SEL-451 Relay

Protection, Automation, and Control System

Instruction Manual

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SCHWEITZER ENGINEERING LABORATORIES, INC.

PM451-01

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Preface

This manual provides information and instructions for installing and operating the SEL-451 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-451 in a power system. Throughout the manual, we provide margin notes next to the text explaining a feature to specify the availability of that feature in the SEL-451-1 and SEL-451-2 versions of the relay.

Manual Overview

The SEL-451 Relay Manual consists of three volumes:

- User's Guide
- Applications Handbook
- Reference Manual

In addition, the SEL-451 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-451 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-451. 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.

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

User's Guide

Section 1: Introduction and Specifications. Introduces SEL-451 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 and how to install optional communications cards (such as the SEL-2701 Ethernet Processor).

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-451; 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:

- 25 kV Overhead Distribution Line Example
- Auto-Reclose Example
- Auto-Reclose and Synchronism check Example
- Circuit Breaker Failure Application Examples

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-451 high-accuracy time-stamping capability; presents real-time load flow/power flow application ideas.

Section 5: Bay Control. Describes the features of the SEL-451-4 Bay Control Relay; presents circuit breaker and disconnect switch logic, one-line diagram display, settings example, and predefined bay configurations.

Section 6: SEL Communications Processor Applications. Provides examples of how to use the SEL-451 with the SEL-2032, SEL-2030, and SEL-2020 Communications Processors for total substation automation solutions.

Section 7: Direct Network Communications. 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, and DCUB; provides trip logic diagrams, and current and voltage source selection details.

Section 2: Auto-Reclosing and Synchronism Check. Explains how to operate the SEL-451 two-circuit breaker multi-shot recloser; 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 Equations. 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-451 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 DNP 3.00 communications protocol and how to apply this protocol to substation integration and automation; provides an example for implementing DNP 3.00 in a substation.

Section 7: Synchrophasors. Describes the Phasor Measurement Unit (PMU) functions of the SEL-451; 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-451 settings and defaults. The organization of the settings is the same as for 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-451 Relay manual in an electronic form that you can search easily.

Conventions

Typographic Conventions

There are three ways to communicate with the SEL-451:

- ➤ 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-451 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-451. 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-451.

Notes

Margin notes serve two purposes in the SEL-451 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.

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>

Step-by-Step Procedures

The SEL-451 Relay Manual contains many step-by-step procedures. These procedures lead you easily and efficiently through complex tasks. Each procedure lists required equipment, as well as the basic knowledge you need to perform the steps in the procedure. Throughout the procedure, the documentation references other SEL-451 Relay Manual sections where you can find more information.

Read the entire procedure before performing the listed steps. Read each step again before you perform it. The format of a single step is the following:

- ➤ Synopsis of the step (if the step involves multiple actions)
- ➤ Tasks to perform the step (listed as a., b., c., etc. if the step involves multiple actions)
- ➤ Explanatory text or how the relay responds (if applicable)

The following text shows sample steps. Steps include explanations, text references, table references, and figure references to further illustrate the step.

Synopsis

Step 1. Establish communication.

a. Press **<Ctrl+T>** to use the serial communications terminal in ACSELERATOR. Tasks

b. Press **<Enter>** to see if the communications link is active between the software and the relay.

You should see the Access Level 0 = prompt in the terminal window.

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

a. Click **Communication > Port Parameters**.

b. Confirm that you have entered the correct passwords in the **Level One Password** dialog box and the **Level Two Password** dialog box.

Step 3. Click **Settings > Read** to read the present configuration in the SEL-451.

The relay sends all configuration and settings data to ACSELERATOR.

Step 4. Select settings by clicking the **+** mark next to the **Group** you want to program on the **Settings** tree view.

This example uses Group 1, as shown in *Figure 1.2*.

Figure Reference

Sample Step-by-Step Instructions

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:

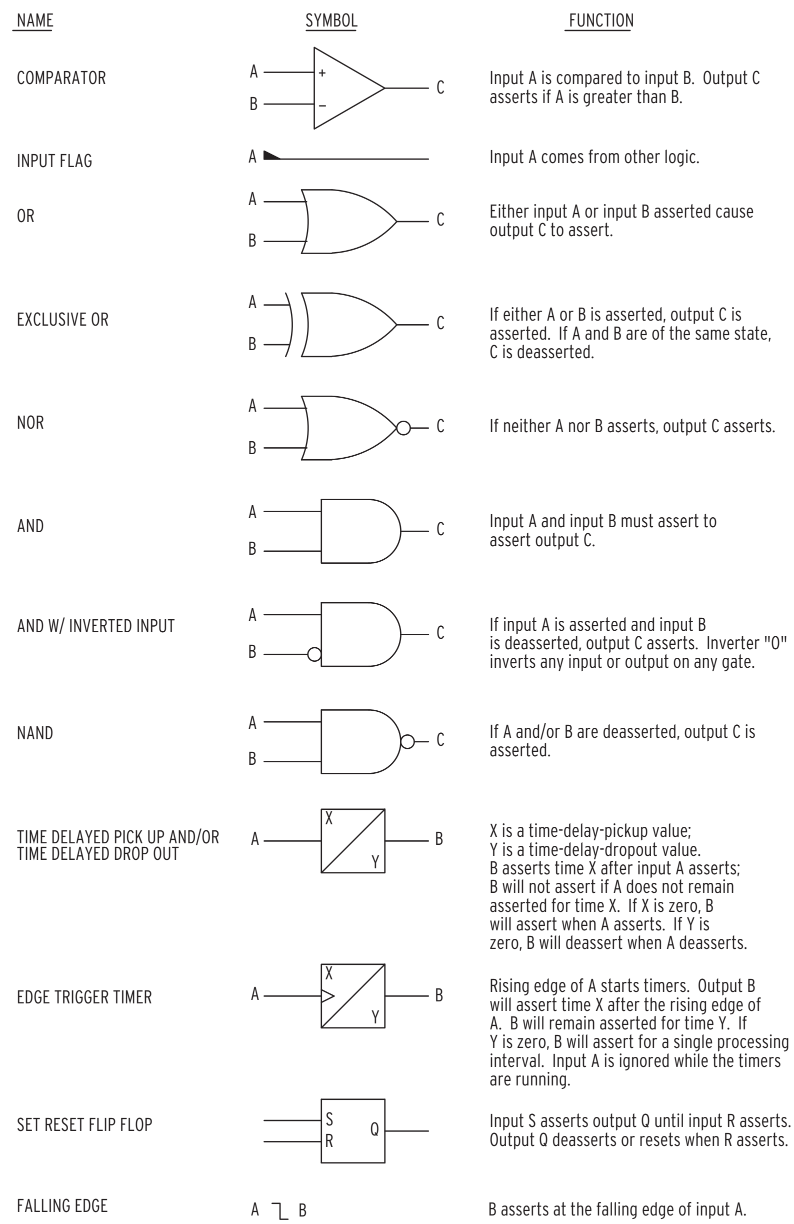
⚠CAUTION
Indicates a potentially hazardous situation that, if not avoided, may result in minor or moderate injury o equipment damage.

⚠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.



SEL-451 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.6.36. 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.6.36]). 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 The outputs in the SEL-451-4 are not designed to break the coil current in the disconnect motor. An auxiliary contact with adequate current interrupting capacity must clear the coil current in the disconnect motor before the output on the SEL-451-4 opens. Failure to observe this safeguard could result in damage to the SEL-451-4 output contacts.	⚠ATTENTION Les contacts de sortie du relais SEL-451-4 ne peuvent pas interrompre le courant de bobine du moteur de sectionneur. Un contact auxiliaire avec un pouvoir de coupure adéquat doit couper le courant de la bobine du moteur du sectionneur avant que le contact de sortie du SEL-451-4 ne s'ouvre. La non-conformité à cette règle de sécurité pourrait endommager les contacts de sortie du SEL-451-4.
⚠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.

English	French
⚠WARNING Do not look into the end of an optical cable connected to an optical output.	⚠AVERTISSEMENT Ne pas regarder vers l'extrémité d'un câble optique raccordé à une sortie optique.
⚠WARNING Do not perform any procedures or adjustments that this instruction manual does not describe.	⚠AVERTISSEMENT Ne pas appliquer une procédure ou un ajustement qui n'est pas décrit explicitement dans ce manuel d'instruction.
⚠WARNING During installation, maintenance, or testing of the optical ports, use only test equipment qualified for Class 1 laser products.	⚠AVERTISSEMENT Durant l'installation, la maintenance ou le test des ports optiques, utilisez exclusivement des équipements de test homologués comme produits de type laser de Classe 1.
⚠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 blessuers ou la mort.

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Section 1

Protection Application Examples

Overview

This section provides detailed instructions for setting the SEL-451 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

Setting calculation guidelines are provided for the following application:

➤ *25 kV Overhead Distribution Line Example on page A.1.1*

Separate protection application examples are provided for the following functions:

➤ *Auto-Reclose Example on page A.1.19*
➤ *Auto-Reclose and Synchronism Check Example on page A.1.25*
➤ *Circuit Breaker Failure Application Examples on page A.1.33*

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.

25 kV Overhead Distribution Line Example

Figure 1.1 shows a distribution system with two substations, S and R, each with one 25 kV feeder that is normally operated in a radial configuration. During certain operating conditions, the feeders may be tied together by a field switch, and directional overcurrent protection is required. No communications are available between the two substations. Each feeder is equipped with an SEL-451 Relay. This application example considers the settings for the SEL-451 at Station S.

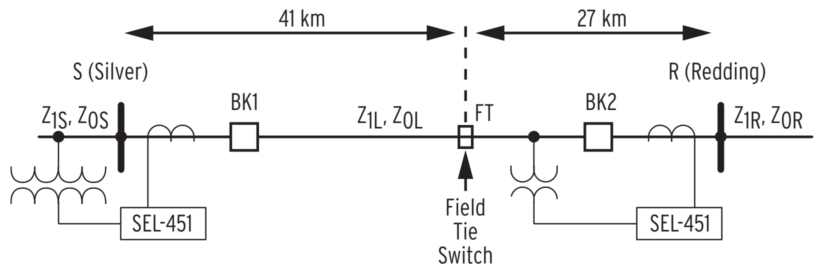

Figure 1.1 25 kV Overhead Distribution Line

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—25 kV Overhead Distribution Line

Parameter	Value
Nominal system line-to-line voltage	25 kV
Nominal relay current	5 A secondary
Nominal frequency	60 Hz
Line length	68 km (total)
Line impedances:	
Z_{1L}, Z_{0L}	12.78 Ω ∠68.86° primary, 45.81 Ω ∠72.47° primary
Source S impedances:	
Z_{1S}, Z_{0S}	1.62 Ω ∠72° primary, 1.95 Ω ∠86° primary
Source R impedances:	
Z_{1R}, Z_{0R}	1.75 Ω ∠72.5° primary, 2.78 Ω ∠82°
PTR (potential transformer ratio)	14.4 kV:120 V = 120
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 1.2* lists the corresponding secondary impedances. Convert the impedances to secondary ohms as follows:

$$k = \frac{CTR}{PTR} = \frac{200}{120} = 1.67$$ **Equation 1.1**

$$\begin{aligned} Z_{1L(secondary)} &= k \bullet Z_{1L(primary)} \\ &= 1.67 \bullet (12.78\ \Omega\angle 68.8 \\ &= 21.35\ \Omega\angle 68.86° \end{aligned}$$ **Equation 1.2**

Table 1.2 Secondary Impedances

Parameter	Value
Line impedances:	
Z_{1L}, Z_{0L}	21.35 Ω ∠68.86° secondary, 76.5 Ω ∠72.47° secondary
Source S impedances:	
Z_{1S}, Z_{0S}	2.71 Ω ∠72° secondary, 3.26 Ω ∠86° secondary
Source R impedances:	
Z_{1R}, Z_{0R}	2.92 Ω ∠72.5° secondary, 4.64 Ω ∠80° secondary

The maximum load current is 900 A primary, and the phases are balanced within 10% under load conditions.

Application Summary

This particular example is for a single circuit breaker application with the following functions and constraints:

- Directional definite-time elements for close-in fault protection
- Directionally-controlled time-overcurrent elements for remote faults and use coordination
- Non-directional time-overcurrent elements for backup protection
- Protection-grade communications channels are not available
- There is no status signal available from the field tie switch, FT

Relay settings that are not mentioned in these examples do not apply to this application example.

Global Settings

General Global Settings

The SEL-451 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 := **Silver — 25 kV** Station Identifier (40 characters)

RID := SEL-451 **Relay** Relay Identifier (40 characters)

Configure the SEL-451 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.

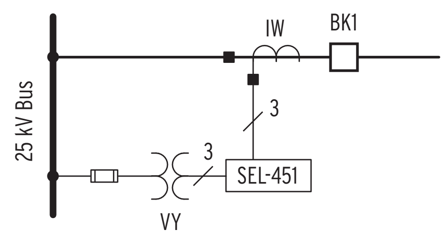

Figure 1.2 Circuit Breaker Arrangement at Station S

Breaker Monitor

Circuit Breaker 1 Inputs

The SEL-451 uses a normally open auxiliary contact 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-451 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 := **200** Current Transformer Ratio—Input W (1–50000)

PTRY := **120** Potential Transformer Ratio—Input Y (1–10000)

VNOMY := **208** PT Nominal Voltage (L-L)—Input Y (60–300 V secondary)

PTRZ := **120** Potential Transformer Ratio—Input Z (1–10000)

VNOMZ := **208** 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 := **21.35** Positive-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)

Z1ANG := **68.86** Positive-Sequence Line Impedance Angle (5.00–90 degrees)

Enter the secondary value of the zero-sequence impedance of the protected line.

Z0MAG := **76.50** Zero-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)

Z0ANG := **72.47** 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 km.

LL := **68** Line Length (0.10–999)

The fault locator uses the values you enter for Z1MAG, Z1ANG, Z0MAG, Z0ANG, and LL.

Relay Configuration

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)

Enable the load-encroachment logic, as the minimum apparent load impedance is near the end-of-line phase overcurrent sensitivity.

ELOAD := **Y** Load Encroachment (Y, N)

Use Level 1 high-set instantaneous phase overcurrent element for SOTF protection, and the corresponding directionally-controlled definite-time phase element for close-in fault detection.

E50P := **1** Phase Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

Use Level 1 directionally-controlled definite-time ground and negative-sequence elements for close-in fault detection.

E50G := **1** Residual Ground Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

E50Q := **1** Negative-Sequence Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

Use inverse-time overcurrent elements for line protection, fuse coordination, and backup protection.

E51S := **5** Selectable Inverse-Time Overcurrent Element (N, 1–6)

Set E32 to AUTO and the relay automatically calculates the settings corresponding to the ground directional element (32G).

E32 := **AUTO** Directional Control (Y, AUTO, N)

Communications-assisted tripping is not required.

ECOMM := **N** Communications-Assisted Tripping (N, DCB, POTT, 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 direction.

Occasional LOP (loss-of-potential) to the relay, while unavoidable, is detectable. When the relay detects the loss-of-potential, the relay can block 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, or enable the forward directional overcurrent elements. Use LOP in this case for alarm only.
Y	The relay disables all voltage-polarized directional 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. 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. Nondirectional inverse-time overcurrent elements will act as backup protection, in case of a loss-of-potential condition.

ELOP := **Y1** Loss-of-Potential (Y, Y1, N)

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.

NOTE: To illustrate the application of switch-onto-fault logic, SOTF will be used in this application example, even though line-side PTs are not being used for relaying.

Apply SOTF when using line-side potentials for relaying. Use nondirectional overcurrent protection to clear close-in faults, because a non-directional overcurrent element is not dependent on voltages. Assign the instantaneous phase overcurrent element to TRSOTF.

TRSOTF := **50P1** Switch-Onto-Fault Trip (SELOGIC Equation)

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 overcurrent 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.1.70*.

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)

Load Encroachment

The relay uses a load-encroachment feature that prevents operation of the phase directional elements during heavy load. This unique feature permits the load to exceed the phase overcurrent element pickup without causing unwanted tripping. See *Load-Encroachment Logic on page R.1.46*.

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 feeder maximum load is given as 900 A, primary. Set load encroachment according to maximum load for the protected line (900A/CTR = 4.5 A secondary). The bus voltage at Station S is 120 V line-to-neutral during maximum load.

$V_{LN} = 120.0$ V

$I_{\phi} = 4.5$ A

Therefore, the minimum load impedance the relay measures is as follows:

$$\begin{aligned} Z_{load} &= \frac{V_{LN}}{I_{\phi}} \\ &= \frac{120.0\ \text{V}}{4.5\ \text{A}} \\ &= 26.7\ \Omega \end{aligned}$$

Equation 1.3

Multiply Z_{load} by a safety factor of 80 percent to account for overload conditions.

$$\begin{aligned} Z_{load} &= 0.8 \bullet 26.7\ \Omega \\ &= 21.36\ \Omega \end{aligned}$$

Equation 1.4

Set the forward load impedance threshold (ZLF) according to the minimum load impedance. The reverse load condition is not used in this application example, so the ZLR setting can be set to the same value as ZLF (there is no "OFF" settings).

ZLF := **21.36** Forward Load Impedance (0.05–64 Ω secondary)

ZLR := **21.36** Reverse Load Impedance (0.05–64 Ω secondary)

Set the load impedance angles according to system data, with some margin (2 degrees in this example). In this application, the forward load power factor is expected to range from 75% (lagging) to 85% (leading). The reverse load power factor is not important, because no reverse-looking directional elements are being used.

Load encroachment is important in this application, because the peak load current exceeds the end-of-line fault current. The reverse load angle settings can be left at the factory default settings.

PLAF := **43.4** Forward Load Positive Angle (–90.0 to +90.0 degrees)

NLAF := **–33.8** Forward Load Negative Angle (–90.0 to +90.0 degrees)

PLAR := **150.0** Reverse Load Positive Angle (+90.0 to +270.0 degrees)

NLAR := **210.0** Reverse Load Negative Angle (+90.0 to +270.0 degrees)

Phase Instantaneous/Definite-Time Overcurrent Elements

NOTE: The overcurrent settings shown for this example are chosen to illustrate the features of the SEL-451. Use your system data and company practices to determine the settings for your application.

Use 50P1, Level 1 phase instantaneous overcurrent element, as a nondirectional high-set phase overcurrent element for SOTF protection. The switch-onto-fault logic is required if line-side potential transformers are used. 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 := **22.00** Level 1 Pickup (OFF, 0.25–100 A secondary)

Use level 1 directionally-controlled definite-time phase elements for close-in fault detection (in the SEL-451, the direction for level 1 elements is always forward). Load encroachment and loss-of-potential control is built-in to the phase directional element. A time-delay of 2 cycles is selected to allow any distribution fuse cutouts time to operate.

67P1D := **2.000** Level 1 Time Delay (0.000–16000 cycles)

67P1TC := **1** Level 1 Torque Control (SELOGIC Equation)

Ground Instantaneous/Definite-Time Overcurrent Elements

Use 67G1T for close-in fault detection. For this application, set the pickup (50G1P) to a value that will allow it to pickup for low-resistance ground faults in the first 2 km of line. A time delay of 2 cycles is selected to allow any distribution fuse cutouts time to operate. The torque control equation contains the factory setting Ground Enabled operator control latch, PLT01. The internal logic makes the level 1 elements respond to forward direction faults.

50G1P := **17.00** Level 1 Pickup (OFF, 0.25–100 A secondary)

67G1TD := **2.000** Level 1 Time Delay (0.000–16000 cycles)

67G1TC := **PLT01** Level 1 Torque Control (SELOGIC Equation)

Negative-Sequence Instantaneous/Definite-Time Overcurrent Elements

Use 67G1T for close-in fault detection. For this application, set the pickup (50Q1P) to a value that will allow it to pickup for phase-to-phase faults in the first 2 km of line. A time delay of 2 cycles is selected to allow any distribution fuse cutouts time to operate. The torque control equation contains the factory setting Ground Enabled operator control latch, PLT01. The internal logic makes the level 1 elements respond to forward direction faults.

50Q1P := **42.00** Level 1 Pickup (OFF, 0.25–100 A secondary)

67Q1TD := **2.000** Level 1 Time Delay (0.000–16000 cycles)

67Q1TC := **PLT01** Level 1 Torque Control (SELOGIC Equation)

Selectable Operating Quantity Time Overcurrent Elements 1-5

Use directionally-controlled inverse-time overcurrent elements for line protection (and fuse coordination) on phase and ground faults. Use non-directional inverse-time overcurrent elements as backup protection.

51S1

Use the first element for phase, directional, set sensitive enough for any three-phase fault on the line. This pickup value is less than the maximum load current, however, the load-encroachment logic (built-in to the phase directional element) will prevent 51S1 from operating during load conditions.

NOTE: Use your company practices and philosophy when determining these settings.

51S1O :=**IMAXL** 51S1 Operate Quantity (IA*n*, IA*n*R,...IMAX*n*, IMAX*n*R, I1L, 3I2L, 3I0*n*)

51S1P := **4.00** 51S1 Overcurrent Pickup (0.25–16 A secondary)

Select the time dial and curve to coordinate with field devices, and the remote terminal. No electromechanical relays are in use, so the electromechanical reset option is not required.

51S1C := **U3** 51S1 Inverse-Time Overcurrent Curve (U1–U5, C1–C5)

51S1TD := **0.70** 51S1 Inverse-Time Overcurrent Time Dial (0.50–15)

51S1RS := **N** 51S1 Inverse-Time Overcurrent Electromechanical Reset (Y, N)

Set the torque control to respond to forward faults.

51S1TC := **F32P** 51S1 Torque Control (SELOGIC Equation)

51S2

Use the second element for ground, directional, set sensitive enough for a ground fault at the midpoint of the line with a low fault resistance with the field tie switch (FT) closed. When the FT is open, or the circuit breaker BK2 at station R is open, the fault resistance coverage will almost double. The compromised sensitivity meets the requirements for the application, which normally operates with FT open.

51S2O := **3I0L** 51S2 Operate Quantity (IAn,IAnR,..,IMAXn,IMAXnR, I1L,3I2L,3I0*n*)

51S2P := **2.30** 51S2 Overcurrent Pickup (0.25–16 A secondary)

Select the time dial and curve to coordinate with field devices, and the remote terminal.

51S2C := **U4** 51S2 Inverse-Time Overcurrent Curve (U1–U5, C1–C5)

51S2TD := **1.00** 51S2 Inverse-Time Overcurrent Time Dial (0.50–15)

51S2RS := **N** 51S2 Inverse-Time Overcurrent Electromechanical Reset (Y, N)

Set the torque control to respond to forward faults, and the Ground Enabled operator control (in default settings).

51S2TC:= **32GF AND PLT01** 51S2 Torque Control (SELOGIC Equation)

51S3

Use the third element for phase, nondirectional, set above the three-phase fault current at the open field tie switch, for backup purposes.

51S3O := **IMAXL** 51S3 Operate Quantity (IAn,IAnR,..,IMAXn, IMAXnR,I1L,3I2L,3I0*n*)

51S3P := **7.00** 51S3 Overcurrent Pickup (0.25–16 A secondary)

Select the time dial and curve to coordinate with bus devices, with a longer time delay than the 51S1.

51S3C := **U1** 51S3 Inverse-Time Overcurrent Curve (U1–U5, C1–C5)

51S3TD := **1.50** 51S3 Inverse-Time Overcurrent Time Dial (0.50–15)

51S3RS := **N** 51S3 Inverse-Time Overcurrent Electromechanical Reset (Y, N)

Set the torque control to logical 1 (always enabled). Load encroachment cannot be used to control this backup element, because the ZLOAD calculation requires voltages.

51S3TC := **1** 51S3 Torque Control (SELOGIC Equation)

51S4

Use the fourth element for ground, nondirectional, set to the same pickup value as the directional ground element (51S2P) for backup purposes.

51S4O := **3I0L** 51S4 Operate Quantity (IAn,IAnR,..,IMAXn, IMAXnR,I1L,3I2L,3I0*n*)

51S4P := **2.30** 51S4 Overcurrent Pickup (0.25–16 A secondary)

Select the time dial and curve to coordinate with bus devices, with a longer time delay than 51S2.

51S4C := **U2** 51S4 Inverse-Time Overcurrent Curve (U1–U5, C1–C5)

51S4TD := **1.00** 51S4 Inverse-Time Overcurrent Time Dial (0.50–15)

51S4RS := **N** 51S4 Inverse-Time Overcurrent Electromechanical Reset (Y, N)

Set the torque control to follow the Ground Enabled operator control (in default settings).

51S4TC := **PLT01** 51S4 Torque Control (SELOGIC Equation)

51S5

Use the fifth element for negative-sequence, nondirectional, for backup purposes. This element should be set low enough to see phase-to-phase faults anywhere on the line, and phase-to-phase-to-ground faults with low fault resistance when the circuit breaker BK2 at station R is open or closed.

51S5O := **3I2L** 51S5 Operate Quantity (IAn,IAnR,..,IMAXn, IMAXnR,I1L,3I2L,3I0*n*)

51S5P := **6.80** 51S5 Overcurrent Pickup (0.25–16 A secondary)

Select the time dial and curve to coordinate with bus devices, with a long time delay.

51S5C := **U1** 51S5 Inverse-Time Overcurrent Curve (U1–U5, C1–C5)

51S5TD := **1.80** 51S5 Inverse-Time Overcurrent Time Dial (0.50–15)

51S5RS := **N** 51S5 Inverse-Time Overcurrent Electromechanical Reset (Y, N)

Set the torque control to follow the Ground Enabled operator control (in default settings).

51S5TC := **PLT01** 51S5 Torque Control (SELOGIC Equation)

Directional Control

The SEL-451 uses an array of directional elements to supervise the 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 residual ground directional overcurrent elements. If Q is not operable, the second listed directional element choice, V, provides directional control for the 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 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, and bus-side PTs are being used. 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.

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 instantaneous/definite-time overcurrent and time-overcurrent protection elements.

Set TR to include the definite time elements, and the time-overcurrent elements.

TR := **67P1T OR 67G1T OR 67Q1T OR 51S1T OR 51S2T OR 51S3T OR 51S4T OR 51S5T** 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.1.6*). Set Level 1 phase instantaneous overcurrent element (50P1) in the TRSOTF SELOGIC control equation.

TRSOTF := **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-451 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-451 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.1.27*.

TULO := **3** Trip Unlatch Option (1, 2, 3, 4)

Trip Timers

The SEL-451 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 (and T3P1) asserts. For this application example, Relay Word bit T3P1 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)

Control Outputs

Main Board

OUT101 trips Circuit Breaker 1. OUT103 is used to indicate an alarm condition for loss-of-potential.

OUT101 := **T3P1**

OUT103 := **LOP**

Example Completed

This completes the application example describing configuration of the SEL-451 for directional overcurrent protection of a 25 kV overhead distribution 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 SEL-451 Settings (Sheet 1 of 4)

Setting	Description	Entry
General Global (Global)		
SID	Station Identifier (40 characters)	Silver - 25 kV
RID	Relay Identifier (40 characters)	SEL-451 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 50G1 OR 50Q1 OR 51S1 OR 51S3 OR 51S4 OR 51S5
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
Breaker 1 Inputs (Breaker Monitoring)		
52AA1	N/O Contact Input—BK1 (SELOGIC Equation)	IN101
Line Configuration Settings (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)	120
VNOMY	PT Nominal Voltage (L-L)—Input Y (60–300 V secondary)	208
PTRZ	Potential Transformer Ratio—Input Z (1–10000)	120
VNOMZ	PT Nominal Voltage (L-L)—Input Z (60–300 V secondary)	208
Z1MAG	Positive-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)	21.35
Z1ANG	Positive-Sequence Line Impedance Angle (5.00–90 degrees)	68.86
Z0MAG	Zero-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)	76.50
Z0ANG	Zero-Sequence Line Impedance Angle (5.00–90 degrees)	72.47
EFLOC	Fault Location (Y, N)	Y
LL	Line Length (0.10–999)	68

Table 1.6 SEL-451 Settings (Sheet 2 of 4)

Setting	Description	Entry
Relay Configuration (Group)		
ESOTF	Switch-Onto-Fault (Y, N)	Y
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)	1
E50Q	Negative-Sequence Inst./Def.-Time O/C Elements (N, 1–4)	1
E51S	Selectable Inverse-Time O/C Elements (N, 1–6)	5
E32	Directional Control (Y, AUTO, N)	AUTO
ECOMM	Communications-Assisted Tripping (N, DCB, POTT, DCUB1, DCUB2)	N
EBFL1	Breaker 1 Failure Logic (N, Y)	N
E25BK1	Synchronism Check for Breaker 1 (Y, N)	N
E79	Reclosing (Y, Y1, N)	N
ELOP	Loss-of-Potential (Y, Y1, N)	Y1
EDEM	Demand Metering (N, THM, ROL)	N
SOTF Scheme Settings (Group)		
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
Load Encroachment (Group)		
ZLF	Forward Load Impedance (0.05–64 Ω secondary)	21.36
ZLR	Reverse Load Impedance (0.05–64 Ω secondary)	21.36
PLAF	Forward Load Positive Angle (–90.0 to +90.0 degrees)	43.4
NLAF	Forward Load Negative Angle (–90.0 to +90.0 degrees)	–33.8
PLAR	Reverse Load Positive Angle (+90.0 to +270.0 degrees)	150.0
NLAR	Reverse Load Negative Angle (+90.0 to +270.0 degrees)	210.0
Phase Instantaneous Overcurrent Pickup Settings (Group)		
50P1P	Level 1 Pickup (OFF, 0.25–100 A secondary)	22.00
Phase Overcurrent Definite-Time Delay (Group)		
67P1D	Level 1 Time Delay (0.000–16000 cycles)	2.000
Phase Overcurrent Torque Control (Group)		
67P1TC	Level 1 Torque Control (SELOGIC Equation)	1
Ground Instantaneous Overcurrent Pickup Settings (Group)		
50G1P	Level 1 Pickup (OFF, 0.25–100 A secondary)	17.00

Table 1.6 SEL-451 Settings (Sheet 3 of 4)

Setting	Description	Entry
Ground Definite-Time Overcurrent Delay (Group)		
67G1TD	Level 1 Time Delay (0.000–16000 cycles)	2.000
Ground Overcurrent Torque Control (Group)		
67G1TC	level 1 Torque Control (SELOGIC Equation)	PLT01
Negative-Sequence Instantaneous Overcurrent Pickup Settings (Group)		
50Q1P	Level 1 Pickup (OFF, 0.25–100 A secondary)	42.00
Negative-Sequence Definite-Time Overcurrent Delay (Group)		
67Q1TD	Level 1 Time Delay (0.000–16000 cycles)	2.000
Negative-Sequence overcurrent Torque Control (Group)		
67Q1TC	Level 1 torque Control (SELOGIC Equation)	PLT01
Selectable Operating Quantity Inverse-Time Overcurrent Element 1 (Group)		
51S1O	51S1 Operate Quantity (IA*n*, IA*n*R, .. , IMAX*n*, IMAX*n*R, I1L, 3I2L, 3I0*n*)	IMAXL
51S1P	51S1 Overcurrent Pickup (0.25–16 A secondary)	4.00
51S1C	51S1 Inverse-Time Overcurrent Curve (U1–U5, C1–C5)	U3
51S1TD	51S1 Inverse-Time Overcurrent Time Dial (0.50–15)	0.70
51S1RS	51S1 Inverse-Time Overcurrent Electromechanical Reset (Y, N)	N
51S1TC	51S1 Torque Control (SELOGIC Equation)	F32P
Selectable Operating Quantity Inverse-Time Overcurrent Element 2 (Group)		
51S2O	51S2 Operate Quantity (IA*n*, IA*n*R, .. , IMAX*n*, IMAX*n*R, I1L, 3I2L, 3I0*n*)	3I0L
51S2P	51S2 Overcurrent Pickup (0.25–16 A secondary)	2.30
51S2C	51S2 Inverse-Time Overcurrent Curve (U1–U5, C1–C5)	U4
51S2TD	51S2 Inverse-Time Overcurrent Time Dial (0.50–15)	1.00
51S2RS	51S2 Inverse-Time Overcurrent Electromechanical Reset (Y, N)	N
51S2TC	51S2 Torque Control (SELOGIC Equation)	32GF AND PLT01
Selectable Operating Quantity Inverse-Time Overcurrent Element 3 (Group)		
51S3O	51S3 Operate Quantity (IA*n*, IA*n*R, .. , IMAX*n*, IMAX*n*R, I1L, 3I2L, 3I0*n*)	IMAXL
51S3P	51S3 Overcurrent Pickup (0.25–16 A secondary)	7.00
51S3C	51S3 Inverse-Time Overcurrent Curve (U1–U5, C1–C5)	U1
51S3TD	51S3 Inverse-Time Overcurrent Time Dial (0.50–15)	1.50
51S3RS	51S3 Inverse-Time Overcurrent Electromechanical Reset (Y, N)	N
51S3TC	51S3 Torque Control (SELOGIC Equation)	1

Table 1.6 SEL-451 Settings (Sheet 4 of 4)

Setting	Description	Entry
Selectable Operating Quantity Inverse-Time Overcurrent Element 4 (Group)		
51S4O	51S4 Operate Quantity (IA*n*, IA*n*R, .. , IMAX*n*, IMAX*n*R, I1L, 3I2L, 3I0*n*)	3I0L
51S4P	51S4 Overcurrent Pickup (0.25–16 A secondary)	2.30
51S4C	51S4 Inverse-Time Overcurrent Curve (U1–U5, C1–C5)	U2
51S4TD	51S4 Inverse-Time Overcurrent Time Dial (0.50–15)	1.00
51S4RS	51S4 Inverse-Time Overcurrent Electromechanical Reset (Y, N)	N
51S4TC	51S4 Torque Control (SELOGIC Equation)	PLT01
Selectable Operating Quantity Inverse-Time Overcurrent Element 5 (Group)		
51S5O	51S5 Operate Quantity (IA*n*, IA*n*R, .. , IMAX*n*, IMAX*n*R, I1L, 3I2L, 3I0*n*)	3I2L
51S5P	51S5 Overcurrent Pickup (0.25–16 A secondary)	6.80
51S5C	51S5 Inverse-Time Overcurrent Curve (U1–U5, C1–C5)	U1
51S5TD	51S5 Inverse-Time Overcurrent Time Dial (0.50–15)	1.80
51S5RS	51S5 Inverse-Time Overcurrent Electromechanical Reset (Y, N)	N
51S5TC	51S5 Torque Control (SELOGIC Equation)	PLT01
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
3POD	Three-Pole Open Dropout Delay (0.000–60 cycles)	0.500
Trip Logic Settings (Group)		
TR	Trip (SELOGIC Equation)	67P1T OR 67G1T OR 67Q1T OR 51S1T OR 51S2T OR 51S3T OR 51S4T OR 51S5T
TRSOTF	Switch-Onto-Fault Trip (SELOGIC Equation)	50P1
ULTR	Unlatch Trip (SELOGIC Equation)	TRGTR
TULO	Trip Unlatch Option (1, 2, 3, 4)	3
TDUR3D	3PT Minimum Trip Duration Time Delay (2.000–8000 cycles)	9.000
Main Board (Outputs)		
OUT101	(SELOGIC Equation)	T3P1
OUT103	(SELOGIC Equation)	LOP

Auto-Reclose Example

Figure 1.3 shows a distribution system substation with one 25 kV feeder that is normally operated in a radial configuration. An independent power producer (IPP), connected to the feeder, operates a turbine co-generator from process steam, and this induction machine is not rated to run in a stand-alone fashion, nor does it have black start capability. Other single-phase and three-phase loads are connected throughout the feeder.

Details of line protection, grounding, and IPP protection are not covered in this example.

This example shows settings for the SEL-451 at substation S, and *Figure 1.5* shows the secondary connections to the relay.

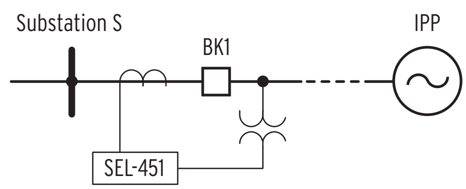

Figure 1.3 25 kV Example Power System

Application Requirements for This Example

Auto-Reclose Mode of Operation

For this application example, an adaptive auto-reclose sequence is required, where the number of auto-reclose shots and the open-interval time delays are a function of the fault type. The different operation scenarios have been characterized into four auto-reclose modes as shown in *Table 1.7*, and graphically represented in *Figure 1.4*.

Table 1.7 Desired Operating Modes for Auto-Reclose Example

Condition	Action	Mode Number
Following a three-phase, or phase-to-phase fault above a high current threshold	Do not auto-reclose (proceed to lockout)	1
Following a three-phase, or phase-to-phase fault, below a high-current threshold	Attempt one auto-reclosure after 300 cycles	2
Following a ground fault above a high-current threshold	Attempt one auto-reclosure after 300 cycles	3
Following a ground fault below a high-current threshold	Attempt two auto-reclosures, the first with a 180 cycle open interval time, and the second with a 300 cycle open interval time	4

In mode 4, the second auto-reclose is aborted if the preceding second trip is one of the fault types described in modes 1 through 3.

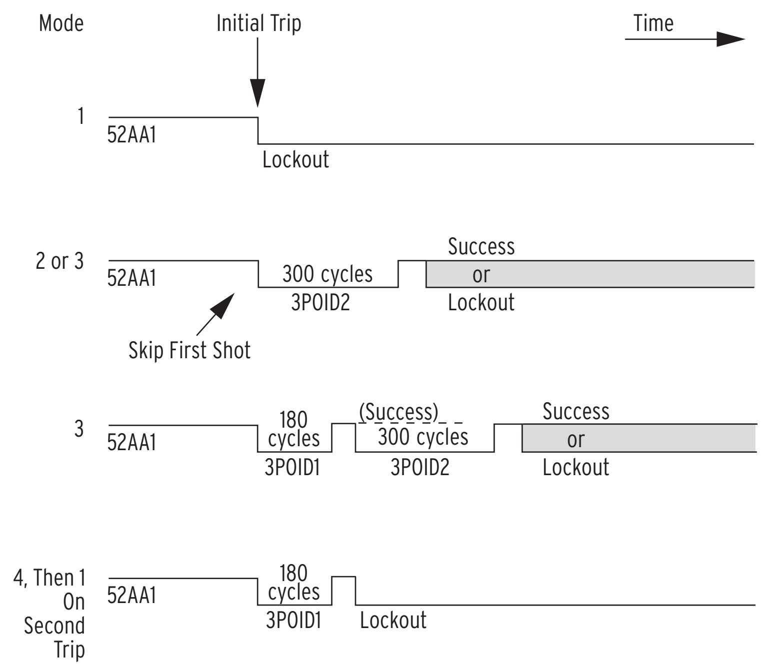

Figure 1.4 Timing of Auto-Reclose Shots for the Four Operating Modes

The reclaim (reset) time after a successful auto-reclose is specified as 900 cycles.

Abort auto-reclosing and go to lockout if any of the following occurs.

- After a trip and open-interval timing, a dead line/live bus condition does not materialize after 180 cycles
- Manual trip
- Reclose Enabled operator control is off (latch output PLT02 = logical 0) or Hot Line Tag operator control is on (latch output PLT04 = logical 0) AND a trip occurs or the breaker is open.
- Bus trip (IN105)
- Circuit breaker failure trip

The SEL-451 Synchronism Check feature is not required in this application example, however, two synchronism check settings must be modified for this application.

The directional element and overcurrent protection setting details are not covered in this example. *Table 1.8* shows the Relay Word bits used in this example. *Table 1.9* lists the desired operation mode as a function of the overcurrent Relay Word bits.

Table 1.8 Relay Word Bits Used in the Auto-Reclose Example (Sheet 1 of 2)

Relay Word Bit	Description	Context
50P1	Phase, instantaneous overcurrent	Detect high current faults
50Q1	Negative-Sequence, instantaneous overcurrent	Detect high-current phase-to-phase faults
50G1	Ground, instantaneous overcurrent	Detect high current ground faults
51S1T	Phase time-overcurrent	Tripping element

Table 1.8 Relay Word Bits Used in the Auto-Reclose Example (Sheet 2 of 2)

Relay Word Bit	Description	Context
51S2T	Ground time-overcurrent	Tripping element
PLT02	Protection latch 02 (factory default settings)	Reclose Enabled operator control
PLT04	Protection latch 04 (factory default settings)	Hot Line tag operator control (logical 0 when Hot Line tag is active)
IN105	Bus trip input	

Table 1.9 Determination of Operating Mode for the Auto-Reclose Example

Relay Word Bit States at Auto-Reclose Initiation (3PRI)[a]					Desired Operating Mode
50P1	50Q1	50G1	51S1T	51S2T	
0	0	0	0	0	4
0	0	0	0	1	4
0	0	1	0	1	3
0	1	0	0	1	3
0	1	1	0	1	3
0	0	x	1	x	2
1	x	x	x	x	1
0	1	x	1	x	1

[a] x = state does not matter

Solution

Auto-Reclose Mode of Operation

The relay initiates auto-reclosing if a trip occurs because of a protective element operation.

Circuit Breaker1 attempts the 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

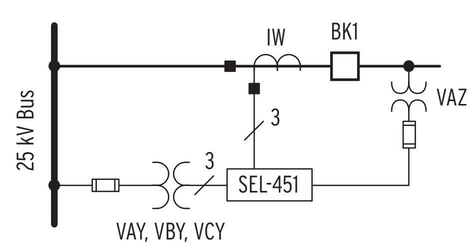

Figure 1.5 Circuit Breaker Secondary Connections at Station S

Relay Settings

Select the relay settings for this application example.

Relay Configuration

Enable synchronism check for circuit breaker 1.

E25BK1 := **Y** Synchronism Check for Breaker 1 (Y, N)

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)

Enable manual close.

EMANCL := **Y** Manual Closing (Y, N)

Synchronism Check Element Reference

Figure 1.5 shows the PT connections for the auto-reclose example. To perform voltage checks on auto-reclose, EVCK must be enabled, and the desired line and bus voltage Relay Word bit (from *Figure 2.14 on page R.2.31*) should be used in the reclose supervision setting(s). The "line" and "bus" designation for the voltage sources are controlled by the SYNCP and SYNCS1 settings, respectively. The rest of the synchronism check settings are not needed in this application example.

Set the Vp source to VAZ (for the dead line check).

SYNCP := **VAZ** Synch Reference (VAY,VBY,VCY,VAZ,VBZ,VCZ)

Set the Vs source to VAY (for the hot bus check).

SYNCS1 := **VAY** Synch Source 1 (VAY,VBY,VCY,VAZ,VBZ,VCZ)

Recloser and Manual Closing

Select two shots of auto-reclose.

N3PSHOT := **2** Number of Three-Pole Reclosures (N, 1–4)

Enable auto-reclose for circuit breaker 1.

E3PR1 := **1** Three-Pole Reclose Enable -BK1 (SELOGIC Equation)

If Circuit Breaker 1 fails to close within 600 cycle 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 the breaker is closed, or trips for any reason.

ULCL1 := **52AA1 OR T3P1** Unlatch Closing for Circuit Breaker 1 (SELOGIC Equation)

Drive the auto-reclose logic to lockout if any of the following occur:

- a mode 1 fault trips the circuit breaker (from *Table 1.9*)
- the Reclose Enable operator control is turned off, or Hot Line Tag is turned on, AND the breaker is open or trips
- a breaker failure trip
- a bus trip

The listed operator control assignments are the same as the factory default settings.

No special considerations are required to block auto-reclose after a manual trip, because the 3PRI setting := 3PT AND NOT (Z2PT OR Z2GT OR Z3PT OR Z3GT OR SOTFT), and Relay Word bit 3PT does not assert for manual trips. If the breaker opens with no reclose initiate condition, the auto-reclose logic will go to lockout.

79DTL := **3PRI AND (50P1 OR 50Q1 AND 51S1T) OR NOT (PLT02 AND PLT04) AND (3PT OR NOT 52AA1) OR BFTRIP1 OR IN105** Recloser Drive to Lockout (SELOGIC Equation)

You can block the reclaim timing. However, it is not necessary for this application example.

79BRCT := **NA** Block Reclaim Timer (SELOGIC Equation)

Set the manual close conditions for circuit breaker 1. The setting is identical to the factory default setting, and incorporates Hot Line Tag supervision.

BK1MCL := **(CC1 OR PB7_PUL) AND PLT04** Breaker 1 Manual Close (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 := **600** Manual Close Reclaim Time Delay (1–999999 cycles)

If Circuit Breaker 1 reclose supervision conditions fail to occur within 180 cycles after the open interval time delay expires, BK1CLST will assert, and the auto-reclose logic goes to lockout.

BK1CLSD := **180** BK1 Reclose Supervision Delay (OFF, 1–999999 cycles)

Three-Pole Reclose

Set the three-pole open interval times equal to 180 and 300 cycles.

3POID1 := **180** Three-Pole Open Interval 1 Delay (1–999999 cycles)

3POID2 := **300** Three-Pole Open Interval 2Delay (1–999999 cycles)

There is no need to enable fast three-pole auto-reclose because we are using the skip shot feature to vary the recloser open interval.

3PFARC := **NA** Three-Pole Fast ARC Enable (SELOGIC Equation)

Set the reset time following an auto-reclose cycle equal to 900 cycles.

3PRCD := **900** Three-Pole Reclaim Time Delay (1–999999 cycles)

NOTE: Do not use the breaker-specific trip outputs T3P1 or T3P2 for auto-reclose initiation, unless you want manual trips to initiate auto-reclose.

Initiate a three-pole auto-reclose cycle when the SEL-451 trips. Communications-assisted tripping is not enabled.

3PRI := **3PT** Three-Pole Reclose Initiation (SELOGIC Equation)

Modify the auto-reclose sequence to provide the modes listed in *Table 1.7*. Refer to *Figure 1.4*. For modes 2 and 3, the first open interval (3POID1 = 180 cycles) is skipped and the second open interval (3POID2 = 300 cycles) is run instead. The skip shot (79SKP) setting is used to accomplish this. Mode 1 takes priority by driving the auto-reclose logic to lockout, so it is not necessary to check for mode 1 in the 79SKP setting.

79SKP := **51S1T OR 51S2T AND (50Q1 OR 50G1)** 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

Enable the voltage check elements.

EVCK := **Y** Reclosing Voltage Check (Y, N)

Set the dead line voltage threshold equal to 25 V secondary.

27LP := **25.0** Dead Line Voltage (1.0–200 V secondary)

Set the live line voltage threshold equal to 80 V secondary.

59LP := **80.0** Live Line Voltage (1.0–200 V secondary)

Set the dead bus voltage threshold for Circuit Breaker 1 equal to 25 V secondary.

27BK1P := **25.0** Breaker 1 Dead Busbar Voltage (1.0–200 V secondary)

Set the live bus voltage threshold for Circuit Breaker 1 equal to 80 V secondary.

59BK1P := **80.0** Breaker 1 Live Busbar Voltage (1.0–200 V secondary)

Example Complete

This completes the application example that describes setting the SEL-451 for adaptive reclosing for a single circuit breaker. Analyze your particular power system to determine the appropriate settings for your application.

Relay Settings

Table 1.10 provides a list of all the SEL-451 auto-reclose settings for this application.

Table 1.10 SEL-451 Settings (Sheet 1 of 2)

Setting	Description	Entry
Relay Configuration		
E25BK1	Synchronism Check for Breaker 1 (Y, N)	Y
E79	Reclosing (Y, Y1, N)	Y
EMANCL	Manual Closing (Y, N)	Y
Recloser Closing (Group)		
N3PSHOT	Number of Three-Pole Reclosures (N, 1–4)	2
E3PR1	Three-Pole Reclose Enable—BK1 (SELOGIC Equation)	1
BKCFD	Breaker Close Failure Delay (OFF, 1–999999 cycles)	600
ULCL1	Unlatch Closing for Breaker 1 (SELOGIC Equation)	52AA1 OR T3P1
79DTL	Recloser Drive to Lockout (SELOGIC Equation)	3PRI AND (50P1 OR 50Q1 AND 51S1T) OR NOT (PLT02 AND PLT04) AND (3PT OR NOT 52AA1) OR BFTRIP1 OR IN105
79BRCT	Block Reclaim Timer (SELOGIC Equation)	NA
BK1MCL	Breaker 1 Manual Close (SELOGIC Equation)	(CC1 OR PB7_PUL) AND PLT04

Table 1.10 SEL-451 Settings (Sheet 2 of 2)

Setting	Description	Entry
3PMRCD	Manual Close Reclaim Time Delay (1–999999 cycles)	600
BK1CLSD	BK1 Reclose Supervision Delay (OFF, 1–999999 cycles)	180
Three-Pole Reclose (Group)		
3POID1	Three-Pole Open Interval 1 Delay (1–999999 cycles)	180
3POID2	Three-Pole Open Interval 2 Delay (1–999999 cycles)	300
3PFARC	Three-Pole Fast Automatic Reclose Enable (SELOGIC Equation)	NA
3PRCD	Three-Pole Reclaim Time Delay (1–999999 cycles)	900
3PRI	Three-Pole Reclose Initiation (SELOGIC Equation)	3PT
79SKP	Skip Reclosing Shot (SELOGIC Equation)	51S1T OR 51S2T AND (50Q1 OR 50G1)
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)	25.0
59LP	Live Line Voltage (1.0–200 V secondary)	80.0
27BK1P	Breaker 1 Dead Busbar Voltage (1.0–200 V secondary)	25.0
59BK1P	Breaker 1 Live Busbar Voltage (1.0–200 V secondary)	80.0

[a] This setting cannot be set to NA or logical 0.

Auto-Reclose and Synchronism Check Example

Use the SEL-451 to provide automatic reclosing and synchronism check for overhead transmission lines. This application example is for double-ended 138 kV lines with SEL-451 protection at each end of the first circuit as shown in *Figure 1.6*. This example shows the settings for the SEL-451 at Station S protecting Line 1 between CB1 and CB2.

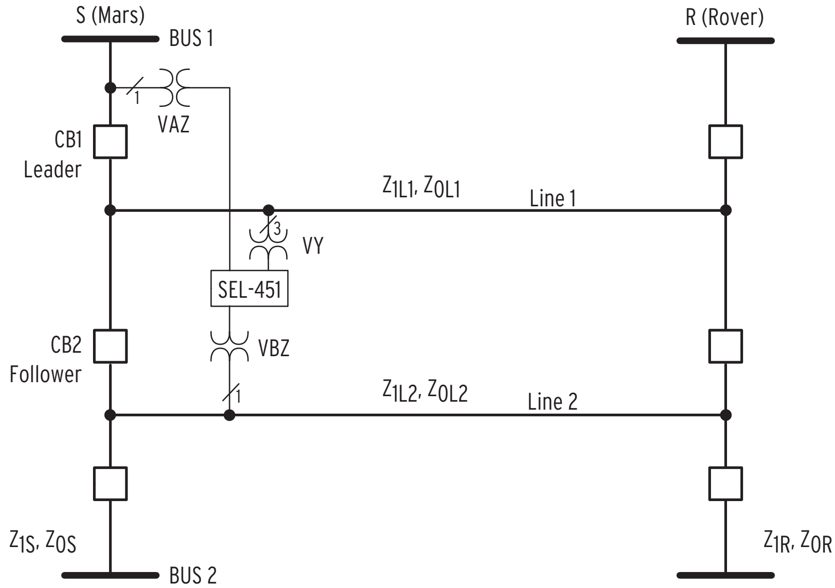

Figure 1.6 138 kV Power System

First set the auto-reclose logic, and then set the synchronism-check function.

Auto-Reclose Application

Apply the SEL-451 for one shot of reclosing.

Select the recloser mode with the enable setting E79 := Y or Y1, and set E3PR1 and E3PR2 to logical 1.

Auto-Reclose Sequence

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-451 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-451 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.

The auto-reclose logic resets after the reclaim timer (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.

Auto-Reclose Solution

Auto-Reclose Conditions

The relay initiates auto-reclosing if a directional overcurrent 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 side 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-451 detects a loss-of-potential condition, the auto-reclose logic drives the auto-reclose function to lockout.

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-451 is to be able to auto-reclose.

Recloser Closing

Select one shot of 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 auto-reclosing.

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 (1–999999 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, 1–999999 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 Circuit Breaker 2 is 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 the breaker is closed.

ULCL1 := **52AA1** Unlatch Closing for Breaker 1 (SELOGIC Equation)

Unlatch the reclose command to Circuit Breaker 2 when the breaker is closed.

ULCL2 := **52AA2** Unlatch Closing for Breaker 2 (SELOGIC Equation)

Drive the auto-reclose logic to lockout if the SEL-451 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 (1–999999 cycles)

If Circuit Breaker 1 reclose supervision condition (setting 3P1CLS) fails 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, 1–999999 cycles)

If Circuit Breaker 2 reclose supervision condition (setting 3P2CLS) fails 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, 1–999999 cycles)

Auto-Reclose Logic

Set the open interval time equal to 30 cycles.

3POID1 := **30** Three-Pole Open Interval 1 Delay (1–999999 cycles)

There is no need to enable fast three-pole auto-reclose because we have already used the first and only shot for this purpose.

3PFARC := **NA** Three-Pole Fast ARC Enable (SELOGIC Equation)

Set the reclaim time following an auto-reclose cycle equal to 900 cycles.

3PRCD := **900** Three-Pole Reclaim Time Delay (1–999999 cycles)

Initiate an auto-reclose cycle when the SEL-451 trips because of directional overcurrent 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 (67P1T OR 67G1T OR COMPRM)** Three-Pole Reclose Initiation (SELOGIC Equation)

You can force the auto-reclose logic to skip a 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 (you cannot set this setting to NA or logical 0; see *Voltage Elements on page A.1.24*).

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 (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

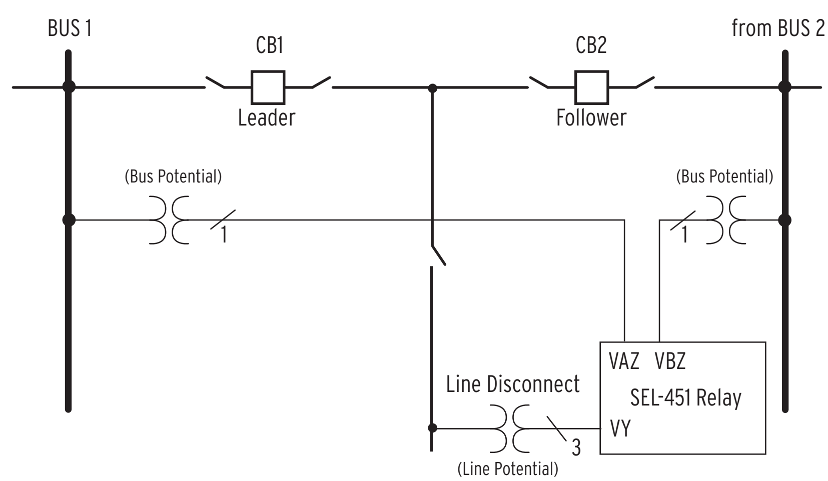

Figure 1.7 Potential Sources

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)

Synchronism-Check Application

Reclose Circuit Breaker 1 following a trip if the line is dead and Bus 1 is hot. Reclose Circuit Breaker 2 following a 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.

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 (0.00–3)

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 := **8.00** Breaker 2 Close Time (1.00–30 cycles)

Block the synchronism check if Circuit Breaker 2 is closed.

BSYNBK2 := **52AA2** Block Synchronism Check—BK2 (SELOGIC Equation)

Example Complete

This completes the application example that describes setting the SEL-451 for auto-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 1.11 provides a list of all the SEL-451 auto-reclose settings for this application.

Table 1.11 SEL-451 Settings (Sheet 1 of 3)

Setting	Description	Entry
Relay Configuration (Group)		
E25BK1	Synchronism Check for Breaker 1 (Y, N)	N
E25BK2	Synchronism Check for Breaker 2 (Y, N)	Y
E79	Reclosing (Y, Y1, N)	Y
EMANCL	Manual Closing (Y, N)	Y
Recloser Closing (Group)		
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 (1–999999 cycles)	15

Table 1.11 SEL-451 Settings (Sheet 2 of 3)

Setting	Description	Entry
BKCFD	Breaker Close Failure Delay (OFF, 1–999999 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
ULCL2	Unlatch Closing for Breaker 2 (SELOGIC Equation)	52AA2
79DTL	Recloser Drive to Lockout SELOGIC Equation)	LOP
79BRCT	Block Reclaim Timer (SELOGIC Equation)	NA
3PMRCD	Manual Close Reclaim Time Delay (1–999999 cycles)	900
BK1CLSD	BK1 Reclose Supervision Delay (OFF, 1–999999 cycles)	300
BK2CLSD	BK2 Reclose Supervision Delay (OFF, 1–999999 cycles)	300
Three-Pole Reclose (Group)		
3POID1	Three-Pole Open Interval 1 Delay (1–999999 cycles)	30
3PFARC	Three-Pole Fast Auto-Reclose Enable (SELOGIC Equation)	NA
3PRCD	Three-Pole Reclaim Time Delay (1–999999 cycles)	900
3PRI	Three-Pole Fast Auto-Reclose Initiate (SELOGIC Equation)	3PT AND (67P1T OR 67G1T 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

Table 1.11 SEL-451 Settings (Sheet 3 of 3)

Setting	Description	Entry
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
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)	8.00
BSYNBK2	Block Synchronism Check—BK2 (SELOGIC Equation)	52AA2

[a] This setting 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-451 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-451 provides protection for basic cases involving both multiphase faults and single-phase faults with a common breaker failure time delay.

Basic Operation

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). When initiated, the relay starts circuit breaker failure timing; the time delay is BFPU1 (Breaker Failure Time Delay—BK1). The SEL-451 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 will 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-451:

- Circuit Breaker Failure Initiation (BFI3P1)
- Phase Fault Current Pickup (50FP1)
- Breaker Failure Pickup Time Delay (BFPU1)

For a detailed description see *Circuit Breaker Failure Trip Logic on page R.1.96*.

Circuit Breaker Failure Initiation (BFI3P1)

All circuit breaker trips typically initiate the circuit breaker failure scheme. The SEL-451 detects power system faults; the relay does not need an external BFI contact for local circuit breaker failure protection applications.

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-451 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)

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.

Timing Sequence

Figure 1.8 illustrates the timing sequence for circuit breaker failure schemes.

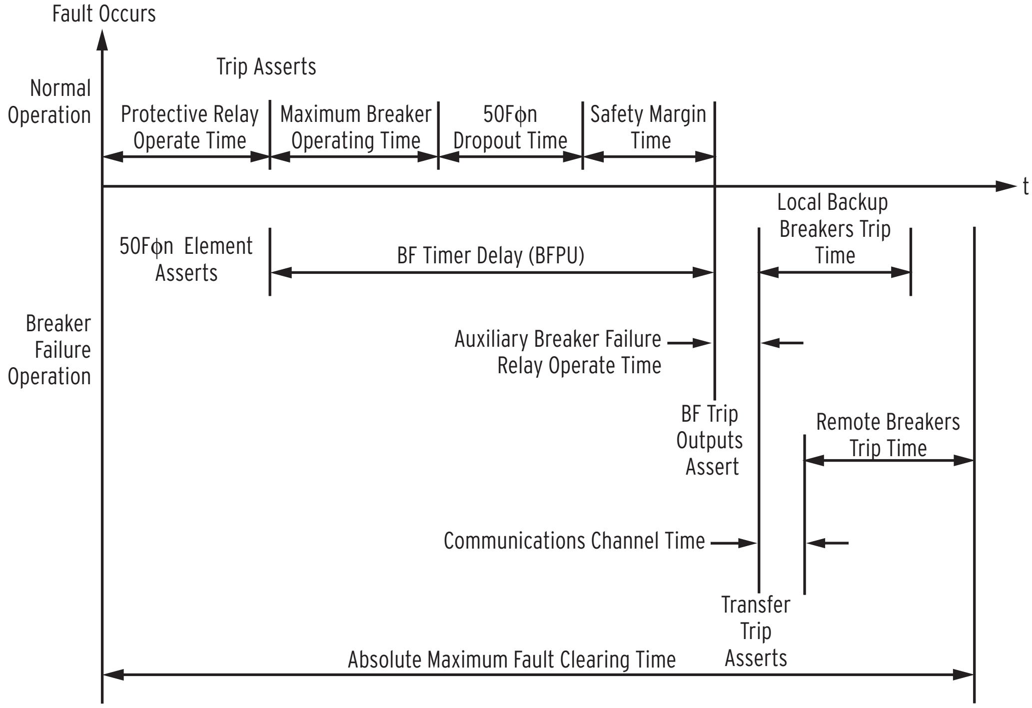

Figure 1.8 Circuit Breaker Failure Timing Diagram

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-451 to provide circuit breaker failure protection for one circuit breaker. This example uses a 25 kV power system similar to the system in *25 kV Overhead Distribution Line Example on page A.1.1*. *Figure 1.9* shows the SEL-451 at the S terminal of the two-terminal line between Silver and Redding. *Table 1.12* provides the related power system parameters.

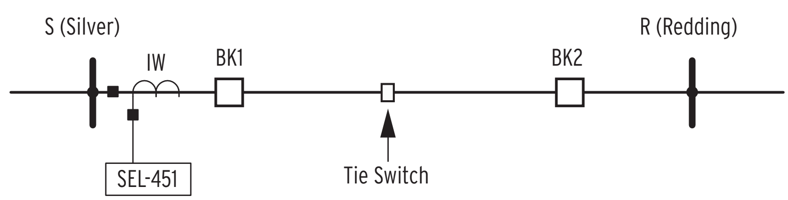

Figure 1.9 25 kV Power System for Circuit Breaker Failure Example 1

Table 1.12 Secondary Quantities

Parameter	Value
Maximum operating current load (I_{load})	4.95 A secondary
Maximum system unbalance	15%

Relay Configuration

Enable circuit breaker failure protection for Circuit Breaker BK1.

EBFL1 := **Y** Breaker 1 Failure Logic (N, Y)

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.1.39*). 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.

$$50FP1 = 120\% \cdot I_{load} = 120\% \cdot 4.95\ A = 5.94\ A$$

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 1.10*):

- Maximum circuit breaker operating time
- 50FA1 maximum dropout time
- Safety margin

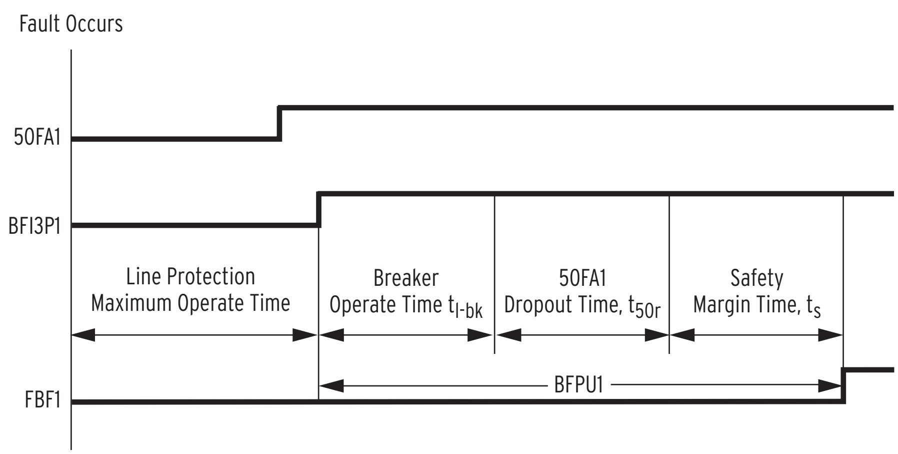

Figure 1.10 Timing Diagram for Setting BFPU1

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 1.8*:

$$\begin{aligned} t_s &= t_t - (t_{1r} + t_{1-bk} + t_{50r} + t_{86} + t_{ch} + t_{r-bk}) \\ &= 17 - (2 + 3 + 1 + 1 + 1 + 3) \\ &= 6 \text{ cycles} \end{aligned}$$

Equation 1.5

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 1.5* to calculate BFPU1:

$$\begin{aligned} \text{BFPU1} &= t_{1-bk} + t_{50r} + t_s \\ &= 3 + 1 + 6 \\ &= 10 \text{ cycles} \end{aligned}$$

Equation 1.6

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).

BFI3P1 := **3PT** Three-Pole 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

NOTE: If a seal-in delay is required, special settings must be used. See Circuit Breaker Failure Protection–Example 2 on page A.1.42

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.

$$50RP1 = 0.15 \bullet I_{load} = 0.15 \bullet 4.95\ A = 0.74\ A$$

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-451 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 1.11* 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**

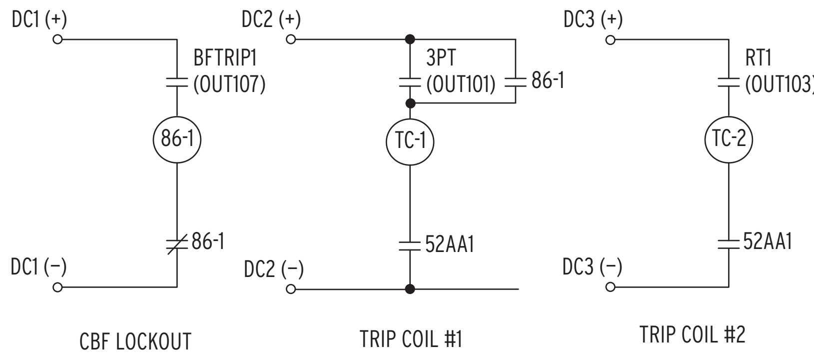

Figure 1.11 Circuit Breaker Failure Trip and Circuit Breaker Trip DC Connections

Example Completed

This completes the application example that describes setting of the SEL-451 for circuit breaker failure protection. Analyze your particular power system to determine the appropriate settings for your application.

Relay Settings

Table 1.13 lists all protection relay settings applied for this example.

Table 1.13 Relay Configuration (Group) (Sheet 1 of 2)

Setting	Description	Entry
EBFL1	Breaker 1 Failure Logic (N, Y)	Y
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
BFI3P1	Three-Pole Breaker Failure Initiate—BK1 (SELOGIC Equation)	3PT
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

Table 1.13 Relay Configuration (Group) (Sheet 2 of 2)

Setting	Description	Entry
Main Board (Outputs)		
OUT101		3PT
OUT103		RT1
OUT107		BFTRIP1

Circuit Breaker Failure Protection—Example 2

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.

Use the SEL-451 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 1.12*). You can apply these same settings for Circuit Breaker BK2.

This example uses a 138 kV power system with two circuit breakers connected to the SEL-451 (see *Figure 1.12*). *Table 1.14* provides the power system parameters.

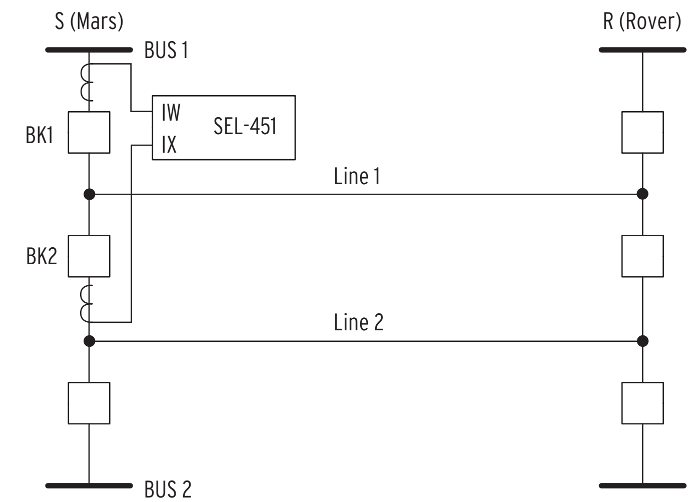

Figure 1.12 138 kV Power System for Circuit Breaker Failure Example 2

Table 1.14 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 circuit breaker failure protection for two circuit breakers.

EBFL1 := **Y** Breaker 1 Failure Logic (Y, N)

EBFL2 := **Y** Breaker 2 Failure Logic (Y, N)

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.

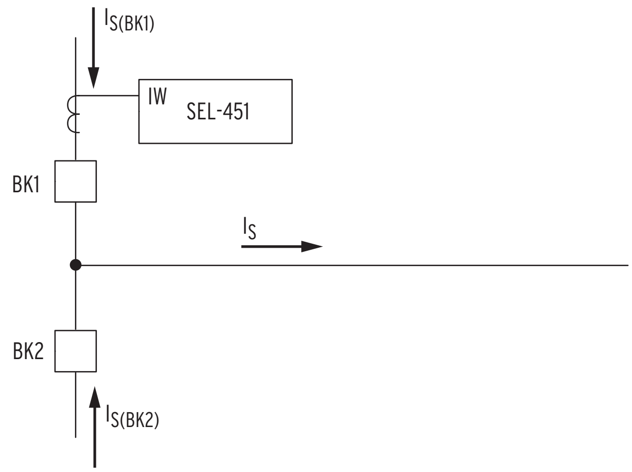

Figure 1.13 Fault Current Distribution Through Faulted Line at Station S

Assume that the total load current (I_S) supplied from Substation S flows through BK1 only; $I_{S(BK1)} = I_S$ (see *Figure 1.13*). 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 1.7

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 1.8

Although the result of this setting calculation is below maximum load (see *Equation 1.7*), 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 fault.

The recommended setting for BFPU1 is the sum of the following (see *Figure 1.14*):

- Maximum circuit breaker operating time
- 50FA1 maximum dropout time
- Safety margin

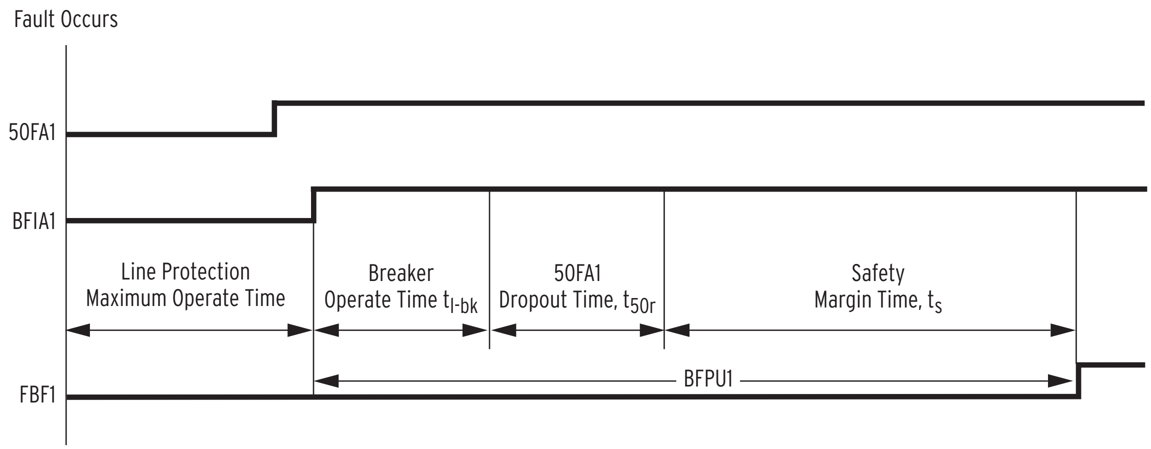

Figure 1.14 Timing Diagram for Setting BFPU1

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 1.8*.

$$\begin{aligned} t_s &= t_t - (t_{1r} + t_{1-bk} + t_{50r} + t_{86} + t_{ch} + t_{r-bk}) \\ &= 15 - (2 + 2 + 1 + 1 + 1 + 2) \\ &= 6 \text{ cycles} \end{aligned}$$

Equation 1.9

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 1.10* to calculate BFPU1:

$$\begin{aligned} \text{BFPU1} &= t_{1-bk} + t_{50r} + t_s \\ &= 3 + 1 + 6 \\ &= 10 \text{ cycles} \end{aligned}$$

Equation 1.10

BFPU1 := **10.000** Breaker Failure Time Delay—BK1 (0.000–6000 cycles)

Retrip Time Delay

The SEL-451 provides retrip timer RTPU1.

The relay should attempt to retrip the protected circuit breaker before a circuit breaker failure trip asserts. Apply the default setting for the retrip time delay on pickup.

RTPU1 := **3.000** Retrip Time Delay—BK1 (0.000–6000 cycles)

Figure 1.15 shows the complete timing sequence for circuit breaker failure operations.

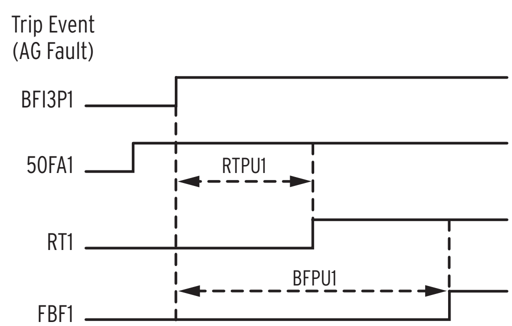

Figure 1.15 Timing Sequence for Circuit Breaker Failure Protection

Circuit Breaker Failure Initiation

Use Relay Word bit BFI3P1 to initiate failure to interrupt fault current circuit breaker failure protection.

BFI3P1 := **PSV04 AND (PCT03Q OR 50FA1 OR 50FB1 OR 50FC1) # Circuit breaker failure extended initiation—Breaker 1** Three-Pole Breaker Failure Initiate—BK1 (SELOGIC Equation)

Note that this breaker failure initiate setting does **not** include the Relay Word bit BFI3PT1, and includes a different-looking SELOGIC expression. This is important because special logic is necessary for this application.

For this two-breaker scheme, a circuit breaker failure initiation seal-in delay (and dropout delay) is required. As discussed in *Special Considerations for Seal-In Delay on page R.1.94*, it is necessary to use some protection free-form SELOGIC control equations to implement the breaker failure timing function. The required logic for circuit breaker 1 is shown in *Figure 1.16*. This logic is a duplicate of the built-in Circuit Breaker Failure Seal-In Logic Diagram shown in *Figure 1.63 on page R.1.99*.

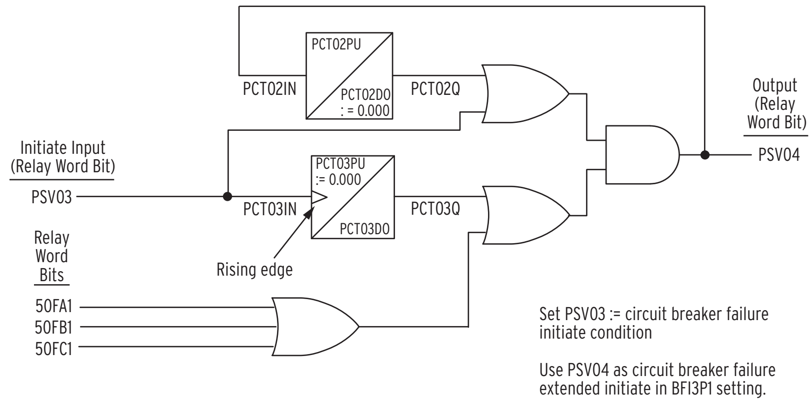

Figure 1.16 Circuit Breaker Failure Seal-In Logic Using Protection Free-Form SELOGIC—Breaker 1

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. Use this feature for this application example because you are protecting dual circuit breakers.

The required dropout delay is 3.000 cycles.

The built-in circuit breaker failure initiate dropout timer will not be used in this application. Instead, use protection free-form SELOGIC equations to implement the dropout timer. Protection conditioning timer 3 will be used for the dropout timing function.

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.

The required seal-in delay is 4.000 cycles.

The built-in circuit breaker failure initiate seal-in timer will not be used in this application. Instead, use protection free-form SELOGIC equations to implement the dropout timer. Protection conditioning timer 2 will be used for the seal-in timing function.

Implement Circuit Breaker Failure Seal-In using Protection Free-Form SELOGIC

To implement the duplicate logic for breaker 1, and circuit breaker 2, make the following settings in the protection free-form SELOGIC control equation settings classes that correspond to the setting groups that will be used in the application. The logic implementation matches *Figure 1.16* for circuit breaker 1.

Circuit Breaker 1

PSV02 := PSV03 # memory element used in fast rising edge detection logic. IMPORTANT: locate this setting before PSV03 setting.

PSV03 := T3P1 # breaker 1 raw initiate signal, before seal-in

PCT02PU := 4.000 # breaker failure initiate seal-in delay, breaker 1

PCT02DO := 0.000 # must be 0.000

PCT02IN := PSV04

PCT03PU := 0.000 # must be 0.000

PCT03DO := 2.875 # set 0.125 cycles less than required circuit breaker failure initiate dropout delay time—breaker 1

PCT03IN := PSV03 AND NOT PSV02 # fast rising edge PSV03 function (similar to R_TRIG PSV03, but asserts one processing interval earlier)

PSV04 := (PCT02Q OR PSV03) AND (PCT03Q OR 50FA1 OR 50FB1 OR 50FC1) # circuit breaker failure extended initiation - breaker 1. Use the expression PSV04 AND (PCT03Q OR 50FA1 OR 50FB1 OR 50FC1) in BFI3P1 setting for fast dropout.

Circuit breaker 2 (similar to circuit breaker 1, with unique SELOGIC elements)

PSV05 := PSV06 # memory element used in fast rising edge detection logic. **IMPORTANT:** locate this setting before PSV06 setting.

PSV06 := T3P2 # breaker 2 raw initiate signal, before seal-in

PCT04PU := 4.000 # breaker failure initiate seal-in delay, breaker 2

PCT04DO := 0.000 # must be 0.000

PCT04IN := PSV07

PCT05PU := 0.000 # must be 0.000

PCT05DO := 2.875 # set 0.125 cycles less than required circuit breaker failure initiate dropout delay time—breaker 2

PCT05IN := PSV06 AND NOT PSV05 # fast rising edge PSV06 function (similar to R_TRIG PSV06, but asserts one processing interval earlier)

PSV07 := (PCT04Q OR PSV06) AND (PCT05Q OR 50FA2 OR 50FB2 OR 50FC2) # circuit breaker failure extended initiation—breaker 2. Use the expression PSV07 AND (PCT05Q OR 50FA2 OR 50FB2 OR 50FC2) in BFI3P2 setting for fast dropout.

With the focus on circuit breaker 1, for the above settings, with the seal-in delay (PCT02PU) greater than the dropout delay (PCT03DO), the logic will seal-in the circuit breaker failure extended initiation (PSV04) if the circuit breaker failure initiate signal (PSV03) is asserted for a time greater than the seal-in delay setting PCT02PU. The seal-in is broken when all 50FA1, 50FB1, 50FC1 elements deassert, regardless of the state of the circuit breaker failure initiate signal.

If instead, the dropout delay (PCT03DO) is set greater than the seal-in delay (PCT02PU), seal-in of PSV04 will take place if the circuit breaker failure initiate signal (PSV03) is asserted for a time greater than the seal-in delay setting PCT02PU. The seal-in is broken when all 50FA1, 50FB1, 50FC1 elements have deasserted AND the dropout time PCT03DO has expired, regardless of the state of the circuit breaker failure initiate signal.

It is possible for the dropout timer to keep the circuit breaker failure extended initiation signal (PSV04) asserted before the overcurrent elements 50FA1, 50FB1, and 50FC1 pickup, or after they drop out. This is useful in breaker-and-a-half or two-breaker schemes where one of the breakers is connected to a weaker source, because it allows the breakers to have the same breaker failure timing. For example, the seal-in of a weak-sourced breaker failure initiation will not have to wait until the stronger-source breaker opens and sufficient fault current can be detected.

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-451 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-451 with an additional INT6 I/O interface board (see *I/O Interface Boards on page U.2.13*).

Assign the trip outputs to the hybrid (high current interrupting) control outputs. Use the high current interrupting control outputs for the retrip signal (RT1) because these outputs 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 := **T3P1**

OUT106 := **BFTRIP1**

OUT107 := **BFTRIP2**

OUT201 := **T3P2**

OUT204 := **RT1**

OUT207 := **RT2**

Figure 1.17 illustrates the corresponding dc connections for Circuit Breaker BK1. Circuit Breaker BK2 connections are similar.

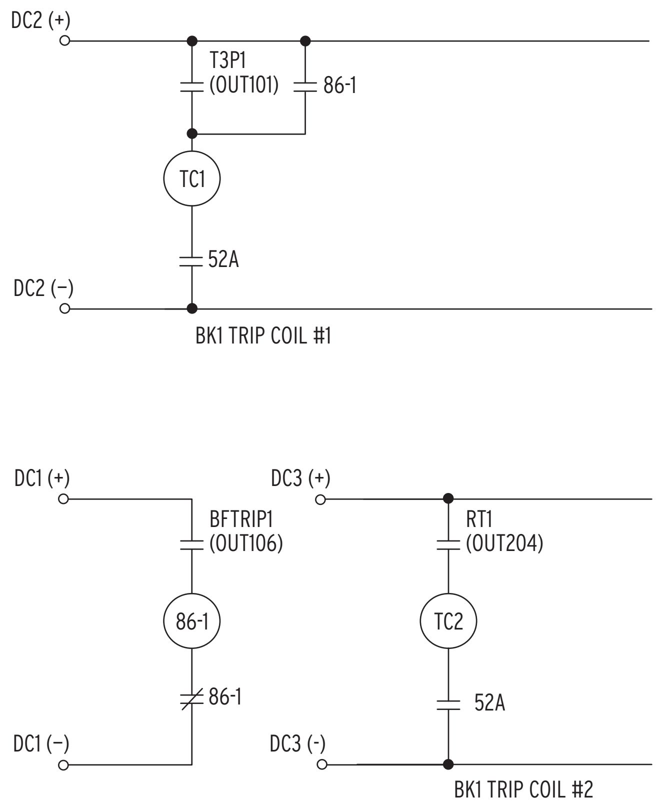

Figure 1.17 Circuit Breaker BK1 DC Connections (Two Trip Coils)

Example Completed

This completes the application example that describes setting the SEL-451 for circuit breaker failure protection. Analyze your particular power system to determine the appropriate settings for your application.

Relay Settings

Table 1.15 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 1.15 Relay Configuration (Group) (Sheet 1 of 3)

Setting	Description	Entry
EBFL1	Breaker 1 Failure Logic (Y, N)	Y
EBFL2	Breaker 2 Failure Logic (Y, N)	Y
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
RTPU1	Retrip Time Delay—BK1 (0.000–6000 cycles)	3.000

Table 1.15 **Relay Configuration (Group)** (Sheet 2 of 3)

Setting	Description	Entry
BFI3P1	Three-Pole Breaker Failure Initiate—BK1	PSV04 AND (PCT03Q OR 50FA1 OR 50FB1 OR 50FC1)
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
Breaker 2 Failure Logic (Group) (only the settings that are different than the Breaker 1 settings are shown)		
BFI3P2	Three-Pole Breaker Failure Initiate–BK2	PSV07 AND (PCT05Q OR 50FA2 OR 50FB2 OR 50FC2)
BFTR2	Breaker Failure Trip–BK2 (SELOGIC Equation)	FBF2
Control Outputs		
OUT101		T3P1
OUT106		BFTRIP1
OUT107		BFTRIP2
OUT201		T3P2
OUT204		RT1
OUT207		RT2
Protection Free-Form Logic (Group)		
# CIRCUIT BREAKER FAILURE INITIATE SEAL-IN LOGIC FOR BREAKER 1		
# ENTER LOGIC IN THE ORDER SHOWN FOR PROPER OPERATION		
PSV02 := PSV03		
PSV03 := T3P1 # BF INITIATE INPUT		
PCT02PU := 4.000 # SEAL-IN DELAY		
PCT02DO := 0.000		
PCT02IN := PSV04		
PCT03PU := 0.000		
PCT03DO := 2.875 # DROPOUT DELAY (ADJUSTED)		
PCT03IN := PSV03 AND NOT PSV02		
PSV04 := (PCT02Q OR PSV03) AND (PCT03Q OR 50FA1 OR 50FB1 OR 50FC1)		

Table 1.15 Relay Configuration (Group) (Sheet 3 of 3)

Setting	Description	Entry
#		
# CIRCUIT BREAKER FAILURE INITIATE SEAL-IN LOGIC FOR BREAKER 2		
# ENTER LOGIC IN THE ORDER SHOWN FOR PROPER OPERATION		
PSV05 := PSV06		
PSV06 := T3P2 # BF INITIATE INPUT		
PCT04PU := 4.000 # SEAL-IN DELAY		
PCT04DO := 0.000		
PCT04IN := PSV07		
PCT05PU := 0.000		
PCT05DO := 2.875 # DROPOUT DELAY (ADJUSTED)		
PCT05IN := PSV06 AND NOT PSV05		
PSV07 := (PCT04Q OR PSV06) AND (PCT05Q OR 50FA2 OR 50FB2 OR 50FC2)		

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Section 2
Monitoring and Metering

The SEL-451 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.2.16*
- *Metering on page A.2.22*

This section explains each of these features and gives practical examples for applying these features in the power system.

Circuit Breaker Monitor

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-451 features advanced circuit breaker monitoring.

Overview

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.2.2*
- *Other Circuit Breaker Monitor Functions on page A.2.8*
- *BREAKER Command on page A.2.13*

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-451 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-451 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-451 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
- Motor run time

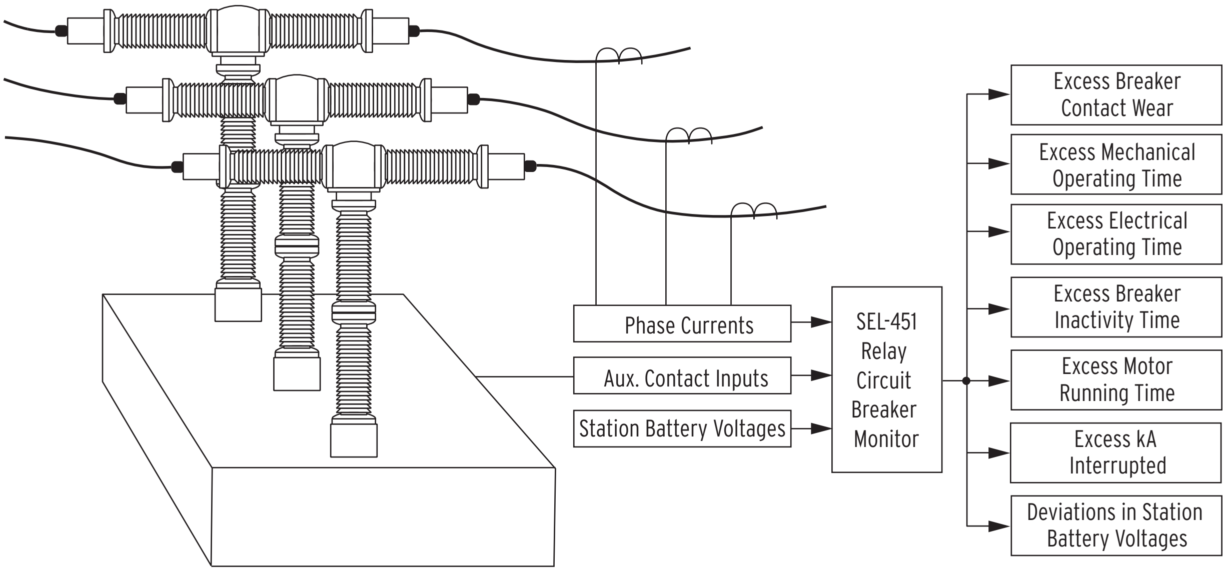

Figure 2.1 SEL-451 Intelligent Circuit Breaker Monitor

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, and interrupted currents. The alarm and reporting features help you operate your substation safely and reliably.

Enabling the Circuit Breaker Monitor

Enable and configure the SEL-451 circuit breaker monitor by using the settings listed in *Table 2.1* for each of two possible circuit breakers. Be sure to configure the relay with the settings that match your circuit breakers. Use the **SET M** command to access the circuit breaker monitor settings.

Table 2.1 Circuit Breaker Monitor Configuration

Name	Description	Range	Default
EB1MON	Enable Circuit Breaker 1 monitoring	Y, N	N
EB2MON	Enable Circuit Breaker 2 monitoring	Y, N	N

Circuit Breaker Contact Wear Monitor

The circuit breaker contact wear monitor in the SEL-451 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-451 compares this information to a predefined circuit breaker maintenance curve to calculate the percent contact wear on a per-pole basis.

The circuit breaker maintenance curve also incorporates the accumulated fault current arcing time ($\Sigma I^2 t$), assuming an identical arcing time for each trip. You can obtain the one-cycle arcing time from circuit breaker manufacturer data.

The SEL-451 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.

The SEL-451 integrates currents and increments the trip counters for the contact wear monitor each time the SELOGIC control equation BM1TRPA 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.4.14* 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-451 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.

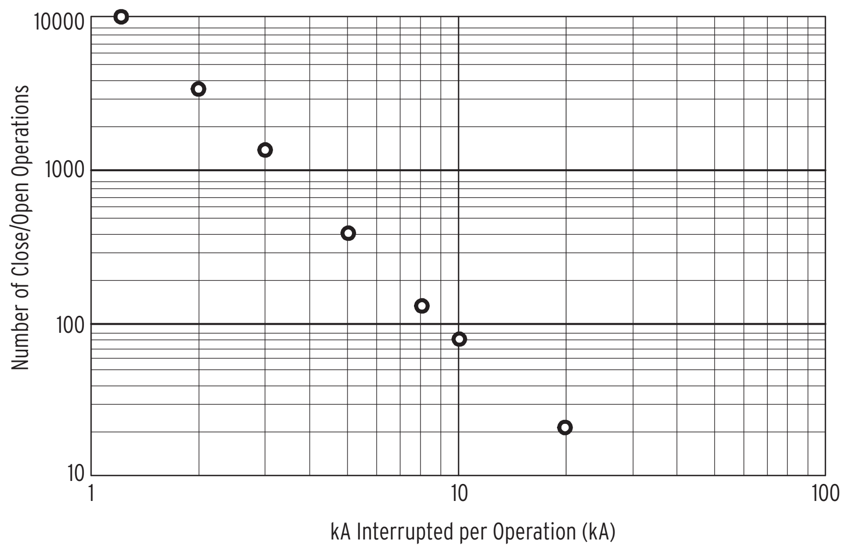

Figure 2.2 Circuit Breaker Maintenance Curve (Manufacturer's Data)

The three set points necessary to reproduce this circuit breaker maintenance curve in the SEL-451 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 0.01 kA steps
B1KASP2	kA Interrupted set point 2—mid	1.0–999 kA in 0.01 kA steps
B1KASP3[a]	kA Interrupted set point 3—max	1.0–999 kA in 0.01 kA steps

[a] The ratio of settings B1KASP3/B1KASP1 must be in the range: 5 ≤ B1KASP3/B1KASP1 ≤ 100

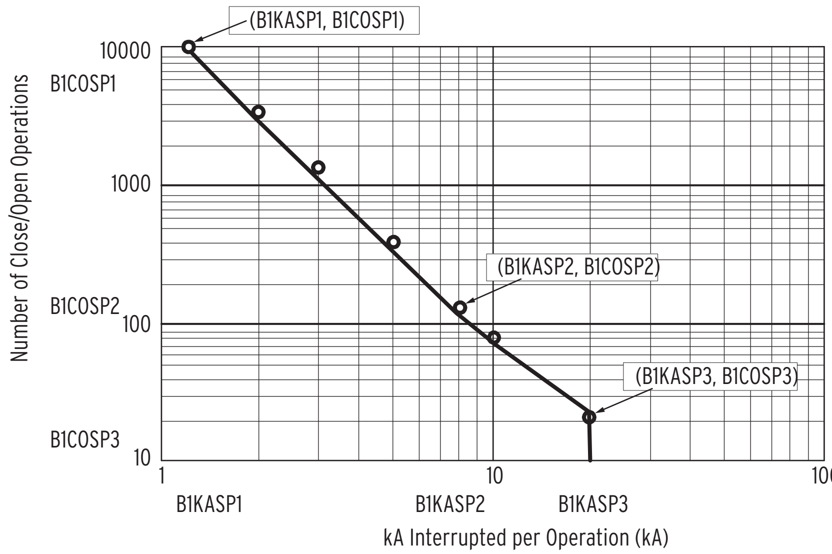

Figure 2.3 Circuit Breaker Contact Wear Curve With SEL-451 Settings

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 := 1.20 and B1COSP1 := 10000. Plot the right set point (B1KASP3, B1COSP3) by setting B1KASP3 := 20.00 and B1COSP3 := 12.00.

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 := 8.00 and B1COSP2 := 150.00.

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 - 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 := 20.00). 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 (the continuous current rating) and B1KASP3 := 40 (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 kA in this example). From the following equations, calculate these settings points to obtain the number of close/open operations:

$$\mathrm{B1COSP1} = \frac{\sum I^2 t}{(\mathrm{B1KASP1})^2 \bullet t_{arc}} = \frac{750}{2^2 \bullet (0.01667 \bullet 1)} := 11250 \quad \textbf{Equation 2.1}$$

$$\mathrm{B1COSP2} = \frac{\sum I^2 t}{(\mathrm{B1KASP2})^2 \bullet t_{arc}} = \frac{750}{10^2 \bullet (0.01667 \bullet 1)} := 450 \quad \textbf{Equation 2.2}$$

$$\mathrm{B1COSP3} = \frac{\sum I^2 t}{(\mathrm{B1KASP3})^2 \bullet t_{arc}} = \frac{750}{40^2 \bullet (0.01667 \bullet 1)} := 28 \quad \textbf{Equation 2.3}$$

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-451, 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.2.15* to preload existing contact wear data). The relay accepts integer values of percentage wear as great as 100 percent. The relay adds the incremental contact wear at the next circuit breaker monitor initiation (and at all subsequent initiations) to the preloaded value to obtain a total wear value. The limit for reporting circuit breaker contact wear is 150 percent for each pole.

Program the SELogic Control Equations for Trip and Close Conditions

Circuit Breaker Monitor Trip Initiation Settings: BM1TRPA. The SEL-451 employs SELogic control equations to initiate the circuit breaker monitor. For Circuit Breaker 1, this setting is BM1TRPA. When detecting a rising edge (a transition from logical 0 to logical 1) of the initiation setting, 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 setting for circuit breaker monitor initiation.

NOTE: The trip counters are reported for each phase, even though the SEL-451 only supports three-pole breakers.

Table 2.4 Circuit Breaker Monitor Initiate SELOGIC Control Equations

Name	Description	Default
BM1TRPA	Breaker Monitor Trip—BK1	T3P1
BM2TRPA	Breaker Monitor Trip—BK2	T3P2

The initiation setting can include both internal and external tripping conditions. In order to capture trip information initiated by devices other than the SEL-451, you must program the SELOGIC control equation BM1TRPA 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 input that is appropriate for your installation. Control Input IN201 is located on the SEL-451 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.2.6.

If you want Circuit Breaker Monitor 1 to initiate for the trip element 3PT, or for external trips, set these SELOGIC control equations from the **SET M** ASCII command or the ACSELERATOR QuickSet **Breaker Monitor Settings** tree view:

BM1TRPA := **3PT OR IN201** Breaker Monitor Trip—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 3-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. The control voltage for this example is 125 Vdc.

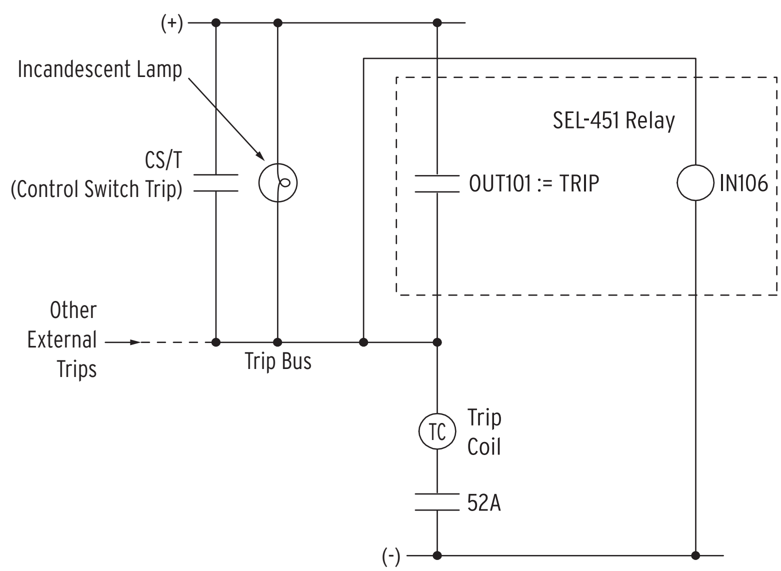

Figure 2.4 Trip Bus Sensing With Relay Input IN106

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.2.6 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.

NOTE: See Control Inputs on page U.2.6 for recommended control input settings.

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.

Circuit Breaker Monitor Close Initiation Settings: BM1CLSA. The SEL-451 employs SELOGIC control equations to initiate the circuit breaker monitor duration timers for close functions. For Circuit Breaker 1, this setting is BM1CLSA. These SELOGIC control equations use Relay Word bits to determine when the circuit breaker monitor times mechanical closing and electrical closing. *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
BM1CLSA	Breaker Monitor Close—BK1	BK1CL
BM2CLSA	Breaker Monitor Close—BK2	BK2CL

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-451 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 52AA1 indicates that the circuit breaker has closed). The SEL-451 measures the three-phase tripping time from the assertion of the BM1TRPA SELOGIC equation to the dropout of the 52AA1 Relay Word bit. Similarly, for mechanical closing time, the relay measures the closing time from the assertion of the BM1CLSA SELOGIC equation to the pickup of the 52AA1 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-451 issues a mechanical slow tripping alarm, B1MSOAL, for 5 seconds when trip or close times exceed these thresholds. See *Figure 2.5* for a Circuit Breaker 1 timing diagram.

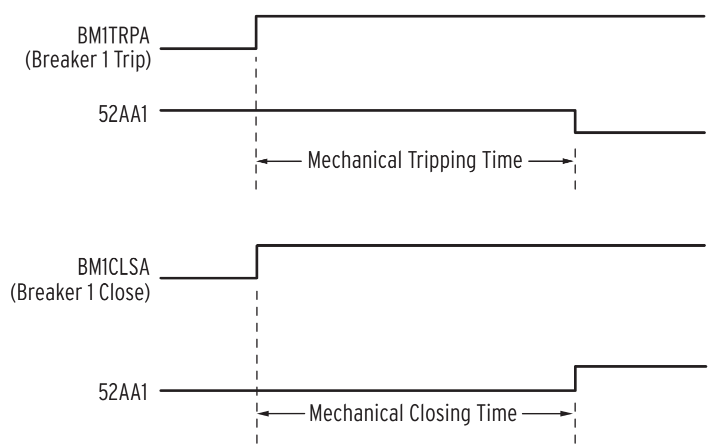

Figure 2.5 Mechanical Operating Time for Circuit Breaker 1

EXAMPLE 2.5 Mechanical Operating Time Settings

Use Circuit Breaker 1 for this example. Connect the circuit breaker normally-open 52A contact through station battery power to IN101. You can use any control input that is appropriate for your installation. The control voltage for this example is 125 Vdc.

Make the control input pickup, dropout, and debounce timer settings as explained in Control Inputs on page U.2.6.

Set the SELOGIC equation to respond to this input.

52AA1 := **IN101** N/O Control Input–BK1 (SELOGIC Equation)

Connect the external trip signal to IN201 and external close signal to IN204. Control Inputs IN201 and IN204 are located on the SEL-451 I/O Interface Board #1, and are either direct-coupled or optoisolated, depending on the specific I/O board ordered. Make the control input settings as explained in Control Inputs on page U.2.6.

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:

EB1MON := **Y** Breaker 1 Monitoring (Y, N)

BM1TRPA := **T3P1 OR IN201** Breaker Monitor Trip–BK1 (SELOGIC Equation)

BM1CLSA := **BK1CL OR IN204** Breaker Monitor Close–BK1 (SELOGIC Equation)

B1MSTRT := **30** Mechanical Slow Trip Alarm Threshold–BK1 (1-999 ms)

B1MSCLT := **70** Mechanical Slow Close Alarm Threshold–BK1 (1-999 ms)

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 52AA1 status change occurred during the time B1MSTRT plus approximately 100 ms after trip initiation (a trip time-out condition)
- No 52AA1 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) contact by testing whether this circuit breaker contact has 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 BM1TRPA SELOGIC equation 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 BM1CLSA 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-451 issues an electrical slow tripping 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.

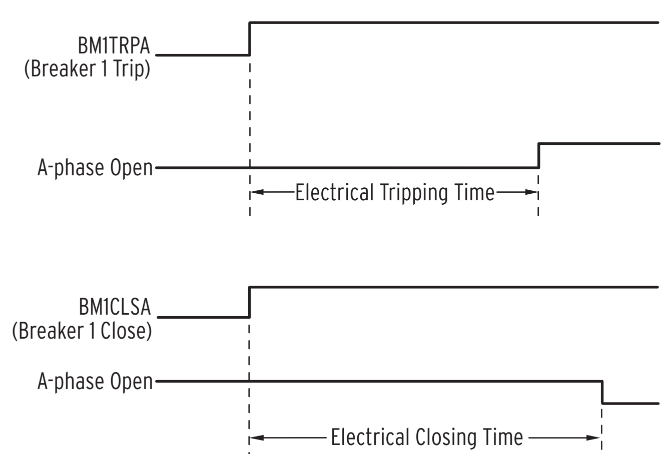

Figure 2.6 Electrical Operating Time for Circuit Breaker 1 A-Phase

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 for this example. Connect any external trip signal to IN201 and external close signal to IN204. This example uses control inputs IN201 and IN204; you can use any control inputs that are appropriate for your installation. The control voltage for this example is 125 Vdc.

Control Inputs IN201 and IN204 are located on the SEL-451 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.2.6.

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:

EB1MON := **Y** Breaker 1 Monitoring (Y, N)

BM1TRPA := **T3P1 OR IN201** Breaker Monitor Trip—BK1 (SELOGIC Equation)

BM1CLSA := **BK1CL OR IN204** Breaker Monitor Close—BK1 (SELOGIC Equation)

B1ESTRT := **25** Electrical Slow Trip Alarm Threshold—BK1 (1–999 ms)

B1ESCLT := **65** Electrical Slow Close Alarm Threshold—BK1 (1–999 ms)

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.

Circuit Breaker Inactivity Time Elapsed

The SEL-451 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 2.7 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-451 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 2.8 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 in 125 Vdc. Control Input IN207 is located on the SEL-451 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.2.6.

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-451 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-451 **BRE** commands. For more information on the **BRE** command, see *BREAKER on page R.9.4*.

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. 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 2.7 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 (BM1TRPA) and for a 30-cycle window at circuit breaker monitor close initiation (BM1CLSA). 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: 03/20/2004  Time: 17:21:42.577
Station A                                  Serial Number: XXXXXXXXXX

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    25.8    25.8   30.1    30.1    30.1


Last Op Minimum DC1 (V)          123     123     123    121     121     121
Last Op Minimum DC2 (V)          126     126     126    128     128     128

Inactivity Time (days)             1       1       1      1       1       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

Ave Motor Runtime (s)             20
Last Motor Runtime(s)             22

                               Alarm   Total Count

Mechanical Operating Time      MSOAL      0
Electrical Operating Time      ESOAL      0
Breaker Inactivity Time        BITAL      0
Motor Runtime                  MRTAL      0
Current (kA) Interrupted       KAIAL      0

LAST BREAKER MONITOR RESET   03/15/2004   07:21:31.067

=>>
```

Figure 2.7 Breaker Report
(For the most recent operation)

Breaker History

The SEL-451 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 BM1TRPA and BM1CLSA (see *Program the SELOGIC Control Equations for Trip and Close Conditions on page A.2.6*). The breaker history report is similar to *Figure 2.8* (shown with typical data).

NOTE: The VDC1 and VDC2 columns only appear if global setting EDCMON is set to 1 or 2.

```
=>BRE 1 H <Enter>
Breaker 1 History Report

Relay 1                                    Date: 03/15/2004  Time: 07:19:27.156
Station A                                  Serial Number: XXXXXXXXXX

No.     Date         Time        Bkr.Op  Op Time(ms)   Pri I   VDC1   VDC2
                                         Elect Mech     (A)    (V)    (V)

1    01/01/2004  12:24:36.216    Trp A    26   28       5460    119    118
2    01/01/2004  12:24:36.216    Trp B    26   28       5260    119    118
3    01/01/2004  12:24:36.216    Trp C    26   28       5160    119    119
4    01/26/2004  16:24:36.214    Cls A    39   35       1020    118    118
5    01/26/2004  16:24:36.214    Cls B    39   35       990     118    118
6    01/26/2004  16:24:36.214    Cls C    39   35       1010    118    118

128
=>
```

Figure 2.8 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 2.9* for both the terminal and ACSELERATOR QuickSet.

NOTE: The operation counters can be preloaded on a per-phase basis (they can be set to different values), but they always increment at the same time.

```
=>BRE 1 P <Enter>

Breaker 1: Preload Contact Wear, Operations Counters, and Accumulated Currents

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 2.9 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.9.5* 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"
"Relay 1","Station A","SEL-451-1-Rxxx-V0-Zxxxxxx-Dyyyymmdd","yyyy"
"BID","yyyy"
"Breaker 1","yyyy"
"AVG_TR_ELEC","LAST_TR_ELEC","AVG_TR_MECH","LAST_TR_MECH","LAST_TR_MINDC1","LAST_TR_MINDC2","TR_INAC(days)","MAX_TR_SCAT(ms)
    ","LAST_TR_SCAT(ms)","AVG_CL_ELEC","LAST_CL_ELEC","AVG_CL_MECH","LAST_CL_MECH","LAST_CL_MINDC1","LAST_CL_MINDC2","CL_INA
    C(days)","MAX_CL_SCAT(ms)","LAST_CL_SCAT(ms)","ACC_CURR(kA)","ACC_WEAR(%)","MAX_INT_CURR(%)","LAST_INT_CURR(%)","NUM_OPE
    RS","yyyy"
fff,fff,fff,fff,fff,fff,iii,fff,fff,fff,fff,fff,fff,fff,fff,iii,fff,fff,fff,fff,fff,fff,iii,"yyyy"
fff,fff,fff,fff,fff,fff,iii,fff,fff,fff,fff,fff,fff,fff,fff,iii,fff,fff,fff,fff,fff,fff,iii,"yyyy"
fff,fff,fff,fff,fff,fff,iii,fff,fff,fff,fff,fff,fff,fff,fff,iii,fff,fff,fff,fff,fff,fff,iii,"yyyy"
"AVG_MOT_RUNTIME","LAST_MOT_RUNTIME","RESET_MONTH","RESET_DAY","RESET_YEAR","RESET_HOUR","RESET_MIN","RESET_SEC","yyyy"
iii,iii,iii,iii,iii,iii,iii,iii,"yyyy"
```

Figure 2.10 Compressed ASCII Circuit Breaker Report

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.

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-451 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 or DC2RP, 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 2.11* shows a typical dual-battery dc system.

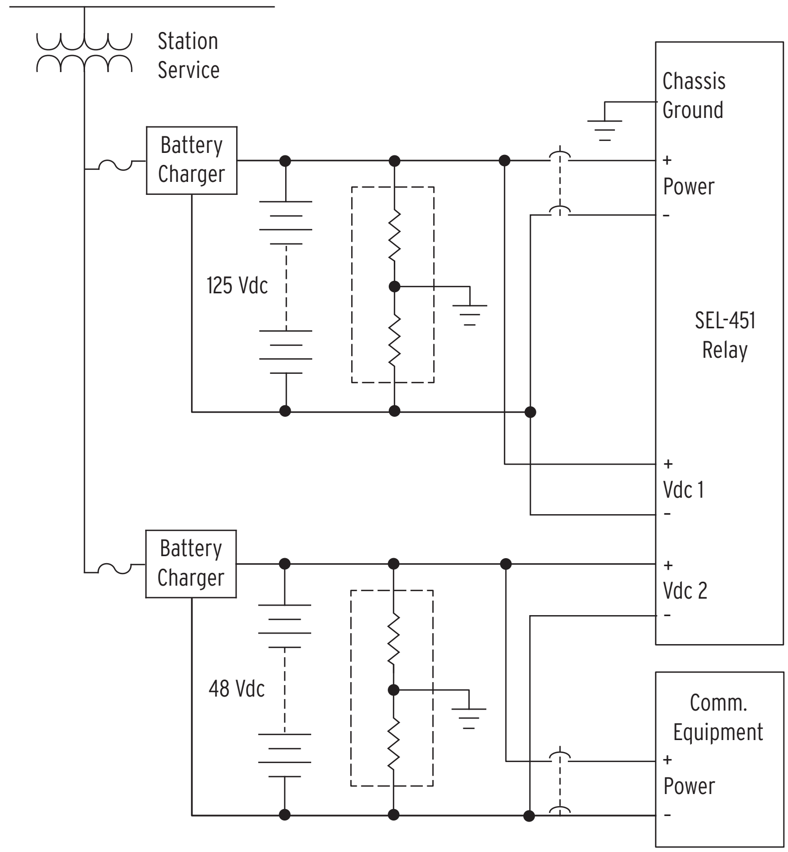

Figure 2.11 Typical Station DC Battery System

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 (see *Circuit Breaker Report on page A.2.13*).

NOTE: First enable Station DC Monitoring (with the Global setting EDCMON := 1 or 2) to access station dc battery monitor settings for one or two channels, respectively.

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 DC1 Monitor Settings and Relay Word Bit Alarms[a]

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)[b]	DC1W
DC1HWP	High Level Warn Pickup (OFF, 15–300 Vdc)[b]	DC1W
DC1HFP	High Level Fail Pickup (OFF, 15–300 Vdc)[b]	DC1F
DC1RP	Peak-to-Peak AC Ripple Pickup (1–300 Vac)[b]	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.

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 (Sheet 1 of 2)

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

Table 2.8 Example DC Battery Voltage Conditions (Sheet 2 of 2)

Condition	Calculation	Battery Voltage (Vdc)
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-451 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-451 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 2.4* 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 2.4

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 2.5* 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 2.5

The SEL-451 uses this voltage ratio to calculate a ground detection factor. *Figure 2.12* shows a graphical representation of the ground detection factor setting and battery system performance.

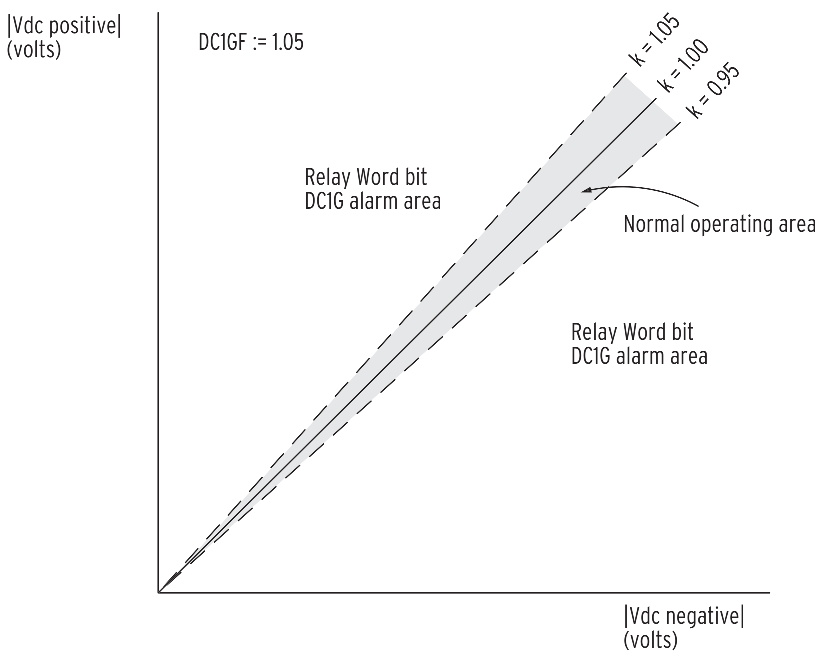

Figure 2.12 Ground Detection Factor Areas

NOTE: Only the upper ground detection factor in Figure 2.12 is entered as a setting. The SEL-451 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-451 monitors battery system voltages and records time stamps for voltage excursions. In addition, the relay records maximum and minimum battery voltages. *Figure 2.13* 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.9.34*.

```
=>MET BAT <Enter>

Relay 1                                      Date: 03/22/2004  Time: 09:37:10.035
Station A                                    Serial Number: XXXXXXXXXX

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 2.13 Battery Metering: Terminal

NOTE: n = 1 or 2.

Any battery voltage between setting DC*n*LWP 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 DC*n*HWP 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 sets unlatch bit Relay Word bit RSC_BAT to end the reset. 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-451 provides five metering modes for measuring power system operations:

- ➤ *Instantaneous Metering on page A.2.23*
- ➤ *Maximum/Minimum Metering on page A.2.27*
- ➤ *Demand Metering on page A.2.29*
- ➤ *Energy Metering on page A.2.33*
- ➤ *Time-Synchronized Metering on page A.2.34*
- ➤ *High-Impedance Fault Metering on page A.2.35*

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-451 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-451 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. *METER on page R.9.34* 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.3.3*); 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—Metering Only[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 2.13*)
MET HIF	Display High-Impedance Fault data
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-451 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-451. 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-451 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-451 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 2.14*).

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.

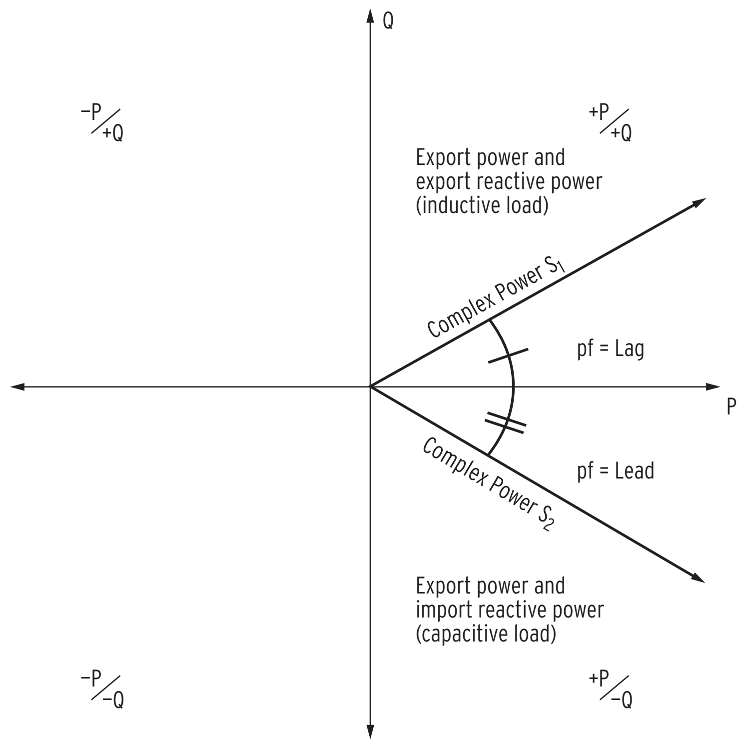

Figure 2.14 Complex Power (P/Q) Plane

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-451 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 2.9* to compute exact error coefficients.

Table 2.15 Instantaneous Metering Accuracy—Voltages, Currents, and Frequency

Quantity	Magnitude Accuracy		Phase Accuracy
	Condition	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 2.9 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 2.6

Figure 2.15 represents the calculated accuracy range. The error is very small, indicating that the SEL-451 measures normal operating currents accurately.

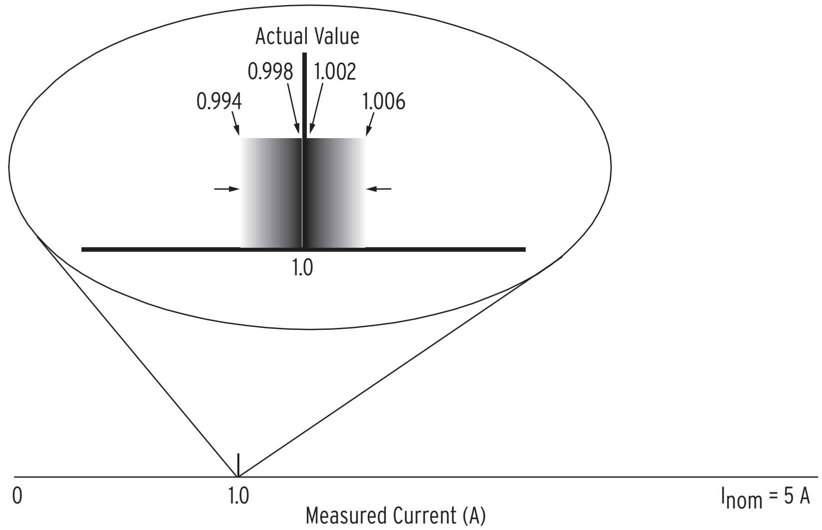

Figure 2.15 Typical Current Measuring Accuracy

When you use *Equation 2.6*, 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 2.9* are very small and qualify the SEL-451 as a high-accuracy meter.

Maximum/Minimum Metering

The SEL-451 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-451 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-451 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.4.34* for an introduction to reading metering quantities. In addition, you can read the maximum/minimum quantities on the SEL-451 front-panel LCD screen. For more information on using the front panel to view metering quantities, see *Meter on page U.5.16*.

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.9.34* and *Meter on page U.5.16*.

Maximum/Minimum Metering Updating and Storage

The SEL-451 updates maximum/minimum values once per power system cycle. The relay stores maximum/minimum values and the corresponding dates and times to nonvolatile storage once per day. If greater than a previously stored maximum or less than a previously stored minimum, the new value overwrites the previous value. Should the relay lose control power, it will restore the maximum/minimum information saved at 23:50 hours on the previous day.

The relay updates maximum/minimum values under the following conditions:

- ➤ DFAULT is deasserted (equals logical 0)
- ➤ The metering value is greater than the previous maximum, or less than the previous minimum, for 2 cycles
- ➤ Voltage input is greater than 13 V secondary
- ➤ Current input is greater than $0.05 \cdot I_{NOM}$ (in secondary 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 approximately 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 instantaneous overcurrent element pickups: FAULT := 51S1 OR 51S2 OR 50P1.

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.2.33*).

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-451 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 2.16* and *Figure 2.17* 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 2.16*).

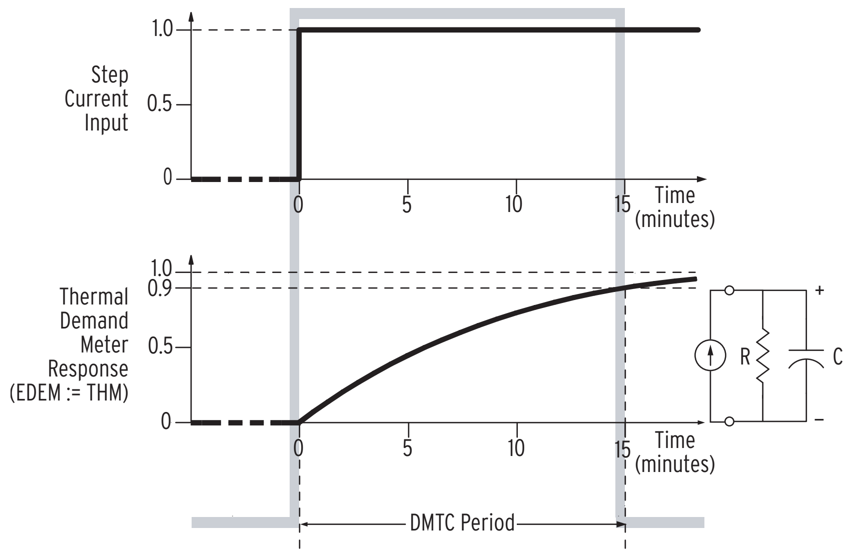

Figure 2.16 Thermal Demand Metering

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 2.17* 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 2.17*. 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 2.17*).

Table 2.19 Rolling Demand Calculations

DMTC Period (see Figure 2.17)	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

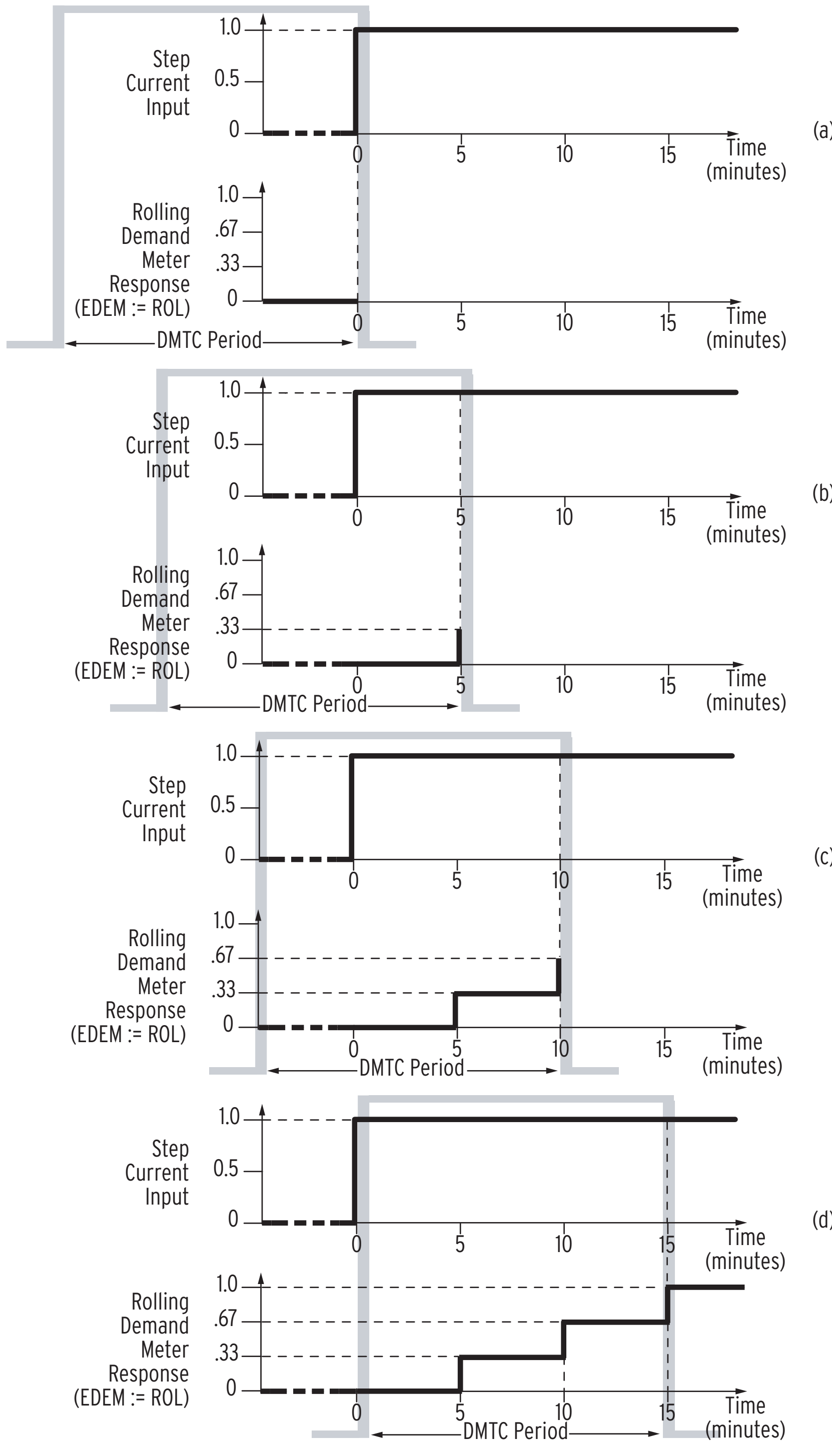

Figure 2.17 Rolling Demand Metering

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	THM
DMTC	Demand meter time constant	5, 10, 15, …, 300 minutes	15
PDEMP	Phase demand current pickup	OFF, (0.10–3.20) • I_{NOM}, secondary	OFF
GDEMP	Residual ground demand current pickup	OFF, (0.10–3.20) • I_{NOM}, secondary	OFF
QDEMP	Negative-sequence demand current pickup	OFF, (0.10–3.20) • I_{NOM}, secondary	OFF

[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 2.18 shows how the SEL-451 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.

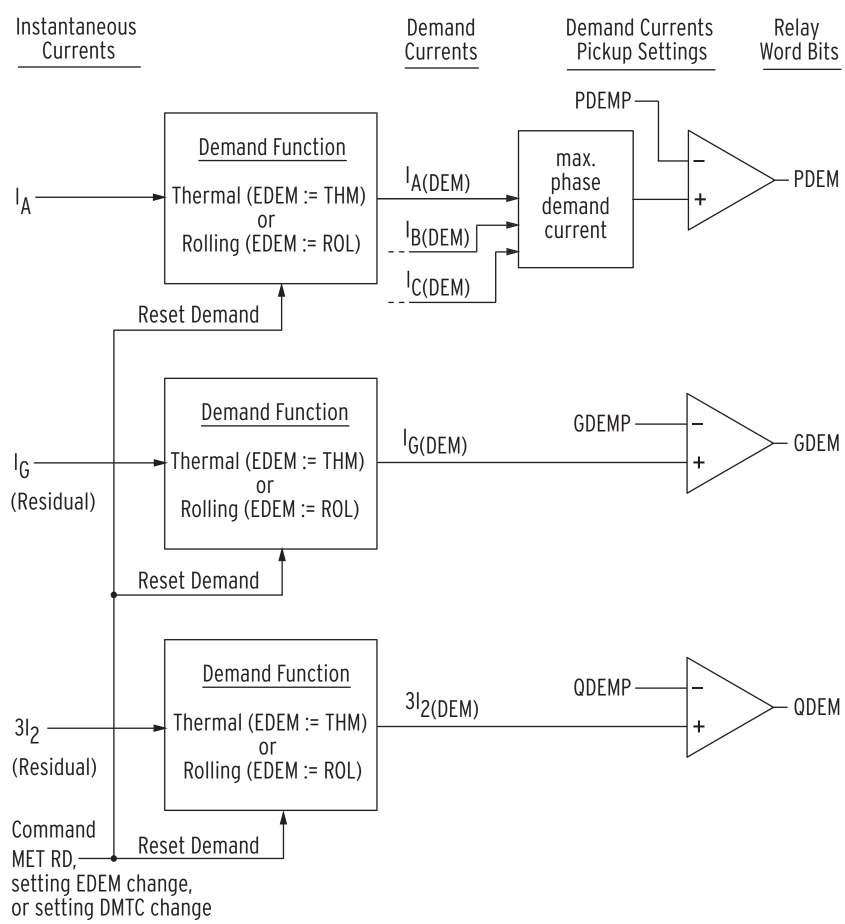

Figure 2.18 Demand Current Logic Outputs

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-451 front-panel LCD screen. For more information on using the front panel to view metering quantities, see *Meter on page U.5.16*.

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.9.34* and *Meter on page U.5.16*.

Demand Metering Updating and Storage

The SEL-451 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.2.29* 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-451 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-451 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.9.34* and in *Meter on page U.5.16*.

Energy Metering Updating and Storage

The SEL-451 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-451 provides synchrophasor measurement with an angle reference according to IEEE Standard C37.118. See *Section 7: Synchrophasors in the Reference Manual* for more information on synchrophasor application. The relay calculates the phasor measurement quantities every 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-451 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 7.5 on page R.7.17* for a sample **MET PM** command response.

The SEL-451 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.4.73* for detailed information.

The **MET PM** command is only available when the SEL-451 is configured for phasor measurement functions (Global settings) and the relay is in high-accuracy timekeeping mode.

High-Impedance Fault Metering

The **MET HIF** command displays the progress of HIF detection in the percentage to their final pickup.

The **MET HIF** command is only available if the Group setting EHIF is set to Y. If the setting is set to N, the relay response will be `HIF Not Enabled`. If EHIF is set to Y, and ITUNE_X is asserted (X = A, B, C) the response will be `HIF algorithm Tuning in Progress`.

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Section 3
Analyzing Data

The SEL-451 Relay features comprehensive power system data analysis capabilities. The relay provides these useful analysis tools:

- *Data Processing on page A.3.1*
- *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.3.13*
- *SER (Sequential Events Recorder) on page A.3.42*

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-451 accepts an IRIG-B clock input for high-accuracy timing. When a suitable external clock is used (such as the SEL-2407), the SEL-451 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-451 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*.

The SEL-451 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-451 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-451.

Raw and Filtered Data

The SEL-451 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-451 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-451 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, 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 is viewed.

The SEL-451 Main Board B and INT2, INT3, INT4, INT7, and INT8 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 is viewed.

The SEL-451 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.4.67* and *Control Inputs on page U.2.6* for details on control inputs.

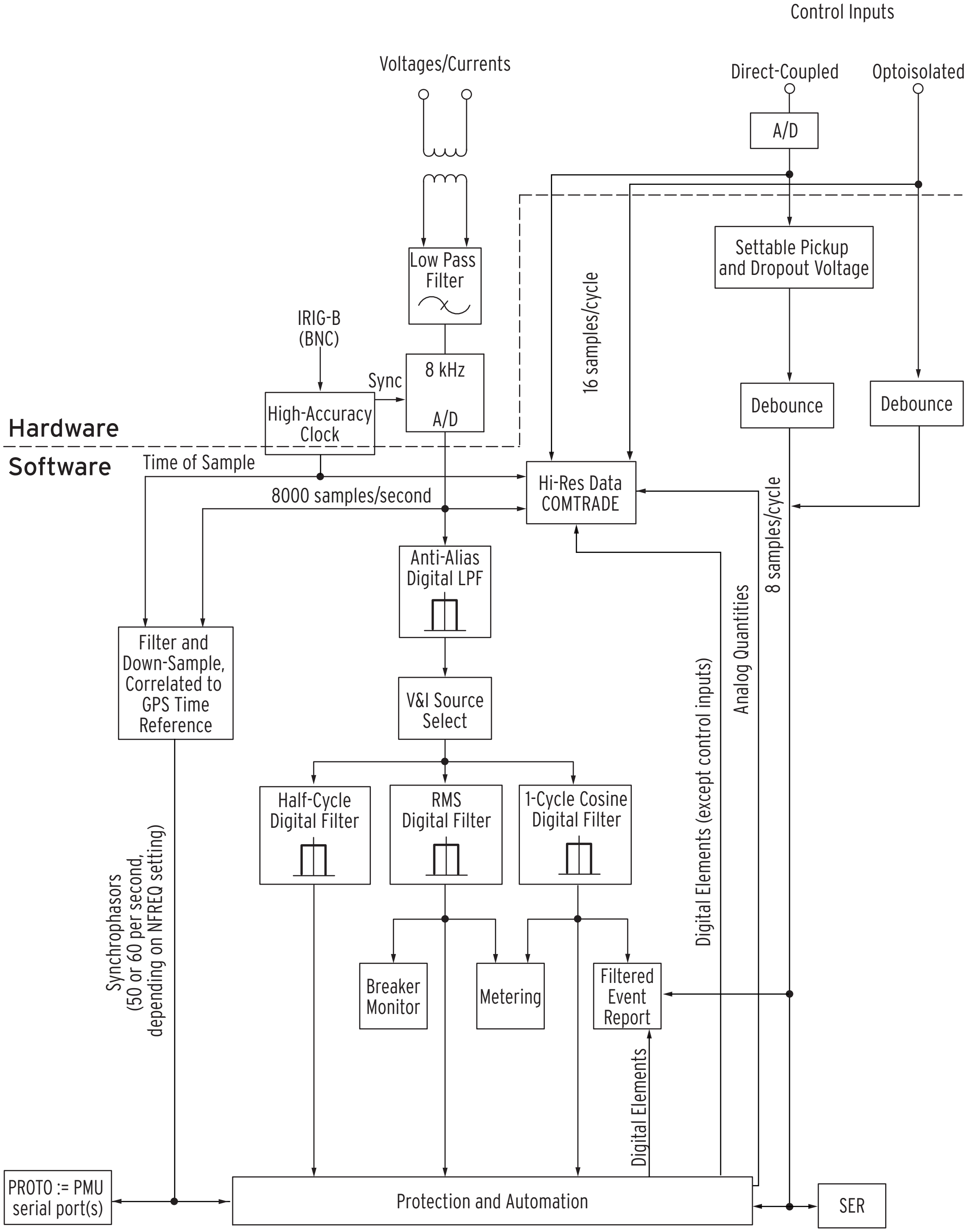

Figure 3.1 SEL-451 Input Processing

Triggering Data Captures and Event Reports

The SEL-451 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.3.42*. 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.9.43* and *Operating the Relay Inputs and Outputs on page U.4.58*.

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.1.86*.

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-451 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 Equations 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 51S1 OR R_TRIG 51S2** Event Report Trigger Equation (SELOGIC Equation)

The element transitions in this setting are from the following Relay Word bits:

- 51S1: Selectable operating quantity time overcurrent element 1 pickup
- 51S2: Selectable operating quantity time overcurrent element 2 pickup

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).

You can also use the falling-edge operator, F_TRIG, to initiate data captures. See *Section 3: SELogic Control Equations 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.9.43.

Program the Group settings SELogic control equation ER as follows:

ER := **R_TRIG 51S1 OR R_TRIG 51S2 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-451 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.9.64* and *Triggering an Event on page U.4.43* for more information on the **TRI** command.

Duration of Data Captures and Event Reports

The SEL-451 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

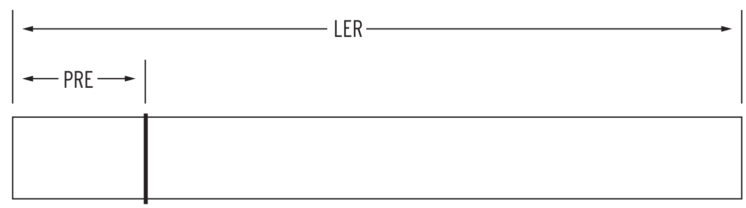

Figure 3.2 Data Capture/Event Report Times

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-451 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-451 features three 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
- High-Impedance Fault oscillography (only available when the relay supports HIF detection) at 1-sample/2cycles

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.

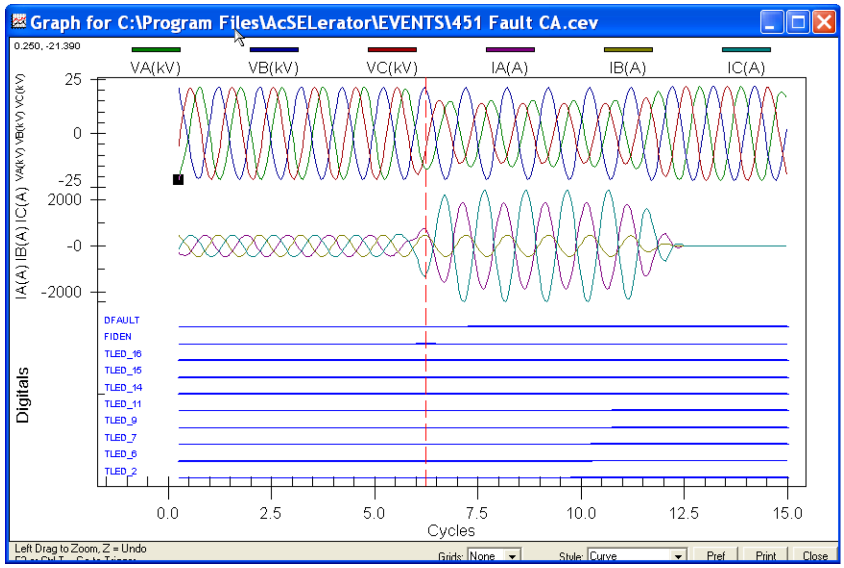

Figure 3.3 Sample SEL-451 Oscillogram

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 10.88 on page R.10.43*.

The SEL-451 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.3.27* and *Settings Section of the Event Report on page A.3.27*). The settings portion is in a comma-delimited format as illustrated in *Figure 3.4*.

```
Relay 1                                      Date: 02/20/2004  Time: 17:14:40.056
Station A                                    Serial Number: 0000000000

Event: CA T              Location:    7.28                   Time Source: OTHER
Event Number: 10014                  Shot 3P: 0        Freq: 60.01     Group: 3
Targets: TIME A_FAULT C_FAULT
Breaker 1: OPEN          Trip Time: 17:14:40.113
Breaker 2: NA
PreFault:     IA     IB      IC      IG    3I2       VA       VB       VC    V1mem
MAG(A/kV)    472    472     472       2      3   21.395   21.396   21.395   19.886
ANG(DEG)   -49.1 -168.9    71.2 -145.7  -90.5      0.0   -166.1     74.0    -31.1

Fault:
MAG(A/kV)   1889    469    2449     174   3458   15.474   21.366   14.114   17.163
ANG(DEG)  -138.1 -168.8    33.6     0.2  175.5    -30.3   -165.8     59.1    -41.5

                                                    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

SET_G1.TXT
[INFO]
RELAYTYPE=SEL-451
FID=SEL-451-1-Rxxx-V0-Zxxxxxx-Dyyyymmdd
BFID=SLBT-4XX-R1xx-V0-Zxxxxxx-Dyyyymmdd
PARTNO=04511415XX111XHX
                                .
                                .
                                .
[G1]
"SID","Station A"
"RID","Relay 1"
"NUMBK",1
"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-451-1-Rxxx-V0-Zxxxxxx-Dyyyymmdd,1999
373,29A,344D
1,IAW,A,,A,0.915985,0,0,-32767,32767,120.0,1,P
2,IBW,B,,A,0.915985,0,0,-32767,32767,120.0,1,P
3,ICW,C,,A,0.915985,0,0,-32767,32767,120.0,1,P
4,IAX,A,,A,0.915985,0,0,-32767,32767,120.0,1,P
5,IBX,B,,A,0.915985,0,0,-32767,32767,120.0,1,P
6,ICX,C,,A,0.915985,0,0,-32767,32767,120.0,1,P
7,VAY,A,,kV,0.002748,0,0,-32767,32767,180.0,1,P
8,VBY,B,,kV,0.002748,0,0,-32767,32767,180.0,1,P
9,VCY,C,,kV,0.002748,0,0,-32767,32767,180.0,1,P
10,VAZ,A,,kV,0.002748,0,0,-32767,32767,180.0,1,P
11,VBZ,B,,kV,0.002748,0,0,-32767,32767,180.0,1,P
12,VCZ,C,,kV,0.002748,0,0,-32767,32767,180.0,1,P
13,VDC1,,,V,0.011153,0.000000,0,-32767,32767,1,1,P
14,VDC2,,,V,0.011153,0.000000,0,-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,TLED_8,,,0
2,TLED_7,,,0
3,TLED_6,,,0
4,TLED_5,,,0
5,TLED_4,,,0
6,TLED_3,,,0

.
.
.

364,UNUSED364,,,0
365,OC1,,,0
366,CC1,,,0
367,OC2,,,0
368,CC2,,,0
60
1
2000,1000
20/02/2004,17:14:39.954836
20/02/2004,17:14:40.056903
BINARY
1
```

COMTRADE Standard
Total Channels, Analog, Digital
Analog Channel Data
Digital (Status) Channel Data
First Data Point
Trigger Point

Figure 3.5 Sample 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-451 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.4.47* 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.4.49*).

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.

High-Impedance Fault Event Oscillography

High-impedance fault oscillography files are available when the relay supports HIF detection. The size of the HIF event report file is determined by the HIFLER setting in effect at the time the HIF event is triggered. Oscillography is available at the rate of 1-sample/2cycles.

The SEL-451 stores high-impedance fault oscillography in binary format and uses COMTRADE file types to output these data:

- .HDR–header file
- .CFG–configuration file
- .DAT–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 output of the HIF Summary command (SUM HIF) as illustrated in *Figure 3.6*.

```
Relay 1                                         Date: 06/10/2007  Time: 08:04:16.698
Station A                                       Serial Number: 0000000000

Event: HIF Fault        HIF Phase: B                         Time Source: OTHER
Event Number: 10003     Downed Conductor: NO                 Freq: 60.03    Group: 1
Breaker 1: CLOSED
Breaker 2: NA

Pre-trigger (A):
IARMS   IBRMS   ICRMS   IGRMS
312.0   238.0   282.0   60.0

Post-trigger (A):
312.0   245.0   281.0   55.0

Pre-trigger (A):
ISMA    ISMB    ISMC    ISMG    SDIA    SDIB    SDIC    SDIG
196.5   100.0   182.0   283.0   236.5   203.5   211.5   164.0

Post-trigger (A):
199.5   259.0   191.5   459.5   247.0   217.0   224.0   202.0
```

Figure 3.6 Sample HIF COMTRADE .HDR Header File

.CFG File

The .CFG file contains data such as sample rates, number of channels, nominal frequency, number of digital quantities, channel information, and transformer ratios (see *Figure 3.7*). A <CR><LF> follows each line.

```
<SID>, <FID>, 1999
##,##A,##D
 1,IARMS,A,,A, scale_rms, 32767*scale_rms,0,-32767,32767,<CTRL>,1,P
 2,IBRMS,B,,A, scale_rms, 32767*scale_rms,0,-32767,32767,<CTRL>,1,P
 3,ICRMS,C,,A, scale_rms, 32767*scale_rms,0,-32767,32767,<CTRL>,1,P
 4,IGRMS,G,,A, scale_rms, 32767*scale_rms,0,-32767,32767,<CTRL>,1,P
 5,SDIA,A,,A, scale_sdi, 32767*scale_sdi,0,-32767,32767,<CTRL>,1,P
 6,SDIB,B,,A, scale_sdi, 32767*scale_sdi,0,-32767,32767,<CTRL>,1,P
 7,SDIC,C,,A, scale_sdi, 32767*scale_sdi,0,-32767,32767,<CTRL>,1,P
 8,SDIG,G,,A, scale_sdi, 32767*scale_sdi,0,-32767,32767,<CTRL>,1,P
 9,SDIAREF,A,,A, scale_sdi, 32767*scale_sdi,0,-32767,32767,<CTRL>,1,P
10,SDIBREF,B,,A, scale_sdi, 32767*scale_sdi,0,-32767,32767,<CTRL>,1,P
11,SDICREF,C,,A, scale_sdi, 32767*scale_sdi,0,-32767,32767,<CTRL>,1,P
12,SDIGREF,G,,A, scale_sdi, 32767*scale_sdi,0,-32767,32767,<CTRL>,1,P
13,ISMA,A,,A, scale_ism, 32767*scale_ism,0,-32767,32767,<CTRL>,1,P
14,ISMB,B,,A, scale_ism, 32767*scale_ism,0,-32767,32767,<CTRL>,1,P
15,ISMC,C,,A, scale_ism, 32767*scale_ism,0,-32767,32767,<CTRL>,1,P
16,ISMG,G,,A, scale_ism, 32767*scale_ism,0,-32767,32767,<CTRL>,1,P
17,ISMAREF,A,,A, scale_ism, 32767*scale_ism,0,-32767,32767,<CTRL>,1,P
18,ISMBREF,B,,A, scale_ism, 32767*scale_ism,0,-32767,32767,<CTRL>,1,P
19,ISMCREF,C,,A, scale_ism, 32767*scale_ism,0,-32767,32767,<CTRL>,1,P
20,ISMGREF,G,,A, scale_ism, 32767*scale_ism,0,-32767,32767,<CTRL>,1,P
21,dA,A,,A, scale_d, 32767*scale_d,0,-32767,32767,<CTRL>,1,P
22,dB,B,,A, scale_d, 32767*scale_d,0,-32767,32767,<CTRL>,1,P
23,dC,C,,A, scale_d, 32767*scale_d,0,-32767,32767,<CTRL>,1,P
24,dG,G,,A, scale_d, 32767*scale_d,0,-32767,32767,<CTRL>,1,P
1,<RWBIT>,,,0
...
##,<RWBIT>,,,0
NFREQ
1
SRATE, <last sample number>
dd/mm/yyyy,hh:mm:ss.ssssss
dd/mm/yyyy,hh:mm:ss.ssssss
BINARY
1
```

Total Channels, Analog, Digital

Analog Channel Data

Digital (Status) Channel Data

First Data Point

Trigger Point

Figure 3.7 Sample HIF 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
- Nominal frequency
- Sample rate and number of samples
- Date and time of first data point

The .CFG file references analog quantities that are particular to High-impedance fault detection. The SDI*x* quantities are the derived Sum of Difference Currents that represent the total non-harmonic contents of the phase and residual currents. The SDI*x*REF quantities are an averaged stable reference of SDI that is used in the detection algorithm. The d*x* quantities are an adaptive tuning threshold that is established based on the trends of the measure SDI. The ISM*x* quantities are the measured total odd-harmonic content of the phase and residual currents. The ISM*x*REF quantities are an averaged stable reference of ISM that is used in the detection algorithm.

.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 software program.

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.9.20*).

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-451 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.5.19*.) 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.9.20*).

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.3.34*.)

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.9.20* 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[a, b, c]	Description[a, b, c]
EVE	Return the most recent event report (including settings and summary) at full length with 4-samples/cycle data.
EVE *n*	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*	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*	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 x is 4 or 8 to represent data resolution of 4 samples/cycle and 8 samples/cycle, respectively.
[c] The parameter yyy represents an event length in cycles.

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 ACSELERATOR QuickSet. The **Analysis > Read History** menu gives you oscillogram/element displays, phasor displays, harmonic analysis, and an event summary for each event you select in the **Relay Event History** dialog box. See *Analyze Events on page U.3.16*, and *Reading the Event History on page U.4.45* 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.4.51* 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 3.8* 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-451 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.6.36* 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.3.18*, *Figure 3.9*, and *Figure 3.10*.

```
Relay 1                                      Date: 02/20/2004  Time: 17:14:40.056
Station A                                    Serial Number: 0000000000
FID=SEL-451-1-Rxxx-V0-Zxxxxxx-Dyyyymmdd       Event Number = 10014      CID=0xxxxx

      Currents (Amps Pri)            Voltages (kV Pri)
    IA     IB     IC     IG     VA     VB     VC    VS1     VS2  V1mem

[1]
  -312    462   -149      2  -21.4   20.7   -5.8   11.5    0.0  -17.1
  -355    -94    448     -1    0.2   -5.3   20.6   -3.0    0.0  -10.2
   312   -462    149     -2   21.4  -20.7    5.7  -11.5    0.0   17.1
   355     94   -448      1   -0.1    5.3  -20.6    3.0    0.0   10.2
                            .
                            .
                            .
[5]
  -312    462   -149      1  -21.4   20.7   -5.7   11.5    0.0  -17.1
  -355    -94    448     -1    0.2   -5.3   20.6   -3.0    0.0  -10.2
   312   -462    149     -2   21.4  -20.7    5.7  -11.5    0.0   17.1
   355     94   -448      1   -0.2    5.3  -20.6    3.0    0.0   10.2
[6]
  -312    462   -149      2  -21.4   20.7   -5.8   11.5    0.0  -17.1
  -355    -94    448     -1    0.2   -5.3   20.6   -3.0    0.0  -10.2
   155   -462    324     17   20.6  -20.7    5.8  -11.5    0.0   17.1
   336     94   -405     25    0.7    5.3  -18.3    3.0    0.0   10.1
[7]
   702    461  -1268   -105  -16.6   20.7   -6.5   11.4    0.0  -16.7>
  -795    -95    866    -24   -4.6   -5.4   14.0   -3.0    0.0  -10.2
 -1399   -460   2033    174   13.4  -20.7    7.2  -11.4    0.0   15.9
  1272     94  -1369     -2    7.7    5.4  -12.2    3.1    0.0   10.5
[8]
  1396    460  -2030   -174  -13.4   20.7   -7.2   11.4    0.0  -15.0
 -1272    -94   1368      2   -7.7   -5.4   12.2   -3.1    0.0  -10.8
 -1396   -460   2030    174   13.4  -20.7    7.2  -11.4    0.0   14.3
  1272     94  -1368     -2    7.7    5.4  -12.2    3.1    0.0   11.0
[9]
  1396    460  -2030   -174  -13.4   20.7   -7.2   11.4    0.0  -13.7
 -1272    -94   1369      2   -7.7   -5.4   12.2   -3.1    0.0  -11.2
 -1396   -460   2030    174   13.4  -20.7    7.2  -11.4    0.0   13.3
  1272     94  -1369     -2    7.7    5.4  -12.2    3.1    0.0   11.3
[10]
  1397    460  -2030   -174  -13.4   20.7   -7.2   11.4    0.0  -12.9*
 -1272    -94   1369      2   -7.7   -5.4   12.2   -3.1    0.0  -11.4
 -1397   -459   2031    174   13.4  -20.7    7.2  -11.4    0.0   12.7
  1273     94  -1369     -2    7.7    5.4  -12.2    3.1    0.0   11.5
[11]
  1397    460  -2031   -174  -13.4   20.7   -7.2   11.4    0.0  -12.5
 -1273    -94   1368      2   -7.7   -5.4   12.2   -3.1    0.0  -11.5
 -1397   -460   2031    174   13.4  -20.7    7.2  -11.4    0.0   12.3
  1272     94  -1368     -2    7.7    5.4  -12.2    3.1    0.0   11.6
[12]
  1263    419  -1837   -156  -13.5   20.7   -7.2   11.5    0.0  -12.2
 -1156   -137   1319     26  -10.0   -5.3   14.6   -3.0    0.0  -11.7
  -562   -188    818     68   14.4  -21.0    6.5  -11.6    0.0   12.3
   519     90   -635    -25   14.0    5.3  -19.1    3.0    0.0   12.2
[13]
    -2      0      3      1  -15.3   21.3   -5.9   11.7    0.0  -12.7
     0      0      0      1  -15.8   -5.4   21.1   -3.1    0.0  -12.9
     0      0     -1     -1   15.3  -21.3    5.9  -11.7    0.0   13.3
     0      0      0      0   15.8    5.4  -21.1    3.1    0.0   13.5
[14]
     0      0      1      1  -15.3   21.3   -5.9   11.7    0.0  -13.8
     0      1      0      0  -15.8   -5.4   21.1   -3.1    0.0  -14.0
     0      0     -1     -1   15.3  -21.3    5.9  -11.7    0.0   14.1
     0      0      0      0   15.8    5.4  -21.1    3.1    0.0   14.4
                            .
                            .
                            .
```

Header

Firmware ID

One Cycle of Data

See Figure 3.9 and Figure 3.10

Trigger

Largest Current (to Event Summary)

Circuit Breaker Open

Figure 3.8 Sample 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 3.8 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 3.8* 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 IB channel data in the event report of *Figure 3.8*. You can process voltage data columns similarly. The drawings in *Figure 3.9* and *Figure 3.10* show one cycle of B-phase current in detail. *Figure 3.9* shows how to relate the event report ac current column data to the sampled waveform and rms values. *Figure 3.10* shows how to find the phasor angle. If you use the larger 8-samples/cycle event report, take every other sample and apply those values in this procedure.

This 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.3.34* 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 3.8*.

(See *Table 3.3* or *EVENT on page R.9.20* 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 IB column of the event report.

Figure 3.8 Cycle [1] data for this example are shown in *Figure 3.9*.

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 IB 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 3.9* yields 471.5 A.

c. Compute phasor magnitudes from the remaining data pairs for Cycle [1].

d. Confirm that all values are similar.

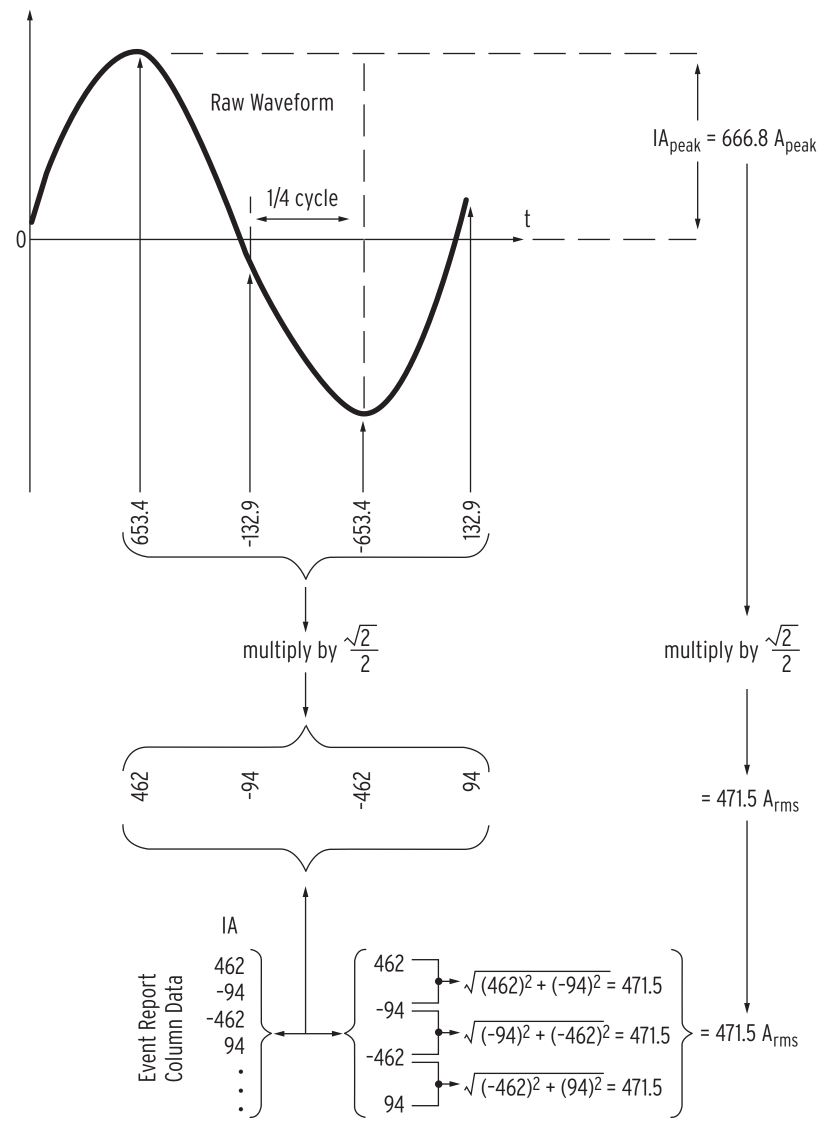

Figure 3.9 Event Report Current Column Data and RMS Current Magnitude

Step 5. Calculate the immediate phase angle:

a. Select the same cycle of data from the IB 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:

$$\theta = \arctan\left(\frac{Y}{X}\right) = \angle \text{Phasor}$$ **Equation 3.2**

In *Equation 3.2*, Y is the first (or previous value) IB column current of a data pair, and X is the present value of the pair.

For this example, the computation shown in *Figure 3.10* yields +101.5 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.

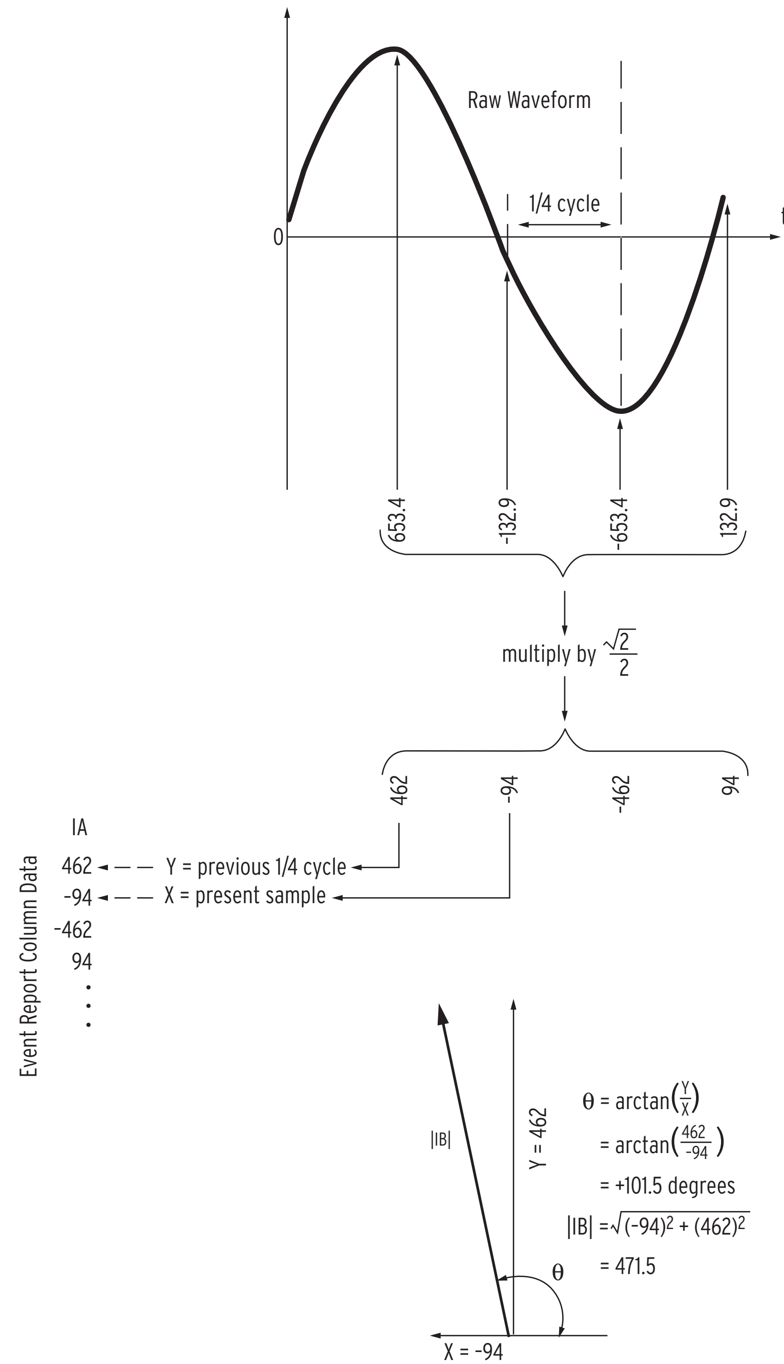

Figure 3.10 Event Report Current Column Data and RMS Current Angle

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 IB column data values you used in *Step 5*.

The angle calculation for the VA data is the following:

$$\begin{aligned} \theta &= \angle VA \\ &= \arctan\left(\frac{Y}{X}\right) \\ &= \arctan\left(\frac{-21.4}{-0.2}\right) \\ &= -89.5° \end{aligned} \qquad \textbf{Equation 3.3}$$

Step 7. Calculate the absolute phase angle:

➢ Subtract the IB angle from the VA angle to obtain the A-phase-referenced phasor angle for IB.

$$\angle VA - \angle IB = -89.5° - (101.5°) = -191.0° \qquad \textbf{Equation 3.4}$$

The rms phasor for current IB at the present sample is 471.5 A ∠–191.0°, 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_B = 471.5 A ∠+101.5°.

The present sample of the sample pair (X = –94) is a scaled instantaneous current value (not an rms quantity) that relates to the rms phasor current value by the expression

$$X = -94 = 471.5 \bullet \cos(101.5°) \qquad \textbf{Equation 3.5}$$

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 3.11* for the locations of items in a sample event report digital section, with factory default event report settings. 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. 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. Figure 3.9 shows the factory default event report digital section.

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 T3P1, T3P2, #, VPOLV, ZLOAD, LOP, the header appears as in *Figure 3.12*. If the Relay Word bits included in the header were assigned aliases, the alias names appear in the report.

```
                                                 B     B  33333 22
                                                BF    BF  PPPPP 55
   VZ           S     66     66     66  55  55  55 BBBKT BBBKT 7SSSSS AA 55
TT PL  FR 33333 O 556677 556677 556677 511 511 511 KKK1R KKK2R 9HHHHH 11 22
33 OOL 33 22222 T 0077PP 0077GG 0077QQ 1SS 1SS 1SS 111CI 222CI C00000 BB AA3
PP LAO 22 QQVGG F PPPP12 GGGG12 QQQQ12 S11 S22 S33 RLCFP RLCFP YTTTTT KK AAP
12 VDP PP FREFR T 1212TT 1212TT 1212TT 1TR 2TR 3TR SOLT1 SOLT2 301234 12 120

[1]
.. *.. *.. ..... . ...... ...... ...... ..* ..* ... *.... ..... .*.... .. *..
.. *.. *.. ..... . ...... ...... ...... ..* ..* ... *.... ..... .*.... .. *..
.. *.. *.. ..... . ...... ...... ...... ..* ..* ... *.... ..... .*.... .. *..
.. *.. *.. ..... . ...... ...... ...... ..* ..* ... *.... ..... .*.... .. *..

                          .
                          .
                          .
[5]
.. *.. *.. ..... . ...... ...... ...... ..* ..* ... *.... ..... .*.... .. *..
.. *.. *.. ..... . ...... ...... ...... ..* ..* ... *.... ..... .*.... .. *..
.. *.. *.. ..... . ...... ...... ...... ..* ..* ... *.... ..... .*.... .. *..
.. *.. *.. ..... . ...... ...... ...... ..* ..* ... *.... ..... .*.... .. *..
[6]
.. *.. *.. ..... . ...... ...... ...... ..* ..* ... *.... ..... .*.... .. *..
.. *.. *.. ..... . ...... ...... ...... ..* ..* ... *.... ..... .*.... .. *..
.. *.. *.. ..... . ...... ...... ...... ..* ..* ... *.... ..... .*.... .. *..
.. *.. *.. ..... . ...... ...... ...... ..* ..* ... *.... ..... .*.... .. *..
[7]
.. *.. *. *..*. . ...... ...... ...... *.. ..* ... *.... ..... .*.... .. *..  >
.. *.. *. *..*. . *.*.*. ...... ...... *.. ..* ... *.... ..... .*.... .. *..
.. *.. *. *..*. . *.*.*. ...... ...... *.. ..* ... *.... ..... .*.... .. *..
.. *.. *. *..*. . *.*.*. ...... ...... *.. ..* ... *.... ..... .*.... .. *..
[8]
.. *.. *. *..*. . *.*.*. ...... ...... *.. ..* ... *.... ..... .*.... .. *..
.. *.. *. *..*. . *.*.*. ...... ...... *.. ..* ... *.... ..... .*.... .. *..
.. *.. *. *..*. . *.*.*. ...... ...... *.. ..* ... *.... ..... .*.... .. *..
.. *.. *. *..*. . *.*.*. ...... ...... *.. ..* ... *.... ..... .*.... .. *..
[9]
.. *.. *. *..*. . *.*.*. ...... ...... *.. ..* ... *.... ..... .*.... .. *..
.. *.. *. *..*. . *.*.*. ...... ...... *.. ..* ... *.... ..... .*.... .. *..
.. *.. *. *..*. . *.*.*. ...... ...... *.. ..* ... *.... ..... .*.... .. *..
.. *.. *. *..*. . *.*.*. ...... ...... *.. ..* ... *.... ..... .*.... .. *..
[10]
.. *.. *. *..*. . *.*.*. ...... ...... *.. ..* ... *.... ..... .*.... .. *..
.. *.. *. *..*. . *.*.*. ...... ...... *.. ..* ... *.... ..... .*.... .. *..
*. *.. *. *..*. . *.*.*. ...... ...... **. ..* ... *.... ..... .*.... .. *..
*. *.. *. *..*. . *.*.*. ...... ...... **. ..* ... *.... ..... .*.... .. *..
[11]
*. *.. *. *..*. . *.*.*. ...... ...... **. ..* ... ..... ..... **.... .. *..
*. *.. *. *..*. . *.*.*. ...... ...... **. ..* ... ..... ..... **.... .. *..
*. *.. *. *..*. . *.*.*. ...... ...... **. ..* ... ..... ..... **.... .. *..
*. *.. *. *..*. . *.*.*. ...... ...... **. ..* ... ..... ..... **.... .. *..
[12]
*. *.. *. *..*. . *.*.*. ...... ...... **. ..* ... ..... ..... **.... .. *..
*. *.. *. *..*. . *.*.*. ...... ...... **. ..* ... ..... ..... **.... .. *..
*. *.. *. *..*. . ...... ...... ...... **. ..* ... ..... ..... **.... .. *..
*. *.. *. *..*. . ...... ...... ...... **. ..* ... ..... ..... **.... .. *..
[13]
*. *.. *. *..*. . ...... ...... ...... ... ..* ... ..... ..... **.... .. *..
*. *.. *. *..*. . ...... ...... ...... ... ..* ... ..... ..... **.... .. *.*
*. *.. .. ..... . ...... ...... ...... ... ..* ... ..... ..... **.... .. ..*
*. *.. .. ..... . ...... ...... ...... ... ..* ... ..... ..... **.... .. ..*
[14]
*. *.. .. ..... . ...... ...... ...... ..* ..* ... ..... ..... **.... .. ..*
*. *.. .. ..... . ...... ...... ...... ..* ..* ... ..... ..... **.... .. ..*
*. *.. .. ..... . ...... ...... ...... ..* ..* ... ..... ..... **.... .. ..*
*. *.. .. ..... . ...... ...... ...... ..* ..* ... ..... ..... **.... .. ..*

                          .
                          .
                          .
[30]
.. *.. .. ..... . ...... ...... ...... ..* ..* ... ..... ..... **.... .. ..*
.. *.. .. ..... . ...... ...... ...... ..* ..* ... ..... ..... **.... .. ..*
.. *.. .. ..... . ...... ...... ...... ..* ..* ... ..... ..... **.... .. ..*
.. *.. .. ..... . ...... ...... ...... ..* ..* ... ..... ..... **.... .. ..*
[31]
.. *.. .. ..... . ...... ...... ...... ..* ..* ... ..... ..... **.... .. ..*
```

Digital Column Labels (first set)

One Cycle of Data

Trigger

51S1T Asserts and T3P1 Asserts

Circuit Breaker Open

(Continued on next page)

(Continued from previous page)

```
 00000000                                                 PPPPPPPP    C
IIIIIII UUUUUUUU RRRRRRRR TTTTTTTT  RCLA  PPPPPPPP PPPPPPPP CCCCCCCC    O
NNNNNNN TTTTTTTT MMMMMMMM MMMMMMMM RBBBND SSSSSSSS LLLLLLLL TTTTTTTT  Z M
1111111 11111111 BBBBBBBB BBBBBBBB OAAOOO VVVVVVVV TTTTTTTT 0000000  3KP PPCO
0000000 00000000 12345678 12345678 KDDKKK 00000000 00000000 12345678 PRER BBCC
1234567 12345678 AAAAAAAA AAAAAAAA AAAAAA 12345678 12345678 QQQQQQQ TBYM 7811

[1]
*...... .......* ........ ........ ...... ........ **.*.... ........ .... ....
*...... .......* ........ ........ ...... ........ **.*.... ........ .... ....
*...... .......* ........ ........ ...... ........ **.*.... ........ .... ....
*...... .......* ........ ........ ...... ........ **.*.... ........ .... ....

                               .
                               .
                               .
[5]
*...... .......* ........ ........ ...... ........ **.*.... ........ .... ....
*...... .......* ........ ........ ...... ........ **.*.... ........ .... ....
*...... .......* ........ ........ ...... ........ **.*.... ........ .... ....
*...... .......* ........ ........ ...... ........ **.*.... ........ .... ....
[6]
*...... .......* ........ ........ ...... ........ **.*.... ........ .... ....
*...... .......* ........ ........ ...... ........ **.*.... ........ .... ....
*...... .......* ........ ........ ...... ........ **.*.... ........ .... ....
*...... .......* ........ ........ ...... ........ **.*.... ........ .... ....
[7]
*...... .......* ........ ........ ...... *....... **.*.... ........ .... ....>        Trigger
*...... .......* ........ ........ ...... *....... **.*.... ........ .... ....
*...... .......* ........ ........ ...... *....... **.*.... ........ .... ....
*...... .......* ........ ........ ...... *....... **.*.... ........ .... ....
[8]
*...... .......* ........ ........ ...... *....... **.*.... ........ .... ....
*...... .......* ........ ........ ...... *....... **.*.... ........ .... ....
*...... .......* ........ ........ ...... *....... **.*.... ........ .... ....
*...... .......* ........ ........ ...... *....... **.*.... ........ .... ....
[9]
*...... .......* ........ ........ ...... *....... **.*.... ........ .... ....
*...... .......* ........ ........ ...... *....... **.*.... ........ .... ....
*...... .......* ........ ........ ...... *....... **.*.... ........ .... ....
*...... .......* ........ ........ ...... *....... **.*.... ........ .... ....
[10]
*...... .......* ........ ........ ...... *....... **.*.... *....... .... ....
*...... .......* ........ ........ ...... *....... **.*.... *....... .... ....
*...... **.....* ........ ........ ...... *....... **.*.... *....... .... ....
*...... **.....* ........ ........ ...... *....... **.*.... *....... .... ....
[11]
*...... **.....* ........ ........ ...... *....... **.*.... *....... .... ....
*...... **.....* ........ ........ ...... *....... **.*.... *....... .... ....
*...... **.....* ........ ........ ...... *....... **.*.... *....... .... ....
*...... **.....* ........ ........ ...... *....... **.*.... *....... .... ....
[12]
*...... **.....* ........ ........ ...... *....... **.*.... *....... .... ....
*...... **.....* ........ ........ ...... *....... **.*.... *....... .... ....
*...... **.....* ........ ........ ...... *....... **.*.... *....... .... ....
*...... **.....* ........ ........ ...... *....... **.*.... *....... .... ....
[13]
*...... **.....* ........ ........ ...... ........ **.*.... ........ .... ....
....... **.....* ........ ........ ...... ........ **.*.... ........ .... ....      Circuit Breaker Open
....... **.....* ........ ........ ...... ........ **.*.... ........ .... ....
....... **.....* ........ ........ ...... ........ **.*.... ........ .... ....
[14]
....... **.....* ........ ........ ...... ........ **.*.... ........ .... ....
....... **.....* ........ ........ ...... ........ **.*.... ........ .... ....
....... **.....* ........ ........ ...... ........ **.*.... ........ .... ....
....... **.....* ........ ........ ...... ........ **.*.... ........ .... ....

                               .
                               .
                               .
[30]
....... .......* ........ ........ ...... ........ **.*.... ........ .... ....
....... .......* ........ ........ ...... ........ **.*.... ........ .... ....
....... .......* ........ ........ ...... ........ **.*.... ........ .... ....
....... .......* ........ ........ ...... ........ **.*.... ........ .... ....
[31]
....... .......* ........ ........ ...... ........ **.*.... ........ .... ....
```

Digital Column Labels (second set)

One Cycle of Data

Figure 3.11 Digital Section of the Event Report

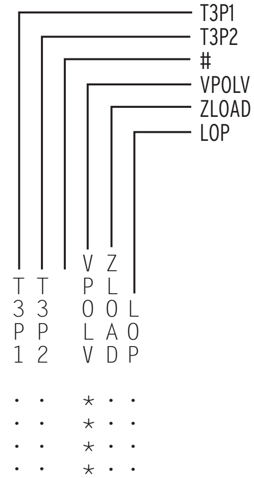

Figure 3.12 Sample Digital Portion of the Event Report

EXAMPLE 3.3 Reading the Digital Portion of the Event Report

This example shows how to read the digital event report shown in Figure 3.11 on page A.3.25. The sample digital event report shows several cycles of 4-samples/cycle data for a CA fault that trips the circuit breaker.

In this particular report, the phase time-overcurrent element 51S1T picks-up in the third sample of Cycle [10]. The relay asserts the tripping Relay Word bit T3P1 when the time-overcurrent element operates because of programming in the TR (Unconditional Tripping) SELOGIC control equation.

Approximately three cycles later, the digital event report shows that the circuit breaker has tripped. In Cycle [13] Relay Word bit 3PO indicates that the relay has detected an open circuit breaker. Contact status 52AA1 dropout is also visible. The one sample overlap is caused by the 1/4-cycle data in the event report being constructed from the logical OR of adjacent 1/8-cycle event report data rows.

Selecting Event Digital Elements

NOTE: The SEL-451 compressed event reports and COMTRADE files may contain additional digital elements as compared to standard (ASCII) event reports. See CEVENT on page A.3.28.

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.10.41* 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 3.13* 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.9.20*).

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.3.31* for a description of the items in the summary portion of the event report.

```
Event: CA T              Location:    7.28                Time Source: OTHER
Event Number: 10014                   Shot 3P: 0       Freq: 60.01     Group: 3
Targets: TIME A_FAULT C_FAULT
Breaker 1: OPEN          Trip Time: 17:14:40.113
Breaker 2: NA
PreFault:     IA      IB      IC      IG     3I2       VA       VB       VC     V1mem
MAG(A/kV)    472     472     472       2       3   21.395   21.396   21.395   19.886
ANG(DEG)   -49.1  -168.9    71.2  -145.7   -90.5      0.0   -166.1     74.0    -31.1

Fault:
MAG(A/kV)   1889     469    2449     174    3458   15.474   21.366   14.114   17.163
ANG(DEG)  -138.1  -168.8    33.6     0.2   175.5    -30.3   -165.8     59.1    -41.5

                                                  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
```

Event Information

Prefault Data

Fault Data

MIRRORED BITS Channel Status (if MIRRORED BITS enabled on any port)

Figure 3.13 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 3.14* for the locations of items included in a sample settings section of an event report. If you want to exclude the settings portion from an event report, use the **EVE NSET** command (see *EVENT on page R.9.20*).

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.9.50* for information on the **SHOW** command, and *Making Simple Settings Changes on page U.4.14* for information on relay settings.

```
Group 3

Line Configuration

CTRW    := 120      CTRX    := 120      PTRY    := 180      VNOMY   := 115
PTRZ    := 180      VNOMZ   := 115      Z1MAG   := 2.14     Z1ANG   := 68.86
Z0MAG   := 6.38     Z0ANG   := 72.47    EFLOC   := Y        LL      := 4.84
                          .
                          .
                          .
Global

General Global Settings

SID     := "Station A"
RID     := "Relay 1"
NUMBK   := 1
BID1    := "Breaker 1"
NFREQ   := 60       PHROT   := ABC      DATE_F  := MDY
FAULT   := 51S1 OR 51S2 OR 50P1
                          .
                          .
                          .
Output

Main Board

OUT101  := T3P1 #BREAKER 1 TRIP
OUT102  := T3P1 #EXTRA BREAKER 1 TRIP
OUT103  := BK1CL #BREAKER 1 CLOSE
OUT104  := NA
OUT105  := NA
OUT106  := NA
OUT107  := NA
OUT108  := NOT (SALARM OR HALARM)
                          .
                          .
                          .
Protection 3

1: PLT01S := PB1_PUL AND NOT PLT01 # GROUND ENABLED
2: PLT01R := PB1_PUL AND PLT01
                          .
                          .
                          .
13: PCT01DO := 0.000000
14: PCT01IN := PSV01 # FOR INST TARGET LED

Alias

Relay Aliases
(Relay Word Bit or Analog Quantity name, 7 Character Alias [0-9 A-Z _])

1: EN,"REL_EN"
```

Active Group Settings

Global Settings

Output Settings

Active Protection Logic Settings

Alias Settings

Figure 3.14 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 3.15*; 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 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 10.88 on page R.10.43*. 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.


```
"FID","RID","SID","03E2"                                                    Report Header
"FID=SEL-451-1-Rxxx-V0-Zxxxxxx-Dyyyymmdd","Relay 1","Station A","xxxx"
"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","0ACA"
2,20,2004,17,14,40,56,"042A"
"EVENT_NUM","EVENT","LOCATION","FREQ","NFREQ","SAM/CYC_A","SAM/CYC_D", "NUM_OF_CYC", "SER_NUM", "PRIM_VAL",     Summary Labels
    "CTR_IA","CTR_IB","CTR_IC","CTR_IG","PTR_VA","PTR_VB","PTR_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","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","VS2_PF","VS2_DEG_PF","V1MEM_PF","V1MEM_DEG_PF","V0_PF","V0_DEG_PF","V2_PF",
    "V2_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","VS1","VS1_DEG","VS2","VS2_DEG","V1MEM",
    "V1MEM_DEG","V0","V0_DEG","V2","V2_DEG","V1","V1_DEG","EFCC"
10014,"CA T",7.28,60.01,60,4,4,30.250,"0000000000","YES",1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,120,120,180,     Summary Data
    180,3,"OPEN",17,14,40,113, , , , ,"NA", , , , , , , , , ,41024,"TIME A_FAULT C_FAULT","0000000000",
    "0000000000",472,-49.07,472,-168.93,472,71.23,1416,-146.77,3,-90.45,472,-48.92,21,0.00,21,-166.13,21,
    74.01,12,-165.71,0,76.50,20,-31.10,6,67.12,6,66.82,20,-31.10,1889,-138.07,469,-168.80,2449,33.58,4807,-
    273.28,3458,175.51,1389,-103.09,15,-30.31,21,-165.84,14,59.12,12,-165.42,0,78.08,17,-41.51,0,-96.91,5,
    68.61,17,-45.29,"6514"
"IA(A)","IB(A)","IC(A)","IG(A)","VA(kV)","VB(kV)","VC(kV)","VS1(kV)","VS2(kV)","V1MEM(kV)","FREQ","TRIG",     Column Labels
    "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 SOTFE ILOP LOP ZLOAD ZLIN ZLOUT FIDEN FSA FSB FSC DFAULT ER EAFSRC * * * 50P1
    50P2 50P3 50P4 67P1 67P2 67P3 67P4 50Q1 50Q2 50Q3 50Q4 67Q1 67Q2 67Q3 67Q4 51S1 51S1T 51S1R 51S1TC 51S2
    51S2T 51S2R 51S2TC 51S3 51S3T 51S3R 51S3TC 51S4 51S4T 51S4R 51S4TC 51S5 51S5T 51S5R 51S5TC 51S6 51S6T
    51S6R 51S6TC 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 * * * * * TRIP 3PT * * * ULTRA * * * * * T3P1 T3P2 BK2LO BK1CL BK2CL LEADBK0 LEADBK1
    LEADBK2 FOLBK0 FOLBK1 52ACL1 * * 52AAL1 * * 52AA1 52AB1 52AC1 * 52ACL2 * * 52AAL2 * * * * * * * VPOLV
    * * F32P R32P F32Q R32Q 32QF 32QR * * 50QF 50QR 50GF 50GR 32QE 32QGE 32VE 32IE F32I R32I F32V R32V
    F32QG R32QG 32GF 32GR RXPRM COMPRM TRPRM * SOTFT * * * 67P1T 67P2T 67P3T 67P4T 50G1 50G2 50G3 50G4
    67Q1T 67Q2T 67Q3T 67Q4T * * * * 3POBK2 3POLINE 3PLSHT BK1RS BK2RS * 79CY3 BK1LO BK1CFT BK2CFT BK1CLSS
    BK2CLSS BK1CLST BK2CLST ULCL1 ULCL2 FOC1 FOBF1 BFTRIP1 BFTR1 BFULTR1 * * * FOC2 FOBF2 BFTRIP2 BFTR2
    BFULTR2 * * * * * * 3PSHOT0 3PSHOT1 3PSHOT2 3PSHOT3 3PSHOT4 59VP 59VS1 25ENBK1 SFZBK1 SFBK1 25W1BK1
    25W2BK1 25A1BK1 59VS2 25ENBK2 SFZBK2 SFBK2 25W1BK2 25W2BK2 25A1BK2 25A2BK2 52AA2 52AB2 52AC2 * * *
    * * LOPHC * * * * 3PO 27APO 27BPO PCT16Q PCT15Q PCT14Q PCT13Q PCT12Q PCT11Q PCT10Q PCT09Q * IN107
    IN106 IN105 IN104 IN103 IN102 IN101 OUT108 OUT107 OUT106 OUT105 OUT104 OUT103 OUT102 OUT101 PSV08
    PSV07 PSV06 PSV05 PSV04 PSV03 PSV02 PSV01 PLT08 PLT07 PLT06 PLT05 PLT04 PLT03 PLT02 PLT01 PCT08Q
    PCT07Q PCT06Q PCT05Q PCT04Q PCT03Q PCT02Q PCT01Q PT Z3RB KEY EKEY ECTT * * * PB1 PB2 PB3 PB4 PB5 PB6
    PB7 PB8 CC2 OC2 CC1 OC1 * * * *","DA31"
-312,462,-149,2,-21.39,20.73,-5.75,11.45,-0.00,-17.10,60.01,     Event Data (Cycle 1)
    ,"0407000000003300000000000000000000000a83800480000000000000100200001000000000800080000b00000000","1E00"
-355,-94,448,-1,0.15,-5.27,20.61,-3.00,0.00,-10.15,60.01,
    ,"0407000000003300000000000000000000000a83800480000000000000100200001000000000800080000b00000000","1D60"
312,-462,149,-2,21.39,-20.74,5.75,-11.45,0.00,17.10,60.01,
    ,"0407000000003300000000000000000000000a83800480000000000000100200001000000000800080000b00000000","1DA7"
355,94,-448,1,-0.15,5.27,-20.61,3.00,-0.00,10.15,60.01,
    ,"0407000000003300000000000000000000000a83800480000000000000100200001000000000800080000b00000000","1D06"
                         .
                         .
                         .
-312,462,-149,1,-21.39,20.73,-5.75,11.45,-0.00,-17.10,60.01,     Event Data (Cycles 5-10)
    ,"0407000000003300000000000000000000000a83800480000000000000100200001000000000800080000b00000000","1DFF"
-355,-94,448,-1,0.15,-5.27,20.61,-3.00,0.00,-10.15,60.01,
    ,"0407000000003300000000000000000000000a83800480000000000000100200001000000000800080000b00000000","1D60"
312,-462,149,-2,21.39,-20.73,5.75,-11.45,0.00,17.10,60.01,
    ,"0407000000003300000000000000000000000a83800480000000000000100200001000000000800080000b00000000","1DA6"
355,94,-448,1,-0.15,5.27,-20.61,3.00,-0.00,10.15,60.01,
    ,"0407000000003300000000000000000000000a83800480000000000000100200001000000000800080000b00000000","1D06"
-312,462,-149,2,-21.39,20.74,-5.75,11.45,-0.00,-17.10,60.01,
    ,"0407000000003300000000000000000000000a83800480000000000000100200001000000000800080000b00000000","1E01"
-355,-94,448,-1,0.15,-5.27,20.61,-3.00,0.00,-10.15,60.01,
    ,"0407000000003300000000000000000000000a83800480000000000000100200001000000000800080000b00000000","1D60"
155,-462,324,17,20.57,-20.73,5.77,-11.45,0.00,17.08,60.01,
    ,"0407000000003300000000000000000000000a83800480cc00000000100200001000000000800080000b00000000","1E1D"
336,94,-405,25,0.68,5.30,-18.27,3.02,-0.00,10.13,60.01,
    ,"0407020000003300000000000000000000000a83800480dc00000000100200001000000000800080000b00000000","1D7B"
702,461,-1268,-105,-16.57,20.71,-6.47,11.43,-0.00,-16.75,60.01,">",
    "0407021000009300000000000000000000000a838004a8fc0a000000100200001000000000800080010b00000000","1FDA"
-795,-95,866,-24,-4.61,-5.35,14.04,-3.05,-0.00,-10.20,60.01,
    ,"0407000088009300000000000000000000000a838004a8fc0a008000100200001000000000800080010b00000000","1EEB"
-1399,-460,2033,174,13.40,-20.68,7.16,-11.42,0.00,15.92,60.01,
    ,"0407000088009300000000000000000000000a838004a8fc0a008000100200001000000000800080010b00000000","1F61"
```


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```
1272,94,-1369,-2,7.71,5.37,-12.16,3.06,-0.00,10.46,60.01,
    ,"04070000880093000000000000000000000000a838004a8fc0a008000100200001000000000800080010b00000000","1E68"
1396,460,-2030,-174,-13.42,20.68,-7.16,11.42,-0.00,-15.00,60.01,
    ,"04070020880093000000000000000000000000a838004a8fc0a008000100200001000000000800080010b00000000","1FAE"
-1272,-94,1368,2,-7.71,-5.37,12.16,-3.06,0.00,-10.75,60.01,
    ,"04070020880093000000000000000000000000a838004a8fc0a008000100200001000000000800080010b00000000","1EC5"
-1396,-460,2030,174,13.41,-20.68,7.16,-11.42,0.00,14.27,60.01,
    ,"04070020880093000000000000000000000000a838004a8fc0a008000100200001000000000800080010b00000000","1F5B"
1272,94,-1368,-2,7.71,5.37,-12.16,3.06,-0.00,10.98,60.01,
    ,"04070020880093000000000000000000000000a838004a8fc0a008000100200001000000000800080010b00000000","1E70"
1396,460,-2030,-174,-13.41,20.68,-7.16,11.42,-0.00,-13.70,60.01,
    ,"04070020880093000000000000000000000000a838004a8fc0a008000100200001000000000800080010b00000000","1FB2"
-1272,-94,1369,2,-7.72,-5.37,12.16,-3.06,0.00,-11.15,60.01,
    ,"04070020880093000000000000000000000000a838004a8fc0a008000100200001000000000800080010b00000000","1EC2"
-1396,-460,2030,174,13.41,-20.68,7.16,-11.42,0.00,13.27,60.01,
    ,"04070020880093000000000000000000000000a838004a8fc0a008000100200001000000000800080010b00000000","1F5A"
1272,94,-1369,-2,7.71,5.37,-12.16,3.06,-0.00,11.28,60.01,
    ,"04070020880093000000000000000000000000a838004a8fc0a008000100200001000000000800080010b00000000","1E6B"
1397,460,-2030,-174,-13.41,20.68,-7.16,11.42,-0.00,-12.93,60.01,"*"
    ,"04070020880093000000000000000000000000a838004a8fc0a008000100200001000000000800080010b01000000","2006"
-1272,-94,1369,2,-7.71,-5.37,12.16,-3.06,0.00,-11.39,60.01,
    ,"04070020880093000000000000000000000000a838004a8fc0a008000100200001000000000800080010b01000000","1EC8"
-1397,-459,2031,174,13.41,-20.68,7.16,-11.42,0.00,12.67,60.01,
    ,"440700208800d300000000000000000018020a838004a8fc0a208000100200001000000000800083010b01000000","1FA7"
1273,94,-1369,-2,7.71,5.37,-12.16,3.06,-0.00,11.47,60.01,
    ,"440700208800d300000000000000000018020a838004a8fc0a208000100200001000000000800083010b01000000","1EAD"
                          .
                          .
                          .
```

Event Data (Cycles 5-10)

```
0,0,0,1,-15.26,21.26,-5.90,11.74,-0.00,-15.31,60.01,
    ,"42a7002000003300000000000000000000800a00004000000000000004200000010000000840000800000b00000000","1C8C"
0,0,-0,0,-15.76,-5.40,21.13,-3.07,0.00,-15.71,60.01,
    ,"42a7002000003300000000000000000000800a00004000000000000004200000010000000840000800000b00000000","1C85"
-0,-0,-0,-1,15.26,-21.26,5.90,-11.74,0.00,15.31,60.01,
    ,"42a7002000003300000000000000000000800a00004000000000000004200000010000000840000800000b00000000","1CE6"
-0,-0,0,-0,15.76,5.40,-21.13,3.07,-0.00,15.71,60.01,
    ,"42a7002000003300000000000000000000800a00004000000000000004200000010000000840000800000b00000000","1C85"
0,0,0,1,-15.27,21.26,-5.90,11.74,-0.00,-15.31,60.01,
    ,"42a7002000003300000000000000000000800a00004000000000000004200000010000000840000800000b00000000","1C8D"
```

Last Part of Event Data

```
"SETTINGS","xxxx"
"Group 3

Line Configuration

CTRW    := 120      CTRX    := 120      PTRY    := 180      VNOMY   := 115
PTRZ    := 180      VNOMZ   := 115      Z1MAG   := 2.14     Z1ANG   := 68.86
Z0MAG   := 6.38     Z0ANG   := 72.47    EFLOC   := Y        LL      := 4.84
                          .
                          .
                          .
```

Active Group Settings

```
Global

General Global Settings

SID     := "Station A"
RID     := "Relay 1"
NUMBK   := 1
BID1    := "Breaker 1"
NFREQ   := 60       PHROT   := ABC      DATE_F  := MDY
FAULT   := 51S1 OR 51S2 OR 50P1
                          .
                          .
                          .
```

Global Settings

```
Output

Main Board

OUT101  := T3P1 #BREAKER 1 TRIP
OUT102  := T3P1 #EXTRA BREAKER 1 TRIP
OUT103  := BK1CL #BREAKER 1 CLOSE
OUT104  := NA
OUT105  := NA
OUT106  := NA
OUT107  := NA
OUT108  := NOT (SALARM OR HALARM)
                          .
                          .
                          .
```

Output Settings

(Continued on next page)

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```
Protection 3

1: PLT01S := PB1_PUL AND NOT PLT01 # GROUND ENABLED
2: PLT01R := PB1_PUL AND PLT01
                                 .
                                 .
                                 .
13: PCT01DO := 0.000000
14: PCT01IN := PSV01 # FOR INST TARGET LED
","xxxx"

Alias

Relay Aliases
(Relay Word Bit or Analog Quantity name, 7 Character Alias [0-9 A-Z _])

1: EN,"REL_EN"
```

Active Protection Logic Settings

Alias Settings

Figure 3.15 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:

```
"04070210000093000000000000000000000000a838004a8fc0a000000100200001000000000800080010
    b0000000"
```

In this HEX-ASCII Relay Word, the 13th character in the HEX-ASCII Relay Word is 9. In binary, this is 1001. Mapping the labels to the digital Column Labels yields the following:

```
51S1   51S1T   51S1R   51S1TC
  1      0       0       1
```

The 51S1 elements are picked up at the first sample of Cycle [7] (see *Figure 3.11*).

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.4.51* 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 3.16* for a sample event summary.

```
Relay 1                                         Date: 02/20/2004  Time: 17:14:40.056
Station A                                       Serial Number: 0000000000

Event: CA T              Location:    7.28                     Time Source: OTHER
Event Number: 10014                   Shot 3P: 0        Freq: 60.01      Group: 3
Targets: TIME A_FAULT C_FAULT
Breaker 1: OPEN          Trip Time: 17:14:40.113
Breaker 2: NA
PreFault:      IA      IB      IC      IG     3I2       VA        VB        VC     V1mem
MAG(A/kV)     472     472     472       2       3   21.395    21.396    21.395    19.886
ANG(DEG)    -49.1  -168.9    71.2  -145.7   -90.5      0.0    -166.1      74.0     -31.1

Fault:
MAG(A/kV)    1889     469    2449     174    3458   15.474    21.366    14.114    17.163
ANG(DEG)   -138.1  -168.8    33.6     0.2   175.5    -30.3    -165.8      59.1     -41.5
                                                  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 (if MIRRORED BITS is enabled on any port)

Figure 3.16 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 (PPS, IRIG-B, etc.)
- 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-451 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.3.34*.)

Table 3.7 lists the **SUM** commands. See *SUMMARY on page R.9.55* 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.3.15).

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 **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 3.17*; this is a comma-delimited ASCII file. The relay appends a four-digit hex checksum at the end of the lines in the Compressed ASCII report.

Items included in the Compressed ASCII 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-451-1-Rxxx-V0-Zxxxxxx-Dyyyymmdd","xxxx"
"EVENT_NUM","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","USEC","EVENT","LOCATION",
    "TIME_SOURCE","SHOT_3P","FREQUENCY","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","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","VS2_PF","VS2_DEG
    _PF","V1MEM_PF","V1MEM_DEG_PF","V0_PF","V0_DEG_PF","V2_PF","V2_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","VS1","VS1_DEG","VS2"
    ,"VS2_DEG","V1MEM","V1MEM_DEG","V0","V0_DEG","V2","V2_DEG","V1","V1_DEG","D6C0"
10014,2,20,2004,17,14,40,56,900,"CA T",7.28,"OTHER",0,60.01,3,"OPEN",17,14,40,113, ,
    , , ,"NA", , , , , , , , ,41024,"TIME A_FAULT C_FAULT","0000000000","0000000000",
    472,-49.07,472,-168.93,472,71.23,2,-145.72,3,-90.45,472,-48.92,21.395,0.00,21.396
    ,-166.13,21.395,74.01,11.840,-165.71,0.001,76.50,19.886,-31.10,5.586,67.12,5.574,
    66.82,19.886,-31.10,1889,-138.07,469,-168.80,2449,33.58,174,0.21,3458,175.51,1389,
    -103.09,15.474,-30.31,21.366,-165.84,14.114,59.12,11.820,-165.42,0.001,78.08,
    17.163,-41.51,0.310,-96.91,4.641,68.61,16.636,-45.29,"6935"

=>>
```

Report Header

Report Labels

Report Data

Figure 3.17 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 3.18* 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 3.18 is a sample event history from a terminal.

```
Relay 1                                         Date: 02/24/2004  Time: 15:20:38.186
Station A                                       Serial Number: 0000000000

#       DATE        TIME      EVENT  LOCAT    CURR GRP TARGETS
10015 02/23/2004 17:42:56.581 TRIG  $$$$.$$     1   3
10014 02/20/2004 17:14:40.056 CA T     7.28  2449   3  TIME A_FAULT C_FAULT
```

Event Number | Event Type | Maximum Current | Active Group

Figure 3.18 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.9.25* for information on the **HIS** command. *Table 3.8* lists the **HIS** commands.

Table 3.8 HIS Command (Sheet 1 of 2)

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.

Table 3.8 HIS Command (Sheet 2 of 2)

Command	Description
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-451-1-Rxxx-V0-Zxxxxxx-Dyyyymmdd","xxxx"
"REC_NUM","REF_NUM","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","USEC","EVENT","GROUP"
    ,"FREQ","FAULT_LOC","SHOT","SHOT_3P","CURR","TARGETS","22C9"
1,10015,2,23,2004,17,42,56,581,100,"TRIG",3,60.00,$$$$.$$,0,0,0," ","xxxx"
2,10014,2,20,2004,17,14,40,56,900,"CA T",3,60.01,7.28,0,0,2448,"TIME A_FAULT C_FAULT","xxxx"
```

Report Header

Report Labels

Report Data

Figure 3.19 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 3.19*; 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.4.51* for file download procedures.

High-Impedance Fault Event Summaries and Histories

High-impedance fault event information is available when the relay supports HIF detection. The relay stores event information in nonvolatile memory, and you can clear the event report memory on a port-by-port basis. Report setting HIFLER determines the length of the stored event report. The relay can store approximately forty minutes of event report data, corresponding to a single stored event at the maximum HIFLER setting of forty minutes, or approximately twenty stored events at the minimum HIFLER setting of two minutes. The length of time reserved within the stored event report for the capture of pretrigger (prefault) data is fixed to 60 seconds (on a 60 Hz system) regardless of the HIFLER setting value. You can view information about a high-impedance fault event in one or more of the following forms:

- HIF event summary
- HIF event history

High-Impedance Fault Event Summary

You can retrieve a shortened version of stored high-impedance fault event oscillography as HIF event summaries. These short-form reports present vital information about a triggered event. See *Figure 3.20* for a sample HIF event summary.

```
Relay 1                                     Date: 06/10/2007  Time: 08:04:16.698
Station A                                   Serial Number: 0000000000

Event: HIF Fault        HIF Phase: B                      Time Source: OTHER
Event Number: 10003     Downed Conductor: NO              Freq: 60.03    Group: 1
Breaker 1: CLOSED
Breaker 2: NA

Pre-trigger (A):
IARMS   IBRMS   ICRMS   IGRMS
312.0   238.0   282.0   60.0

Post-trigger (A):
312.0   245.0   281.0   55.0

Pre-trigger (A):
ISMA    ISMB    ISMC    ISMG    SDIA    SDIB    SDIC    SDIG
196.5   100.0   182.0   283.0   236.5   203.5   211.5   164.0

Post-trigger (A):
199.5   259.0   191.5   459.5   247.0   217.0   224.0   202.0
```

Figure 3.20 Sample HIF Event Summary Report

The event summary contains the following information:

- Standard report header
  - Relay and terminal identification
  - Event date and time
- Event type
- HIF Phase
- Time source (HIRIG, OTHER)
- Event number
- Downed Conductor
- System frequency

- Active group at trigger time
- Circuit breaker status
- Pre-trigger and post-trigger phase currents, sum of difference currents, and total odd harmonic content of currents (from the initial trigger point and the first point of the event report)

Table 3.9 lists event types in fault reporting priority. For example, alarm event types have reporting priority over triggered events. Events may be triggered in one of two ways. The **TRI HIF** command will trigger an event (see *TRIGGER on page R.9.64* for complete information on the **TRI** command) locally. Report SELOGIC setting HIFER allows for triggering an event remotely. This setting can also be programmed in a manner to aid in simulaneous event triggering in multiple relays.

Table 3.9 HIF Event Types

Event	Event Trigger
HIF ALARM	Assertion of any one of the following RWBs and if no HIF fault has occurred: HIA1_A, HIA1_B, HIA1_C, HIA1_G, HIA2_A, HIA2_B, HIA2_C, HIA2_G
HIF FAULT	Assertion of any one of the following RWBs: HIF1_A, HIF1_B, HIF1_C, HIF1_G, HIF2_A, HIF2_B, HIF2_C, HIF2_G
HIF Ext. TRI	Assertion of HIFER SELogic variable.
HIF TRI	Execution of the TRI HIF command.

Table 3.10 lists HIF phase involvement conditions. Multiple phases may be listed if more than one phase involvement is detected. If a HIF fault occurs (HIF*x_x*), alarmed phases are not listed. When an event report is triggered for any of these conditions, Relay Word bit HIFREC is asserted until the HIF event report is finished being collected. The relay will not generate additional event reports for triggering conditions that follow the initial triggering condition and are within the same report.

Table 3.10 HIF Event Phases

Phase	Conditions
A	Assertion of any one of the following RWBs: HIA1_A, HIA2_A, HIF1_A, HIF2_A
B	Assertion of any one of the following RWBs: HIA1_B, HIA2_B, HIF1_B, HIF2_B
C	Assertion of any one of the following RWBs: HIA1_C, HIA2_C, HIF1_C, HIF2_C
G	Assertion of any one of the following RWBs: HIA1_G, HIA2_G, HIF1_G, HIF2_G

HIRIG is reported in the Time Source field is TSOK is asserted at the time of the event trigger, otherwise OTHER is reported. The event number displayed corresponds to the HIS HIF report number.

When a high-impedance fault is caused by a down-conductor, there may be a load current reduction. Depending on the position of the down conductor and the amount of load dropped, this load reduction event may or may not be detectable back in a substation. The Load Reduction Element is used to detect any load reduction at the time that a high-impedance fault is detected. The element is used to report a possible down-conductor event. *Table 3.11* lists HIF downed conductor conditions.

Table 3.11 HIF Downed Conductor

Downed Conductor	Conditions
YES	Assertion of any one of the following RWBs: HIA1_A, HIA1_B, HIA1_C, HIA1_G, HIA2_A, HIA2_B, HIA2_C, HIA2_G, HIF1_A, HIF1_B, HIF1_C, HIF1_G, HIF2_A, HIF2_B, HIF2_C, HIF2_G AND LR*X* bit asserts where *X* is the same phase as the alarm or fault phase.
NO	When the above is not true.

The system frequency is displayed as measured at the time of trigger to two decimal places. The active settings group at the time of trigger is displayed. The state of the breaker is displayed as determined by the 52*n*CL*x* (*x*=1,2 *n*=A, B, C) Relay Word Bits. If all 52*n*CL*x* bits for a breaker are set, the state is defined as CLOSED, otherwise the breaker is defined as OPEN. NA is used when the second breaker does not exist as determined by settings. Pre-trigger currents are obtained from the first sample in the event report, while post-trigger currents are obtained from the initial trigger sample.

Viewing the HIF Event Summary

Access the HIF 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 HIF 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 HIF N(EXT)** command to view that summary.

You can use the **SUM HIF** command to retrieve HIF 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 HIF** command history report; see *High-Impedance Fault Event History on page A.3.40*.)

Table 3.12 lists the **SUM HIF** commands. See *SUMMARY on page R.9.55* for complete information on the **SUM** command.

Table 3.12 SUM HIF Command

Command	Description
SUM HIF	Return the most recent HIF event summary.
SUM HIF *n*	Return an event summary for HIF event *n*[a].
SUM HIF ACK	Acknowledge the HIF event summary on the present communications port.
SUM HIF 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.3.15).

CSUMMARY HIF

The relay outputs a Compressed ASCII HIF summary report for SCADA and other automation applications. Issue ASCII command **CSU HIF** to view the Compressed ASCII HIF summary report. A sample of the summary report appears in *Figure 3.21*; this is a comma-delimited ASCII file. The relay appends a fourdigit 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 *Section 9: ASCII Command Reference* for more information on the Compressed ASCII command set.

```
"RID","SID","FID","yyyy",
"Relay 1","Station A","FID=SEL-451-2-Rxxx-V0-Zxxxxxx-Dyyyymmdd","yyyy"
"REF_NUM","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","USEC","EVENT","HIF
PHASE", "TIME_SOURCE","DOWNED CONDUCTOR", "FREQUENCY",
"GROUP","BREAKER1","BREAKER2","IARMS_PF","IBRMS_PF","ICRMS_PF","IGRMS_PF","IARMS",
"IBRMS","ICRMS","IGRMS","ISMA_PF","ISMB_PF","ISMC_PF","ISMG_PF","SDIA_PF","SDIB_PF",
"SDIC_PF","SDIG_PF","ISMA","ISMB","ISMC","ISMG","SDIA","SDIB","SDIC","SDIG","yyyy"
xxxxx,xx,xx,xxxx,xx,xx,xx,xxxx,xxxx,"EVENT TYPE","HIF PHASE","TIME SOURCE","DOWNED
CONDUCTOR" XX.XX,X, "BREAKER1 STATUS","BREAKER2 STATUS",
xxxxx,xxxxx,xxxxx,xxxxx,xxxxx,xxxxx,xxxxx,xxxxx,xxx.x, xxx.x, xxx.x, xxx.x, xxx.x,
xxx.x, xxx.x, xxx.x, xxx.x, xxx.x, xxx.x, xxx.x, xxx.x, xxx.x, xxx.x, xxx.x "yyyy"
```

Report Header

Report Labels

Report Data

Figure 3.21 Sample Compressed ASCII HIF Summary

High-Impedance Fault Event History

The HIF 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 3.22* for a sample event history.

The HIF 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
- Downed Conductor
- Active group at the trigger instant

```
Relay 1                                                    Date: 06/10/2007 Time: 08:06:13.33
Station A                                                  Serial Number: 0000000000

#       DATE          TIME        EVENT                 Downed Conductor    GRP
10003 06/10/2007 08:04:16.698    HIF Fault    B              NO             1
10002 06/09/2007 07:13:48.734    HIF Fault    B              NO             1
10001 06/08/2007 15:07:13.293    HIF Fault    A,B,C          NO             1
10000 06/08/2007 14:55:02.457    HIF TRI                     NO             1
```

Event Number

Event Type

Figure 3.22 Sample HIF Event History

The event types and downed conductor status in the event history are determined in the same manner as in the event summary (see *High-Impedance Fault Event Summary on page A.3.37*).

Viewing the HIF Event History

Access the HIF history report from the communications ports and communications cards. View and download HIF history reports from Access Level 1 and higher. You can also clear or reset HIF history data from Access Levels 1 and higher. You can independently clear/reset HIF 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 HIF history data from all ports (with the **HIS HIF CA** and **HIS HIF RA** commands).

Use the **HIS HIF** command from a terminal to obtain the HIF 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. *Table 3.8* lists the **HIS HIF** commands. See *HISTORY on page R.9.25* for complete information on the **HIS** command.

Table 3.13 HIS HIF Command

Command	Description
HIS HIF	Return event histories with the oldest at the bottom of the list and the most recent at the top of the list.
HIS HIF 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 HIF *date1*	Return the event summaries on date *date1*[a].
HIS HIF *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 HIF C	Clear all event data on the present port.
HIS HIF R	Clear all event data on the present port.
HIS HIF CA	Clear event data for all ports.
HIS HIF RA	Clear event data for all ports.

[a] Use the same date format as Global setting DATE_F.

CHISTORY HIF

The relay outputs a Compressed HIF history report for SCADA and other automation applications. Issue the **CHI HIF** command to view the Compressed HIF history report. A sample of the report appears in *Figure 3.23*; 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 HIF history report are similar to those included in the HIF 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.

```
"RID","SID","FID","03e2"
"Relay 1","Station A","FID=SEL-451-2-Rxxx-V0-Zxxxxxx-Dyyyymmdd","0f90"
"REC_NUM","REF_NUM","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","USEC","EVENT","Downed Conductor","FREQ","1BD1"
1,10000,5,14,2007,15,49,4,272,400,"HIF TRI ","NO",60.00,"0B16"
1,10003,6,10,2007,8,4,16,698,400,"HIF Fault ","NO",60.00,"0B46"
2,10002,6,9,2007,7,13,48,734,400,"HIF Fault ","NO",60.00,"0B4C"
3,10001,6,8,2007,15,7,13,293,400,"HIF Fault ","NO",60.00,"0B4B"
4,10000,6,8,2007,14,55,2,457,400,"HIF TRI ","NO",60.00,"0B17"
```

Figure 3.23 Sample Compressed HIF History Report

SER (Sequential Events Recorder)

The SEL-451 Sequential Events Recorder (SER) gives you detailed information on relay states and relay element operation. The SER captures and time-tags state changes of Relay Word bit elements and relay conditions. These conditions include power-up, relay enable and disable, group changes, settings changes, memory overflow, diagnostic restarts, and SER autoremoval/reinsertion. The SEL-451 stores the latest 1000 SER entries to nonvolatile memory. *Figure 3.24* is a sample SEL-451 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: 02/20/2004  Time: 17:20:59.980
Station A                                   Serial Number: 0000000000

FID=SEL-451-1-Rxxx-V0-Zxxxxxx-Dyyyymmdd

#      DATE         TIME          ELEMENT              STATE
20    02/20/2004  17:14:40.054   51S1                 Asserted
19    02/20/2004  17:14:40.061   50P1                 Asserted
18    02/20/2004  17:14:40.113   51S1T                Asserted
17    02/20/2004  17:14:40.113   Breaker 1 TRIP       Asserted
16    02/20/2004  17:14:40.121   Reclose Cycle        Asserted
15    02/20/2004  17:14:40.121   Breaker 1 Reset      Deasserted
14    02/20/2004  17:14:40.144   50P1                 Deasserted
13    02/20/2004  17:14:40.154   51S1T                Deasserted
12    02/20/2004  17:14:40.154   51S1                 Deasserted
11    02/20/2004  17:14:40.161   Breaker 1 Status     Open
10    02/20/2004  17:14:40.313   Breaker 1 TRIP       Deasserted
9     02/20/2004  17:14:45.187   Breaker 1 CLOSE      Asserted
8     02/20/2004  17:14:45.187   Reclose Shot 1       Asserted
7     02/20/2004  17:14:45.187   Reclose Shot 0       Deasserted
6     02/20/2004  17:14:45.254   Breaker 1 Status     Closed
5     02/20/2004  17:14:45.271   Breaker 1 CLOSE      Deasserted
4     02/20/2004  17:15:00.271   Breaker 1 Reset      Asserted
3     02/20/2004  17:15:00.271   Reclose Cycle        Deasserted
2     02/20/2004  17:15:00.271   Reclose Shot 0       Asserted
1     02/20/2004  17:15:00.271   Reclose Shot 1       Deasserted
```

SER Number

Relay Element or Condition

Figure 3.24 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 3.14* or the *SER on page R.9.43*).

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 3.14* or *Section 9: ASCII Command Reference in the Reference Manual* for more information on the **SER** command.

Table 3.14 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 **Tools > Meter and Control** menu item gives you the SER report. See *Viewing SER Records on page U.4.52* 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 3.25*; 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.9.15* for more information on the Compressed ASCII command set.

```
"RID","SID","FID","03e2"                                                        Report Header
"Relay 1","Station A","SEL-451-1-Rxxx-V0-Zxxxxxx-Dyyyymmdd","xxxx"
"#","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","ELEMENT","STATE","xxxx"     Report Labels
1,2,20,2004,17,15,0,271,"Reclose Shot 1","Deasserted","xxxx"
2,2,20,2004,17,15,0,271,"Reclose Shot 0","Asserted","xxxx"
3,2,20,2004,17,15,0,271,"Reclose Cycle","Deasserted","xxxx"
4,2,20,2004,17,15,0,271,"Breaker 1 Reset","Asserted","xxxx"
5,2,20,2004,17,14,45,271,"Breaker 1 CLOSE","Deasserted","xxxx"
6,2,20,2004,17,14,45,254,"Breaker 1 Status","Closed","xxxx"
7,2,20,2004,17,14,45,187,"Reclose Shot 0","Deasserted","xxxx"
8,2,20,2004,17,14,45,187,"Reclose Shot 1","Asserted","xxxx"
9,2,20,2004,17,14,45,187,"Breaker 1 CLOSE","Asserted","xxxx"
10,2,20,2004,17,14,40,313,"Breaker 1 TRIP","Deasserted","xxxx"                  SER Data (20 records)
11,2,20,2004,17,14,40,161,"Breaker 1 Status","Open","xxxx"
12,2,20,2004,17,14,40,154,"51S1","Deasserted","xxxx"
13,2,20,2004,17,14,40,154,"51S1T","Deasserted","xxxx"
14,2,20,2004,17,14,40,144,"50P1","Deasserted","xxxx"
15,2,20,2004,17,14,40,121,"Breaker 1 Reset","Deasserted","xxxx"
16,2,20,2004,17,14,40,121,"Reclose Cycle","Asserted","xxxx"
17,2,20,2004,17,14,40,113,"Breaker 1 TRIP","Asserted","xxxx"
18,2,20,2004,17,14,40,113,"51S1T","Asserted","xxxx"
19,2,20,2004,17,14,40,61,"50P1","Asserted","xxxx"
20,2,20,2004,17,14,40,54,"51S1","Asserted","xxxx"
```

Figure 3.25 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.4.57* 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.4.19*). 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.4.52* 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.4.52*.

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.9.43*).

Section 4
Time-Synchronized Measurements

The SEL-451 Relay records power system events with very high accuracy when you provide high-accuracy clock input signals, such as from a GPS receiver. SEL-451 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 *C37.118, IEEE 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-451**.**

This section presents details on these measurements as well as suggestions for further application areas. The topics of this section are the following:

Relay Configuration for High-Accuracy Timekeeping

The SEL-451 features two IRIG-B timekeeping modes, IRIG and high-accuracy IRIG, called HIRIG.

The HIRIG mode replaces the PPS mode in previous SEL-451 relays, which required a separate 1k PPS time input in firmware versions R103 and earlier. Relay Word bit TSOK asserts when the SEL-451 is in HIRIG mode (see *Table 4.9 on page U.4.74*).

The SEL-451 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.4.73* for details on the time-source connections of the SEL-451, including the changes made to the SEL-451 hardware and firmware version R104.

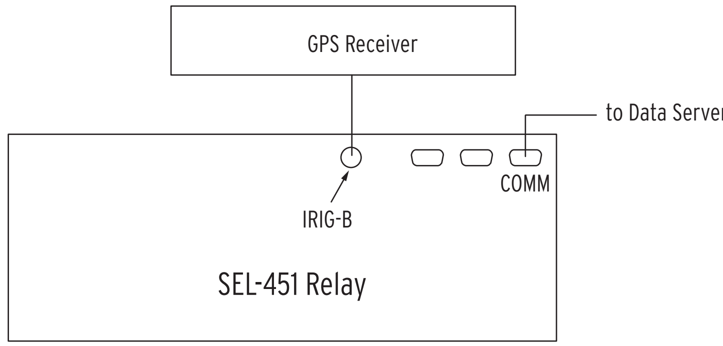


Figure 4.1 High-Accuracy Timekeeping Connections

Time-Synchronized Triggers

Program the SEL-451 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-451

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.7.16.

Perform the following steps to trigger an event data capture in the SEL-451 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 QuickSet® 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 **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-451.

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**, as shown in *Figure 4.2*.

You will see the **Protection Free Form Logic Settings** dialog box.

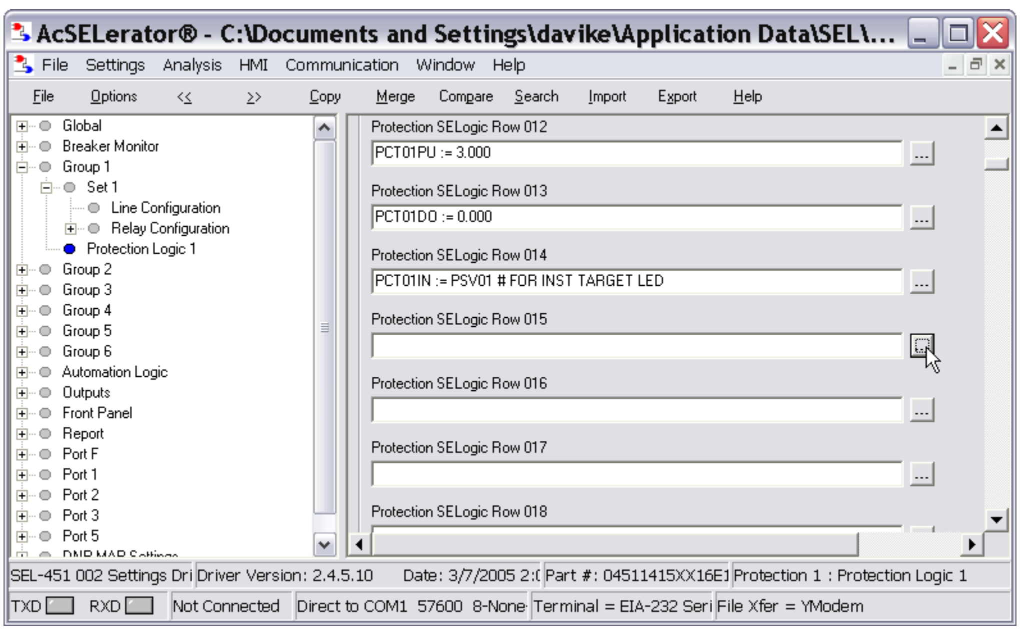


Figure 4.2 Selecting Protection Logic 1 Settings in ACSELERATOR

Step 5. Enter time trigger settings:

a. Click the ... icon 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 > Time and Date Management**.

d. Double click **THR** (Time in Hours).

e. Use the **#** character to add a comment to the line.

f. When finished, click **Accept**.

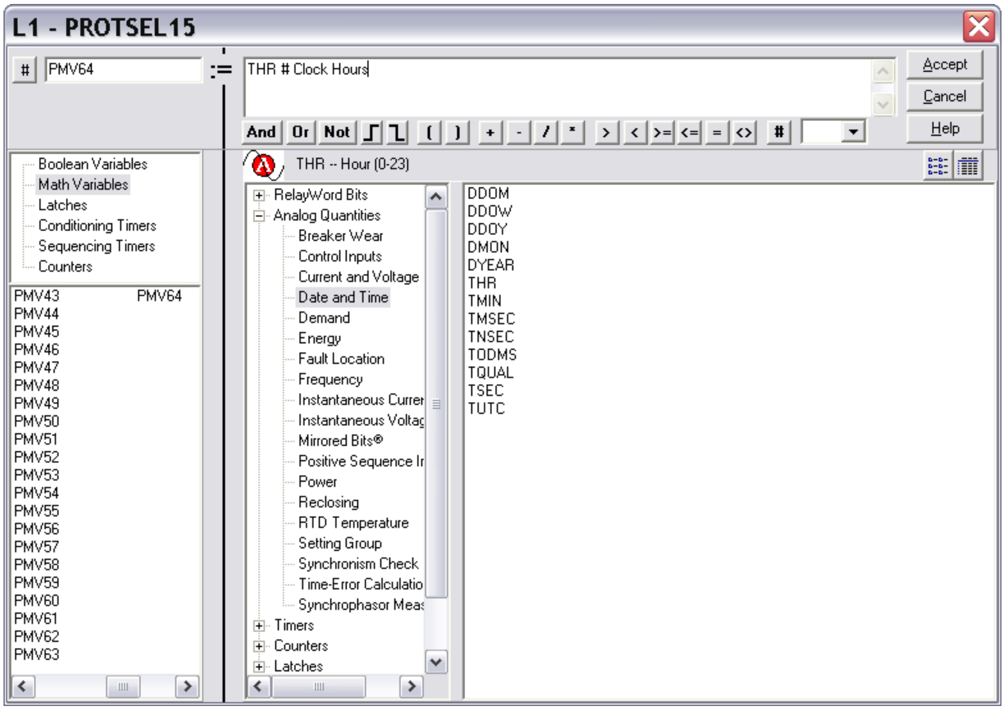


Figure 4.3 Setting PMV64 With the Expression Builder Dialog Box

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:

1: **PMV64 := THR # Clock hours**

2: **PMV63 := TMIN # Clock minutes**

3: **PMV62 := TSEC # Clock seconds**

4: **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-451 protection logic processing.

Step 7. Select settings:

a. Click the **+** mark next to **Relay Configuration** as shown in *Figure 4.4*.

b. Click the **Trip Logic** and **ER Trigger** branch.

You will see the **Trip Logic Settings** dialog box (see *Figure 4.4*).

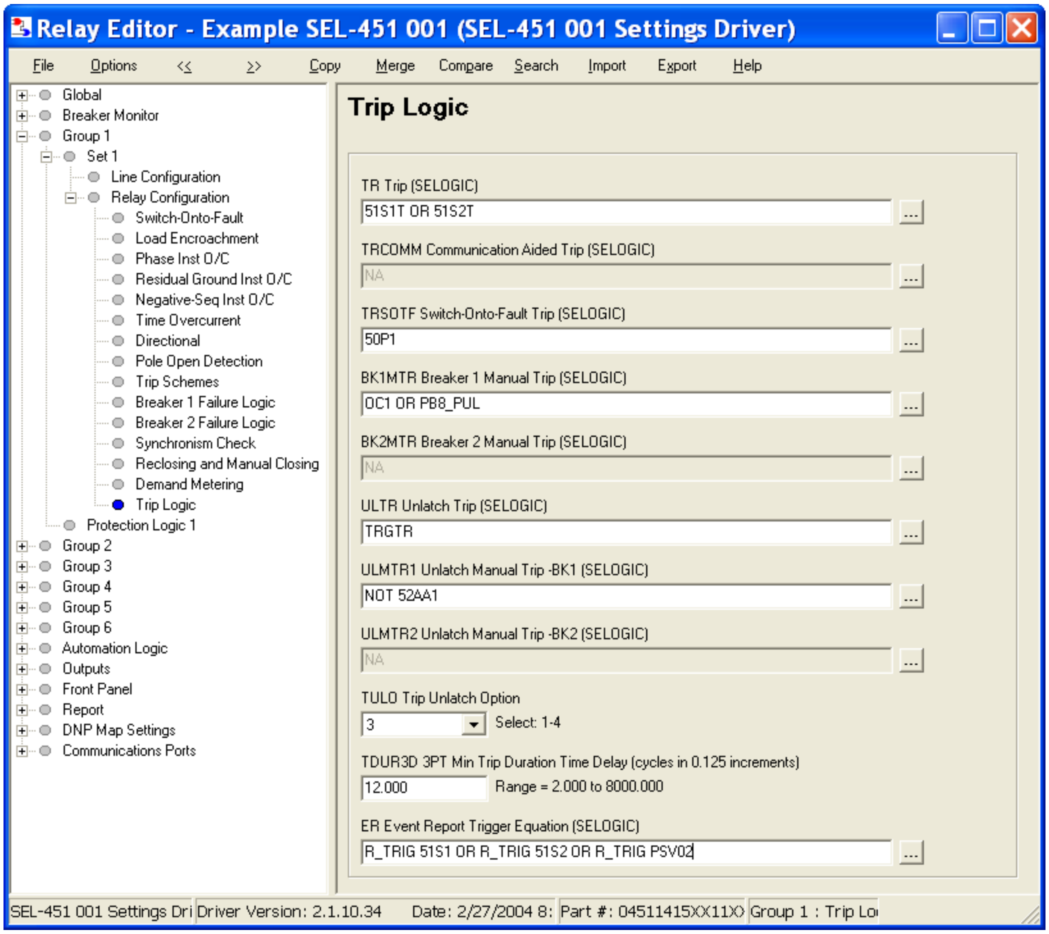


Figure 4.4 Selecting Trip Logic and ER Trigger Settings in ACSELERATOR

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-451:

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 4.5*.

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 4.5*.

If you see no error message, the new settings are loaded in the relay.

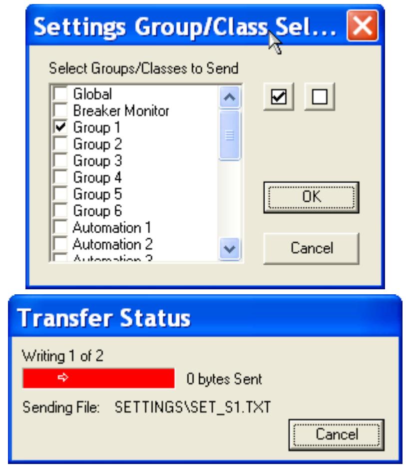


Figure 4.5 Uploading Group Settings to the SEL-451

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.4.43* 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-451 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-451 relays in the power system to implement dynamic phasor determination. *Figure 4.6* shows an example of a 230 kV overhead transmission line with a SEL-451 at each terminal. Connect GPS receivers at each substation to provide very high-accuracy time signal inputs for each relay.

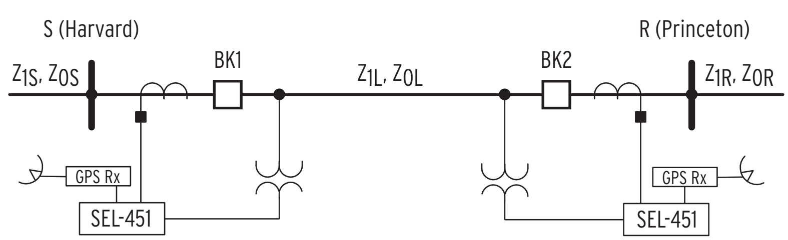


Figure 4.6 230 kV Transmission Line System

With synchronized and time-stamped binary COMTRADE data, you can develop automated computer algorithms for comparing these data from different locations in the power system.

In particular, you can use fault data extracted from two relays. Use third-party software to filter the binary COMTRADE data so that the signals are composed of fundamental quantities only (50 Hz or 60 Hz). You can also use third-party software to convert the binary COMTRADE data to ASCII COMTRADE files. Use the Phasor Diagram in the SEL-5601 Analytic Assistant to select the appropriate prefault and post-fault quantities.

Power Flow Analysis

Use the SEL-451 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 Fast Messaging protocol to collect synchronized voltage and current data. Use this information to confirm your power flow models.

Four SEL-451 relays are installed in the power system shown in *Figure 4.7*. Substations S and R provide generation for the load at Substation T.

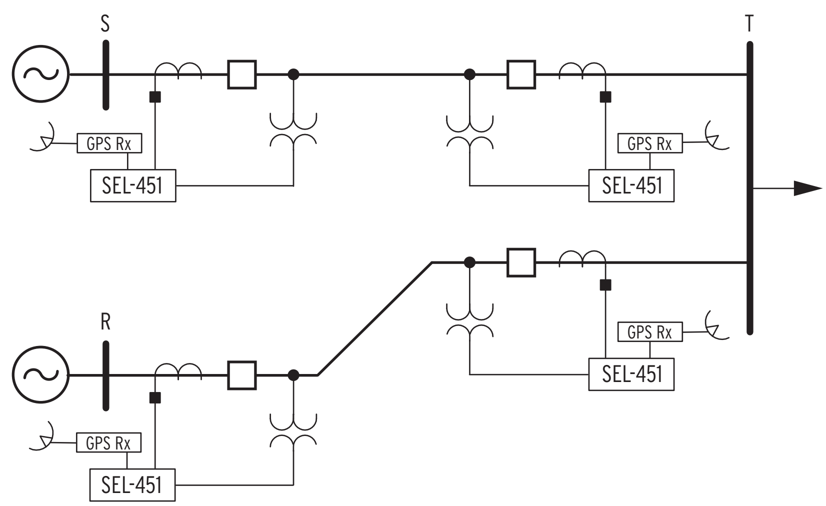


Figure 4.7 500 kV Three Bus Power System

Table 4.1 lists the voltage and current measured by the four SEL-451 relays at one particular time.

Table 4.1 SEL-451 Voltage and Current Measurement (Sheet 1 of 2)

Voltage		Current	
SEL-451 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-451 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°

Table 4.1 SEL-451 Voltage and Current Measurement (Sheet 2 of 2)

Voltage		Current	
SEL-451 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°
SEL-451 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.

$$\begin{aligned} S_{3\phi} &= P_{3\phi} + jQ_{3\phi} \\ &= \sqrt{3} \bullet V_{pp} \bullet I^*_L \\ &= 3 \bullet V_p \bullet I^*_L \end{aligned} \quad \textbf{Equation 4.1}$$

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:

$$\begin{aligned} S_T &= S_{T-S} + S_{T-R} \\ &= -306.5\ \text{MW} + j5.4\ \text{MVAR} \end{aligned}$$

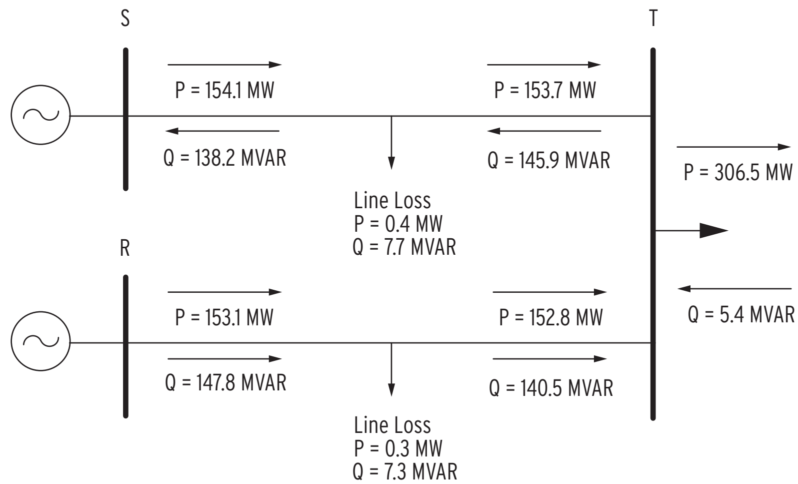


Figure 4.8 Power Flow Solution

Use the power flow solution to verify the instantaneous positive sequence impedances of your system transmission lines.

State Estimation Verification

Electric utility control centers have used state estimation to monitor the state of the power system for the past 20 years. The state estimator calculates the state of the power system 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-451 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-451 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
Bay Control

Overview

The SEL-451-4 Relay option provides bay configuration display in one-line diagram form on the front-panel screen with disconnect and breaker control capabilities for over 25 predefined user selectable bay types. Additional user-selectable bay types are available via an ACSELERATOR QuickSet SEL-5030 Software interface that can be downloaded at www.selinc.com. With the bay control, you can control as many as ten disconnects and two breakers depending on the choice of one-line diagram. Certain one-line diagrams provide status for as many as three breakers. You can operate disconnects and breakers with ASCII commands, SELOGIC® control equations, Fast Operate Messages, and from the one-line diagram. One-line diagrams include user-configurable apparatus labels and as many as six user-definable analog quantities. This section covers all aspects of the SEL-451-4 bay control relay.

Circuit Breaker Status Logic

The circuit breaker status logic is the same in all models of the SEL-451. The circuit breaker state and circuit breaker alarm conditions are determined by the circuit breaker status logic. This section presents the SEL-451 circuit breaker status logic:

- *Circuit Breaker Status Logic on page A.5.3*

Disconnect Logic

The disconnect logic in the SEL-451-4 safely operates the disconnect switches and reports status of the disconnect switches. The SEL-451-4 disconnect logic is independent for each of the disconnect switches. This section presents the SEL-451 disconnect logic and definitions of close, open, and undetermined state indications:

- *Disconnect Switch Close and Open Control Logic on page A.5.3*
- *Disconnect Switch Status and Alarm Logic on page A.5.6*
- *Close and Open Immobility Timer Logic on page A.5.9*
- *Close, Open, and Undetermined State Indications on page A.5.11*

Bay Control Front-Panel Operations

The one-line diagram in the SEL-451-4 presents the bay configuration on the front-panel display. Breaker and disconnect switch control within the one-line diagram is one of the supported means of operating breakers and disconnect switches. This section presents the unique one-line diagram front-panel operations in the SEL-451-4 and definitions of symbols in the one-line diagrams:

- *SEL-451-4 Front Panel on page A.5.13*
- *One-Line Diagram and One-Line Diagram Labels on page A.5.14*
- *Front-Panel Pushbutton Navigation Operations in the One-Line Diagram on page A.5.15*
- *Circuit Breaker and Disconnect Definitions and State Representations on page A.5.15*
- *Circuit Breaker and Disconnect Switch Operations From the Front Panel on page A.5.17*

ACSELERATOR QuickSet SEL-5030 Software Bay Control Screens

For the bay control, ACSELERATOR QuickSet® SEL-5030 Software includes interactive one-line diagram settings screens. This section presents ACSELERATOR QuickSet one-line diagram setting screen functionality:

- *Bay Control Settings Interface on page A.5.23*

Bay Control Example Application

An example of setting up a Bus 1, Bus 2, and Transfer Bus application in the SEL-451-4 is presented in this section:

- *Bus 1, Bus 2, and Transfer BUS Bay With Ground Switch (MIMIC := 4) on page A.5.28*

Predefined Bay Control One-line Diagrams

The SEL-451-4 supports as many as 25 user-selectable bay configurations. Take great care to select a bay configuration that exactly matches the bay configuration being controlled. This section defines the one-line diagram and illustrates 25 of the bay configurations supported in the SEL-451-4:

- *One-Line Diagram on page A.5.35*
- *Main Bus and Auxiliary Bus on page A.5.36*
- *Bus 1, Bus 2, and Transfer Bus on page A.5.38*
- *Main Bus and Transfer Bus on page A.5.40*
- *Main Bus on page A.5.41*
- *Breaker-and-a-Half on page A.5.42*
- *Ring Bus on page A.5.45*
- *Double Bus Double Breaker on page A.5.46*
- *Source Transfer Bus on page A.5.48*

Circuit Breaker Status Logic

Circuit Breaker Status Logic

The SEL-451 includes circuit breaker status logic for two circuit breakers. The circuit breaker status logic for Circuit Breaker 1 and Circuit Breaker 2 are identical. The circuit breaker status logic uses the 52AA1 Relay Word bit and open phase detection logic to determine the state of Circuit Breaker 1, and declare Circuit Breaker 1 alarm conditions. A Circuit Breaker 1 alarm condition is declared by the circuit breaker status logic, when Relay Word bit 52AA1 deasserts and current is detected by the open phase detection logic. See *Circuit Breaker Status Logic on page R.1.91* for a complete description of circuit breaker status logic Relay Word bits and circuit breaker status logic diagrams.

The SEL-451 includes internal circuit breaker status logic for two circuit breakers. The SEL-451-4 additionally includes SELOGIC control equations in the Bay settings for user-configurable circuit breaker status and alarm logic for up to three circuit breakers.

Disconnect Logic

Disconnect Switch Close and Open Control Logic

Introduction

The Disconnect Switch Close and Open Control Logic generates the output signal necessary to perform the open and close disconnect operations. For disconnect switch control operations to complete, close and open signals remain asserted with settable seal-in timers, 89CSIT*m* and 89OSIT*m*. All disconnect operation methods drive the Close and Open Control Logic in the SEL-451-4 (HMI, ASCII, SELOGIC control equations, and Fast Operate). The SEL-451-4 provides independent control for as many as ten disconnect switches.

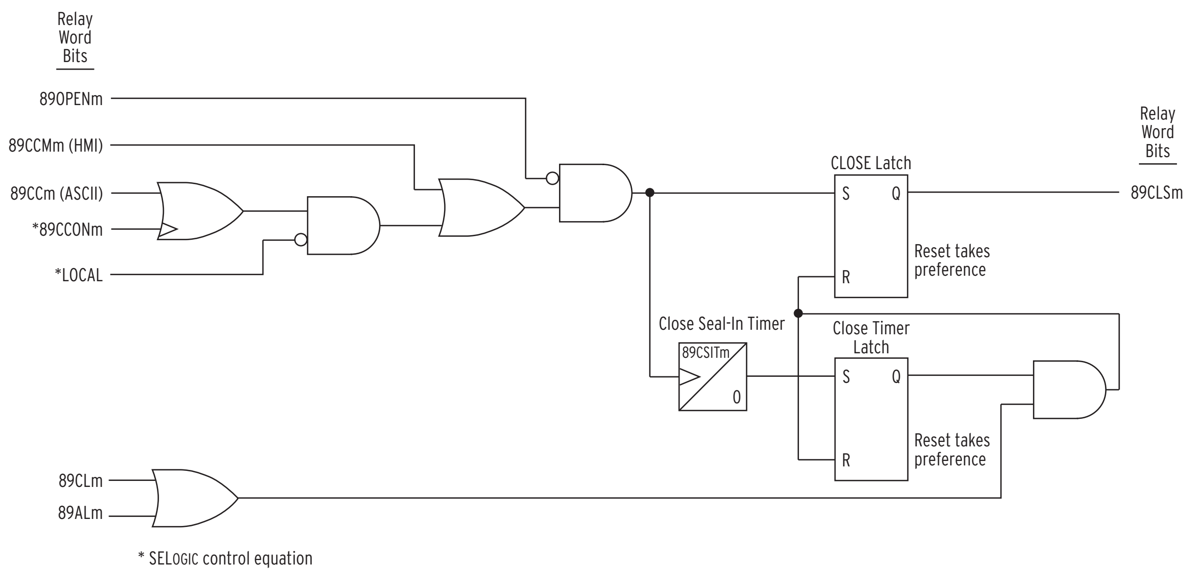


Figure 5.1 Disconnect Switch Close Logic

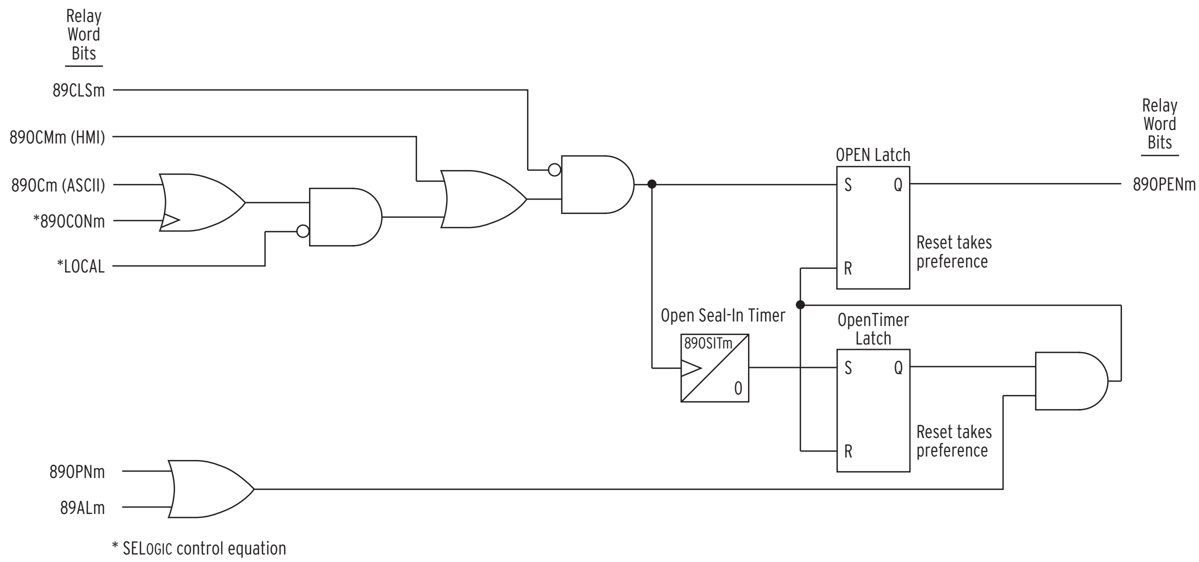


Figure 5.2 Disconnect Switch Open Logic

Disconnect Switch Close and Open Control Logic Status Inputs

89CLSm, 89OPENm

Disconnect Switch Close Logic (*Figure 5.1*) and Open Logic (*Figure 5.2*) generate Relay Word bits 89CLS*m* and 89OPEN*m*. These are inputs to the opposing logic, for example, Relay Word bit 89CLS*m* is an input to the Disconnect Open Logic for Disconnect *m*. These inputs guarantee that an open and close disconnect signal cannot occur at the same time.

89CLm, 89OPNm

The 89CL*m* and 89OPN*m* Relay Word bits report the state of the disconnect switches. If Relay Word bit 89CL*m* is asserted, the disconnect switch is closed; if Relay Word bit 89OPN*m* is asserted, the disconnect switch is open. See *Figure 5.3* for a description of these inputs. When Relay Word bit 89CL*m* asserts and the close seal-in timer expires, the 89CLS*m* signal deasserts. When Relay Word bit 89OPN*m* asserts and the open seal-in timer expires, the 89OPEN*m* signal deasserts.

89ALm

The disconnect switch status and alarm logic in *Figure 5.3* generates the 89AL*m* Relay Word bit. When Relay Word bit 89AL*m* asserts and the associated seal-in timers expire, the 89CLS*m*/89OPEN*m* signals deassert.

LOCAL

The LOCAL Relay Word bit is the result of the LOCAL SELOGIC control equation found in the Bay settings class, see *Bay Settings (SEL-451-4 Relay) on page R.10.49*. When the LOCAL Relay Word bit is deasserted, the **89CLOSE**, **89OPEN**, SELOGIC disconnect close/open, and Fast Operate disconnect close/open commands can perform disconnect close and open operations.

Disconnect Switch Close and Open Control Logic Action Inputs

89CCONm, 89OCONm

89CCON*m* and 89OCON*m* SELOGIC control equations are for programmable close and open disconnect switch operations, see *Bay Settings (SEL-451-4 Relay) on page R.10.49*. The LOCAL Relay Word bit must be deasserted for the SELOGIC close or open to initiate a disconnect switch operation. Use care when using SELOGIC control equations for disconnect switch operations; this disconnect operate method is not supervised by the breaker jumper or appropriate relay access levels as is the case with other disconnect operation methods.

89CCMm, 89OCMm

89CCM*m* and 89OCM*m* Relay Word bits pulse for one-quarter cycle when close or open disconnect operations are executed from the one-line diagram. The LOCAL Relay Word bit must be asserted, as shown in *Figure 5.4* and *Figure 5.5*, for Relay Word bits 89CCM*m* or 89OCM*m* to assert.

89CCm, 89OCm

The **89CLOSE** command or Fast Operate disconnect close message, pulses Relay Word bit 89CC*m* for one-quarter cycle. The **89OPEN** command or Fast Operate disconnect open message, pulses Relay Word bit 89OC*m* for one-quarter cycle. The LOCAL Relay Word bit must be deasserted for a disconnect switch operation to be initiated by a Fast Operate message or **89CLOSE** and **89OPEN** commands.

Disconnect Switch Close and Open Control Logic Settings

89CSITm, 89OSITm

89CSIT*m* and 89OSIT*m* settings are for defining the time required for the disconnect switch to complete a close or open operation. See *Bay Settings (SEL-451-4 Relay) on page R.10.49* for seal-in timer setting definitions.

Disconnect Switch Close and Open Control Logic Output

89CLSm, 89OPENm

The 89CLS*m* and 89OPEN*m* Relay Word bits are used in SELOGIC output equations to perform close and open disconnect switch operations.

Disconnect Switch Close and Open Control Logic Processing

Figure 5.1 shows the Disconnect Switch Close Logic and *Figure 5.2* shows the Disconnect Switch Open Logic.

In a normal close operation, the 89OPEN*m* Relay Word bit is deasserted. With the 89OPEN*m* Relay Word bit deasserted, any of the SEL-451-4 disconnect switch operate methods set the CLOSE Latch and initiate the Close Seal-In Timer, 89CSIT*m*. Set Relay Word bit 89CLS*m* into a SELOGIC output equation to drive the motor of the disconnect switch. The output of the CLOSE Latch sets the 89CLS*m* output. The Close Seal-In Timer, 89CSIT*m*, keeps Relay Word bit 89CLS*m* asserted long enough for the disconnect operation to complete. The 89CL*m* input typically asserts before the disconnect switch has fully completed the close operation. For this reason, set the 89CSIT*m* time to be longer than the expected disconnect switch operate time. To account for slow operate times due to cold weather or low battery

⚠CAUTION
The outputs in the SEL-451-4 are not designed to break the coil current in the disconnect motor. An auxiliary contact with adequate current interrupting capacity must clear the coil current in the disconnect motor before the output on the SEL-451-4 opens. Failure to observe this safeguard could result in damage to the SEL-451-4 output contacts.

voltage, set the 89CSIT*m* time 10 to 15 percent longer than the expected operate time. This guarantees that the disconnect switch has fully operated before the 89CLS*m* signal is removed. When the 89CSIT*m* seal-in timer expires and the disconnect switch normally open contact closes (89CL*m* asserted), the 89CLS*m* output deasserts. This completes an open-to-close cycle of the Disconnect Close Logic; the Disconnect Open Logic in *Figure 5.2* behaves in the same manner.

Disconnect switch status and alarm logic in *Figure 5.3* generates Relay Word bit 89AL*m*. When Relay Word bit 89AL*m* asserts, a disconnect alarm condition exists. The 89AL*m* Relay Word bit ensures that the close or open signal does not remain asserted when a disconnect switch alarm condition exists. When Relay Word bit 89AL*m* asserts and the seal-in timer expires, the 89CLS*m* or 89OPEN*m* signals deassert.

When a close operation is accidentally initiated with the disconnect switch already closed, the 89CLS*m* Relay Word bit asserts for 89CSIT*m* time. If an open command was sent within the 89CSIT*m* time, an open and close signal could be sent to the disconnect switch at the same time. The 89CLS*m* Relay Word bit input to the Disconnect Switch Open Logic guarantees that open and close commands are not transmitted to the disconnect switch simultaneously. When the 89CLS*m* Relay Word bit deasserts, an open command can be performed. The Relay Word bit 89OPEN*m* input to the Disconnect Switch Close Logic serves the same purpose.

Disconnect Switch Status and Alarm Logic

Introduction

The disconnect switch auxiliary contacts are inputs to the Disconnect Switch Status and Alarm Logic as shown in *Figure 5.3*. SELOGIC control equation 89AM*m* is the input for the normally open a auxiliary contact, and SELOGIC control equation 89BM*m* is the input for the normally closed b auxiliary contact. For the Status and Alarm Logic to function correctly, wire the a and b contacts each to separate inputs on the SEL-451-4. Depending on the one-line diagram selected, as many as ten disconnect switches are supported. This means that for ten disconnect switches, you should wire twenty relay contact inputs to the disconnect switch auxiliary contacts. When ordering the SEL-451-4, consider the number of inputs required for the bay configuration being controlled. The number of auxiliary contacts for some bay configurations may require that the SEL-451-4 be configured with additional I/O boards; see the SEL-451 Model Option Table for ordering options.

Disconnect operations are possible with only one auxiliary contact input, but the Status and Alarm Logic will not provide accurate Alarm, Operation in Progress, or Bus-zone protection reporting. When only one auxiliary contact is available for input, set one SELOGIC control equation to the available auxiliary contact input and invert the other SELOGIC control equation:

89AMm := **IN102**

89BMm := **!IN102**

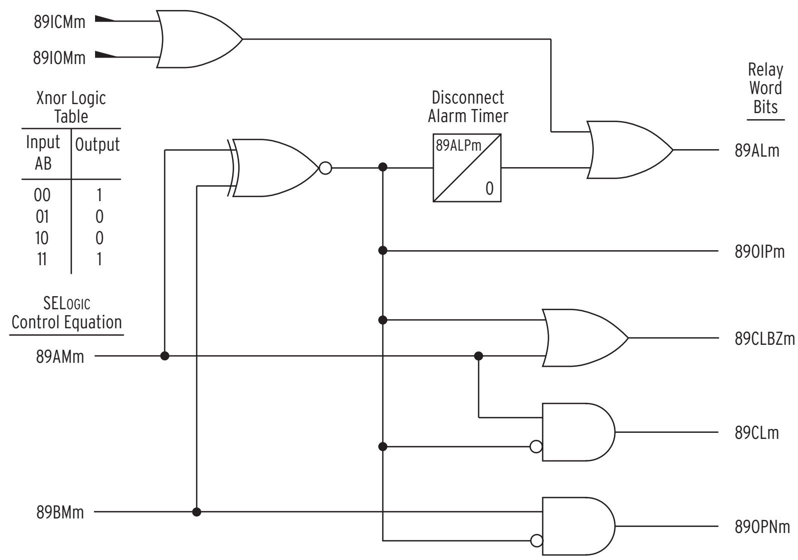


Figure 5.3 Disconnect Switch Status and Alarm Logic

Disconnect Switch Status and Alarm Logic Inputs

89AMm, 89BMm

The 89AM*m* and 89BM*m* SELOGIC control equations represent the normally open and normally closed disconnect switch auxiliary contacts. Typically, these are set to SEL-451-4 inputs that are wired to the auxiliary contacts.

89ICMm, 89IOMm

If the close or open immobility timer expires, 89ICM*m* or 89IOM*m* asserts. Expiration of the immobility timer indicates that the disconnect failed to move for a disconnect switch close or open command executed from the one-line diagram. See *Close and Open Immobility Timer Logic on page A.5.9*.

Disconnect Switch Status and Alarm Logic Settings

89ALPm

This setting in the Bay settings class defines the disconnect switch alarm time. See *Bay Settings (SEL-451-4 Relay) on page R.10.49*.

Disconnect Switch Status and Alarm Logic Outputs

89ALm

If a disconnect switch operation executed from the one-line diagram does not initiate, the 89CSIT*m* or 89OSIT*m* timer expires and the 89AL*m* Relay Word bit asserts. See *Close and Open Immobility Timer Logic on page A.5.9*. The 89AL*m* Relay Word bit also asserts after the 89ALP*m* timer expires. Expiration of the 89ALP*m* timer indicates that an initiated disconnect operation failed to complete and the disconnect switch is in an undetermined state.

89OIPm

When Relay Word bit 89OIP*m* asserts, a disconnect switch operation is in progress. Relay Word bit 89OIP asserts when the states of the 89BM*m* and 89AM*m* Relay Word bits are the same, i.e., both asserted or both deasserted.

89CLBZm

This Relay Word bit asserts when the disconnect operation is in progress or when the disconnect switch is closed (89AM*m* asserted). The 89CLBZ*m* Relay Word bit is used for Bus Zone protection purposes.

89CLm

When Relay Word bit 89CL*m* asserts, the disconnect switch is closed.

89OPNm

When Relay Word bit 89OPN*m* asserts, the disconnect switch is open.

Disconnect Switch Status and Alarm Logic Processing

Figure 5.3 shows the Disconnect Switch Status and Alarm Logic. Inputs to this logic are the Normally Open (89AM*m*) and Normally Closed (89BM*m*) disconnect switch auxiliary contacts. As discussed before, the SEL-451-4 supports as many as ten disconnect switches, depending on the one-line diagram contents. For proper execution of this logic, the SEL-451-4 requires input from each of the disconnect switch auxiliary contacts (89AM*m*, 89BM*m*). When ordering the SEL-451-4 for bay control, remember that an optional I/O board may be needed for some bay configurations.

To understand the logic in *Figure 5.3*, consider an open-to-close operation. The first disconnect operation scenario looks at a successful open-to-close disconnect switch operation; a successful close-to-open operation is similar. In the open state, 89AM*m* is deasserted and 89BM*m* is asserted. Once a close command is initiated in the SEL-451-4, the disconnect switch starts to move and 89BM*m* deasserts. When 89BM*m* deasserts, the 89ALP*m* pickup timer starts to time. With 89BM*m* deasserted, the state of the disconnect switch cannot be determined, because both disconnect switch auxiliary contacts are deasserted. Set the 89ALP*m* timer longer than the expected undetermined disconnect state time, but less than the 89CSIT*m* or 89OSIT*m* seal-in timers. If the 89ALP*m* timer expires, the 89AL*m* Relay Word bit asserts. Relay Word bit 89AL*m* asserts when the disconnect operation does not complete successfully. When the 89ALP*m* timer begins timing, the operation in progress, Relay Word bit 89OIP*m*, and Relay Word bit 89CLBZ*m* assert. The 89CLBZ*m* Relay Word bit is for bus-zone protection, this bit asserts when the 89BM*m* input deasserts.

During the disconnect switch operation-in-progress condition, Relay Word bits 89CL*m* and 89OPN*m* are both deasserted to indicate that the state of the disconnect switch is undetermined. Once the disconnect switch auxiliary contact Relay Word bit 89AM*m* asserts, the condition has been met to declare the disconnect switch closed. When this condition occurs, the 89CL*m* Relay Word bit asserts, 89ALP*m* stops timing, and the 89OIP*m* Relay Word bit deasserts. This sequence completes a successful open-to-close disconnect switch operation.

The second scenario regarding the Disconnect Switch Status and Alarm Logic involves an unsuccessful open-to-close operation. The operation up to the point when the 89ALP*m* starts timing is the same as discussed previously.

When the 89ALP*m* timer is timing, the disconnect switch has started to move. If the disconnect switch operation does not complete in the 89ALP*m* time, the SEL-451-4 asserts Relay Word bit 89AL*m* and reports the state of the disconnect switch as undetermined.

Close and Open Immobility Timer Logic

Introduction

The Close and Open Immobility Timer Logic detects when a disconnect operation failed to initiate.

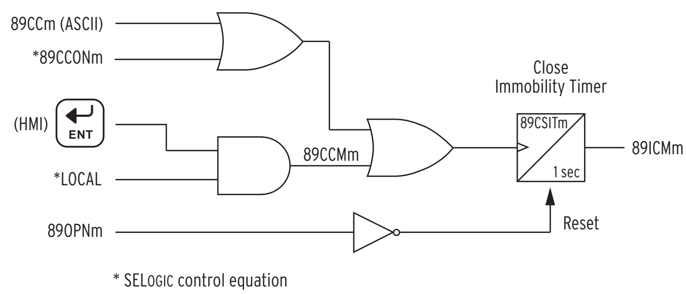


Figure 5.4 Close Immobility Timer Logic

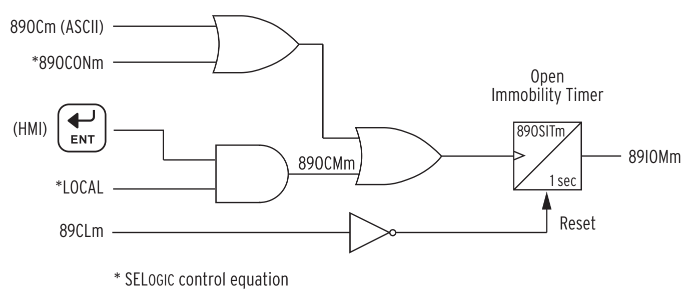


Figure 5.5 Open Immobility Timer Logic

Close and Open Immobility Timer Logic Inputs

LOCAL

The LOCAL Relay Word bit supervises local disconnect control and is based on the LOCAL SELOGIC control equation in the Bay settings class. See *Bay Settings (SEL-451-4 Relay) on page R.10.49*. Disconnect switch operations from the one-line diagram are possible when the LOCAL Relay Word bit is asserted, in other words, the LOCAL Relay Word bit prevents control from the HMI without proper supervision.

89CCm, 89OCm

Relay Word bit 89CC*m* asserts for one-quarter cycle for an **89CLOSE** command or Fast Operate close message. 89OC*m* asserts for one-quarter cycle for an **89OPEN** command or Fast Operate open message.

89CCONm, 89OCONm

Relay Word bit 89CCON*m* asserts when the disconnect *m* close SELOGIC control equation is true. Relay Word bit 89OCON*m* asserts when the disconnect *m* open SELogic control equation is true.

89CCMm, 89OCMm

Relay Word bits 89CCM*m* and 89OCM*m* assert for one-quarter cycle when the LOCAL Relay Word bit asserts and a close or open disconnect command is executed from the one-line diagram.

89CLm, 89OPNm

The 89CL*m* and 89OPN*m* inputs report the state of the disconnect switch. See *Disconnect Switch Status and Alarm Logic on page A.5.6*. If Relay Word bit 89CL*m* is asserted, the disconnect switch is closed; if Relay Word bit 89OPN*m* is asserted, the disconnect switch is open.

Close and Open Immobility Timer Logic Settings

89CSITm, 89OSITm

89CSIT*m* and 89OSIT*m* timer settings in the Bay settings class define the close and open seal-in timers. See *Bay Settings (SEL-451-4 Relay) on page R.10.49*.

Close and Open Immobility Timer Logic Outputs

89ICMm, 89IOMm

When 89ICM*m* or 89IOM*m* asserts, the close or open immobility timer has expired. Any disconnect close operate method that failed to initiate successfully asserts 89ICM*m*. Any disconnect open operate method that failed to initiate successfully asserts 89IOM*m*.

Close and Open Immobility Timer Logic Processing

The Close Immobility Timer Logic detects when one of the close disconnect switch methods does not initiate successfully. The Open Immobility Timer Logic is similar.

When a close disconnect is initiated, the rising edge triggered Close Immobility Timer starts timing. Once the disconnect switch starts to move, Relay Word bit 89OPN*m* deasserts. If the 89OPN*m* Relay Word bit deasserts, the close immobility timer resets and the 89ICM*m* remains deasserted. If the 89OPNm Relay Word bit stays asserted, the close immobility timer does not reset. After the close immobility timer expires, 89ICM*m* asserts for one second. When 89ICM*m* asserts, the close operation failed to initiate. 89ICM*m* is an input to the disconnect switch status and alarm logic for alarm condition indications. See *Disconnect Switch Status and Alarm Logic on page A.5.6*.

This logic also uses the LOCAL Relay Word bit to supervise front-panel operations. With the LOCAL Relay Word bit deasserted, no disconnect operations can be initiated from the one-line diagram. With the LOCAL Relay Word bit asserted, Relay Word bit 89CCM*m* asserts for one-quarter cycle when the **ENT** pushbutton is pressed and a disconnect switch is highlighted in the one-line diagram.

Close, Open, and Undetermined State Indications

This subsection discusses the way the close and open immobility timers work in conjunction with the disconnect alarm timer to provide disconnect control and alarm indications. When the disconnect switch main contact is stationary (closed or open) the state of the disconnect switch is easily determined.

If the disconnect switch main contact is open:

- normally closed b auxiliary contact (89BM*m* asserted) is closed
- normally open a auxiliary contact (89AM*m* deasserted) is open

If the disconnect switch main contact is closed:

- normally closed b auxiliary contact (89BM*m* deasserted) is open
- normally open a auxiliary contact (89AM*m* asserted) is closed

If an operation of the disconnect switch is in progress, the state of the disconnect switch main contact is undetermined. Any undetermined state of the disconnect switch main contact should be monitored. The SEL-451-4 can be configured to wait for the disconnect switch operation to complete and issue an alarm if the disconnect switch remains in the undetermined state longer than the 89ALP*m* time. *Figure 5.6* illustrates how the state of the auxiliary contacts change for an open-to-close operation in progress and how the 89CSIT*m* and 89ALP*m* timers are configured to manage the undetermined time. The close-to-open scenario would be similar.

With the disconnect switch in the open state, the normally closed b auxiliary contact is closed (89BM*m* asserted) and the normally open a auxiliary contact is open (89AM*m* deasserted). The 89CSIT*m* seal-in timer starts timing when a disconnect switch close command is issued; see *Disconnect Switch Close and Open Control Logic on page A.5.3*. The output of the 89CSIT*m* seal-in timer keeps the close signal asserted for the duration of the expected disconnect switch operate time. Set the seal-in timer 10 to 15 percent longer than the expected disconnect operate time, to allow for slow disconnect operation times caused by cold temperatures or low battery voltages.

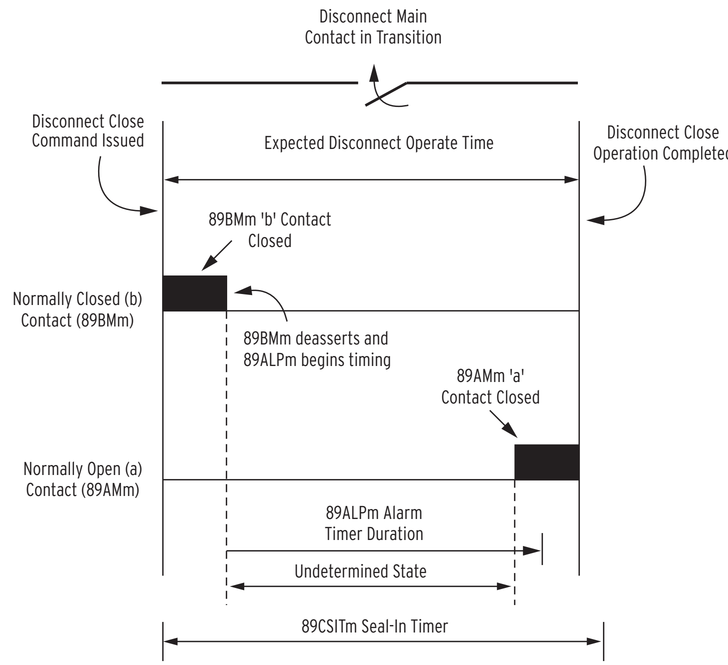


Figure 5.6 Disconnect in Transition

When the normally closed auxiliary contact (SELOGIC input 89BM*m*) deasserts, the disconnect switch is in an undetermined state. No proper position indication from either of the disconnect switch auxiliary contacts (89BM*m* or 89AM*m*) is available. Once the auxiliary normally closed contact (SELOGIC input 89BM*m*) deasserts, the 89ALP*m* timer starts timing. The 89ALP*m* timer monitors the undetermined state of the disconnect switch. For the 89ALP*m* timer to initialize, the disconnect switch has to move a minimum distance to open the normally closed auxiliary contact (open-to-close operation). Set the 89ALP*m* timer longer than the expected undetermined state time, but less than the 89CSIT*m* seal-in timer. If the normally open auxiliary contact fails to close within the undetermined state time, the 89ALP*m* timer expires and an alarm condition is declared. See *Disconnect Switch Status and Alarm Logic on page A.5.6*.

The Close Immobility Logic starts the Close Immobility Timer for an operation where the disconnect switch does not move the minimum distance to open the normally closed auxiliary contact (open-to-close operation). When the close immobility timer expires, an alarm condition is declared and Relay Word bit 89AL*m* asserts. If the disconnect moves enough to open the normally closed auxiliary contact, the Close Immobility timer resets and no alarm condition is declared. See *Figure 5.4*.

Bay Control Front-Panel Operations

SEL-451-4 Front Panel

Figure 5.7 shows the front-panel pushbuttons for the SEL-451-4. With default settings, some pushbutton operations in the SEL-451-4 differ from pushbutton operations in other SEL-451 relays.

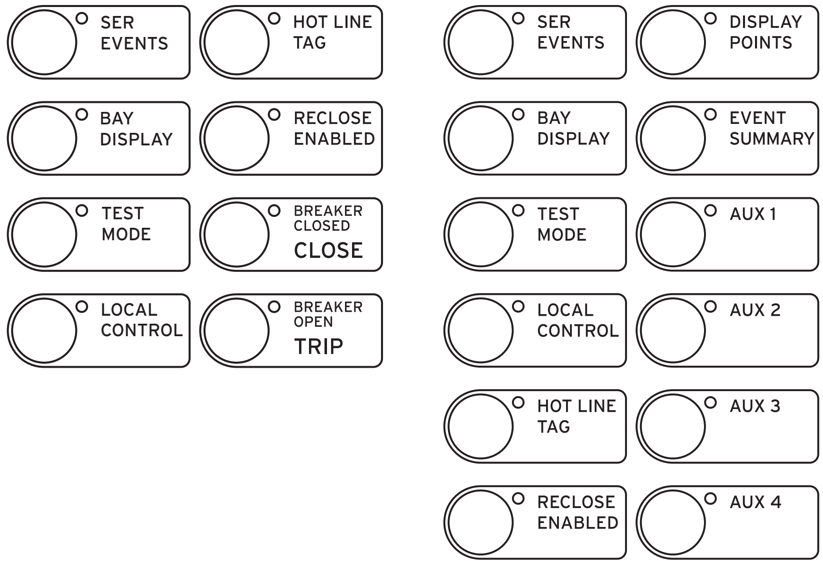


Figure 5.7 SEL-451-4 Front-Panel Pushbuttons

The right-side pushbutton functions are common to the SEL-451 family of relays; descriptions of these pushbuttons are found in *Front-Panel Operator Control Pushbuttons on page U.5.42*. The pushbutton functions unique to the SEL-451-4 are described in *Figure 5.8*.

SELOGIC Setting	Operator Control Pushbutton LED	Description
PB1_LED = PB1 #SER EVENTS	SER EVENTS	Press this operator control pushbutton to display the SER Events on the front panel screen. Selectable Operator Pushbutton programming for HMI screen display is discussed in ①. The corresponding LED illuminates when the pushbutton is pressed.
PB2_LED = PB2 #BAY DISPLAY	BAY DISPLAY	Press this operator control pushbutton to display the Bay Control on the front panel screen. Operator Pushbutton programming for HMI screen display is discussed in ①. The corresponding LED illuminates when the pushbutton is pressed.
PB3_LED = PLT03 #TEST MODE	TEST MODE	Press this operator control pushbutton to enable/disable test mode. To utilize this feature, see the test mode discussion in ②. The corresponding LED illuminates to indicate the enabled state.
PB4_LED = LOCAL #LOCAL CONTROL	LOCAL CONTROL	Press this operator control pushbutton to enable/disable local disconnect control. The corresponding LED illuminates to indicate the enabled state.

① Front-Panel Operator Control Pushbuttons on page U.5.42, ② Test Mode on page A.5.14

Figure 5.8 SEL-451-4 Operator Control Pushbuttons

Test Mode

Test mode provides the ability to test logic, but not to actually operate an output. With the default settings, protection latch three (PLT03) is controlled by front-panel pushbutton 3 (PB3). PB3 enables/disables test mode by asserting and deasserting Relay Word bit PLT03. Below is an example of output logic that uses test mode. When Relay Word bit PLT03 asserts, test mode is enabled and the output logic below does not operate. When Relay Word bit PLT03 deasserts, test mode is disabled and the output logic below operates.

OUT103 := **89CLS1 AND NOT 52CLS1 AND NOT PLT03**

OUT104 := **89OPEN1 AND NOT 52CLS1 AND NOT PLT03**

One-Line Diagram and One-Line Diagram Labels

Figure 5.9 is an example of one of 25 selectable one-line diagrams in the SEL-451-4. Select the one-line diagram from the MIMIC setting in the Bay settings class. If an additional user-selectable bay type has been configured, it is selected by setting MIMIC to any number in the range of 26–100. The Bay settings class also has additional Bay class settings for defining labels and analog quantities. See *Bay Settings (SEL-451-4 Relay) on page R.10.49*. One-line diagrams are comprised of the following (see *Predefined Bay Control One-Line Diagrams on page A.5.35* for apparatus supported within each predefined one-line diagram):

- Bay Names and Bay Labels (Bay Labels available in one-line diagrams 14, 17, 18, and 23. All other one-line diagrams use the Bay Name.)
- Busbars and Busbar Labels
- Breakers and Breaker Labels
- Disconnect Switches and Disconnect Switch Labels
- Analog display points

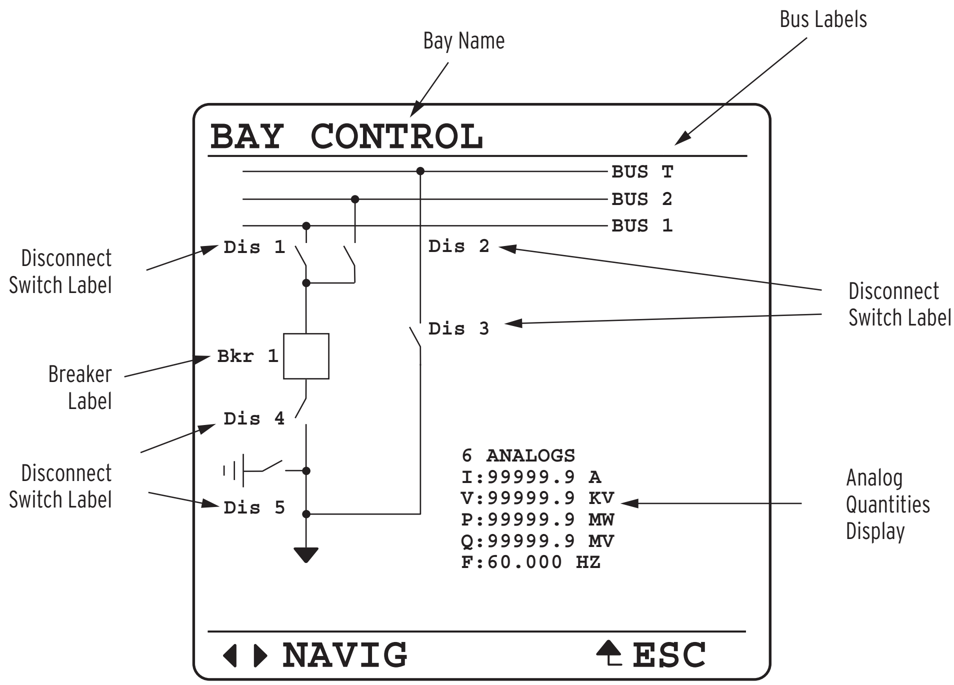


Figure 5.9 Bay Control One-Line Diagram

Front-Panel Pushbutton Navigation Operations in the One-Line Diagram

Navigation within the one-line diagram requires that the front-panel access level be at Breaker Access Level or higher and the Breaker Jumper be installed. If navigation is attempted when:

- the front panel is not at the Breaker Access Level or higher and passwords are enabled, the relay prompts for the Breaker Access Level password as illustrated in *Password on page U.5.15*.
- the Breaker Jumper is not installed, the `Breaker Control Disabled Please Install the Breaker Jumper` message briefly appears on the screen.

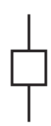
Use the arrow pushbuttons on the front panel to navigate within the one-line diagram. When you first select the one-line diagram, none of the apparatus on the one-line diagram are highlighted. Press a **Left Arrow** or **Right Arrow** pushbutton to enter the one-line diagram and highlight the apparatus in the one-line diagram. Once you enter the one-line diagram, navigation between the disconnect switch and circuit breaker symbols in the one-line diagram is as follows:

- Pressing the **Right Arrow** or **Down Arrow** key highlights the elements from left-to-right and top-to-bottom.
- When reaching the right-most bottom element, the following **Right Arrow** or **Down Arrow** keystroke “rolls over” and again highlights the left-most top element.
- The **Left Arrow** or **Up Arrow** key operates in reverse, i.e., from right-to-left, and bottom-to-top.
- Select the highlighted symbol: **ENT**
- Go back to the previous screen: **ESC**

Circuit Breaker and Disconnect Definitions and State Representations

Table 5.1 shows the apparatus definitions and symbols displayed on the one-line diagram.

Table 5.1 Circuit Breaker and Disconnect Switch Definitions

Circuit Breaker Open	Circuit Breaker Closed	Disconnect Open	Disconnect Closed
			

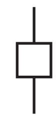
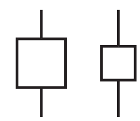
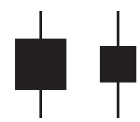
NOTE: The intermediate states only apply to disconnect switches because circuit breaker operations have a short duration.

Each apparatus (circuit breaker or disconnect switch) can be in one of the following six states:

- Open, not highlighted
- Open, highlighted
- Closed, not highlighted
- Closed, highlighted
- Intermediate, not highlighted (intermediate = transition between open and closed states)
- Intermediate, highlighted

Table 5.2 describes how the one-line diagram represents the different states of the breakers, and how highlighting the breaker affects the display of the symbol.

Table 5.2 Circuit Breaker State Representations

Apparatus Position	Symbol	Asserted Relay Word Bit
Circuit breaker open, not highlighted		NOT 52CLSM*m*
Circuit breaker open, highlighted[a]		NOT 52CLSM*m*
Circuit breaker closed, not highlighted		52CLSM*m*
Circuit breaker closed, highlighted[a]		52CLSM*m*

[a] When the circuit breaker is highlighted, the two symbols shown alternate in the display.

Table 5.3 describes how the one-line diagram represents the different states of the disconnect switches, and how highlighting the disconnect switch affects the display of the symbol. Unlike the fast operation time of the circuit breaker, the disconnect switch operation-in-progress time is longer than the breaker operation time. Table 5.3 describes how apparatus appear in the one-line diagram when a disconnect operation is in progress.

Table 5.3 Disconnect Switch State Representations (Sheet 1 of 2)

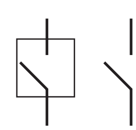
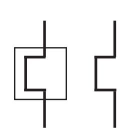
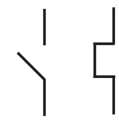
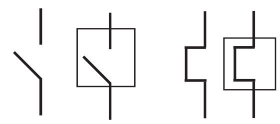
Apparatus Position	Symbol	Asserted Relay Word Bit
Disconnect open, not highlighted		89OPN*k*
Disconnect closed, not highlighted		89CL*k*
Disconnect open, highlighted[a]		89OPN*k*
Disconnect closed, highlighted[a]		89CL*k*

Table 5.3 Disconnect Switch State Representations (Sheet 2 of 2)

Apparatus Position	Symbol	Asserted Relay Word Bit
Disconnect Operation In Progress, not highlighted[b]		89OIP*k*
Disconnect Operation In Progress, highlighted[c]		89OIP*k*

[a] When the disconnect switch is highlighted and no operation is in progress, a square box alternately frames the switch symbol.

[b] For a disconnect switch operation in progress where the disconnect switch is not highlighted, the symbol displayed is the present state symbol and then the opposite state symbol. This sequence repeats until the disconnect switch operation completes.

[c] For a disconnect switch operation in progress where the disconnect is highlighted, the symbol displayed is the present state symbol, then the present state symbol highlighted, then the opposite state symbol, and finally the opposite state symbol highlighted. This sequence repeats until the disconnect switch operation completes.

The one-line diagram indicates highlighted text with a box around the current selection.

Circuit Breaker and Disconnect Switch Operations From the Front Panel

Circuit Breaker Open/Close

Control of as many as two circuit breakers is offered within the one-line diagram. However, the Global NUMBK setting determines the actual number of breakers controlled in the one-line diagram. Only highlighted breakers on the one-line diagram can initiate breaker open or close operations from the HMI. The NUMBK setting controls circuit breaker highlighting in the one-line diagram. If NUMBK := 1, only Breaker 1 will highlight; if NUMBK := 2, Breakers 1 and 2 will highlight. The NUMBK setting does not provide circuit breaker control for breakers that do not exist on the selected one-line diagram. Although status for as many as three circuit breakers is available in certain one-line diagrams, operation is only supported for Breakers 1 and 2. Because Breaker 3 is for status only, the NUMBK setting does not accept three as a setting.

Figure 5.10 shows the Breaker Control Screens available when the **ENT** pushbutton is pressed with the circuit breaker highlighted, *Figure 5.10* (a). Pressing the **ENT** pushbutton with the breaker highlighted and the LOCAL Relay Word bit asserted displays the Breaker Control Screen in *Figure 5.10* (b). After you enter the screen in *Figure 5.10* (b), the relay performs the circuit breaker operations as outlined in *BREAKER CONTROL on page U.5.24*. If the LOCAL Relay Word bit is not asserted when the **ENT** pushbutton is pressed, the relay displays the screen in *Figure 5.10* (c) for three seconds and then returns to the screen in *Figure 5.10* (a).

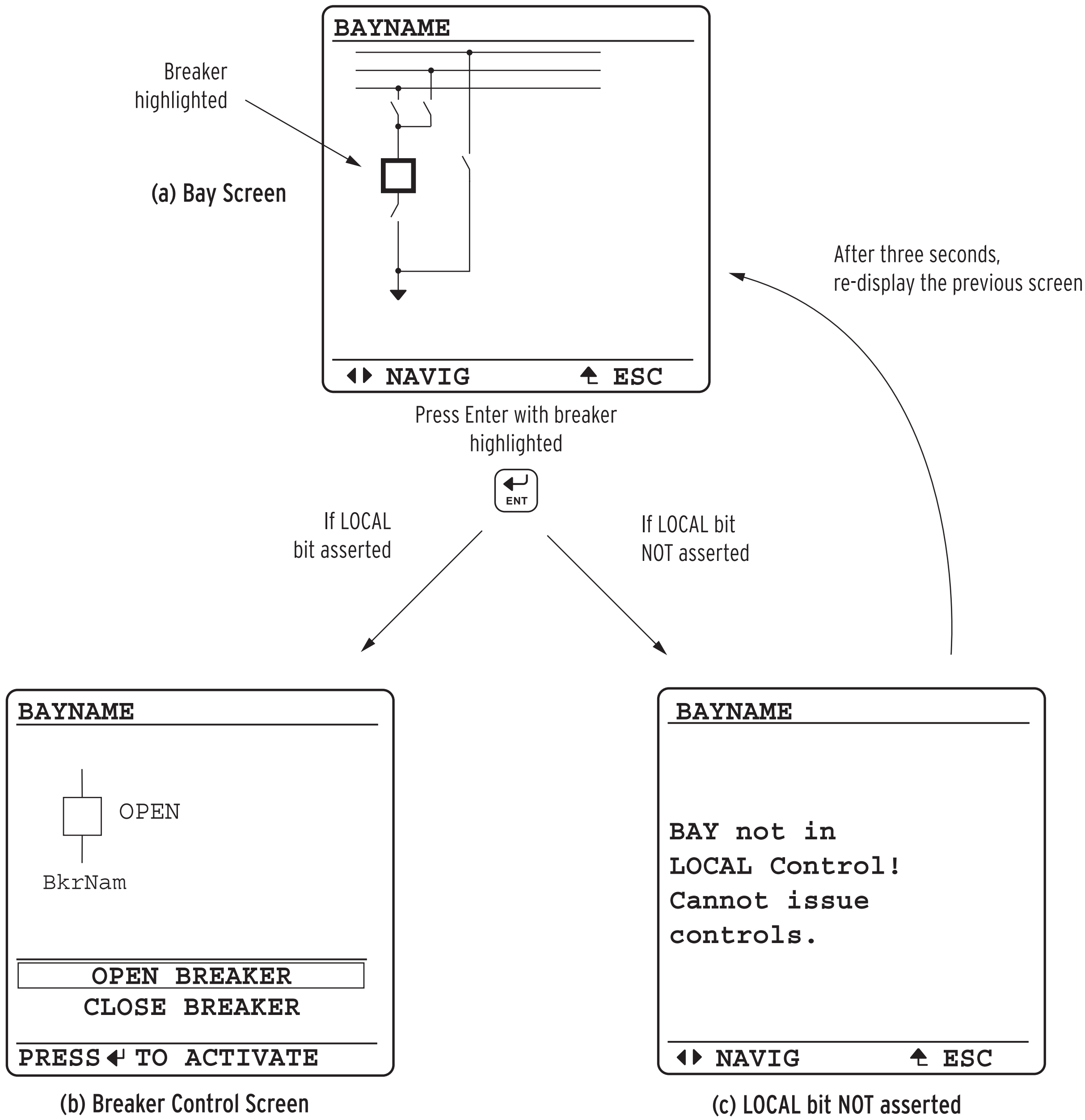


Figure 5.10 Screens for Circuit Breaker Selection

Disconnect Switch Open/Close

Figure 5.11 shows the Disconnect Control Screens available when you press the **ENT** pushbutton with the disconnect switch highlighted, *Figure 5.11* (a). If the LOCAL Relay Word bit is asserted and the disconnect switch is highlighted when you press the **ENT** pushbutton, the Disconnect Control Screen in *Figure 5.11* (b) appears. Use the **Up Arrow** and **Down Arrow** pushbuttons to navigate between the disconnect control functions in *Figure 5.11* (b). If the LOCAL Relay Word bit is not asserted when the **ENT** pushbutton is pressed, the relay displays screen in *Figure 5.11* (c) for three seconds and then returns to the screen in *Figure 5.11* (a).

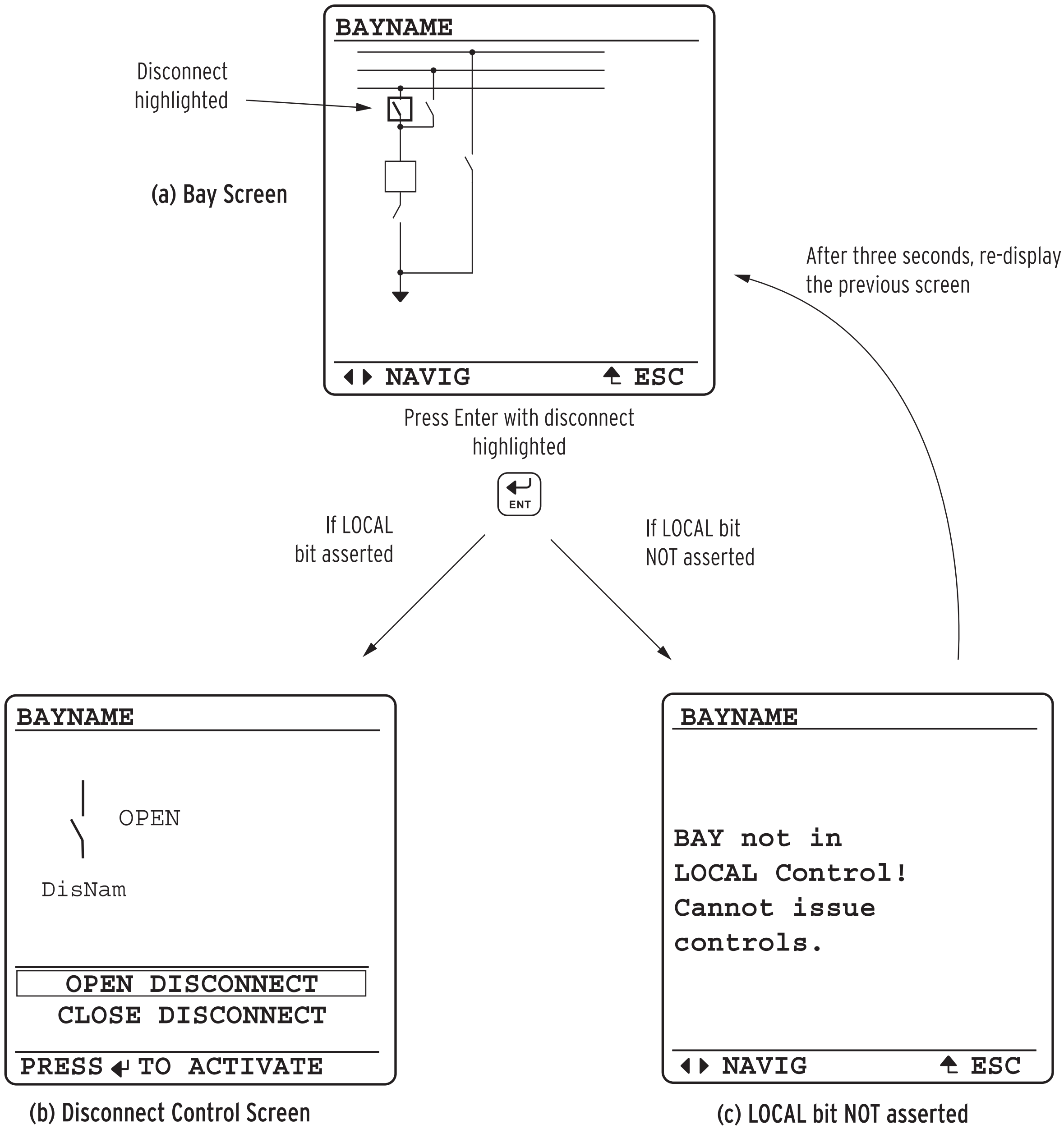


Figure 5.11 Screens for Disconnect Switch Selection

Figure 5.12, *Figure 5.13*, and *Figure 5.14* show all the possible screens during an open-to-close operation of Disconnect 1. Operation of Disconnect 2–Disconnect 5 is identical. Close-to-open operations are similar, the only difference being that the open Relay Word bits apply instead of the close Relay Word bits. The screen in *Figure 5.12* (a) is displayed after you press the **ENT** pushbutton with Disconnect 1 open and highlighted in the one-line diagram. *Figure 5.12* (a) is Screen (c) in *Figure 5.11*.

When you enter the disconnect screen in *Figure 5.12* (a), the state that the disconnect switch is in is highlighted, in other words, if Relay Word bit 89OPN1 is asserted, the `OPEN DISCONNECT` text has a box drawn around it.

To close the disconnect switch, use the **Up Arrow** or **Down Arrow** pushbutton to highlight the `CLOSE DISCONNECT` text.

If Relay Word bit 89CCM1 asserts after you press the **ENT** key, the relay displays the screen with the caption CLOSE COMMAND ISSUED in *Figure 5.12* (c) for three seconds. While the disconnect operation is in progress, the relay displays the screen with the caption IN PROGRESS in *Figure 5.13* (a) and the disconnect symbol alternately displays the present state symbol and the opposite state symbol. If another disconnect operation attempt is made while a disconnect operation is in progress, the relay displays the screen with the caption *NOT ALLOWED* in *Figure 5.13* (b) for three seconds and then the relay returns to the screen in *Figure 5.13* (a).

If Relay Word bit 89CCM1 does not assert, the relay displays the *NOT ALLOWED* error message shown in *Figure 5.12* (d) for three seconds and then displays again the screen in *Figure 5.12* (b).

When Relay Word bit 89CCM1 asserts, the Close Immobility Timer starts. If Relay Word bit 89CCM1 asserts, two scenarios are possible: the disconnect fails to close, or the disconnect closes successfully. In the case of a successful close operation, the relay displays the screen in *Figure 5.14* (b).

Failing to close also has two possible scenarios: the disconnect starts to move, but does not complete the operation, or the disconnect switch operation does not initiate.

When Relay Word bit 89OPN1 deasserts, the Close Immobility timer resets, indicating that the disconnect switch has started to move. If Relay Word bit 89CL1 fails to assert in the expected operation time, the disconnect switch has failed to complete the close operation in the expected time. Failure of the 89CL1 Relay Word bit to assert in the expected disconnect switch operation time causes the 89AL1 Relay Word bit to assert. When Relay Word bit 89AL1 asserts, the relay displays the screen *Figure 5.14* (a); see *Disconnect Switch Status and Alarm Logic on page A.5.6*.

If Relay Word bit 89OPN1 fails to deassert before the Close Immobility Timer expires, Relay Word bit 89ICM1 asserts and the relay displays the screen with the caption STATUS UNKNOWN in *Figure 5.14* (a). See *Close and Open Immobility Timer Logic on page A.5.9* for more information regarding the close and open immobility timer logic.

When the disconnect operation completes successfully, the relay displays the screen in *Figure 5.14* (b) until the front-panel timer times out or the **ESC** pushbutton is pressed.

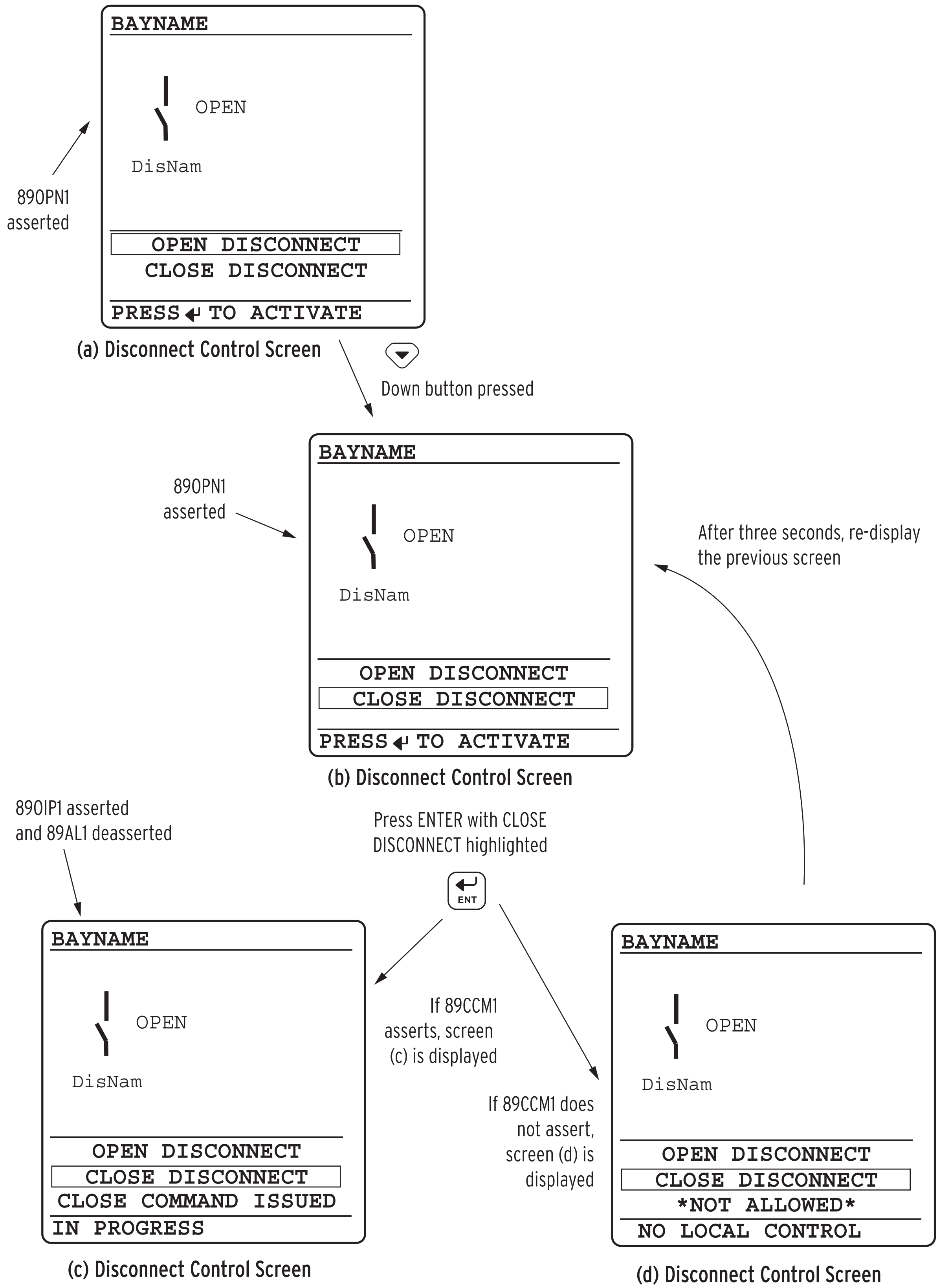


Figure 5.12 HMI Disconnect Operation Initiation

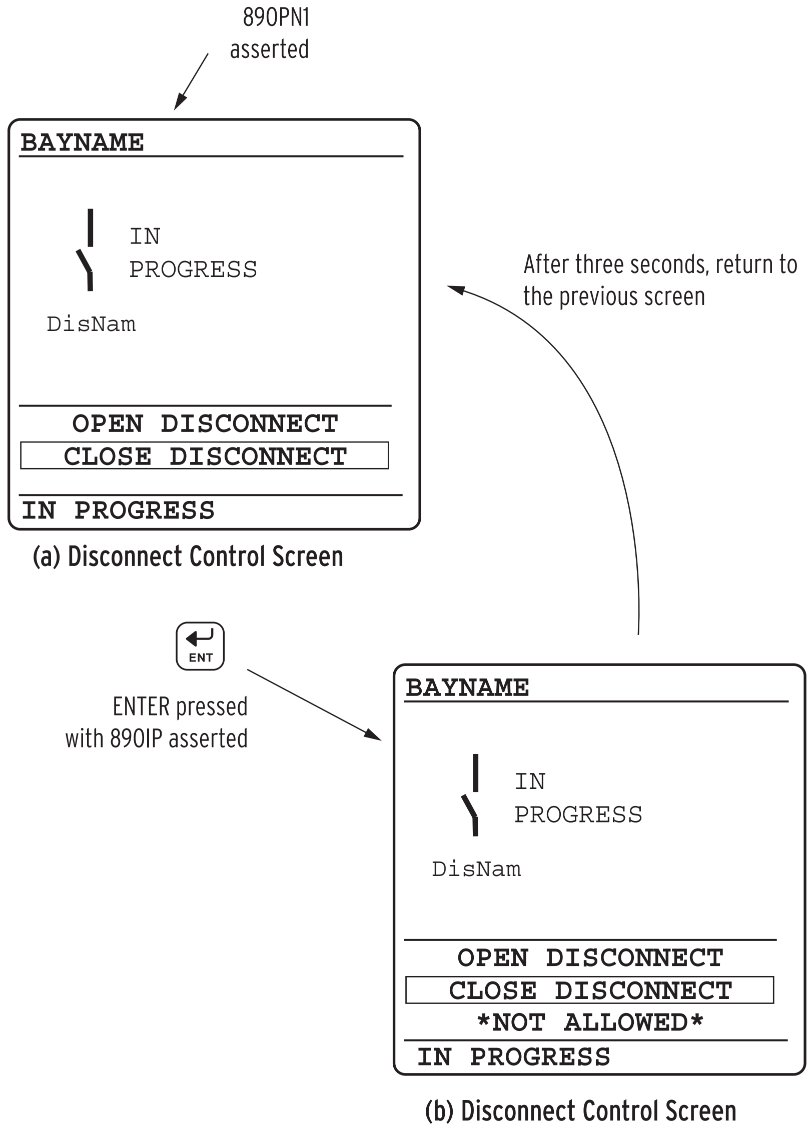


Figure 5.13 HMI Disconnect Operation in Progress

When you initially enter the Disconnect Control Screen, the disconnect switch is in one of four states: disconnect open (89OPN*m*), disconnect closed (89CL*m*), disconnect undetermined without alarm (89OIP*m*), or disconnect undetermined with alarm (89AL*m*). If Relay Word bit 89OIP*m* is asserted, the relay displays the screen in *Figure 5.13* (a); if Relay Word bit 89AL*m* is asserted, the relay displays the screen in *Figure 5.14* (a). If both Relay Word bits 89OIP*m* and 89AL*m* are asserted, Relay Word bit 89AL*m* takes priority. If Relay Word bit 89OPN*m* is asserted, the relay displays the screen in *Figure 5.12* (a). This is the initial screen for an open-to-close operation. If Relay Word bit 89CL*m* is asserted, the relay displays the screen in *Figure 5.14* (b). This is the initial screen for a close-to-open operation.

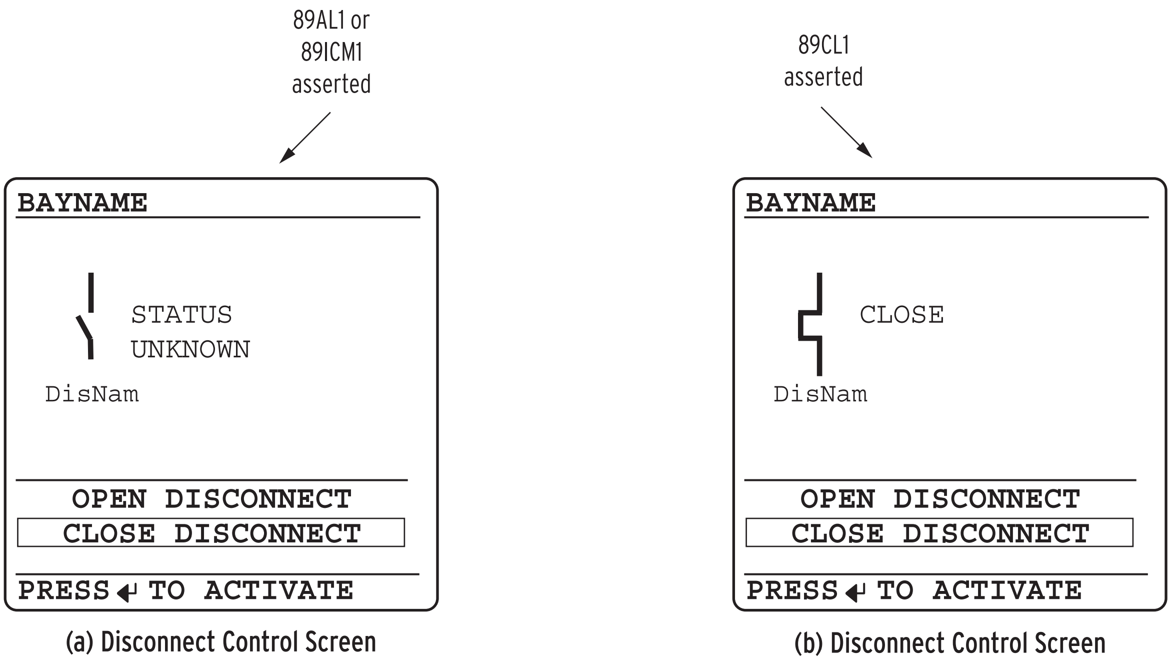


Figure 5.14 HMI Disconnect Operation Completed

ACSELERATOR QuickSet SEL-5030 Software Bay Control Screens

Bay Control Settings Interface

There are two ways to enter Bay Control apparatus settings using the ACSELERATOR QuickSet settings interface. Entry of all Bay Control apparatus settings is available by scrolling below the one-line diagram image shown in *Figure 5.15*. ACSELERATOR QuickSet also provides an interactive bay control setting entry method. Select an apparatus label on the one-line diagram image and ACSELERATOR QuickSet displays a form with apparatus-specific settings. Enter apparatus-specific settings on this form. For assistance in setting the SEL-451-4 using the ACSELERATOR QuickSet software, see *Create and Manage Relay Settings on page U.3.10*.

Figure 5.15 illustrates the interactive bay control setting form in ACSELERATOR QuickSet. Click on an apparatus label in the one-line diagram image and ACSELERATOR QuickSet displays a form with apparatus-specific settings.

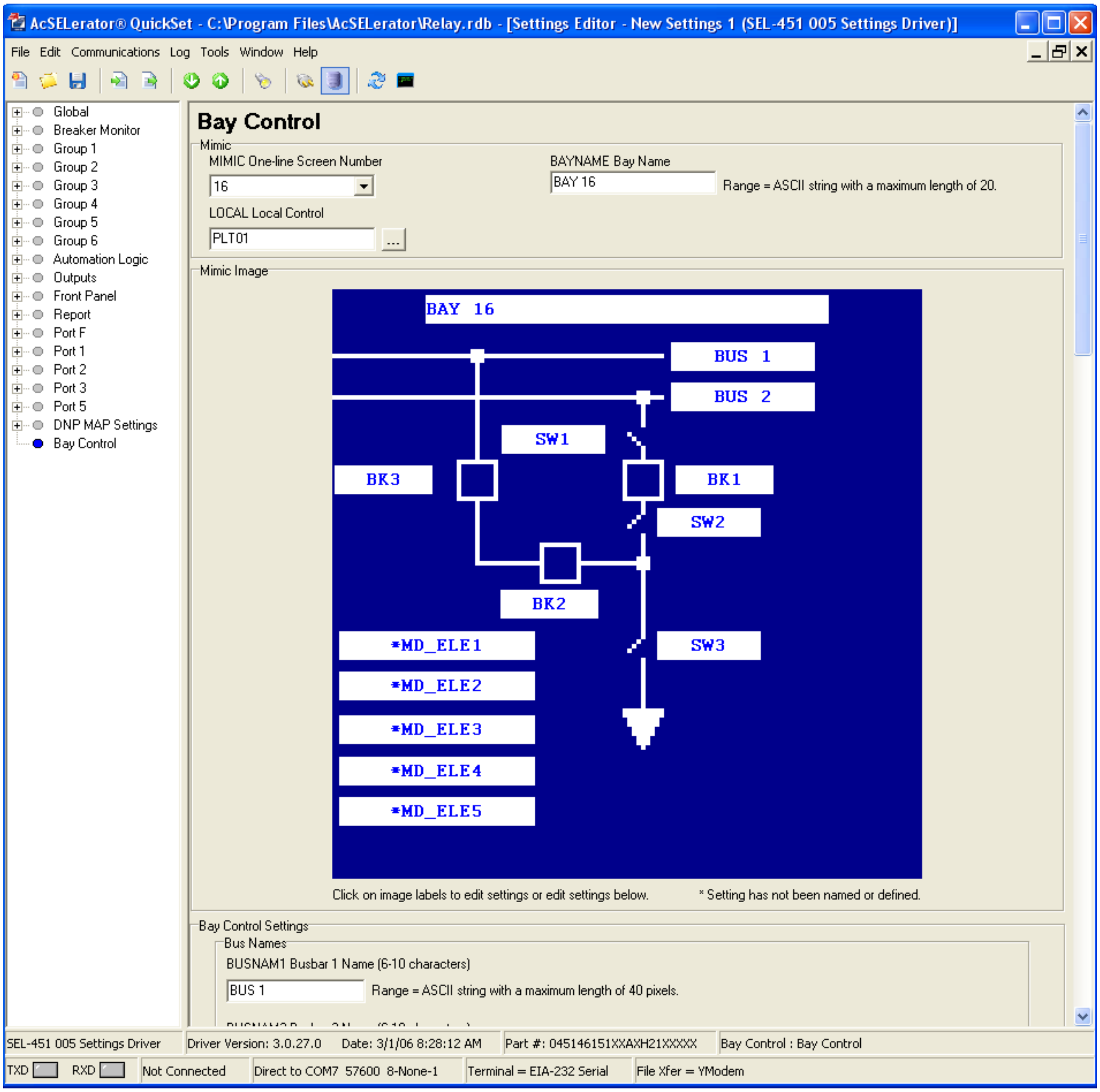


Figure 5.15 Interactive Bay Control Setting Form

After you click on `SW1` in the one-line diagram image, the form illustrated in *Figure 5.16* appears. Enter apparatus specific settings on this form. When you click **OK**, the form is closed and the settings are updated in the Bay Control settings. If you click **Cancel**, the form is closed and settings are not saved. Interactive setting operations for all disconnect switches are identical.

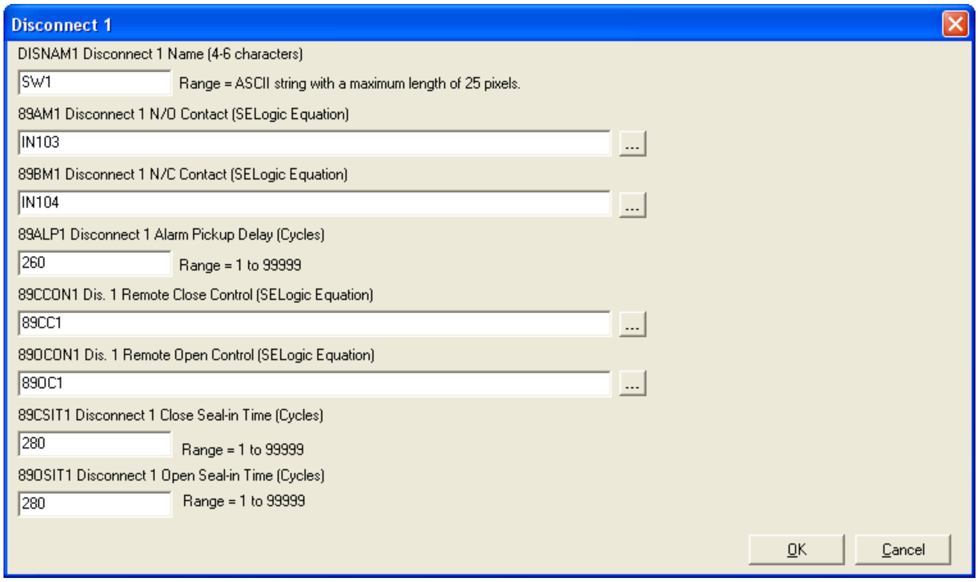


Figure 5.16 Disconnect 1 Settings

Similarly, clicking on BK1 in the one-line diagram image displays the form illustrated in *Figure 5.17*. Enter apparatus-specific settings on this form. When **OK** is clicked, the form is closed and the settings are updated in the Bay Control settings. When **Cancel** is clicked, the form is closed and settings are not saved. Interactive settings operations for all circuit breakers are identical.

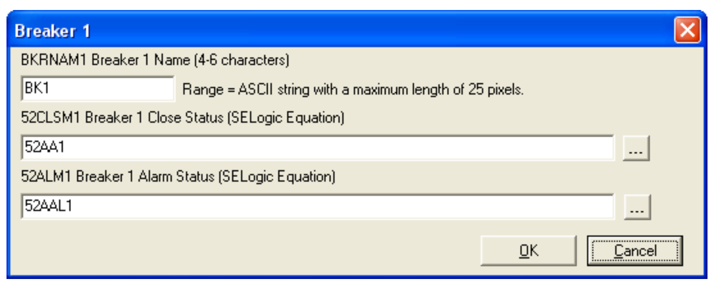
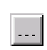


Figure 5.17 Breaker 1 Settings

Click on analog display label MD_ELE1 in the interactive one-line diagram (*Figure 5.15*) to display the form in *Figure 5.18*. Click on the Expression Builder button



to display the form in *Figure 5.19*. The Expression Builder helps build the analog quantity setting string. Press the Expression Builder button on the form in *Figure 5.19* to find the Analog or Fixed Element for display. See *Display Points on page U.5.11* for examples of setting Analog Display Points.

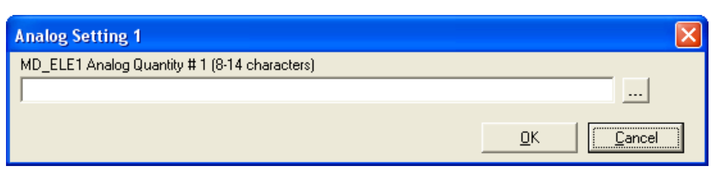


Figure 5.18 Analog Quantity Setting Form

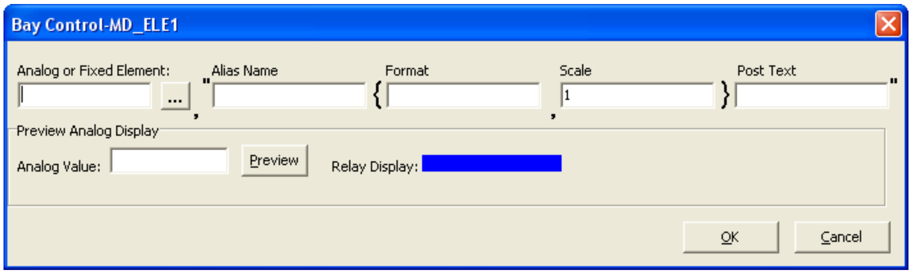


Figure 5.19 Analog Quantity Expression Builder

Figure 5.20 illustrates the form when a fixed element is selected. A fixed element only requires an Alias Name as input. *Figure 5.21* illustrates the form when an analog element is selected. Analog elements accept Alias Name, Format, Scale, and Post Text as input. *Figure 5.20* and *Figure 5.21* also illustrate the use of the analog preview function. Click **Preview** and the form displays an example of how the fixed element or analog quantity appears on the front panel. This capability can be useful to verify the desired display of the analog quantity before sending the settings to the bay control.

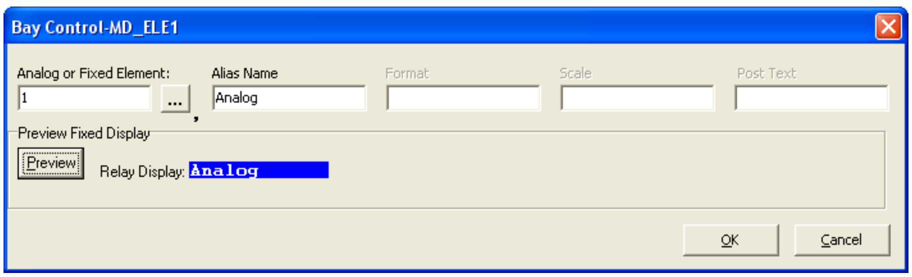


Figure 5.20 Analog Quantity Expression Builder for Fixed Element

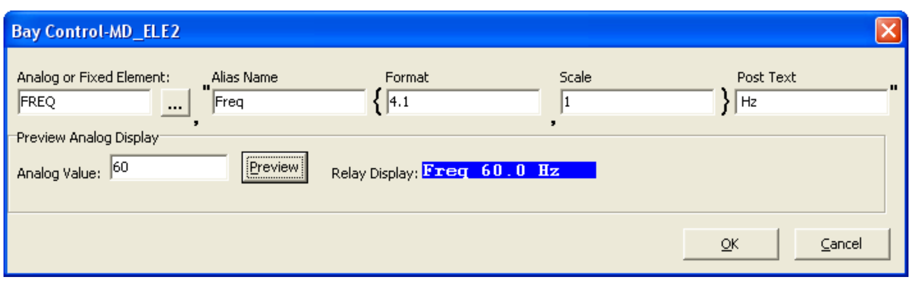


Figure 5.21 Analog Quantity Expression Builder for Analog Element

Click **OK** to close the **Bay Control-MD_ELE1** form and update the analog quantity settings in the **Analog Setting 1** form, as shown in *Figure 5.22*. Click **OK** again to close the **Analog Setting 1** form in *Figure 5.22*, and update the newly entered Analog Quantity settings in the Bay Control settings. If **Cancel** is clicked, the form is closed and settings are not saved.

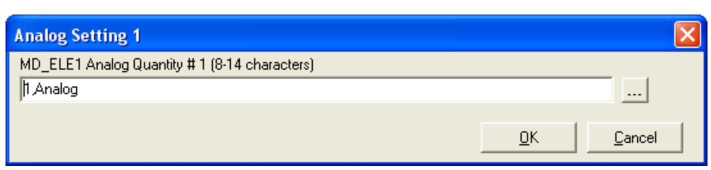


Figure 5.22 Analog Quantity Setting Form—Fixed Element

Click **OK** to close the **Bay Control-MD_ELE2** form and update the analog quantity settings in the **Analog Setting 2** form, as shown in *Figure 5.23*. Click **OK** again to close the **Analog Setting 2** form in *Figure 5.23*, and update the newly entered Analog Quantity settings in the Bay Control settings. If **Cancel** is clicked, the form is closed and settings are not saved.

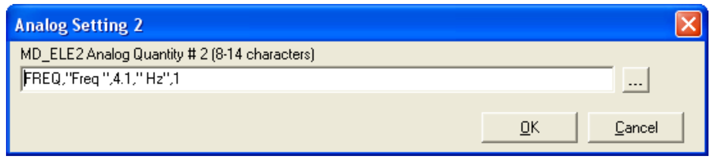


Figure 5.23 Analog Quantity Setting Form—Analog Element

Figure 5.24 shows the **Bay Control** setting screen after accepting the analog quantity settings entered above.

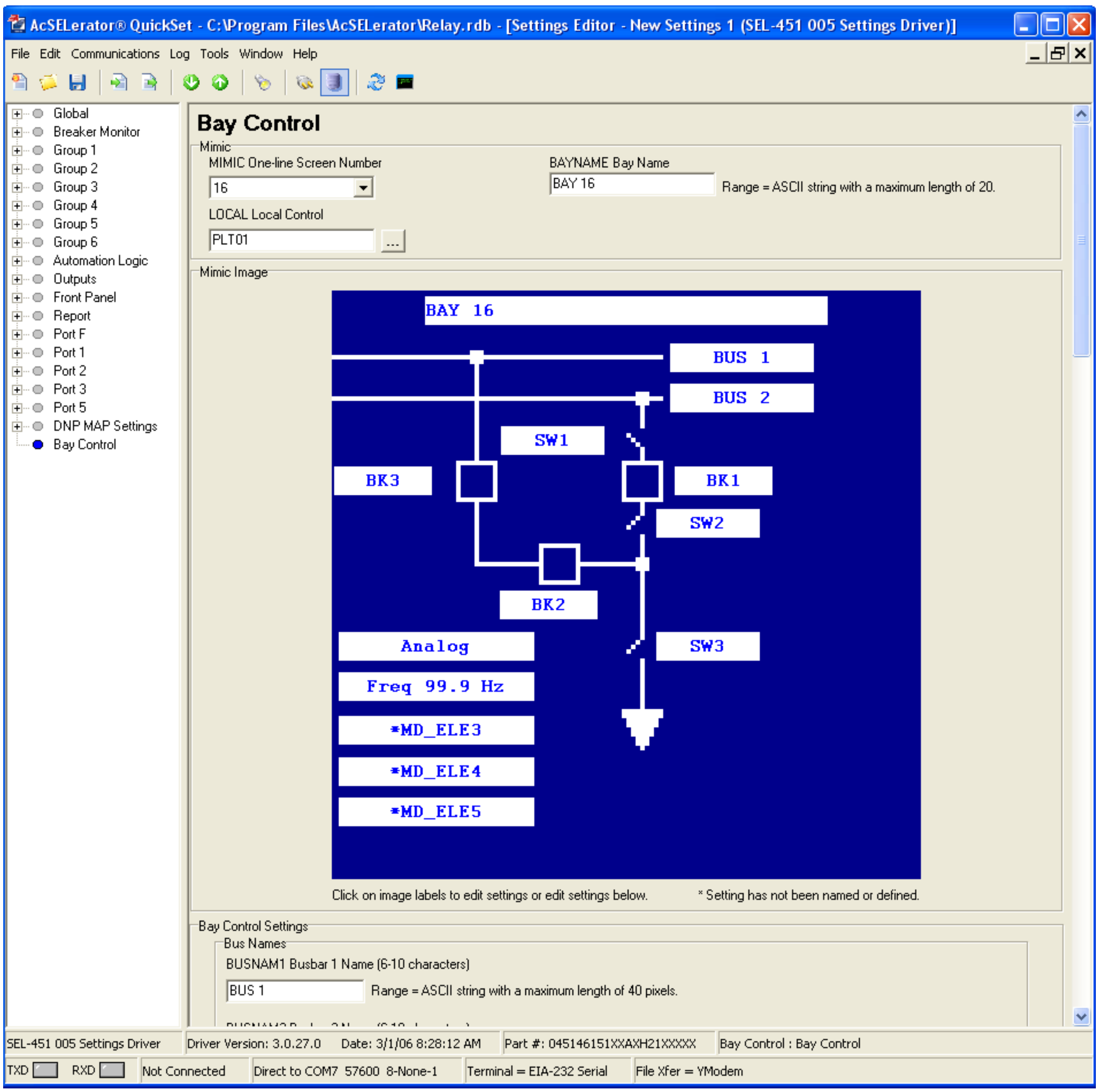


Figure 5.24 Interactive Bay Control Setting Form

Bay Control Example Application

Bus 1, Bus 2, and Transfer BUS Bay With Ground Switch (MIMIC := 4)

Figure 5.25 illustrates the Bus 1, Bus 2, and Transfer Bus Bay with Ground Switch (MIMIC := 4). The Bay configuration used in this example provides five disconnect switches, one breaker, and the ability to display as many as six Analog Quantities. The labels and Analog Quantities shown in *Figure 5.25* are all a result of the settings entered in this example. See *Table 5.3* for a complete list of Bay settings for this application.

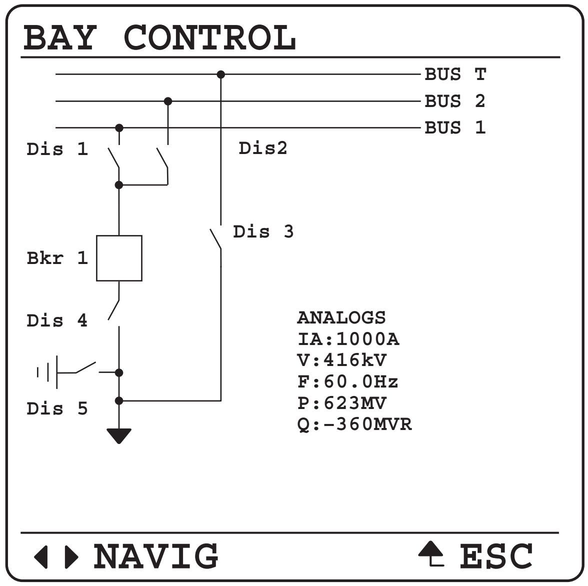


Figure 5.25 Illustration of One-Line Diagram After Entering Example Settings

Bay Control Settings

General One-Line Settings

One-Line Diagram. This setting selects the one-line diagram that defines the bay configuration; it must exactly match the bay configuration being controlled. Failure to select the exact one-line diagram that describes the bay configuration being controlled could result in misapplications. Refer to *Predefined Bay Control One-Line Diagrams on page A.5.35* for illustrations of all 25 predefined one-line diagrams.

MIMIC := **4**

Bay Name. Enter a bay name (up to 20 characters) that defines the bay being controlled.

BAYNAME := **BAY CONTROL**

Bay Label. As many as two bay labels are available in one-line diagrams 14, 17, 18, and 23. BAYLAB1 and BAYLAB2 settings can accept as many as eight characters, depending on the pixel width of the string, see *Bay Settings (SEL-451-4 Relay) on page R.10.49*.

BAYLAB1 or BAYLAB2 are not required because the MIMIC setting selected in this example does not include bay labels. If MIMIC 14, 17, 18, or 23 had been selected, the relay would have prompted for BAYLAB1 and BAYLAB2 settings.

Busbar Information

Bus-Name Labels. Based on the MIMIC setting, the SEL-451-4 provides as many as nine bus-name labels in the one-line diagram. With MIMIC set to 4, the SEL-451-4 requires three bus-name labels, one for the transfer bus, one for Bus 2, and one for Bus 1. The top-most bus in the one-line diagram is BUSNAM1 and the bottom-most bus in the one-line diagram is the highest number bus available for the selected MIMIC setting, three in this case.

Enter bus-name labels (up to 10 characters) that describe each bus in the one-line diagram.

The actual number of characters accepted depends on the pixel width of the string; see *Bay Settings (SEL-451-4 Relay) on page R.10.49*.

BUSNAM1 := **Bus T**

BUSNAM2 := **Bus 2**

BUSNAM3 := **Bus 1**

Breaker Information

The SEL-451-4 displays breaker information for as many as three breakers. For the bay configuration in this example, the SEL-451-4 displays one. If more breakers were supported, based on the MIMIC setting selected, the settings associated with additional breakers would follow Breaker 1 settings.

Breaker Name Label. Enter a breaker name (up to six characters) that describes each circuit breaker in the one-line diagram.

The actual number of characters accepted depends on pixel width of the string; see *Bay Settings (SEL-451-4 Relay) on page R.10.49*.

BKRNAM1 := **Bkr 1**

Breaker Status. This SELOGIC control equation reports breaker close status and breaker alarm status. Any bit in the SEL-451-4 Relay Word can be programmed into this SELOGIC control equation, as well as logical operators. See *Section 3: SELOGIC Control Equations in the Reference Manual* for SELOGIC programming examples. The equations below return the state of the Bkr 1 status and any Bkr 1 alarm conditions.

52CLSM1 := **52ACL1**

52ALM1 := **52AAL1**

Disconnect Information

The SEL-451-4 provides disconnect switch information for as many as ten disconnect switches. For the bay configuration selected in this example, the SEL-451-4 supports five disconnect switches.

Disconnect Name Label. Enter disconnect labels of as many as six characters in length that describe each disconnect switch in the one-line diagram. The actual number of characters accepted depends on pixel width of the string; see *Bay Settings (SEL-451-4 Relay) on page R.10.49*.

DISNAM1 := **Dis 1**

Disconnect Status. Wire the normally open and normally closed auxiliary contacts from the disconnect switch to SEL-451-4 inputs, and program the relay inputs into 89AM1 and 89BM1 SELOGIC control equations.

The 89AM1 and 89BM1 SELOGIC control equations report the state of the disconnect switch auxiliary contacts. Both equations must be programmed for the Disconnect Switch Status and Alarm Logic to function correctly.

89AM1 := **IN103**

89BM1 := **IN104**

Disconnect Alarm Pickup Delay. This setting monitors disconnect open/close operations (the undetermined time) of the disconnect switch. When the disconnect alarm timer expires, an alarm condition exists and the 89AL1 Relay Word bit asserts. Set the 89ALP*m* timer longer than the expected operation (undetermined state) time, but less than the 89CSIT*m* or 89OSIT*m* seal-in timers. The expected disconnect operation time in this example is 250 cycles. 89ALP*m* is entered in cycles and has a range of 1–99999.

89ALP1 := **260**

Disconnect Close/Open Control. Program SELOGIC control equations 89CCON*n* and 89OCON*n* to close or open disconnect switch *n*, respectively. Great care needs to be used when programming these equations because there are no breaker jumper supervision or access level safeguards in place for this disconnect operate method. The settings in this example close the disconnect switch when Remote Bit 1 is set and open the disconnect switch when Remote Bit 1 is cleared. The 89CCON1 SELOGIC example below also includes additional supervision logic where the close operation only operates if Breaker 1 is open (NOT 52CLS1) and the disconnect switch is in the opposite state (89OPN1). When these conditions are met, a close disconnect operation will initiate. Relay Word bit 89CLS1 is the output of the seal-in timer and asserts when Relay Word bit 89CCON1 asserts. Relay Word bit 89OPN1 deasserts as soon as the disconnect switch starts to move. The OR combination of Relay Word bit 89CLS1 and 89OPN1 keeps the close disconnect signal asserted until the disconnect operation has completed. The SELOGIC control equations below demonstrate disconnect lockout control in the SEL-451-4. The 89OCON1 SELOGIC control equation illustrates the same type of supervision for the disconnect switch open logic.

89CCON1 := **RB01 AND (89OPN1 OR 89CLS1) AND NOT 52CLSM1**

89OCON1 := **NOT RB01 AND (89CL1 OR 89OPEN1) AND NOT 52CLSM1**

Disconnect Close/Open Seal-in Timers. The seal-in timers assert the close or open signal long enough to allow the disconnect operation to complete. Set the seal-in timer 10 to 15 percent longer than the expected disconnect operate time to give the disconnect switch time to complete the operation. 89CSIT*m* and 89OSIT*m* are entered in cycles and have a range of 1–99999. The example shown anticipates a disconnect switch operate time of approximately 250 cycles.

Cold weather and low battery voltages can impact operation times. Be sure to consider these conditions when setting the seal-in timers.

The SEL-451-4 contacts must not be used to break the motor coil current. An auxiliary contact with adequate current interrupting capacity must first interrupt current supply to the motor before the relay contact opens. Include the auxiliary contact clearing time when setting the disconnect seal-in timer.

89CSIT1 := **280**

89OSIT1 := **280**

Disconnect 2–5. Disconnect switch settings 2–5 are similar to the Disconnect Switch 1 examples above. See *Table 5.4* for a complete list of Bay Class settings for this application.

One-Line Analog Display

One-line diagrams in the SEL-451-4 can contain as many as six Analog Quantity display points. The MIMIC setting selected in this example displays six Analog Display points. See *Display Points on page U.5.11* for Display Point programming. The settings below illustrate how to display text and Analog Quantities available in the mimic display. If analog display points are not required to appear in the one-line diagram, leave the setting(s) blank, and the relay will only display the defined display points.

1. 1, "Analogs"
2. IAWM, "IA:{4.0,1}A"
3. VABFM, "V:{3.0,1}kV"
4. FREQ, "F:{4.1,1}Hz"
5. 3P, "P:{3.0,1}MW"
6. 3Q_F, "Q:{3.0,1}MVR"

Control Selection

The LOCAL SELOGIC control equation enables local and remote control of the disconnect switch. This example illustrates how the SEL-451-4 input contact **IN107** can accommodate existing bay controls that use a key to manually change from remote to local control. The key switch is made to actuate a contact when the key is turned, as shown in *Figure 5.26*. With the contact of the switch wired to the SEL-451-4 input, the key switch provides local and remote control. Make the following setting to enable LOCAL control when **IN107** is asserted.

LOCAL := **IN107**

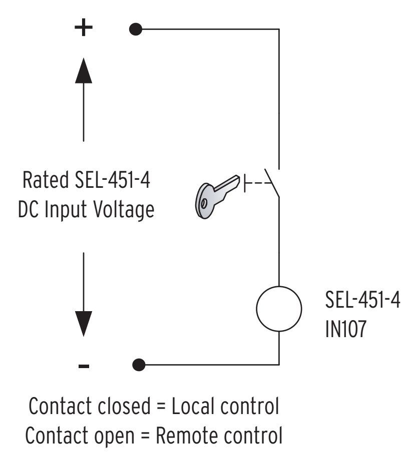


Figure 5.26 Illustration of Local and Remote Control Logic With Key Control

Front-Panel Settings

Selectable Screens for the Front Panel

The one-line diagram is one of the screens that are available for display in the rotating display. To display RMS_V, RMS_I, and ONELINE screens on the rotating display every five seconds, make the following Front-Panel Settings.

SCROLD := **5**

RMS_V := **Y**

RMS_I := **Y**

RMS_VPP := **N**

RMS_W := **N**

FUNDVAR := **N**

RMS_VA := **N**

RMS_PF := **N**

RMS_BK1 := **N**

RMS_BK2 := **N**

STA_BAT := **N**

FUND_VI := **N**

FUNDSEQ := **N**

FUND_BK := **N**

ONELINE := **Y**

The following settings in the Front-Panel settings provide immediate display of the one-line diagram screen when Pushbutton 2 is pressed.

PB2_HMI := **BC**

Output Settings

Output Logic Settings

This illustrates the ability to program disconnect lockout protection for the selected one-line diagram. To eliminate the danger of closing or opening the ground switch on an energized line, the disconnect switch cannot operate unless Breaker 1 is open. When the Disconnect 1 close command is executed (89CLS1), OUT103 only asserts if the state of Breaker 1 is open (NOT 52CLS1). This illustrates disconnect switch lockout protection through SELOGIC control equations. The SELOGIC control equation for OUT104 below illustrates similar lockout protection for the disconnect switch open operation. Wire OUT103 to the disconnect switch closing circuit and OUT104 to the disconnect switch opening circuit.

OUT103 := **89CLS1 AND NOT 52CLSM1**

OUT104 := **89OPEN1 AND NOT 52CLSM1**

Another example of disconnect lockout would be to ensure that Dis 3 never closes when the ground disconnect switch Dis 5 is closed. Enter the SELOGIC control equation below for Dis 3 switch lockout protection. 89CLS3 is the close disconnect switch Relay Word bit for Disconnect 3 and the 89OPN5 Relay Word bit is the status of Disconnect 5. The SELOGIC control equation below will not assert OUT201 unless both conditions are true.

OUT201 := **89CLS3 AND 89OPN5**

⚠CAUTION
The outputs in the SEL-451-4 are not designed to break the coil current in the disconnect motor. An auxiliary contact with adequate current-interrupting capacity must clear the coil current in the disconnect motor before the output on the SEL-451-4 opens. Failure to observe this safeguard could result in damage to the SEL-451-4 output contacts.

These are just a few examples of disconnect lockout control. Use Relay Word bits in the SEL-451-4 and SELOGIC programming to design lockout control scenarios required for the configuration being controlled.

The SELOGIC Output settings listed in *Table 5.4* are example close and open disconnect equations with disconnect lockout control for switches 1–5.

Table 5.4 Application Example Bay Control Settings for Bus 1, Bus 2, and Transfer Bus Bay With Ground Switch Application (Sheet 1 of 2)

Setting	Description	Entry
	General One-Line Settings	
MIMIC	One-line Screen Number (1–100)	4
BAYNAME	Bay Name (20 Characters)	BAY CONTROL
	Busbar Information	
BUSNAM1	Busbar 1 Name (40 pixels, 6–10 Characters)	Bus T
BUSNAM2	Busbar 2 Name (40 pixels, 6–10 Characters)	Bus 2
BUSNAM3	Busbar 3 Name (40 pixels, 6–10 Characters)	Bus 1
	Breaker Information	
BKRNAM1	Breaker 1 Name (25 pixels, 4–6 Characters)	Bkr 1
52CLSM1	Breaker 1 Close Status (SELOGIC Equation)	52ACL1
52ALM1	Breaker 1 Alarm Status (SELOGIC Equation)	52AAL1
	Disconnect Information	
DISNAM1	Disconnect 1 Name (25 pixels, 4–6 Characters)	Dis 1
89AM1	Disconnect 1 N/O Contact (SELOGIC Equation)	IN103
89BM1	Disconnect 1 N/C Contact (SELOGIC Equation)	IN104
89ALP1	Disconnect 1 Alarm Pickup Delay (1–99999 cyc)	260
89CCON1	Disconnect 1 Close Control (SELOGIC Equation)	RB01 AND (89OPN1 OR 89CLS1) AND NOT 52CLSM1
89OCON1	Disconnect 1 Open Control (SELOGIC Equation)	NOT RB01 AND (89CL1 OR 89OPEN1) AND NOT 52CLSM1
89CSIT1	Disconnect 1 Close Seal-in Time (1–99999 cyc)	280
89OSIT1	Disconnect 1 Open Seal-in Time (1–99999 cyc)	280
DISNAM2	Disconnect 2 Name (25 pixels, 4–6 Characters)	Dis 2
89AM2	Disconnect 2 N/O Contact (SELOGIC Equation)	IN105
89BM2	Disconnect 2 N/C Contact (SELOGIC Equation)	IN106
89ALP2	Disconnect 2 Alarm Pickup Delay (1–99999 cyc)	260
89CCON2	Disconnect 2 Close Control (SELOGIC Equation)	RB02 AND (89OPN2 OR 89CLS2) AND NOT 52CLSM1
89OCON2	Disconnect 2 Open Control (SELOGIC Equation)	NOT RB02 AND (89CL2 OR 89OPEN2) AND NOT 52CLSM1
89CSIT2	Disconnect 2 Close Seal-in Time (1–99999 cyc)	280
89OSIT2	Disconnect 2 Open Seal-in Time (1–99999 cyc)	280
DISNAM3	Disconnect 3 Name (25 pixels, 4–6 Characters)	Dis 3
89AM3	Disconnect 3 N/O Contact (SELOGIC Equation)	IN201
89BM3	Disconnect 3 N/C Contact (SELOGIC Equation)	IN202
89ALP3	Disconnect 3 Alarm Pickup Delay (1–99999 cyc)	260
89CCON3	Disconnect 3 Close Control (SELOGIC Equation)	RB03 AND (89OPN3 OR 89CLS3) AND NOT 52CLSM1

Table 5.4 Application Example Bay Control Settings for Bus 1, Bus 2, and Transfer Bus Bay With Ground Switch Application (Sheet 2 of 2)

Setting	Description	Entry
89OCON3	Disconnect 3 Open Control (SELOGIC Equation)	NOT RB03 AND (89CL3 OR 89OPEN3) AND NOT 52CLSM1
89CSIT3	Disconnect 3 Close Seal-in Time (1–99999 cyc)	280
89OSIT3	Disconnect 3 Open Seal-in Time (1–99999 cyc)	280
DISNAM4	Disconnect 4 Name (25 pixels, 4–6 Characters)	Dis 4
89AM4	Disconnect 4 N/O Contact (SELOGIC Equation)	IN203
89BM4	Disconnect 4 N/C Contact (SELOGIC Equation)	IN204
89ALP4	Disconnect 4 Alarm Pickup Delay (1–99999 cyc)	260
89CCON4	Disconnect 4 Close Control (SELOGIC Equation)	RB04 AND (89OPN4 OR 89CLS4) AND NOT 52CLSM1
89OCON4	Disconnect 4 Open Control (SELOGIC Equation)	NOT RB04 AND (89CL4 OR 89OPEN4) AND NOT 52CLSM1
89CSIT4	Disconnect 4 Close Seal-in Time (1–99999 cyc)	280
89OSIT4	Disconnect 4 Open Seal-in Time (1–99999 cyc)	280
DISNAM5	Disconnect 5 Name (25 pixels, 4–6 Characters)	Dis 5
89AM5	Disconnect 5 N/O Contact (SELOGIC Equation)	IN205
89BM5	Disconnect 5 N/C Contact (SELOGIC Equation)	IN206
89ALP5	Disconnect 5 Alarm Pickup Delay (1–99999 cyc)	260
89CCON5	Disconnect 5 Close Control (SELOGIC Equation)	RB05 AND (89OPN5 OR 89CLS5) AND NOT 52CLSM1
89OCON5	Disconnect 5 Open Control (SELOGIC Equation)	NOT RB05 AND (89CL5 OR 89OPEN5) AND NOT 52CLSM1
89CSIT5	Disconnect 5 Close Seal-in Time (1–99999 cyc)	280
89OSIT5	Disconnect 5 Open Seal-in Time (1–99999 cyc)	280
	One-Line Analog Display	
1		1, “Analogs”
2		IAWM, “IA:{4.0,1}A”
3		VABFM, “V:{3.0,1}kV”
4		FREQ, “F:{4.1,1}Hz”
5		3P, “P:{3.0,1}MW”
6		3Q_F, “Q:{3.0,1}MVR”
	Control Selection	
LOCAL	Local Control (SELOGIC control equation)	IN107

Table 5.5 Application Example Front-Panel Settings (Sheet 1 of 2)

Setting	Description	Entry
	Selectable Screens for the Front Panel	
SCROLD	Front Panel Display Update Rate (OFF, 1–15 secs)	5
RMS_V	RMS Line Voltage Screen (Y, N)	Y
RMS_I	RMS Line Current Screen (Y, N)	Y
RMS_VPP	RMS Line Voltage Phase-to-Phase Screen	N
RMS_W	RMS Active Power Screen	N
FUNDVAR	Fundamental Reactive Power Screen	N
RMS_VA	RMS Apparent Power Screen	N
RMS_PF	RMS Power Factor Screen	N

Table 5.5 Application Example Front-Panel Settings (Sheet 2 of 2)

Setting	Description	Entry
RMS_BK1	RMS Breaker 1 Currents Screen	N
RMS_BK2	RMS Breaker 2 Currents Screen	N
STA_BAT	Station Battery Screen	N
FUND_VI	Fundamental Voltage and Current Screen	N
FUNDSEQ	Fundamental Sequence Quantities Screen	N
FUND_BK	Fundamental Breaker Currents Screen	N
ONELINE	One-Line Bay Control Diagram	Y
	Selectable Operator Pushbuttons	
PB2_HMI	Pushbutton 2 HMI Screen	BC

Table 5.6 Application Example Output Settings, Output SELOGIC Control Equations

Setting	Description	Entry
OUT103	OUT103 SELOGIC control equation	89CLS1 AND NOT 52CLSM1
OUT104	OUT104 SELOGIC control equation	89OPEN1 AND NOT 52CLSM1
OUT105	OUT105 SELOGIC control equation	89CLS2 AND NOT 52CLSM1
OUT106	OUT106 SELOGIC control equation	89OPEN2 AND NOT 52CLSM1
OUT201	OUT201 SELOGIC control equation	89CLS3 AND 89OPN5
OUT202	OUT202 SELOGIC control equation	89OPEN3 AND 52CLSM1
OUT203	OUT203 SELOGIC control equation	89CLS4 AND NOT 52CLSM1
OUT204	OUT204 SELOGIC control equation	89OPEN4 AND NOT 52CLSM1
OUT205	OUT205 SELOGIC control equation	89CLS5 AND NOT 52CLSM1
OUT206	OUT206 SELOGIC control equation	89OPEN5 AND NOT 52CLSM1

Predefined Bay Control One-Line Diagrams

One-Line Diagram

Apparatus Support

Maximum Number of Buses:	9
Maximum Number of Disconnect Switches:	10
Maximum Number of Breakers for Control:	2
Maximum Number of Breakers for Status Display:	3
Maximum Number of Analog Display Points:	6

One-Line Diagram Labels

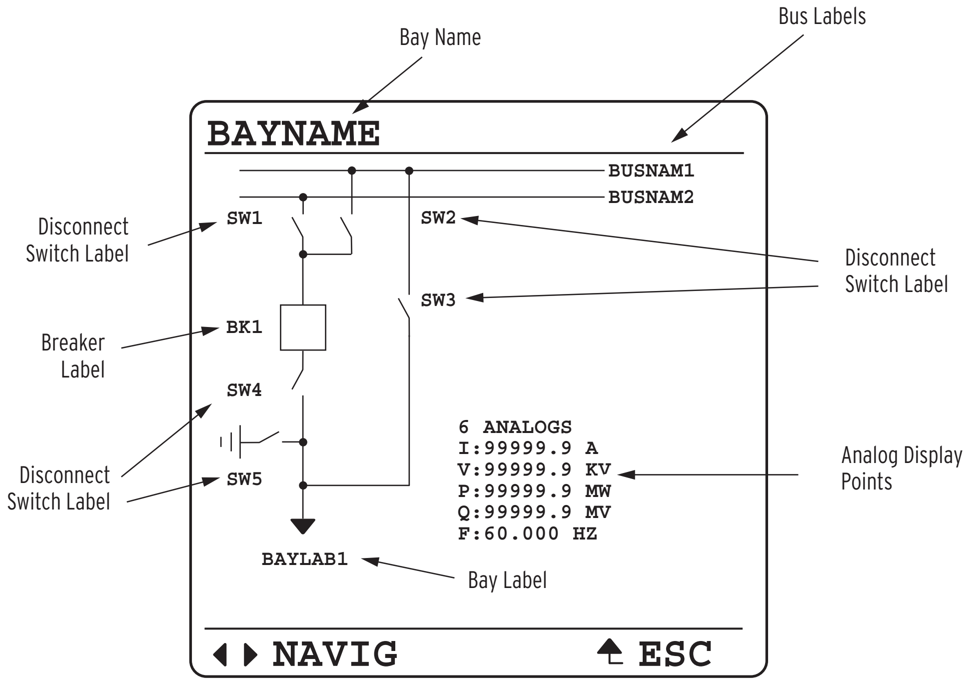


Figure 5.27 Illustration of One-Line Diagram With Labels

The following pages illustrate all of the predefined bay control configurations in the SEL-451-4. Select the bay configuration that exactly matches the bay configuration being controlled. *Figure 5.28*–*Figure 5.50* illustrate one-line diagrams 1–25. *Table 5.7*–*Table 5.18* list apparatus support for one-line diagrams 1–25.

Main Bus and Auxiliary Bus

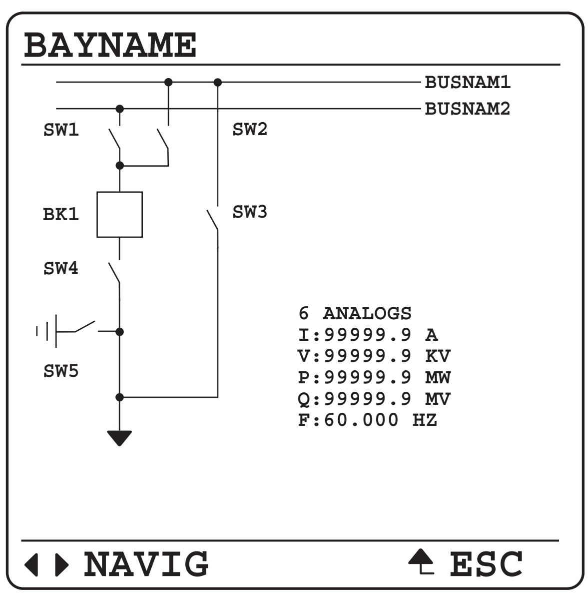


Figure 5.28 Bay With Ground SW (Option 1)

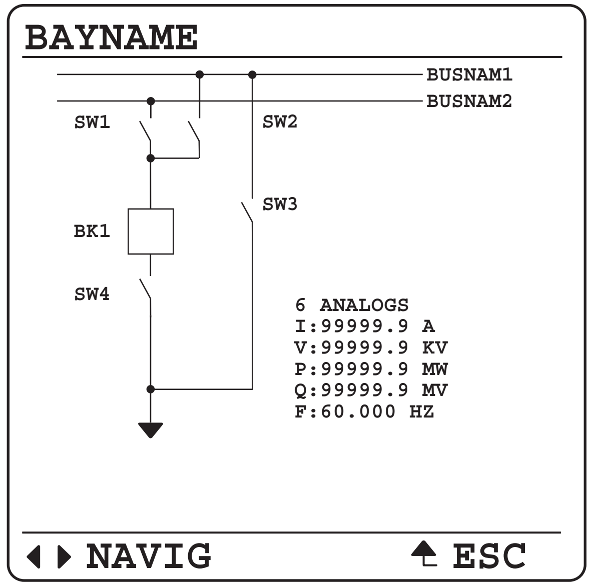


Figure 5.29 Bay Without Ground SW (Option 2)

Table 5.7 Mimic 1 and Mimic 2 Apparatus Support

Apparatus	Option 1	Option 2
Bus Names	2	2
Bay Labels	0	0
Breakers	1	1
Disconnects	5	4
One-Line Analog Display	6	6

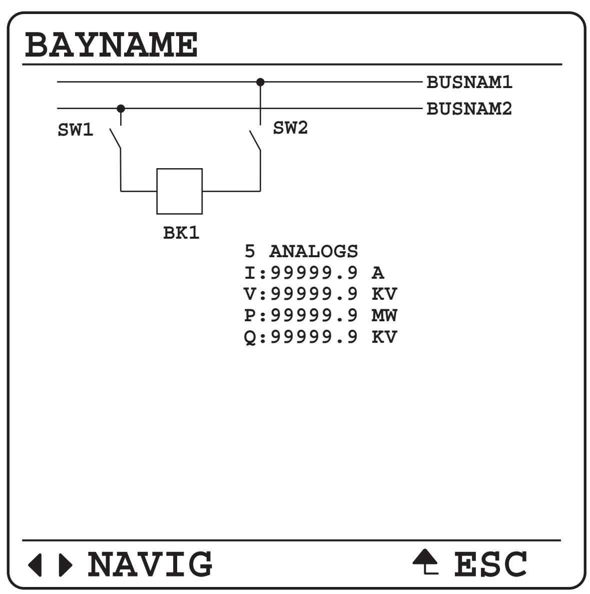


Figure 5.30 Tie Breaker Bay (Option 3)

Table 5.8 Mimic 3 Apparatus Support

Apparatus	Option 3
Bus Names	2
Bay Labels	0
Breakers	1
Disconnects	2
One-Line Analog Display	5

Bus 1, Bus 2, and Transfer Bus

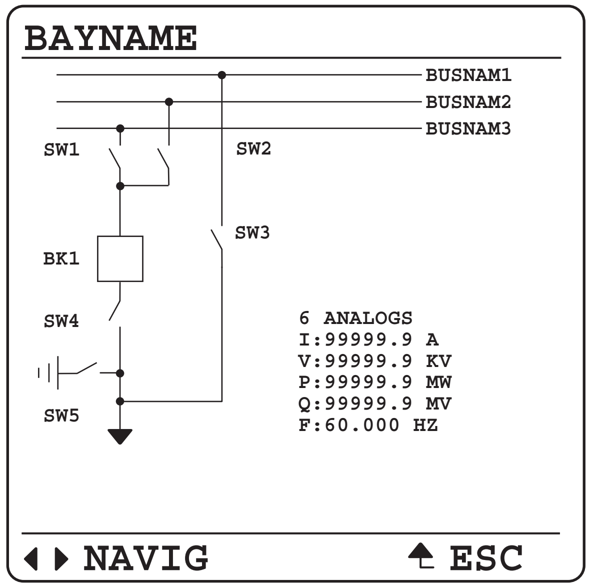


Figure 5.31 Bay With Ground SW (Option 4)

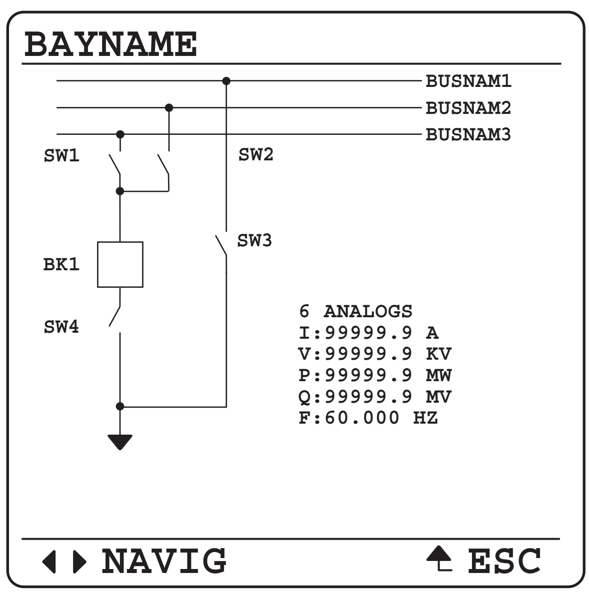


Figure 5.32 Bay Without Ground SW (Option 5)

Table 5.9 Mimic 4 and Mimic 5 Apparatus Support

Apparatus	Option 4	Option 5
Bus Names	3	3
Bay Labels	0	0
Breakers	1	1
Disconnects	5	4
One-Line Analog Display	6	6

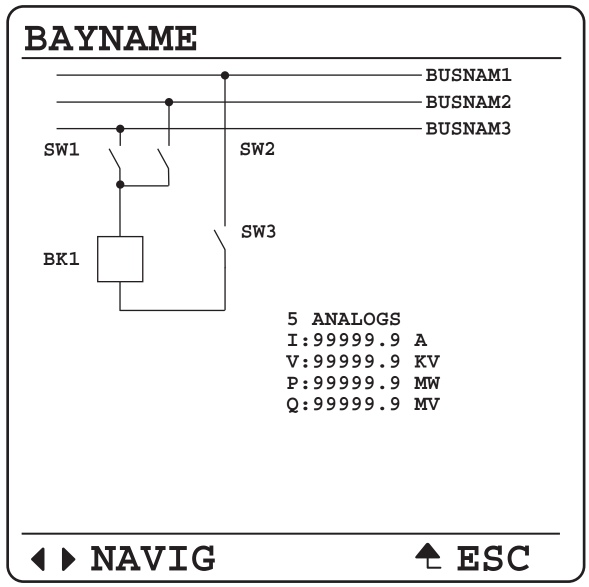


Figure 5.33 Transfer Bay (Option 6)

Table 5.10 Mimic 6 Apparatus Support

Apparatus	Option 6
Bus Names	3
Bay Labels	0
Breakers	1
Disconnects	3
One-Line Analog Display	5

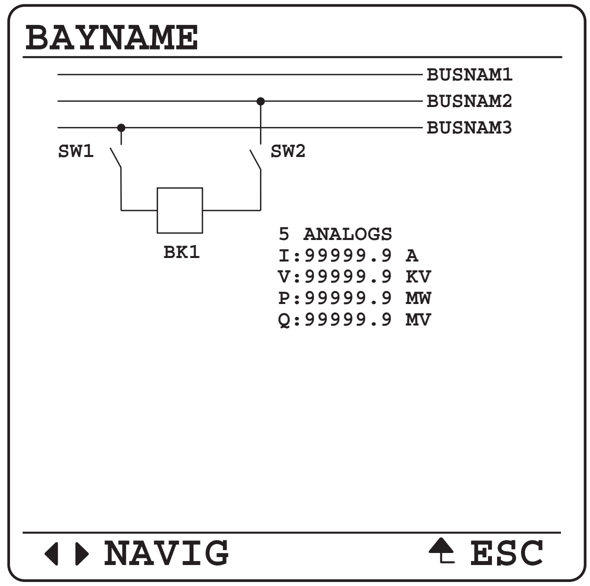


Figure 5.34 Tie-Breaker Bay (Option 7)

Table 5.11 Mimic 7 Apparatus Support

Apparatus	Option 7
Bus Names	3
Bay Labels	0
Breakers	1
Disconnects	2
One-Line Analog Display	5

Main Bus and Transfer Bus

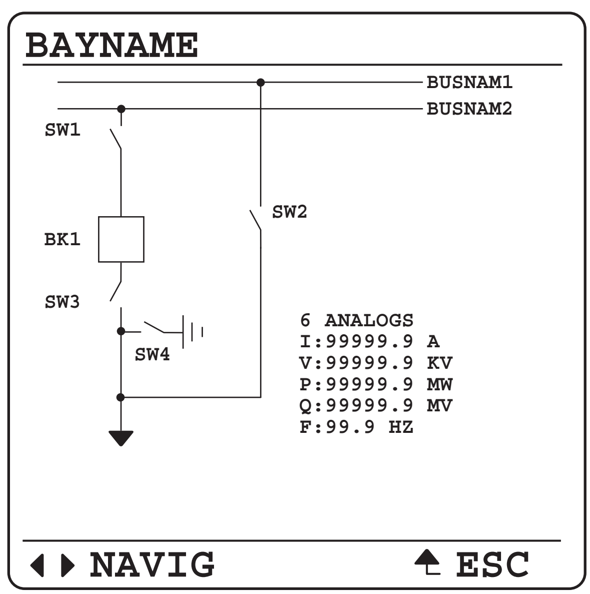


Figure 5.35 Bay With Ground SW (Option 8)

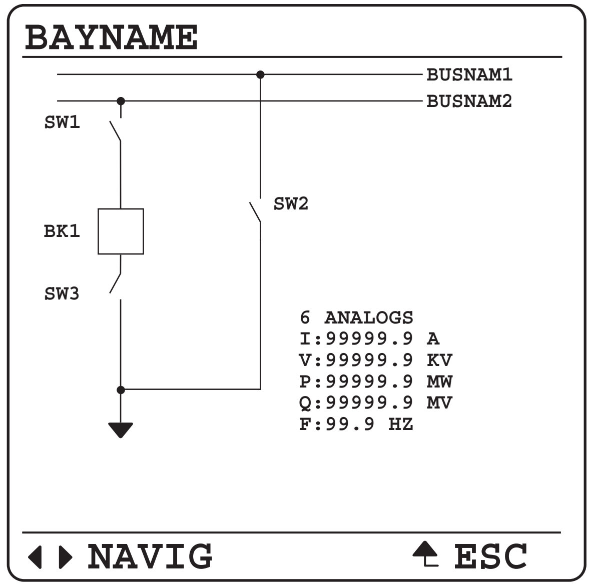


Figure 5.36 Bay Without Ground SW (Option 9)

Table 5.12 Mimic 8 and Mimic 9 Apparatus Support

Apparatus	Option 8	Option 9
Bus Names	2	2
Bay Labels	0	0
Breakers	1	1
Disconnects	4	3
One-Line Analog Display	6	6

Main Bus

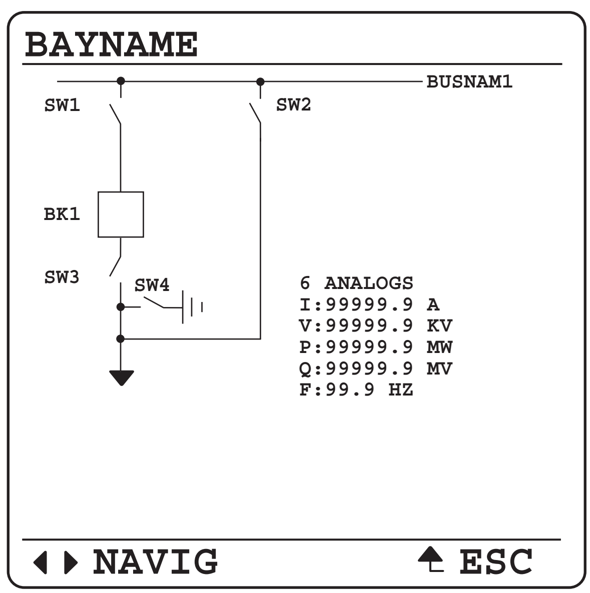


Figure 5.37 Bay With Ground SW (Option 10)

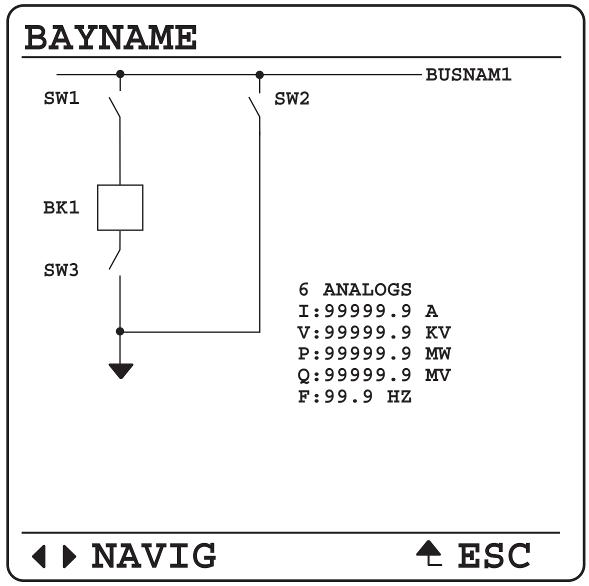


Figure 5.38 Bay Without Ground SW (Option 11)

Table 5.13 Mimic 10 and Mimic 11 Apparatus Support

Apparatus	Option 10	Option 11
Bus Names	1	1
Bay Labels	0	0
Breakers	1	1
Disconnects	4	3
One-Line Analog Display	6	6

Breaker-and-a-Half

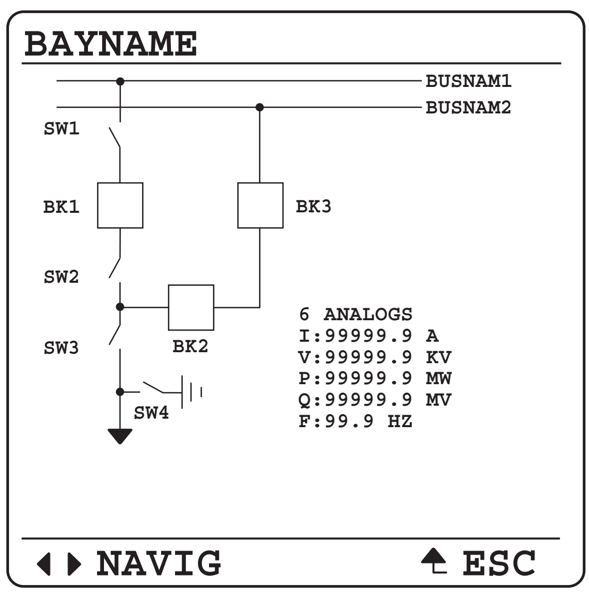


Figure 5.39 Left Breaker Bay With Ground SW (Option 12)

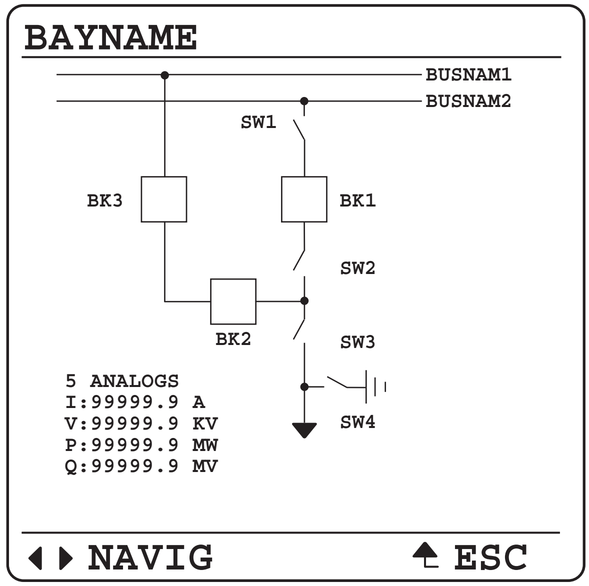


Figure 5.40 Right Breaker Bay With Ground SW (Option 13)

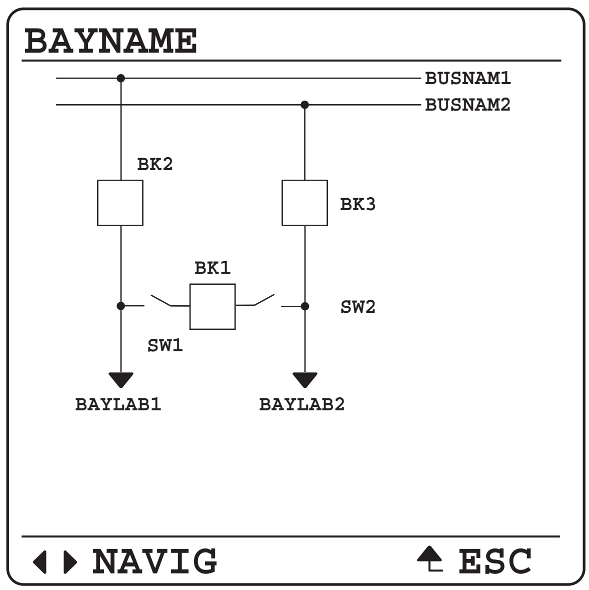


Figure 5.41 Middle Breaker Bay (Option 14)

Table 5.14 Mimic 12, Mimic 13, and Mimic 14 Apparatus Support

Apparatus	Option 12	Option 13	Option 14
Bus Names	2	2	2
Bay Labels	0	0	2
Breakers	3	3	3
Disconnects	4	4	2
One-Line Analog Display	6	5	0

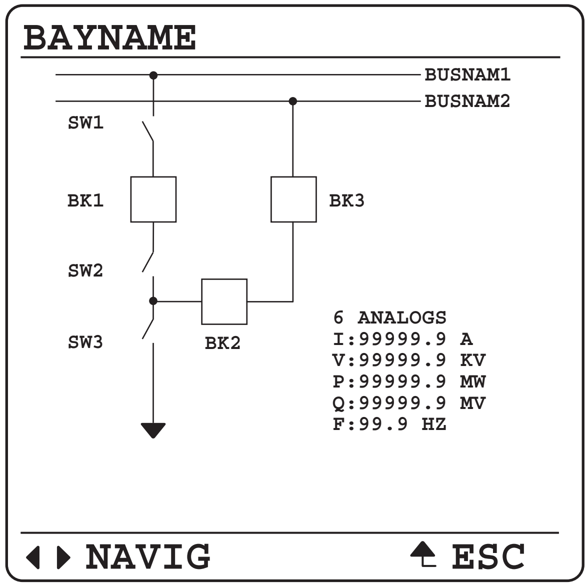


Figure 5.42 Left Breaker Bay Without Ground SW (Option 15)

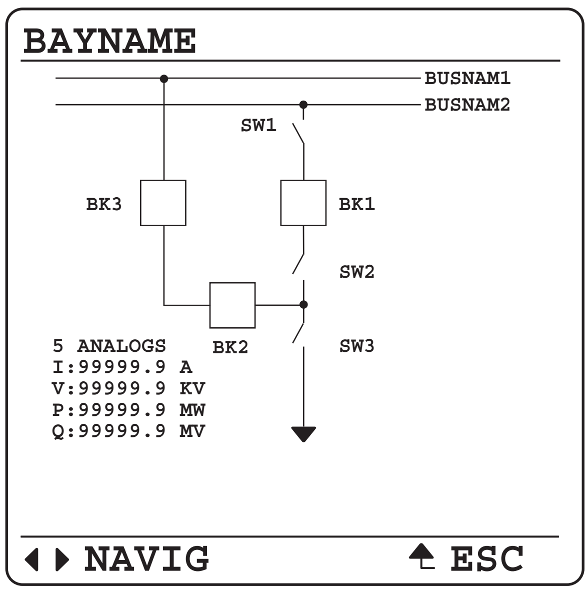


Figure 5.43 Right Breaker Bay Without Ground SW (Option 16)

Table 5.15 Mimic 15 and Mimic 16 Apparatus Support

Apparatus	Option 15	Option 16
Bus Names	2	2
Bay Labels	0	0
Breakers	3	3
Disconnects	3	3
One-Line Analog Display	6	5

Ring Bus

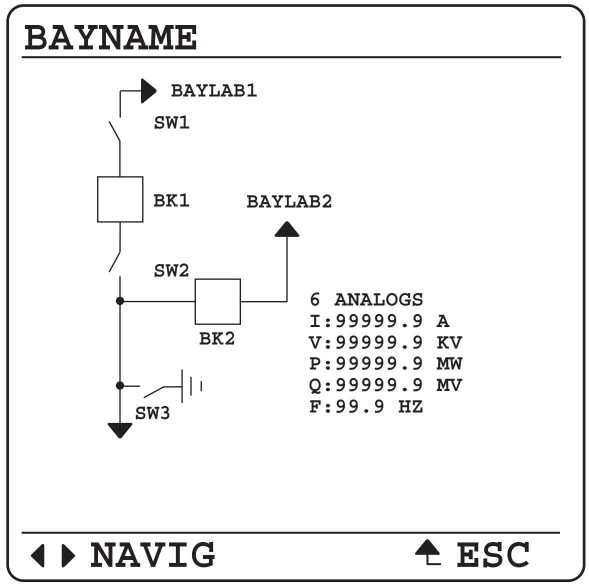


Figure 5.44 Bay With Ground SW (Option 17)

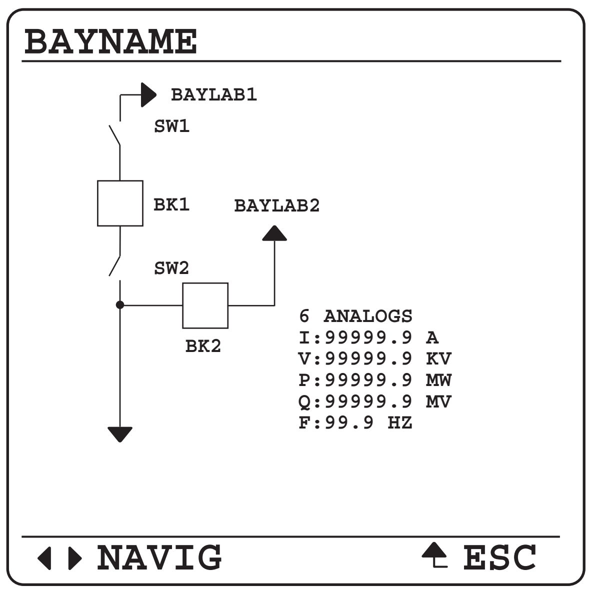


Figure 5.45 Bay Without Ground SW (Option 18)

Table 5.16 Mimic 17 and Mimic 18 Apparatus Support

Apparatus	Option 17	Option 18
Bus Names	0	0
Bay Labels	2	2
Breakers	2	2
Disconnects	3	2
One-Line Analog Display	6	6

Double Bus Double Breaker

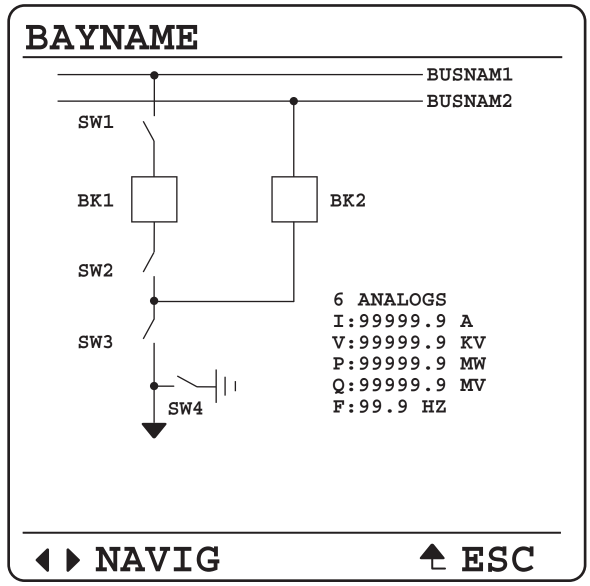


Figure 5.46 Left Breaker Bay With Ground SW (Option 19)

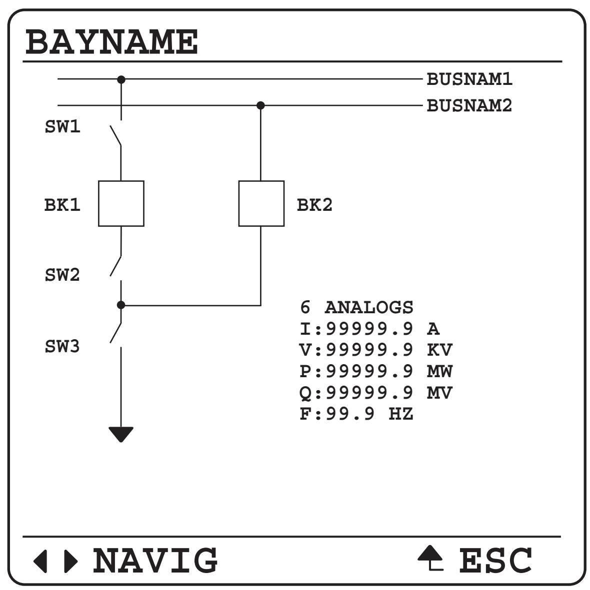


Figure 5.47 Left Breaker Bay Without Ground SW (Option 20)

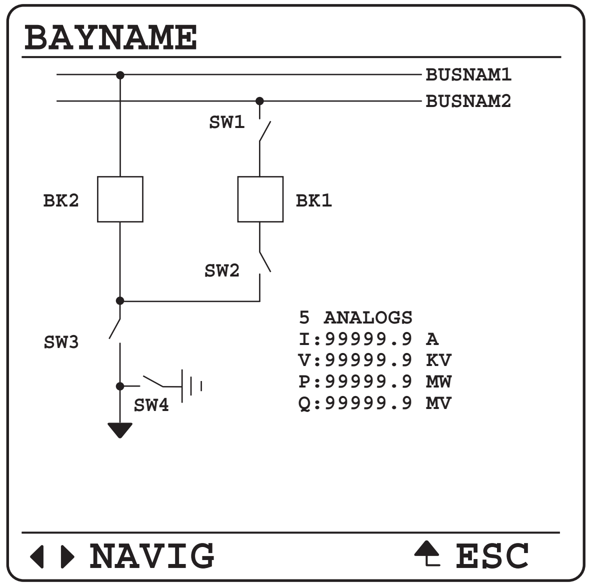


Figure 5.48 Right Breaker Bay With Ground SW Option 21)

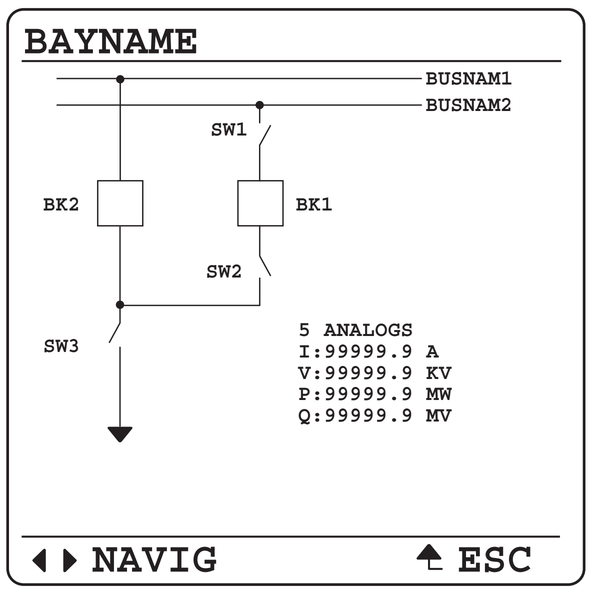


Figure 5.49 Right Breaker Bay Without Ground SW (Option 22)

Table 5.17 Mimic 19, Mimic 20, Mimic 21, and Mimic 22 Apparatus Support

Apparatus	Option 19	Option 20	Option 21	Option 22
Bus Names	2	2	2	2
Bay Labels	0	0	0	0
Breakers	2	2	2	2
Disconnects	4	3	4	3
One-Line Analog Display	6	6	5	5

Source Transfer Bus

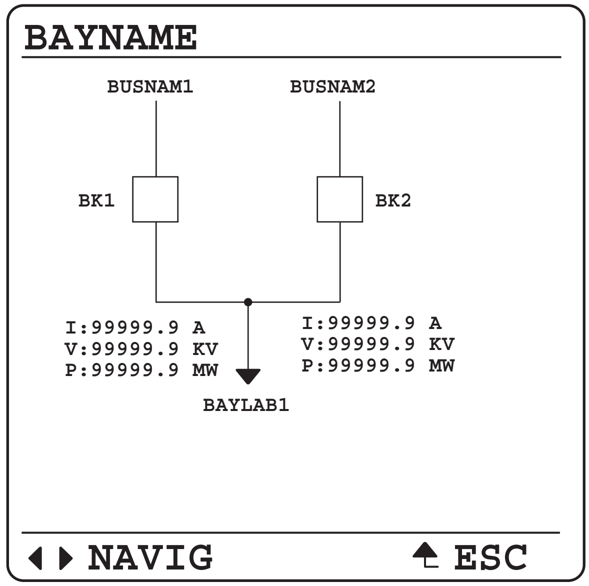


Figure 5.50 Source Transfer (Option 23)

Table 5.18 Mimic 23 Apparatus Support

Apparatus	Option 23
Bus Names	2
Bay Labels	1
Breakers	2
Disconnects	0
One-Line Analog Display	6

Bus Throw-Over

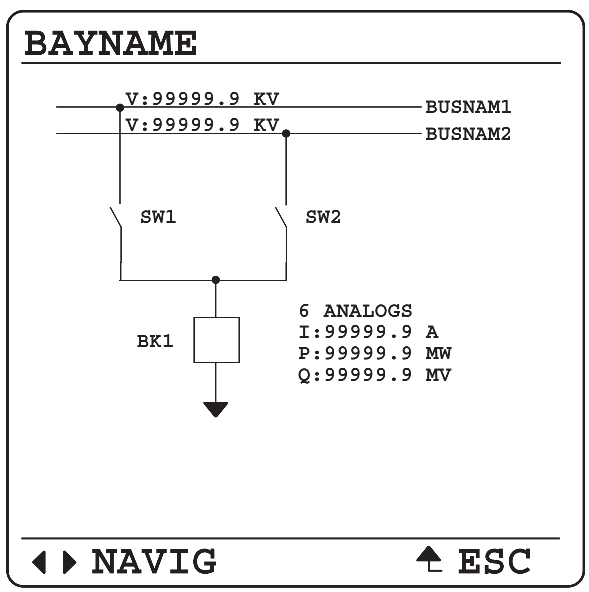


Figure 5.51 Bus Throw-Over Type 1 (Option 24)

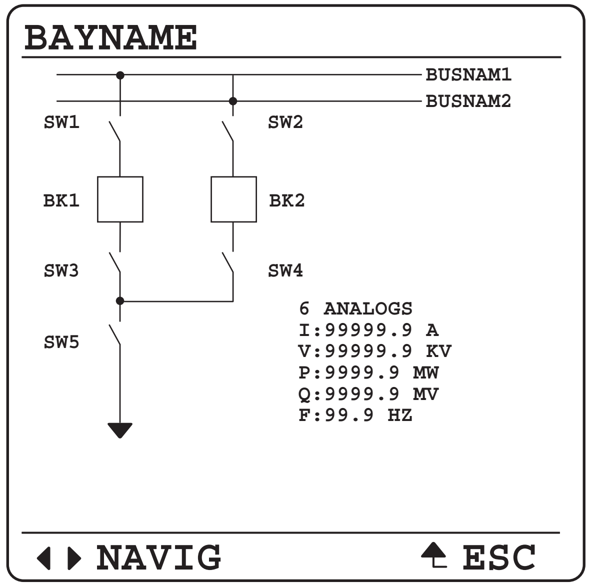


Figure 5.52 Bus Throw-Over Type 2 (Option 25)

Table 5.19 Mimic 24 and Mimic 25 Apparatus Support

Apparatus	Option 24	Option 25
Bus Names	2	2
Bay Labels	0	0
Breakers	1	2
Disconnects	2	5
One-Line Analog Display	6	6

Bay Character Set

Figure 5.53 shows the different characters available for the Bay mimic names.

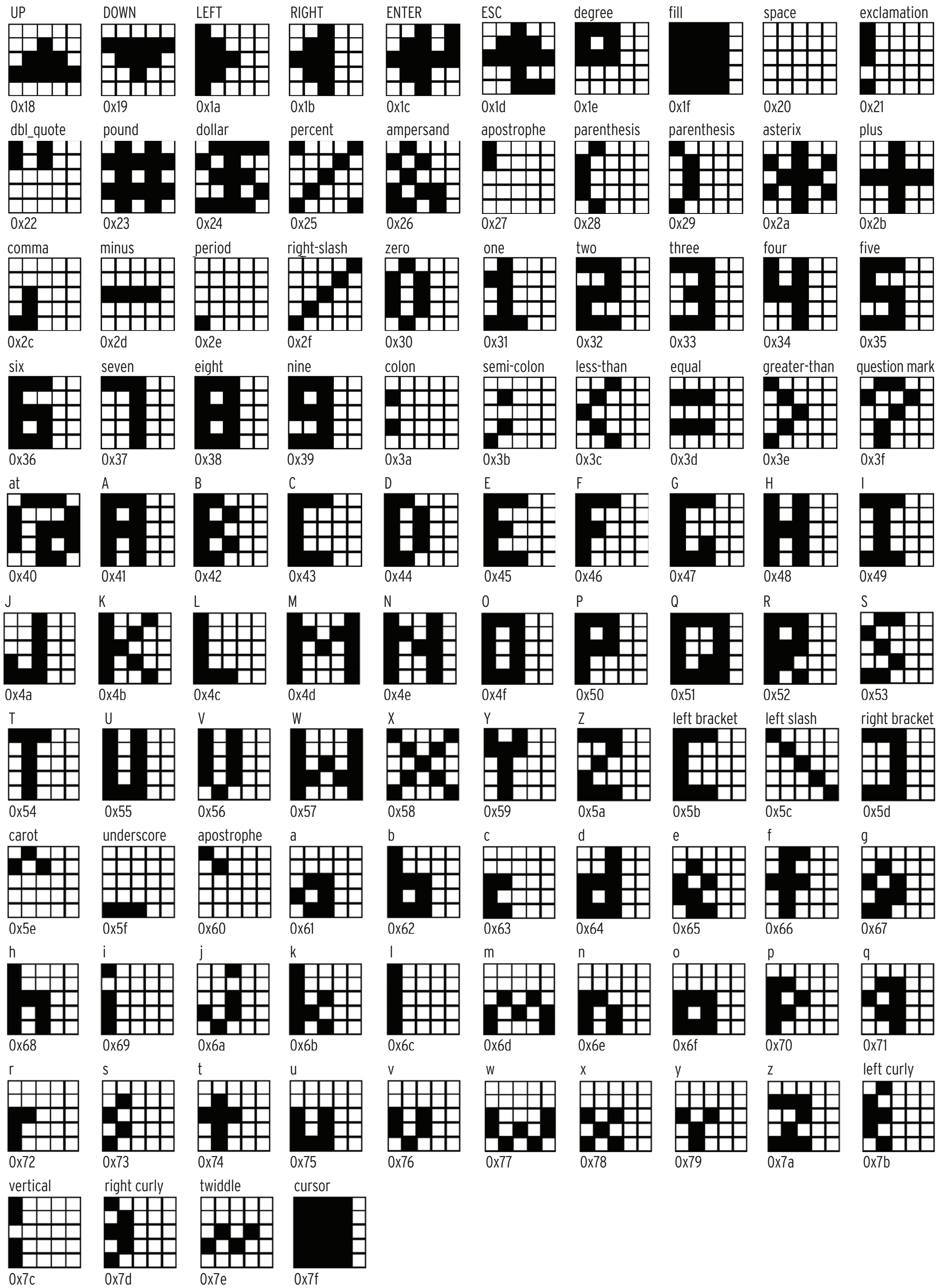


Figure 5.53 Bay Character Set

Section 6
SEL Communications Processor Applications

This section describes applications in which the SEL-451 Relay is applied in a seystem integration architecture that includes SEL Communications Processors, the SEL-2032, SEL-2030 and SEL-2020. This section addresses the following topics:

- ➤ *SEL Communications Processors on page A.6.1*
- ➤ *SEL Communications Processor and Relay Architecture on page A.6.3*
- ➤ *SEL Communications Processor Example on page A.6.5*

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

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*.

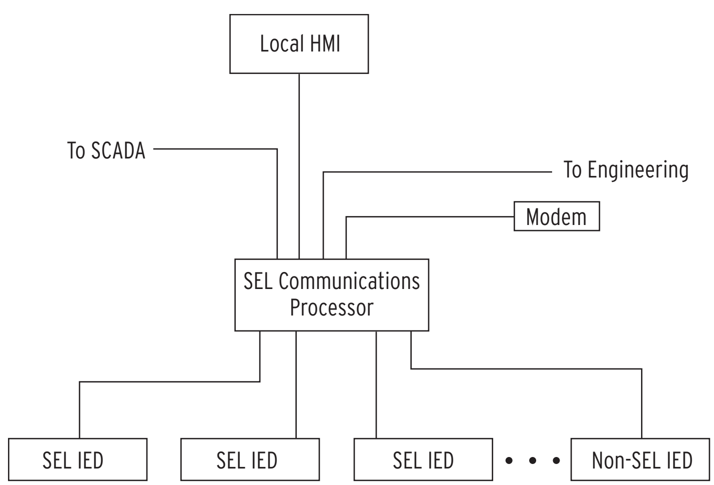


Figure 6.1 SEL Communications Processor Star Integration Network

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
- Single point of access for Fast SER data

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.4.73 for details.

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 Processor forward data to the upper-tier SEL Communications Processor that serves as the central point of access to substation data and station IEDs.

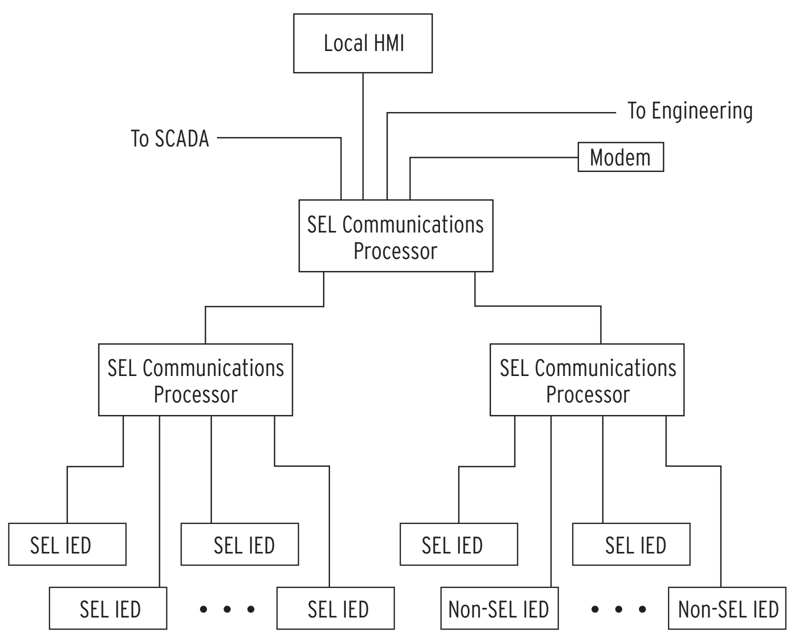


Figure 6.2 Multitiered SEL Communications Processor Architecture

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)
DNP3 Level 2 Slave (Ethernet)[a]	DNP3 masters (Ethernet)
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[b]	Modbus Plus peers with global data and Modbus Plus masters
FTP (File Transfer Protocol)[a]	FTP clients
Telnet[a]	Telnet servers and clients
UCA2 GOMSFE[a]	UCA2 protocol masters
UCA2 GOOSE[a]	UCA2 protocol and peers

[a] Requires SEL-2701 Ethernet Processor.
[b] Requires SEL-2711 Modbus Plus protocol 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-451 and an SEL communications processor is shown in *Figure 6.1*. In this architecture, the SEL communications processor collects data from the SEL-451 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 dataset optimized to each data consumer, you can significantly increase the utilization efficiency on each link. A system that uses the SEL communications processor 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-451. The communications processor presents the SEL-451 data as models in a virtual device domain similar to the way they would appear if the SEL-451 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 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 Ethernet card 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).

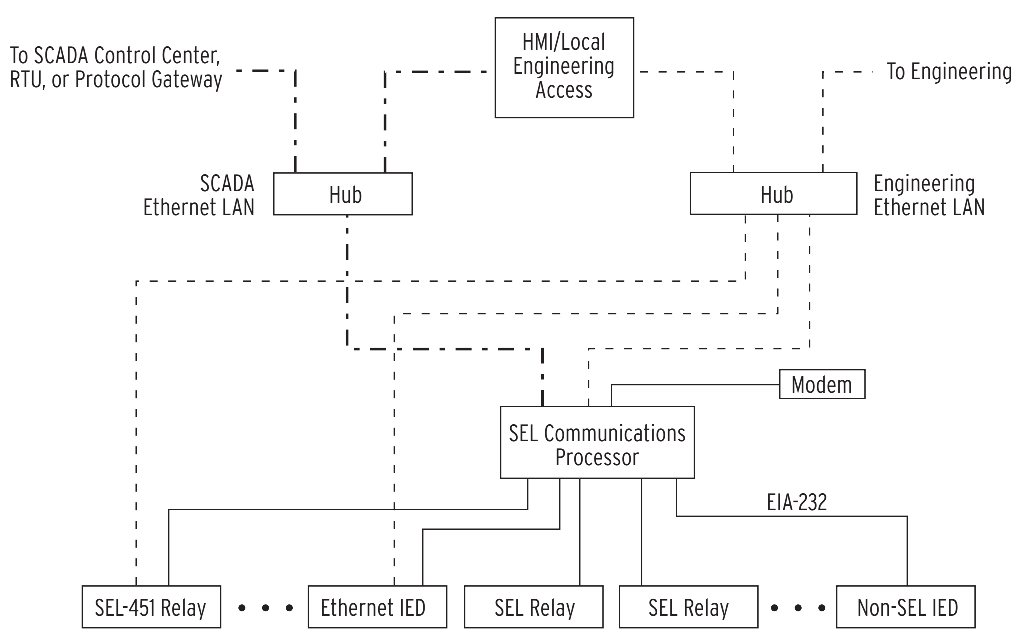


Figure 6.3 Enhancing Multidrop Networks With the SEL Communications Processor

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-451. The physical configuration used in this example is shown in *Figure 6.4*.

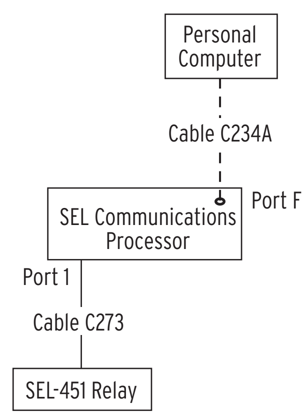


Figure 6.4 Example SEL Relay and SEL Communications Processor Configuration

Table 6.2 shows the PORT 1 settings for the SEL communications processor.

Table 6.2 SEL Communications Processor 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	N	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-451.

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-451 via the three automatic messages: 20TARGET, 20METER, and 20DEMAND.

Table 6.4 SEL Communications Processor Port 1 Automatic Messaging Settings

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
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-451 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

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-451 free-form automation logic.

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.

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 AG2002-14: SEL-421 Relay Fast Messages* for more information on using the SEL Fast Meter and Fast Message protocol with the SEL-451.

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[a]	200Bh	float[2][b]
IB1[a]	200Fh	float[2][b]
IC1[a]	2013h	float[2][b]
IA2[c]	2017h	float[2][b]
IB2[c]	201Bh	float[2][b]
IC2[c]	201Fh	float[2][b]
IA3[d]	2023h	float[2][b]
IB3[d]	2027h	float[2][b]
IC3[d]	202Bh	float[2][b]

Table 6.6 SEL Communications Processor METER Region Map (Sheet 2 of 2)

Item	Starting Address	Type
VA	202Fh	float[2][b]
VB	2033h	float[2][b]
VC	2037h	float[2][b]
FREQ	203Bh	float[2][e]
AMV001	203Fh	float[2][e]
AMV002	2043h	float[2][e]
AMV003	2047h	float[2][e]
AMV004	204Bh	float[2][e]
IAB(A)	204Fh	float[2][b]
IBC(A)	2053h	float[2][b]
ICA(A)	2057h	float[2][b]
VAB(V)	205Bh	float[2][b]
VBC(V)	205Fh	float[2][b]
VCA(V)	2063h	float[2][b]
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][b]
I1(A)	207Bh	float[2][b]
I2(A)	207Fh	float[2][b]
V0(V)	2083h	float[2][b]
V1(V)	2087h	float[2][b]
V2(V)	208Bh	float[2][b]

[a] Line currents.
[b] The first two addresses contain quantity; the second two addresses contain angle in degrees. Both values in IEEE 32-bit floating point format.
[c] Breaker 1 currents.
[d] Breaker 2 currents.
[e] The first two addresses contain the quantity in IEEE 32-bit floating point format; the second two addresses always contain 0.

Table 6.7 is a sample list of Relay Word bits available in the SEL communications processor for the memory area within D2 (Data Region 2) depending on the SEL-451 options.

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	*	79CY3	BK1LO
2809h	BK2LO	BK1CL	BK2CL	LEADBK0	LEADBK1	LEADBK2	FOLBK0	FOLBK1
280Ah	B1OPHA	B1OPHB	B1OPHC	B2OPHA	B2OPHB	B2OPHC	LOPHA	LOPHB
280Bh	LOPHC	*	*	*	*	3PO	27APO	27BPO
280Ch	27CPO	*	*	*	*	*	*	*
280Dh	52ACL1	*	*	52AAL1	*	*	52AA1	52AB1
280Eh	52AC1	*	52ACL2	*	*	52AAL2	*	*
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	CCOK	*	*	*
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	OUT313	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-451. You must enable Fast Operate messages using the FASTOP setting in the SEL-451 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-451.

Breaker bits BR1 and BR2 operate differently than remote bits. There are no breaker bits in the SEL-451. For Circuit Breaker 1, when you set BR1, the SEL communications processor sends a message to the SEL-451 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-451 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-451. Operation for Circuit Breaker 2 with BR2, OC2, and CC2 is similar.

When the communications processor is connected to a SEL-451-4 relay, the communications processor breaker bits BR3 through BR7 control disconnect switches 1–5. Setting the BR3 bit in the communications processor sends a message to the SEL-451-4 relay that asserts Relay Word bit 89OC1 for one processing interval. If the LOCAL Relay Word bit is deasserted in the SEL-451-4 relay, Relay Word bit 89OPEN1 asserts (see *Figure 5.2*). Clearing the BR3 bit in the communications processor sends a message to the SEL-451-4 relay that asserts 89CC1 for one processing interval. If the LOCAL Relay Word bit is deasserted, Relay Word bit 89CLS1 asserts (see *Figure 5.1*).

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Section 7

Direct Network Communications

This section describes applications in which the SEL-451 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-451 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-451 is an Ethernet card with FTP, Telnet, DNP3, IEC 61850 protocols, and synchrophasors. This is a factory-installed option available at the time of purchase of a new SEL-451 or as a factory-installed conversion to an existing relay.

The SEL-451 includes a protocol card slot. This slot supports an SEL standard interface for network protocol cards. Communication between the SEL-451 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-451. 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-451 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.4.73 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-451.

Serial Networking

The protocols available on the SEL-451 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*.

The DNP3 settings (serial and Ethernet) and operation are described in *Section 6: DNP3 Communications in the Reference Manual*. The serial DNP3 interface has the capabilities summarized in *Table 7.1*.

NOTE: In order to use DNP3 features, including virtual terminal connections, your DNP3 master device must support the required standard DNP3 objects and operations.

Table 7.1 DNP3 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.

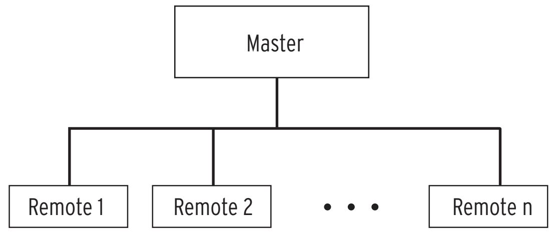

Figure 7.1 DNP3 Multidrop Network Topology

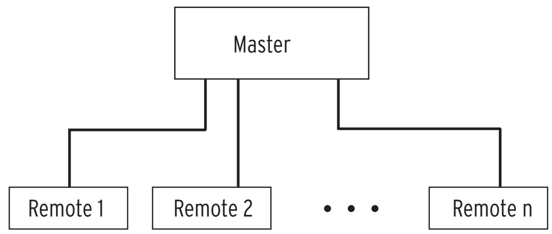

Figure 7.2 DNP3 Star Network Topology

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 a 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.

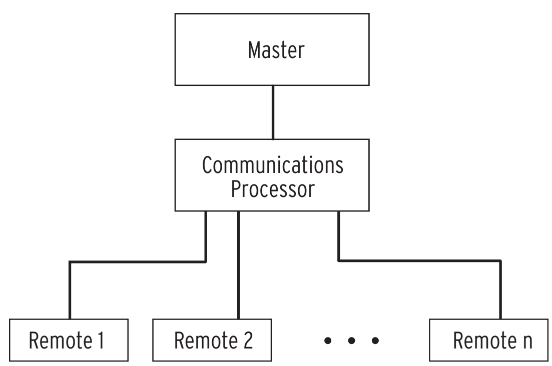

Figure 7.3 DNP3 Network With Communications Processor

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-451 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.

As with other communications interfaces, you must choose a data exchange protocol that operates over the Ethernet network link in order to exchange data. The SEL-451 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

NOTE: Fast SER is not supported over Ethernet in SEL-451 model relays with SEL-2701/SEL-2702 Ethernet cards.

The SEL-451 Ethernet card provides Ethernet networking 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	RJ-45	CAT 5 (Category 5 twisted pair) cable
10BASE-F	Standard ST	Multimode fiber-optic cable
100BASE-FX	Standard ST	Multimode fiber-optic cable

FTP

Use FTP (File Transfer Protocol) to access data stored in files in the SEL-451. 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-451 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-451. One SEL-451 directory contains snapshots of data regions within the SEL-451 database. The other SEL-451 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 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-451
- ERR.TXT file—contains any errors encountered during the CID file download
- CFG.XML file—contains the Ethernet card and SEL-451 configuration information

Telnet

Use Telnet to connect to the SEL-451 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 enables 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-451 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

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-451, not an intermediate device
Control output relay blocks	Operator-initiated control through remote bits
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-451 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-451 relay.

See *Section 6: DNP3 Communications in the Reference Manual* for information on configuring and using DNP LAN/WAN for the SEL-451.

SEL Software

The SEL-451 configuration software, ACSELERATOR QuickSet® SEL-5030 Software, can connect to, configure, and control an SEL-451 with an Ethernet card. You can use ACSELERATOR QuickSet to choose a connection type and provide the required information for a network connection. With this capability, you can configure and control SEL-451 relays from a local substation LAN (Local Area Network) or from an engineering workstation across a WAN (Wide Area Network). The ACSELERATOR Architect® 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-451 using the Ethernet card. *Figure 7.4* shows the Ethernet network topology.

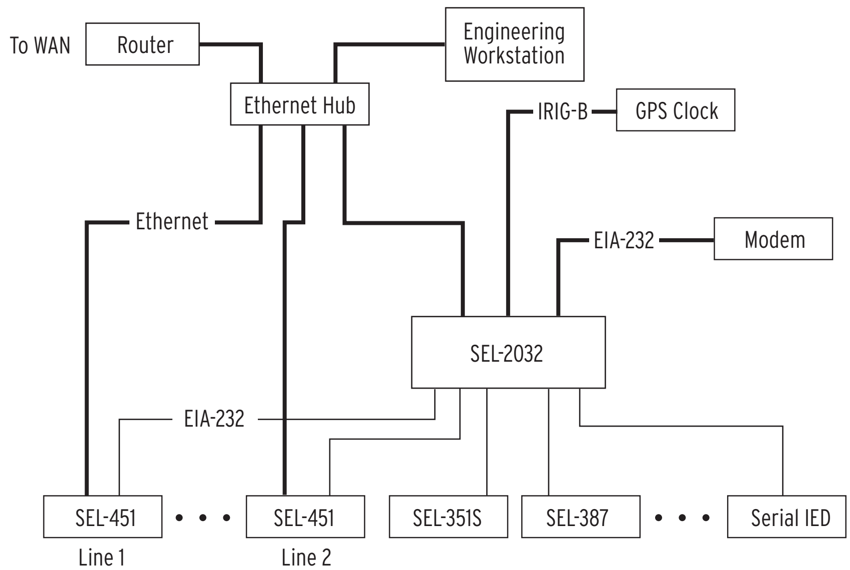

Figure 7.4 Example Direct Networking Topology

Application

In this application, all IEDs connect to the Ethernet network. The SEL-451 relays and the SEL-2032 Communications Processor 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-451 relays. The engineer can also use Telnet to establish a terminal connection to the SEL-451 relays or through the SEL-2032 to one of the serial IEDs in order to configure these devices or obtain diagnostic information.

There is a serial cable from the SEL-2032 to the SEL-451 relays. This cable provides IRIG-B time synchronization from the SEL-2032 that is synchronized by the GPS clock attached to the SEL-2032. The SEL-2032 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-2032 clock. During long periods of loss of synchronization, the SEL-2032 clock drift will become noticeable, but all substation devices will remain synchronized relative to each other and the SEL-2032 clock. The serial cables also allow the SEL-2032 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-451 configure the Ethernet card. **PORT 5** settings for this example are shown in *Table 7.4*.

Table 7.4 SEL-451 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	Y	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	SEL-2701 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 SEL-2701 enable; not used in this application
T1RECV	Y	Telnet session to SEL-451 enable
T1PNUM	23	Host Telnet TCP/IP port

Table 7.4 SEL-451 Port 5 Direct Networking Settings (Sheet 2 of 2)

Setting Name	Setting	Description
T2CBAN	SEL-2701 TERMINAL SERVER:	SEL-2701 Telnet connect banner
T2RECV	Y	Telnet session to SEL-2701 enable
T2PNUM	1024	SEL-2701 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-451. 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-451.

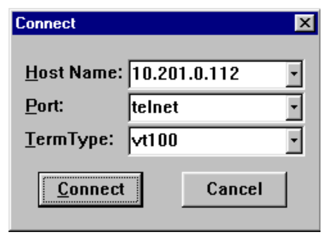

Figure 7.5 Telnet Connection Dialog Box

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 <Enter>
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-451
SEL-2701
DD01_SEL-451
CFG.TXT
226 Closing data connection.
42 bytes received in 0.00 seconds (42000.00 Kbytes/sec)

ftp> cd Relay 1 <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-451-1-Rxxx-V0-Zxxx-Dyyyymmdd
BFID=SLBT-CFS-X000
PARTNO=SEL-04511415XX165HX
[IOBOARDS]
[COMCARDS]
, SEL-2701-Rxxx-V0-Z000000-Dyyyymmdd, SLBT-2701-Rxxx-V0-Z000000-Dyyyymmdd, 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","SEL-2701 FTP SERVER:"
"FTPIDLE",5
"FTPANMS","N"
"FTPAUSR","ACC"
"T1CBAN","HOST TERMINAL SERVER:"
"T1INIT","N"
"T1RECV","Y"
"T1PNUM",23
"T2CBAN","SEL-2701 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 := "SEL-2701 FTP SERVER:"
FTPIDLE := 5
FTPANMS := "N"
FTPAUSR := ""
T1CBAN  := "HOST TERMINAL SERVER:"
T1INIT  := "N"
T1RECV  := "Y"
T1PNUM  := 23
T2CBAN  := "SEL-2701 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

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-451 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-451 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-451 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 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 C37.118 IEEE 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-451 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 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-451 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.

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-451 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-451 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.

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 Logical Node 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 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.

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-451 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 independent of load levels.

Local Bits The Relay Word bit outputs of local control switches that you access through the SEL-451 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-451 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.

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 IEC 61850.

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.

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-451 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 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-Open Logic Logic that determines the conditions that the relay uses to indicate an open circuit breaker pole.

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-451 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.

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.

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 an IEC 61850 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 ($3I_0 = I_A + I_B + I_C$).

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-451 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 SEL-5030 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.

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.

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.

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.

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.

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 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.

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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-451 Relay Command Summary

Command[a, b]	Description
2ACCESS	Go to Access Level 2 (complete relay monitoring and control)
89CLOSE *n*	Close disconnect switch *n* in SEL-451-4 (*n* = disconnect switches 1–10)
89OPEN *n*	Open disconnect switch *n* in SEL-451-4 (*n* = disconnect switches 1–10)
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 data (*c* = A is channel A; *c* = B is channel B; *c* = M is either enabled single channel)
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
HIZ	Displays a report of ground overcurrent high-impedance fault (50G HIZ) detection activity.
ID	Display the firmware id, user id, device code, part number, and configuration information
INI HIF	Restarts the 24-hour tuning process used in high-impedance fault detection.
IRIG	Update the internal clock/calendar from the IRIG-B input
LOG HIF	Displays the progress of the HIF detection in the percentage to their final pickup.
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)

Command[a, b]	Description
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)
QUIT	Reduce access level to Access Level 0 (exit relay control)
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*	Automation Logic Block 1–10	Automation SELOGIC control equations
B	Bay	Bay Control Settings (SEL-451-4)
D	DNP3	Direct Network Protocol remapping (serial port only)
F	Front Panel	Front-panel HMI settings
G	Global 1–6	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

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