current real component (I_X terminal)	A[a]
IGD	Zero-sequence demand current	A[a]
IGPKD	Zero-sequence peak demand current	A[a]
IN101A–IN107A[e]	Digital input values available as floating point quantities between 0 and 255. Multiply value by 1.023 to obtain volts.	A/D counts
IN201A–IN208A[e]	Digital input values available as floating point quantities between 0 and 255. Multiply value by 1.279 to obtain volts.	A/D counts
IN301A–IN308A[e]	Digital input values available as floating point quantities between 0 and 255. Multiply value by 1.279 to obtain volts.	A/D counts
IPFIM	Filtered instantaneous polarizing current magnitude	A
L3I2A	Negative-sequence 10-cycle average current angle (line)	degrees
L3I2FIA	Negative-sequence instantaneous current angle (line)	degrees
L3I2FIM	Negative-sequence instantaneous current magnitude (line)	A
L3I2M	Negative-sequence 10-cycle average current magnitude (line)	A[a]
LI1A	Positive-sequence 10-cycle average current angle (line)	degrees
LI1FIA	Positive-sequence instantaneous current angle (line)	degrees

Table B.1 Analog Quantities Sorted Alphabetically (Sheet 5 of 7)

Label	Description	Units
LI1FIM	Positive-sequence instantaneous current magnitude (line)	A
LI1M	Positive-sequence 10-cycle average current magnitude (line)	A[a]
LIAFA, LIBFA, LICFA	Phase 10-cycle average fundamental current angle (line)	degrees
LIAFIA, LIBFIA, LICFIA	Phase filtered instantaneous current angle (line)	degrees
LIAFIM, LIBFIM, LICFIM	Phase filtered instantaneous current magnitude (line)	A
LIAFM, LIBFM, LICFM	Phase 10-cycle average fundamental current magnitude (line)	A
LIARMS, LIBRMS, LICRMS	Phase 10-cycle average rms current (line)	A[a]
LIGA	Zero-sequence 10-cycle average current angle (line)	degrees
LIGFIA	Zero-sequence instantaneous current angle (line)	degrees
LIGFIM	Zero-sequence instantaneous current magnitude (line)	A
LIGM	Zero-sequence 10-cycle average current magnitude (line)	A[a]
MB1A–MB7A	MIRRORED BITS® communications A Channel received analog values	NA
MB1B–MB7B	MIRRORED BITS communications B Channel received analog values	NA
MWHAIN, MWHBIN, MWHCIN	Phase negative (import) energy	MWh[a]
MWHAOUT, MWHBOUT, MWHCOUT	Phase positive (export) energy	MWh[a]
MWHAT, MWHBT, MWHCT	Phase total energy	MWh[a]
NVS1M	Normalized synchronizing voltage 1	V
NVS2M	Normalized synchronizing voltage 2	V
PA, PB, PC	Phase real power	MW[a]
PA_f, PB_f, PC_f	Phase fundamental real power	MW[a]
PAD, PBD, PCD	Phase demand real power	MW[a]
PAPKD, PBPKD, PCPKD	Phase peak demand real power	MW[a]
PCN01CV–PCN32CV	Protection counter current value	NA
PCN01PV–PCN32PV	Protection counter preset value	NA
PCT01DO–PCT32DO	Protection conditioning timer dropout time	cycles
PCT01PU–PCT32PU	Protection conditioning timer pickup time	cycles
PFA, PFB, PFC	Phase power factor	NA
PMV01–PMV64	Protection SELOGIC control equation math variable	NA
PST01ET–PST32ET	Protection sequencing timer elapsed time	cycles
PST01PT–PST32PT	Protection sequencing timer preset time	cycles
PTRY	PTRY setting from active group, divided by 1000	NA
PTRZ	PTRZ setting from active group, divided by 1000	NA
QA_f, QB_f, QC_f	Phase fundamental reactive power	MVAr[a]
QAD, QBD, QCD	Phase demand reactive power	MVAr[a]
QAPKD, QBPKD, QCPKD	Phase peak demand reactive power	MVAr[a]
RA001–RA256	Remote analogs from Ethernet card.	NA
RTCA01–RTCA08	RTC Remote Analog Values, Channel A	
RTCAP01–RTCAP32	RTC Remote Phasor Values, Channel A	
RTCB01–RTCB08	RTC Remote Analog Values, Channel B	
RTCBP01–RTCBP32	RTC Remote Phasor Values, Channel B	
RTCDFA	RTC Remote Frequency Rate of Change, Channel A	HZ/s

Table B.1 Analog Quantities Sorted Alphabetically (Sheet 6 of 7)

Label	Description	Units
RTCDFB	RTC Remote Frequency Rate of Change, Channel B	HZ/s
RTCFA	RTC Remote Frequency, Channel A	Hz
RTCFB	RTC Remote Frequency, Channel B	Hz
RTD01–RTD12	Instantaneous temperatures from the SEL-2600	°C
SA_f, SB_f, SC_f	Phase fundamental apparent power	MVA[a]
SHOT1_1	Total number of first-shot single-pole reclosures	NA
SHOT1_2	Total number of second-shot single-pole reclosures	NA
SHOT1_T	Total number of single-pole reclosures	NA
SHOT3_1	Total number of first-shot three-pole reclosures	NA
SHOT3_2	Total number of second-shot three-pole reclosures	NA
SHOT3_3	Total number of third-shot three-pole reclosures	NA
SHOT3_4	Total number of fourth-shot three-pole reclosures	NA
SHOT3_T	Total number of three-pole reclosures	NA
SLIP1	Synchronism-check element 1 slip frequency	Hz
SLIP2	Synchronism-check element 2 slip frequency	Hz
SODPM	Second-of-day of the synchrophasor data	seconds
SODPMD	Aligned synchrophasors second-of-day	seconds
SPSHOT	Present value of single-pole shot counter	NA
TE	Time error	seconds
TECORR[f]	Time-error correction factor	seconds
THR	Hour (0–23)	hours
TMIN	Minute (0–59)	minutes
TMSEC	Milliseconds (0–999)	ms
TNSEC	Nanoseconds (0–999999)	ns
TODMS	Time of day in milliseconds (0–86399999)	ms
TQUAL	Worst-case IRIG-B clock time error	seconds
TSEC	Seconds (0–59)	seconds
TUTC	Offset from IRIG-B time to UTC time	hours
UA, UB, UC	Phase apparent power	MVA[a]
UAD, UBD, UCD	Phase demand apparent power	MVA[a]
UAPKD, UBPKD, UCPKD	Phase peak demand apparent power	MVA[a]
V1A	Positive-sequence 10-cycle average voltage angle	degrees
V1FIA	Positive-sequence instantaneous voltage angle	degrees
V1FIM	Positive-sequence instantaneous voltage magnitude	V
V1LPMA	Synchrophasor positive-sequence voltage angle	degrees
V1LPMAD	Aligned synchrophasor positive-sequence voltage angle	degrees
V1LPMI	Synchrophasor positive-sequence voltage, imaginary component	kV[a]
V1LPMID	Aligned synchrophasor positive-sequence voltage imaginary component	kV[a]
V1LPMM	Synchrophasor positive-sequence voltage magnitude	kV[a]
V1LPMMD	Aligned synchrophasor positive-sequence voltage magnitude	kV[a]
V1LPMR	Synchrophasor positive-sequence voltage, real component	kV[a]

Table B.1 Analog Quantities Sorted Alphabetically (Sheet 7 of 7)

Label	Description	Units
V1LPMRD	Aligned synchrophasor positive-sequence voltage real component	kV[a]
V1M	Positive-sequence 10-cycle average voltage magnitude	kV[a]
VABFA, VBCFA, VCAFA	Phase-to-phase 10-cycle average fundamental voltage angle	degrees
VABFM, VBCFM, VCAFM	Phase-to-phase 10-cycle average fundamental voltage magnitude	kV[a]
VABRMS, VBCRMS, VCARMS	Phase-to-phase 10-cycle average rms voltage	kV[a]
VAFA, VBFA, VCFA	Phase 10-cycle average fundamental voltage angle	degrees
VAFIA, VBFIA, VCFIA	Phase filtered instantaneous voltage angle	degrees
VAFIM, VBFIM, VCFIM	Phase filtered instantaneous voltage magnitude	V
VAFM, VBFM, VCFM	Phase 10-cycle average fundamental voltage magnitude	kV[a]
VALPMA, VBLPMA, VCLPMA	Synchrophasor voltage angle	degrees
VALPMAD, VBLPMAD, VCLPMAD	Aligned synchrophasor voltage angle	degrees
VALPMI, VBLPMI, VCLPMI	Synchrophasor voltage, imaginary component	kV[a]
VALPMID, VBLPMID, VCLPMID	Aligned synchrophasor voltage, imaginary component	kV[a]
VALPMM, VBLPMM, VCLPMM	Synchrophasor voltage magnitude	kV[a]
VALPMMD, VBLPMMD, VCLPMMD	Aligned synchrophasor voltage magnitude	kV[a]
VALPMR, VBLPMR, VCLPMR	Synchrophasor voltage, real component	kV[a]
VALPMRD, VBLPMRD, VCLPMRD	Aligned synchrophasor voltage, real component	kV[a]
VARMS, VBRMS, VCRMS	Phase 10-cycle average rms voltage	kV[a]
VAYM, VBYM, VCYM	Phase filtered instantaneous voltage magnitude (V_Y terminals)	V
VAZM, VBZM, VCZM	Phase filtered instantaneous voltage magnitude (V_Z terminals)	V
VPM	Synchronism-check polarizing voltage magnitude	V
Z1FA	Positive-sequence instantaneous impedance angle	degrees
Z1FM	Positive-sequence instantaneous impedance magnitude	Ω

[a] Primary value of measurement.
[b] Encoded value: 1 = Sun, 2 = Mon, 3 = Tue, 4 = Wed, 5 = Thu, 6 = Fri, 7 = Sat.
[c] Measured value if the relay can track frequency, otherwise FREQ = nominal frequency setting NFREQ, and DFDT is undefined.
[d] See Fault Location on page R.1.19 for more information on this value.
[e] Digital input values are not available for boards that have optoisolated inputs.
[f] Copy of last value set by **TEC** command or DNP3.

Quantities Listed by Function

Table B.2 Analog Quantities Sorted By Function (Sheet 1 of 7)

Label	Description	Units
Current		
IPFIM	Filtered instantaneous polarizing current magnitude	A
IAWM, IBWM, ICWM	Phase filtered instantaneous current magnitude (I_W terminals)	A
IAXM, IBXM, ICXM	Phase filtered instantaneous current magnitude (I_X terminals)	A
LIAFIM, LIBFIM, LICFIM	Phase filtered instantaneous current magnitude (line)	A
LIAFIA, LIBFIA, LICFIA	Phase filtered instantaneous current angle (line)	degrees
LIAFM, LIBFM, LICFM	Phase 10-cycle average fundamental current magnitude (line)	A[a]
LIAFA, LIBFA, LICFA	Phase 10-cycle average fundamental current angle (line)	degrees
LIARMS, LIBRMS, LICRMS	Phase 10-cycle average rms current (line)	A[a]
LI1FIM	Positive-sequence instantaneous current magnitude (line)	A
LI1FIA	Positive-sequence instantaneous current angle (line)	degrees
LI1M	Positive-sequence 10-cycle average current magnitude (line)	A[a]
LI1A	Positive-sequence 10-cycle average current angle (line)	degrees
L3I2FIM	Negative-sequence instantaneous current magnitude (line)	A
L3I2FIA	Negative-sequence instantaneous current angle (line)	degrees
L3I2M	Negative-sequence 10-cycle average current magnitude (line)	A[a]
L3I2A	Negative-sequence 10-cycle average current angle (line)	degrees
LIGFIM	Zero-sequence instantaneous current magnitude (line)	A
LIGFIA	Zero-sequence instantaneous current angle (line)	degrees
LIGM	Zero-sequence 10-cycle average current magnitude (line)	A[a]
LIGA	Zero-sequence 10-cycle average current angle (line)	degrees
B1IAFIM, B1IBFIM, B1ICFIM	Circuit Breaker 1 phase filtered instantaneous current magnitude	A
B2IAFIM, B2IBFIM, B2ICFIM	Circuit Breaker 2 phase filtered instantaneous current magnitude	A
B1IAFM, B1IBFM, B1ICFM	Circuit Breaker 1 phase 10-cycle average fundamental current magnitude	A[a]
B2IAFM, B2IBFM, B2ICFM	Circuit Breaker 2 phase 10-cycle average fundamental current magnitude	A[a]
B1IAFA, B1IBFA, B1ICFA	Circuit Breaker 1 phase 10-cycle average fundamental current angle	degrees
B2IAFA, B2IBFA, B2ICFA	Circuit Breaker 2 phase 10-cycle average fundamental current angle	degrees
B1IARMS, B1IBRMS, B1ICRMS	Circuit Breaker 1 phase 10-cycle average rms current	A[a]
B2IARMS, B2IBRMS, B2ICRMS	Circuit Breaker 2 phase 10-cycle average rms current	A[a]
B1IGFIM	Circuit Breaker 1 zero-sequence instantaneous current magnitude	A
B2IGFIM	Circuit Breaker 2 zero-sequence instantaneous current magnitude	A
Voltage		
VAYM, VBYM, VCYM	Phase filtered instantaneous voltage magnitude (V_Y terminals)	V
VAZM, VBZM, VCZM	Phase filtered instantaneous voltage magnitude (V_Z terminals)	V
VAFIM, VBFIM, VCFIM	Phase filtered instantaneous voltage magnitude	V
VAFIA, VBFIA, VCFIA	Phase filtered instantaneous voltage angle	degrees
VAFM, VBFM, VCFM	Phase 10-cycle average fundamental voltage magnitude	kV[a]
VAFA, VBFA, VCFA	Phase 10-cycle average fundamental voltage angle	degrees

Table B.2 Analog Quantities Sorted By Function (Sheet 2 of 7)

Label	Description	Units
VARMS, VBRMS, VCRMS	Phase 10-cycle average rms voltage	kV[a]
VABFM, VBCFM, VCAFM	Phase-to-phase 10-cycle average fundamental voltage magnitude	kV[a]
VABFA, VBCFA, VCAFA	Phase-to-phase 10-cycle average fundamental voltage angle	degrees
VABRMS, VBCRMS, VCARMS	Phase-to-phase 10-cycle average rms voltage	kV[a]
V1FIM	Positive-sequence instantaneous voltage magnitude	V
V1FIA	Positive-sequence instantaneous voltage angle	degrees
V1M	Positive-sequence 10-cycle average voltage magnitude	kV[a]
V1A	Positive-sequence 10-cycle average voltage angle	degrees
3V2FIM	Negative-sequence instantaneous voltage magnitude	V
3V2FIA	Negative-sequence instantaneous voltage angle	degrees
3V2M	Negative-sequence 10-cycle average voltage magnitude	kV[a]
3V2A	Negative-sequence 10-cycle average voltage angle	degrees
3V0FIM	Zero-sequence instantaneous voltage magnitude	V
3V0FIA	Zero-sequence instantaneous voltage angle	degrees
3V0M	Zero-sequence 10-cycle average voltage magnitude	kV[a]
3V0A	Zero-sequence 10-cycle average voltage angle	degrees
Synchronism Check		
VPM	Synchronism-check polarizing voltage magnitude	V
NVS1M	Normalized synchronizing voltage 1	V
NVS2M	Normalized synchronizing voltage 2	V
ANG1DIF	Synchronizing angle difference 1	degrees
ANG2DIF	Synchronizing angle difference 2	degrees
SLIP1	Synchronism-check element 1 slip frequency	Hz
SLIP2	Synchronism-check element 2 slip frequency	Hz
Frequency		
FREQ	Measured system frequency[b]	Hz
FREQPM	System Frequency from Synchrophasors[b]	Hz
DFDT	Rate-of-change of frequency, df/dt[b]	Hz/s
DC Monitor		
DC1, DC2	Filtered dc monitor voltage	V
DC1PO, DC2PO	Average positive-to-ground dc voltage	V
DC1NE, DC2NE	Average negative-to-ground dc voltage	V
DC1RI, DC2RI	AC ripple of dc voltage	V
DC1MIN, DC2MIN	Minimum dc voltage	V
DC1MAX, DC2MAX	Maximum dc voltage	V
Power		
PA_f, PB_f, PC_f	Phase fundamental real power	MW[a]
3P_f	Three-phase fundamental real power	MW[a]
PA, PB, PC	Phase real power	MW[a]
3P	Three-phase real power	MW[a]
QA_f, QB_f, QC_f	Phase fundamental reactive power	MVAr[a]

Table B.2 Analog Quantities Sorted By Function (Sheet 3 of 7)

Label	Description	Units
3Q_f	Three-phase fundamental reactive power	MVAr[a]
SA_f, SB_f, SC_f	Phase fundamental apparent power	MVA[a]
3S_f	Three-phase fundamental apparent power	MVA[a]
UA, UB, UC	Phase apparent power	MVA[a]
3U	Three-phase apparent power	MVA[a]
DPFA, DPFB, DPFC	Phase displacement power factor	NA
3DPF	Three-phase displacement power factor	NA
PFA, PFB, PFC	Phase power factor	NA
3PF	Three-phase power factor	NA
Demand		
IAPKD, IBPKD, ICPKD	Phase peak demand current	A[a]
3I2PKD	Negative-sequence peak demand current	A[a]
IGPKD	Zero-sequence peak demand current	A[a]
PAPKD, PBPKD, PCPKD	Phase peak demand real power	MW[a]
3PPKD	Three-phase peak demand real power	MW[a]
QAPKD, QBPKD, QCPKD	Phase peak demand reactive power	MVAr[a]
3QPKD	Three-phase peak demand reactive power	MVAr[a]
UAPKD, UBPKD, UCPKD	Phase peak demand apparent power	MVA[a]
3UPKD	Three-phase peak demand apparent power	MVA[a]
IAD, IBD, ICD	Phase demand current	A[a]
3I2D	Negative-sequence demand current	A[a]
IGD	Zero-sequence demand current	A[a]
PAD, PBD, PCD	Phase demand real power	MW[a]
3PD	Three-phase demand real power	MW[a]
QAD, QBD, QCD	Phase demand reactive power	MVAr[a]
3QD	Three-phase demand reactive power	MVAr[a]
UAD, UBD, UCD	Phase demand apparent power	MVA[a]
3UD	Three-phase demand apparent power	MVA[a]
Energy		
MWHAOUT, MWHBOUT, MWH-COUT	Phase positive (export) energy	MWh[a]
MWHAIN, MWHBIN, MWHCIN	Phase negative (import) energy	MWh[a]
MWHAT, MWHBT, MWHCT	Phase total energy	MWh[a]
3MWHOUT	Three-phase positive (export) energy	MWh[a]
3MWHIN	Three-phase negative (import) energy	MWh[a]
3MWH3T	Three-phase total energy	MWh[a]
RTD Temperature		
RTD01–RTD12	Instantaneous temperatures from the SEL-2600	°C
Mirrored Bits		
MB1A–MB7A	Mirrored Bits communications A Channel received analog values	NA
MB1B–MB7B	Mirrored Bits communications B Channel received analog values	NA

Table B.2 Analog Quantities Sorted By Function (Sheet 4 of 7)

Label	Description	Units
SELogic and Automation Elements		
PMV01–PMV64	Protection SELogic control equation math variable	NA
PCT01PU–PCT32PU	Protection conditioning timer pickup time	cycles
PCT01DO–PCT32DO	Protection conditioning timer dropout time	cycles
PST01ET–PST32ET	Protection sequencing timer elapsed time	cycles
PST01PT–PST32PT	Protection sequencing timer preset time	cycles
PCN01CV–PCN32CV	Protection counter current value	NA
PCN01PV–PCN32PV	Protection counter preset value	NA
AMV001–AMV256	Automation SELogic control equation math variable	NA
AST01ET–AST32ET	Automation sequencing timer elapsed time	seconds
AST01PT–AST32PT	Automation sequencing timer preset time	seconds
ACN01CV–ACN32CV	Automation counter current value	NA
ACN01PV–ACN32PV	Automation counter preset value	NA
Setting Group		
ACTGRP	Active group setting	NA
Breaker Wear		
B1BCWPA, B1BCWPB, B1BCWPC	Circuit Breaker 1 contact wear	percent
B2BCWPA, B2BCWPB, B2BCWPC	Circuit Breaker 2 contact wear	percent
Date and Time		
TODMS	Time of day in milliseconds (0–86399999)	ms
THR	Hour (0–23)	hours
TMIN	Minute (0–59)	minutes
TSEC	Seconds (0–59)	seconds
TMSEC	Milliseconds (0–999)	ms
TNSEC	Nanoseconds (0–999999)	ns
DDOW	Day of the week[c]	NA
DDOM	Day of the month	NA
DDOY	Day of the year (1–365)	NA
DMON	Month	NA
DYEAR	Year	NA
TUTC	Offset from IRIG-B time to UTC time	hours
TQUAL	Worst-case IRIG-B clock time error	seconds
Time-Error Calculation		
TECORR[d]	Time error correction factor	seconds
TE	Time error	seconds
Reclosing		
SPSHOT	Present value of single-pole shot counter	NA
3PSHOT	Present value of three-pole shot counter	NA
SHOT1_1	Total number of first-shot single-pole reclosures	NA
SHOT1_2	Total number of second-shot single-pole reclosures	NA
SHOT1_T	Total number of single-pole reclosures	NA

Table B.2 Analog Quantities Sorted By Function (Sheet 5 of 7)

Label	Description	Units
SHOT3_1	Total number of first-shot three-pole reclosures	NA
SHOT3_2	Total number of second-shot three-pole reclosures	NA
SHOT3_3	Total number of third-shot three-pole reclosures	NA
SHOT3_4	Total number of fourth-shot three-pole reclosures	NA
SHOT3_T	Total number of three-pole reclosures	NA
Fault Location		
FLOC	Fault location[e]	per-unit
Positive-Sequence Impedance		
Z1FM	Positive-sequence instantaneous impedance magnitude	Ω
Z1FA	Positive-sequence instantaneous impedance angle	degrees
Current and Voltage Scaling Settings		
CTRW	CTRW setting from active group	NA
CTRX	CTRX setting from active group	NA
PTRY	PTRY setting from active group, divided by 1000	NA
PTRZ	PTRZ setting from active group, divided by 1000	NA
Synchrophasor Measurements		
IAWPMM, IBWPMM, ICWPMM	Synchrophasor current magnitude (I_W terminals)	A[a]
IAWPMA, IBWPMA, ICWPMA	Synchrophasor current angle (I_W terminals)	degrees
IAWPMR, IBWPMR, ICWPMR	Synchrophasor current, real component (I_W terminals)	A[a]
IAWPMI, IBWPMI, ICWPMI	Synchrophasor current, imaginary component (I_W terminals)	A[a]
IAXPMM, IBXPMM, ICXPMM	Synchrophasor current magnitude (I_X terminals)	A[a]
IAXPMA, IBXPMA, ICXPMA	Synchrophasor current angle (I_X terminals)	degrees
IAXPMR, IBXPMR, ICXPMR	Synchrophasor current, real component (I_X terminals)	A[a]
IAXPMI, IBXPMI, ICXPMI	Synchrophasor current, imaginary component (I_X terminals)	A[a]
IASPMM, IBSPMM, ICSPMM	Synchrophasor current magnitude (I_W + I_X terminals)	A[a]
IASPMA, IBSPMA, ICSPMA	Synchrophasor current angle (I_W + I_X terminals)	degrees
IASPMR, IBSPMR, ICSPMR	Synchrophasor current, real component (I_W + I_X terminals)	A[a]
IASPMI, IBSPMI, ICSPMI	Synchrophasor current, imaginary component (I_W + I_X terminals)	A[a]
I1WPMM	Synchrophasor positive-sequence current magnitude (I_W terminals)	A[a]
I1WPMA	Synchrophasor positive-sequence current angle (I_W terminals)	degrees
I1WPMR	Synchrophasor positive-sequence current, real component (I_W terminals)	A[a]
I1WPMI	Synchrophasor positive-sequence current, imaginary component (I_W terminals)	A[a]
I1XPMM	Synchrophasor positive-sequence current magnitude (I_X terminals)	A[a]
I1XPMA	Synchrophasor positive-sequence current angle (I_X terminals)	degrees
I1XPMR	Synchrophasor positive-sequence current, real component (I_X terminals)	A[a]
I1XPMI	Synchrophasor positive-sequence current, imaginary component (I_X terminals)	A[a]
I1SPMM	Synchrophasor positive-sequence current magnitude (I_W + I_X terminals)	A[a]
I1SPMA	Synchrophasor positive-sequence current angle (I_W + I_X terminals)	degrees
I1SPMR	Synchrophasor positive-sequence current, real component (I_W + I_X terminals)	A[a]

Table B.2 Analog Quantities Sorted By Function (Sheet 6 of 7)

Label	Description	Units
I1SPMI	Synchrophasor positive-sequence current, imaginary component (I_W + I_X terminals)	A[a]
VALPMM, VBLPMM, VCLPMM	Synchrophasor voltage magnitude	kV[a]
VALPMA, VBLPMA, VCLPMA	Synchrophasor voltage angle	degrees
VALPMR, VBLPMR, VCLPMR	Synchrophasor voltage, real component	kV[a]
VALPMI, VBLPMI, VCLPMI	Synchrophasor voltage, imaginary component	kV[a]
V1LPMM	Synchrophasor positive-sequence voltage magnitude	kV[a]
V1LPMA	Synchrophasor positive-sequence voltage angle	degrees
V1LPMR	Synchrophasor positive-sequence voltage, real component	kV[a]
V1LPMI	Synchrophasor positive-sequence voltage, imaginary component	kV[a]
SODPM	Second-of-day of the synchrophasor data	seconds
FOSPM	Fraction-of-second of the synchrophasor data	seconds
Aligned and Remote Synchrophasors		
SODPMD	Aligned synchrophasors second-of-day	second
FOSPMD	Aligned synchrophasor fraction-of-second	seconds
FREQPMD	Aligned system frequency	Hz
DFDTD	Aligned rate-of-change of frequency, df/dt	Hz/s
IAWPMMD, IBWPMMD, ICWPMMD	Aligned synchrophasor current magnitude (I_W terminal)	A[a]
IAWPMAD, IBWPMAD, ICWPMAD	Aligned synchrophasor current angle (I_W terminal)	degrees
IAWPMRD, IBWPMRD, ICWPMRD	Aligned synchrophasor current real component (I_W terminal)	A[a]
IAWPMID, IBWPMID, ICWPMID	Aligned synchrophasor current imaginary component (I_W terminal)	A[a]
I1WPMMD	Aligned synchrophasor positive-sequence current magnitude (I_W terminal)	A[a]
I1WPMAD	Aligned synchrophasor positive-sequence current angle (I_W terminal)	degrees
I1WPMRD	Aligned synchrophasor positive-sequence current real component (I_W terminal)	A[a]
I1WPMID	Aligned synchrophasor positive-sequence current imaginary component (I_W terminal)	A[a]
IAXPMMD, IBXPMMD, ICXPMMD	Aligned synchrophasor current magnitude (I_X terminal)	A[a]
IAXPMAD, IBXPMAD, ICXPMAD	Aligned synchrophasor current angle (I_X terminal)	degrees
IAXPMRD, IBXPMRD, ICXPMRD	Aligned synchrophasor current real component (I_X terminal)	A[a]
IAXPMID, IBXPMID, ICXPMID	Aligned synchrophasor current imaginary component (I_X terminal)	A[a]
I1XPMMD	Aligned synchrophasor positive-sequence current magnitude (I_X terminal)	A[a]
I1XPMAD	Aligned synchrophasor positive-sequence current angle (I_X terminal)	degrees
I1XPMRD	Aligned synchrophasor positive-sequence current real component (I_X terminal)	A[a]
I1XPMID	Aligned synchrophasor positive-sequence current imaginary component (I_X terminal)	A[a]
IASPMMD, IBSPMMD, ICSPMMD	Aligned synchrophasor current magnitude (I_W + I_X terminals)	A[a]
IASPMAD, IBSPMAD, ICSPMAD	Aligned synchrophasor current angle (I_W + I_X terminals)	degrees
IASPMRD, IBSPMRD, ICSPMRD	Aligned synchrophasor current real component (I_W + I_X terminals)	A[a]
IASPMID, IBSPMID, ICSPMID	Aligned synchrophasor current imaginary component (I_W + I_X terminals)	A[a]

Table B.2 Analog Quantities Sorted By Function (Sheet 7 of 7)

Label	Description	Units
I1SPMMD	Aligned synchrophasor positive-sequence current magnitude (I_W + I_X terminals)	A[a]
I1SPMAD	Aligned synchrophasor positive-sequence current angle (I_W + I_X terminals)	degrees
I1SPMRD	Aligned synchrophasor positive-sequence current real component (I_W + I_X terminals)	A[a]
I1SPMID	Aligned synchrophasor positive-sequence current imaginary component (I_W + I_X terminals)	A[a]
VALPMMD, VBLPMMD, VCLPMMD	Aligned synchrophasor voltage magnitude	kV[a]
VALPMAD, VBLPMAD, VCLPMAD	Aligned synchrophasor voltage angle	degrees
VALPMRD, VBLPMRD, VCLPMRD	Aligned synchrophasor voltage, real component	kV[a]
VALPMID, VBLPMID, VCLPMID	Aligned synchrophasor voltage, imaginary component	kV[a]
V1LPMMD	Aligned synchrophasor positive-sequence voltage magnitude	kV[a]
V1LPMAD	Aligned synchrophasor positive-sequence voltage angle	degrees
V1LPMRD	Aligned synchrophasor positive-sequence voltage real component	kV[a]
V1LPMID	Aligned synchrophasor positive-sequence voltage imaginary component	kV[a]
RTCFA	RTC Remote Frequency, Channel A	Hz
RTCDFA	RTC Remote Frequency Rate of Change, Channel A	Hz/s
RTCAP01–RTCAP32	RTC Remote Phasor Values, Channel A	
RTCA01–RTCA08	RTC Remote Analog Values, Channel A	
RTCFB	RTC Remote Frequency, Channel B	Hz
RTCDFB	RTC Remote Frequency Rate of Change, Channel B	Hz/s
RTCBP01–RTCBP32	RTC Remote Phasor Values, Channel B	
RTCB01–RTCB08	RTC Remote Analog Values, Channel B	
Control Inputs		
IN101A–IN107A[f]	Digital input values available as floating point quantities between 0 and 255. Multiply value by 1.023 to obtain volts.	A/D counts
IN201A–IN208A[f]	Digital input values available as floating point quantities between 0 and 255. Multiply value by 1.279 to obtain volts.	A/D counts
IN301A–IN308A[f]	Digital input values available as floating point quantities between 0 and 255. Multiply value by 1.279 to obtain volts.	A/D counts
Database Structure		
RA001–RA256	Remote analogs from Ethernet card.	NA

[a] Primary value of measurement.
[b] Measured value if the relay can track frequency, otherwise FREQ = nominal frequency setting NFREQ, and DFDT is undefined.
[c] Encoded value: 1 = Sun, 2 = Mon, 3 = Tue, 4 = Wed, 5 = Thu, 6 = Fri, 7 = Sat.
[d] Copy of last value set by **TEC** command or DNP3.
[e] See Fault Location on page R.1.19 for more information on this value.
[f] Digital input analog values are not available for boards that have optoisolated inputs.

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 The designation of the vertical height of a device in rack units. One rack unit, U, is approximately 1.75 inches or 44.45 mm.

A Abbreviation for amps or amperes; 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 DNP 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 DNP 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 DNP settings.

ACSELERATOR Architect® SEL-5032 Software ACSELERATOR Architect is an add-on to the ACSELERATOR Suite that utilizes 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 SEL-421 is presently using from among six settings groups available in the relay.

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.

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
25	Synchronism-check element
27	Undervoltage Element
32	Directional Elements
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-amps (VA), kilovolt-amps (kVA), or megavolt-amps (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 SEL-421 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 an SEL-421 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 auto-dial modems from an ASCII terminal (usually EIA-232 connected) or a PC (personal computer) containing software allowing emulation of such a terminal.

Autoconfiguration The ability to determine relay type, model number, metering capability, port ID, baud 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.

Auto-Reclose-Drive-to-Lockout A logical condition that drives the auto-reclose 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.

Bandpass Filter A filter that passes frequencies within a certain range and blocks all frequencies outside this range.

Best Choice Ground Directional Supervision™ 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.

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 due to transport flow control constraints or loss of connection. Buffered reporting provides sequence-of-events (SOE) functionality.

C37.118 IEEE C37.118, Standard for Synchrophasors for Power Systems

Category A collection of similar relay settings.

CCVT Coupling-capacitor 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.

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 SEL-421 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, DNP settings, Protection SELOGIC control equations, Automation SELOGIC control equations, and Output SELOGIC control equations.

Cold Start Beginning a system from power up without carryover of previous system activities.

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.

COMTRADE Abbreviation for Common Format for Transient Data Exchange. The SEL-421 supports the IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems, IEEE C37.111–1999.

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.
Coordination Timer	A timer that delays an overreaching element so that a downstream device has time to operate.
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.
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 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 current transformer; 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 communication 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 an SEL-421 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 SEL-421 uses in DNP 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.

Direct Tripping Local or remote protection elements provide tripping without any additional supervision.

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.

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.

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 in order 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.

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, prefault and fault voltages, currents, and sequence current, and MIRRORED BITS® communications channel status (if enabled).

The relay sends an event report summary (if auto messaging is enabled) to the relay serial port a few seconds after an event.

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 RTD communications.

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.

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.

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.

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.

HMI Human machine interface.

Homogeneous System A power system with nearly the same angle (<5 ° difference) for the impedance angles of the local source, the protected line, and the remote source.

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.

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.

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 SEL-421 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.

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.

Jitter Time, amplitude, frequency, or phase-related abrupt, spurious variations in duration, magnitude, or frequency.

L/R Circuit inductive/resistive ratio.

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 SEL-421 front panel. 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 SEL-421 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.

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.

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 deenergized.

NOT Operator A logical operator that produces the inverse value.

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.

Override Values Test values you enter in Fast Meter, DNP, 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 SEL-421 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.

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 current transformer 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 SEL-421 relays had a TIME 1k PPS input.

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 deenergization of all control outputs.

PT Potential transformer. Also referred to as a voltage transformer or VT.

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, DNP 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, DNP binary output operation, or a UCA control operation.

Report Settings Event report and Sequential Events Recorder 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.

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.

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.

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 SEL-421 has self-tests that validate the relay power supply, microprocessor, memory, and other critical systems.

SELOGIC Expression Builder A rules-based editor within the ACSELERATOR QuickSet software program for programming SELOGIC control equations.

SELOGIC Math Variables Math calculation result storage locations.

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.

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. 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.

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-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.

SIR Source-to-line impedance ratio.

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.

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 lower-case 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.

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.

Telnet An Internet protocol 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 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.

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 pre-determined time.

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 intelligent electronic devices.

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.

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 imbalance 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.

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.

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 ACSELERATOR 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.

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Page numbers appearing in bold mark the location of the topic's primary discussion.

U=User's Guide; A=Applications Handbook; R=Reference Manual

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SEL-421 Relay Command Summary

Command[a, b]	Description
2ACCESS	Go to Access Level 2 (complete relay monitoring and control)
AACCESS	Go to Access Level A (automation control)
ACCESS	Go to Access Level 1 (monitor relay)
BACCESS	Go to Access Level B (monitor relay and control circuit breakers)
BNAME	ASCII names of all relay status bits (Fast Meter)
BREAKER *n*	Display the circuit breaker report and breaker history; preload and reset breaker monitor data (*n* = 1 is BK1; *n* = 2 is BK2)
CASCII	Generate the Compressed ASCII response configuration message
CBREAKER	BREAKER command for the Compressed ASCII response
CEVENT	EVENT command for the Compressed ASCII response
CHISTORY	HISTORY command for the Compressed ASCII response
CLOSE *n*	Close the circuit breaker (*n* = 1 is BK1; *n* = 2 is BK2)
COMM *c*	Display relay-to-relay MIRRORED BITS communications or remote synchrophasor data (*c* = A is channel A; *c* = B is channel B; *c* = M is either enabled single channel; *c* = RTC for remote synchrophasors)
CONTROL *nn*	Set, clear, or pulse an internal remote bit (*nn* is the remote bit number from 01–32)
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)
CSER	SER command for the Compressed ASCII response
CSTATUS	STATUS command for the Compressed ASCII response
CSUMMARY	SUMMARY command for the Compressed ASCII response
DATE	Display and set the date
DNAME X	ASCII names of all relay digital I/O (Fast Meter)
DNP	Access or modify serial port DNP3 settings (similar to SHOW D and SET D)
EVENT	Display and acknowledge event reports
FILE	Transfer data between the relay and external software
GROUP	Display the active group number or select the active group
HELP	Display available commands or command help at each access level
HISTORY	View event summaries/histories; clear event 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
MAP 1	Analyze the communications card database
METER	Display metering data and internal relay operating variables
OACCESS	Go to Access Level O (output control)
OPEN *n*	Open the circuit breaker (*n* = 1 is BK1; *n* = 2 is BK2)
PACCESS	Go to Access Level P (protection control)
PASSWORD	Change relay passwords
PORT	Connect to a remote relay via MIRRORED BITS virtual terminal (for port number *p* = 1–3, and F), or the Ethernet card (port *p* = 5)
PULSE OUT*nnn*	Pulse a relay control output (OUT*nnn* is a control output number)

Command[a, b]	Description
QUIT	Reduce access level to Access Level 0 (exit relay control)
RTC	Display configuration of received remote synchrophasors
SER	View Sequential Events Recorder reports
SET[c]	Enter relay settings
SHOW[c]	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	View summary event reports
TARGET	Display relay elements for a row in the Relay Word table
TEC	Display time-error estimate; display or modify time-error correction value.
TEST DB	Display or place values in the communications card database (useful for Ethernet protocol read tests)
TEST DNP	Display or place values in the serial port DNP3 object map
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 communications card database

[a] See Section 9: ASCII Command Reference in the Reference Manual.
[b] For help on a specific command, type **HELP [command] <Enter>** at an ASCII terminal communicating with the relay.
[c] See the table below for SET/SHOW options.

SET/SHOW Command Options

Option	Setting Type	Description
[S] ***n***	Group Settings 1–6	Particular application settings
A ***n***[a]	Automation Logic Block 1–10	Automation SELOGIC control equations
D	DNP3	Direct Network Protocol remapping (serial port only)
F	Front Panel	Front-panel HMI settings
G	Global	Relay-wide settings
L ***n***	Protection Logic Group 1–6	Protection SELOGIC control equations
M	Breaker Monitor	Circuit breaker monitor settings
O	Outputs	Output SELOGIC control equations
P ***n***	Port 1–3, F, 5	Communications port settings
R	Report	Event report and SER settings
T	Alias	Alias names for analog quantities and Relay Word bits

[a] The SEL-421-1 and the SEL-421-2 have only one instance of automation logic settings.

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